NORTH AMERICAN
OIL SANDS CORPORATION

North American Oil Sands Corporation
A wholly-owned affiliate of StatoilHydro ASA
Upgrader Project

Volume 1

1 INTRODUCTION
2 APPLICATION FOR APPROVAL
3 THE PROJECT
4 INFRASTRUCTURE, UTILITIES AND OFFSITES
5 ENERGY AND MATERIAL BALANCES
6 ENVIRONMENTAL MANAGEMENT
7 C&R PLAN
8 SUMMARY OF THE EIA
9 SOCIO-ECONOMIC SUMMARY
10 PUBLIC CONSULTATION
11 LITERATURE CITED

Volume 2

1 IMPACT ASSESSMENT APPROACH
2 AIR
3 NOISE
4 HEALTH

Volume 3

5 HYDROGEOLOGY
6 HYDROLOGY
7 SURFACE WATER QUALITY
8 FISH AND FISH HABITAT

Volume 4

9 SOILS
10 VEGETATION
11 WILDLIFE
12 BIODIVERSITY

Volume 5

13 LAND USE
14 LIGHT
15 SEIA
16 HISTORICAL RESOURCES

StatoilHydro

December 14, 2007

Alberta Energy and Utilities Board
Applications Branch
Resources Applications
640 – 5 Avenue SW
Calgary, Alberta T2P 3G4

Attention: **Terry Abel**
Manager

Alberta Environment
Northeast Boreal Region
Environmental Service
111, 4999 – 98 Avenue
Edmonton, Alberta T6B 2X3

Attention: **Kem Singh,**
Approvals Manager

Alberta Environment
Northeast Boreal Region
Environmental Service
111, 4999 – 98 Avenue
Edmonton, Alberta T6B 2X3

Attention: **Mike Boyd**
Regional Environmental Manager

Dear Sirs:

Re: Application for Approval of the North American Oil Sands Corporation Upgrader Project

North American hereby applies to Alberta Environment and the EUB for:

- for approval to construct, operate, and reclaim an oil sands processing plant (bitumen upgrader); and
- for approval and licenses to use (withdraw, divert and confine) surface water and divert natural surface waters (on, around or away from the Project site).

In support of these approval requests, North American Oil Sands Corporation submits the attached document titled Application for Approval of the Upgrader Project. Please contact the undersigned at 234-0123 if you have any questions.

Sincerely,
North American Oil Sands Corporation
A fully owned affiliate of StatoilHydro

ORIGINAL SIGNED BY:

Gareth R. Crandall, P.Eng.
Senior Vice President, Upgrader

Cc: Craig Popoff
Director, Regulatory Affairs, Environment and Safety-Projects

Attachment: Application for Approval of the Upgrader Project

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TABLE OF CONTENTS

TABLES

FIGURES

1 IMPACT ASSESSMENT APPROACH

1.1 Introduction

North American Oil Sands Corporation (North American) is an integrated oil sands company operating in Alberta. North American proposes to build a bitumen upgrading facility in Strathcona County northeast of Edmonton, Alberta. North American is wholly-owned by StatoilHydro ASA (StatoilHydro).

The purpose of the North American Upgrader Project (the Project) Environmental Impact Assessment (EIA) is to explain the environmental and socio-economic effects of the Project individually, as well as in conjunction with other existing and planned projects in the local and regional study areas.

This EIA has been prepared in accordance with the requirements prescribed under the *Alberta Environmental Protection and Enhancement Act* and the Final Terms of Reference (TOR) for the Project (Volume 1, Appendix A). The EIA forms part of North American's joint application to the Alberta Energy and Utilities Board (EUB) and Alberta Environment (AENV).

In March 2007, North American released both the Public Disclosure Document (PDD) (Volume 1, Appendix E) and the Proposed TOR to AENV, the EUB, and all community stakeholders as noted in Volume 1, Section 10.4.1.

An open house was held on April 17, 2007, in the Hamlet of Josephburg and another was held on April 18, 2007, in the Town of Lamont. These open houses were advertised by mail drops in Bruderheim, Lamont, and Rural Route 2 Fort Saskatchewan. An open house was held in Bruderheim on January 25, 2007. Advertisements were also placed in local newspapers and direct mail was sent to landowners within 5 km of the Upgrader site and other interested stakeholders in the stakeholder database. The open houses featured a number of displays, copies of the PDD, and the Proposed TOR. North American staff were on hand to answer questions. Based on stakeholder input, AENV finalized the TOR on October 18, 2007.

1.2 Stakeholder Relations

North American is committed to creating and maintaining a constructive dialogue with regional stakeholders to ensure the environmental, social and economic sustainability of the Project. As such, the consultation process is designed to be ongoing from initial planning through construction, operation and decommissioning of the Project.

The primary objective of North American's public consultation program is to develop and maintain the trust of all stakeholders. The specific goals of North American's public consultation program are to:

- effectively identify stakeholders;
- make contact with all identified stakeholders;
- proactively provide stakeholders with clear and relevant information;
- identify stakeholder issues and concerns;
- involve community stakeholders in planning, design and implementation of the Project in order to address these concerns; and

- be a good neighbour.

Through these processes, stakeholders have the opportunity to:

- review information relative to the planning, development and implementation of the Project;
- identify issues and concerns relative to the planning and implementation of Project processes;
- provide feedback on the Project planning process and, where possible, improve North American's overall development plans; and
- receive feedback from North American on community stakeholder concerns.

1.3 Organization of the EIA

The Project EIA is comprised of five volumes (Table 1.3-1). The Application (Volume 1) provides the TOR cross reference table as well as the detailed Project and process descriptions. Volumes 2 through 5 address the remaining EIA requirements prescribed in the TOR (Volume 1, Appendix A).

Table 1.3-1 Overview of the Joint Application/EIA Report Table of Contents

APPLICATION	**VOLUME 1**
	Introduction Application for Project Approval The Project Infrastructure, Utilities and Off-sites Energy and Material Balances Environmental Management Conservation and Reclamation Plan Summary of the EIA Socio-Economic Summary Public Consultation Literature Cited
EIA	**VOLUME 2**
	Impact Assessment Approach Air Noise Health
	VOLUME 3
	Hydrogeology Hydrology Surface Water Quality Fish and Fish Habitat
	VOLUME 4
	Soils Vegetation and Wetlands Wildlife Biodiversity
	VOLUME 5
	Land Use Light Socio-Economic Impact Assessment Historical Resources

1.4 The Project

North American plans to develop the Upgrader in several phases to attain the full Project capacity of 1,610 m^3/h (243,000 barrels per stream day [bpsd]) of bitumen feed. This target capacity is staged largely to match the planned bitumen production from North American's upstream bitumen production facilities. Surplus upgrading capacity will be offered to other producers.

To simplify the explanation of reaching the target capacity this document refers to only two phases: Phase 1 at 530 m^3/h (80,000 bpsd) of bitumen feed, and the Project at 1,610 m^3/h (243,000 bpsd). The Project includes all of the facilities to reach the target capacity of the Upgrader plus the addition of two stages of petroleum coke (petcoke) gasification to produce hydrogen, electrical power and Synthetic Natural Gas (SNG).

Based on the plan outlined in Volume 1, Phase 1 is estimated to come onstream by 2014. Further expansion and subsequent phases should allow the Upgrader to reach full bitumen processing capacity by 2020. The Project, including two stages of gasification, is expected to be fully operational by 2025.

North American's development plan is based on the use of currently available and commercially proven coking technology and hydroprocessing as the main building blocks for the upgrading scheme. This selection was based on engineering studies, upstream and downstream commercial considerations, and a thorough assessment of a number of processing technologies.

Each phase of the Upgrader incorporates increasing energy efficiency steps. In addition to plans to reduce CO_2 emissions, North American will be ready to recover CO_2 from the hydrogen plant in Phase 1 and the gasification units. StatoilHydro is engaged in many research and development activities to reduce CO_2 emissions and is a world leader in recovering and sequestering CO_2. This experience will be incorporated into North American's projects.

The Upgrader development will be constructed during a time when a number of other projects are also planned for construction in the region. North American has carefully developed a construction plan that is fully cognizant of this high level of activity, primarily by developing the Project in stages that are sized to be more manageable than building a much larger scale project at one time.

The Upgrader will provide many benefits to Alberta. By undertaking this value added step, Albertans will be the beneficiaries of a modern processing facility that will employ approximately 600 long-term employees who will live in the region, create economic opportunities for hundreds of local businesses, provide taxes to the region, and bringing benefits to the nearby communities. Finally, the Upgrader will be a "building block" as it encourages other developments and businesses in the region, which should help this region to be a continuing economic player for decades to come.

1.4.1 Project Location and Site Selection

North American has acquired 540 ha (1,351 acres) of land in Strathcona County, Alberta, in a region referred to as the Alberta Industrial Heartland (AIH), for the purpose of building the Upgrader. This region already contains an upgrader, a refinery and several petrochemical plants. Additional projects are under development or planned by others for this region. The site is located approximately 15 km from Fort Saskatchewan, Alberta, and is approximately 3 km west of Bruderheim, Alberta. This location has many advantages including: close proximity to a skilled labour force and a major oil sands feedstock and product pipeline hub, industrial zoning designation, synergies with nearby petrochemical facilities and opportunities to recover carbon dioxide (CO_2) for use in enhanced conventional oil recovery programs or sequestration in depleted reservoirs.

The Upgrader site is located within portions of Sections 26, 27, 35 and 36, Township 55, Range 21 W4M and SE¼ Section 2 Township 56 Range 21 W4M. The site is large enough to include the Project process units, as well as tank farms, water treatment, warehouses, office space, and employee/contractor parking. A portion of the site will remain undeveloped to preserve existing wetlands.

A thorough evaluation of several site options was undertaken. The primary alternative location was near the SAGD facilities near Conklin, Alberta.

The decision to locate in the AIH at the site west of Bruderheim was made based on a number of criteria. The AIH has zoning already in place to accommodate projects of this nature. The site is close to pipelines, and utility and transportation infrastructure. It is in close proximity to the North Saskatchewan River as a water supply, other upgraders, petrochemical plants, and a refinery, which should facilitate beneficial business arrangements with third party facilities. Finally, it is likely that a CO_2 pipeline system will be built in this region, which would allow the potential for North American to recover CO_2 and have the ability to transport it to a storage location.

Locating the Upgrader near Conklin offered potential synergies with the SAGD operations, but there were also challenges related to footprint and water supply and disposal that were not easily resolved. After completing an intensive location analysis, including risks and benefits, the AIH location was chosen.

1.4.2 Key Initiatives, Project Strategies and Management Approach

Each phase of the Upgrader will be constructed in several large execution packages. An integrated North American project management team will coordinate the full execution of each phase.

The Upgrader is designed to achieve a high level of sulphur recovery, and will use the best available technology that is technically and economically feasible for burner applications. The Project will be well prepared should the Alberta Government proceed with establishing caps on both SO_2 and NO_x emissions in the AIH.

North American plans to be ready to recover CO_2 from the Upgrader, starting with Phase 1. This plan is based on a regional outlet for the CO_2, adequate infrastructure to transport the CO_2, and an appropriate fiscal and regulatory regime for carbon capture.

The justification for gasification of petcoke to produce hydrogen rather than generation of hydrogen from natural gas is based on a high price environment for natural gas, or a shortage of natural gas for industrial use. Gasification generates substantial CO_2 emissions, but most of these emissions can be readily recovered for carbon sequestration. When gasification is implemented, water requirements will increase significantly. Actual implementation of the gasification stages, though, will be dependent primarily on it being the most viable option for providing an energy alternative to natural gas, and the most effective way of recovering the additional CO_2 emissions associated with alternative fuels. If North American implements gasification in the Project, it will be accompanied by development plans for CO_2 recovery, transportation, and storage/sequestration.

Water requirements for the Project are based on having sufficient water to meet all of the upgrading requirements including both stages of gasification. Although the gasification units require substantial volumes of water, increasing levels of water conservation, including zero liquid discharge processes, will enable North American to satisfy water demands for both stages of gasification.

1.4.3 Process Overview

The Upgrader will be built in the AIH near other upgrading facilities and corresponding infrastructure. It will be close to the pipeline corridor between the oil sands producing areas and Edmonton. An overview of the process is presented in Figure 1.4-1.

Phase 1 will start with a capacity 530 m^3/h (80,000 bpsd) of bitumen feed and will expand through subsequent phases to bring the upgrading capacity to 1,610 m^3/h (243,000 bpsd) of bitumen feed by 2020. Petcoke gasification will be introduced in two stages, the first coming into service in 2018 and producing hydrogen for the hydroprocessing units, and the second by 2025 generating SNG and electrical power and consuming the bulk of the petcoke from the cokers. Support units such as sulphur recovery and wastewater treatment will expand as the need arises.

Bitumen, a heavy viscous oil, will be converted into products that can be processed by refineries by removing carbon from the bitumen and adding hydrogen to produce lighter hydrocarbon products. The Upgrader will receive a dilbit stream from North American's upstream developments by pipeline, and potentially from other bitumen producing operations. Diluent is a natural gas condensate and is required to promote oil water separation in the bitumen production facilities and to reduce the viscosity for pipeline transportation. The bitumen blend processing capacity will reach 2,299 m^3/h (347,000 bpsd), returning 689 m^3/h (104,000 bpsd) of diluent to the upstream bitumen production facilities.

Diluent will be returned to the bitumen production area by pipeline. Pipeline service may be provided by others, or may be developed by North American under a separate application. Synthetic Crude Oil (SCO) will either be delivered to Edmonton by others, or in a new SCO pipeline developed by North American, which would also be under a separate application.

The Upgrader will consist of primary upgrading (carbon rejection through delayed coking), secondary upgrading (hydrogen addition through hydroprocessing), utilities and off-site services. A natural gas based hydrogen plant will be provided in Phase 1, and for the Project, additional hydrogen will be provided by petcoke gasification. The off-site facilities include storage tanks, by-product handling equipment, minimal storage for petcoke, sulphur, Liquefied Petroleum Gas (LPG), as well as rail loading equipment.

Hydroprocessing is used to produce a sweet SCO, which is a blend of naphtha, gas oil and butane. Naphtha and gas oil, the two main coker products, are stabilized in the hydroprocessing units, with the addition of hydrogen. The hydroprocessing units also remove impurities such as sulphur and nitrogen through treating in a hydrogen environment over a metal-impregnated catalyst.

Diluent bitumen blend will be fed from storage tanks to the diluent recovery unit. The diluent recovery unit separates the diluent from the bitumen for shipment back to the upstream bitumen production facilities. The lighter material called light gas oil contained in the bitumen is removed and sent directly to the hydroprocessing units. The remaining heavier bitumen feeds the delayed coker unit. The delayed coker unit is a semi-continuous thermal cracking process in which bitumen feedstock is converted into lighter, cracked hydrocarbon products.

The Project requirements for hydrogen will be provided through a combination of steam methane reformation, purchases from others, and the gasification of petcoke which is a by-product of the delayed coker unit. The hydrogen required in the hydroprocessing step in Phase 1 will be produced through the steam methane reformation of natural gas. During Phase 1, the petcoke will be shipped from the site by rail for sale to market. Fuel gas produced in the Upgrader will be used in the upgrading heaters and boilers after the hydrogen sulphide (H_2S) is removed in an amine absorber. The acid gas (H_2S rich stream) that is recovered in the amine regenerator will be sent to the sulphur recovery unit to recover the sulphur for sale to market.

Water is required to provide cooling as well as for processing. North American is requesting approval to withdraw water from the North Saskatchewan River. It is also working with industry and government to further explore ways to conserve, recycle and reuse water.

A rail spur will be part of the Upgrader. It will be accessible by both Canadian National Railway (CNR) and Canadian Pacific Railway (CPR). Sufficient track will be provided in the spur to accommodate unit trains.

An administration building will be provided that includes a control room, laboratory and offices. Maintenance and warehousing facilities will also be constructed.

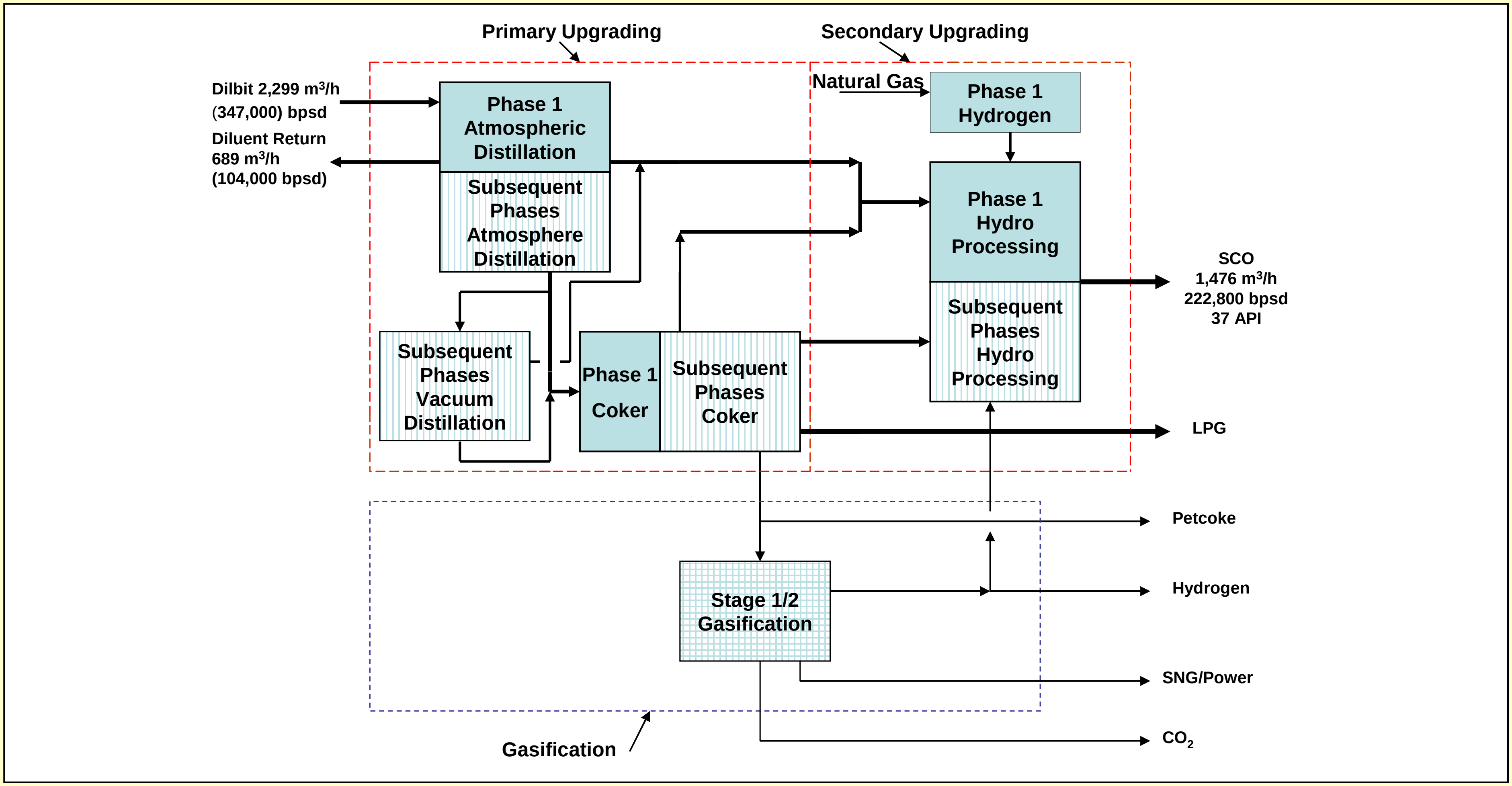
Water to the Upgrader will be withdrawn from the North Saskatchewan River. A water intake, pumphouse, river water pipeline and effluent pipeline will be constructed.

1.4.4 Project Schedule

The Project schedule is shown in Figure 1.4-2. The schedule is approximate and subject to modification in response to the receipt of regulatory approvals, business considerations and weather factors. Assuming favorable regulatory approval and market conditions, construction of the Project is scheduled to begin in 2010 with Phase 1 production commencing in 2014. Full SCO production from the Project is expected to occur by 2020, with the second stage of gasification complete and operational by 2025.

Stakeholders have been consulted since the fall of 2006 and will continue to be involved throughout the development process. It is North American's intention to continue communication and interaction with the surrounding communities throughout the life of the Project.

The Upgrader is being designed to operate for many years. With proper maintenance and systematic replacement of equipment that has reached the end of its operating life, the Upgrader may remain in operation for over 50 years. It will be able to process a range of bitumen qualities, and could also source supply from other producers.



The Project Overview

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:

Revision Date:
Nov 5/07

File:
Figure 1.1-1 Project Overview_Nov5.doc

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BF

Checked:
BE

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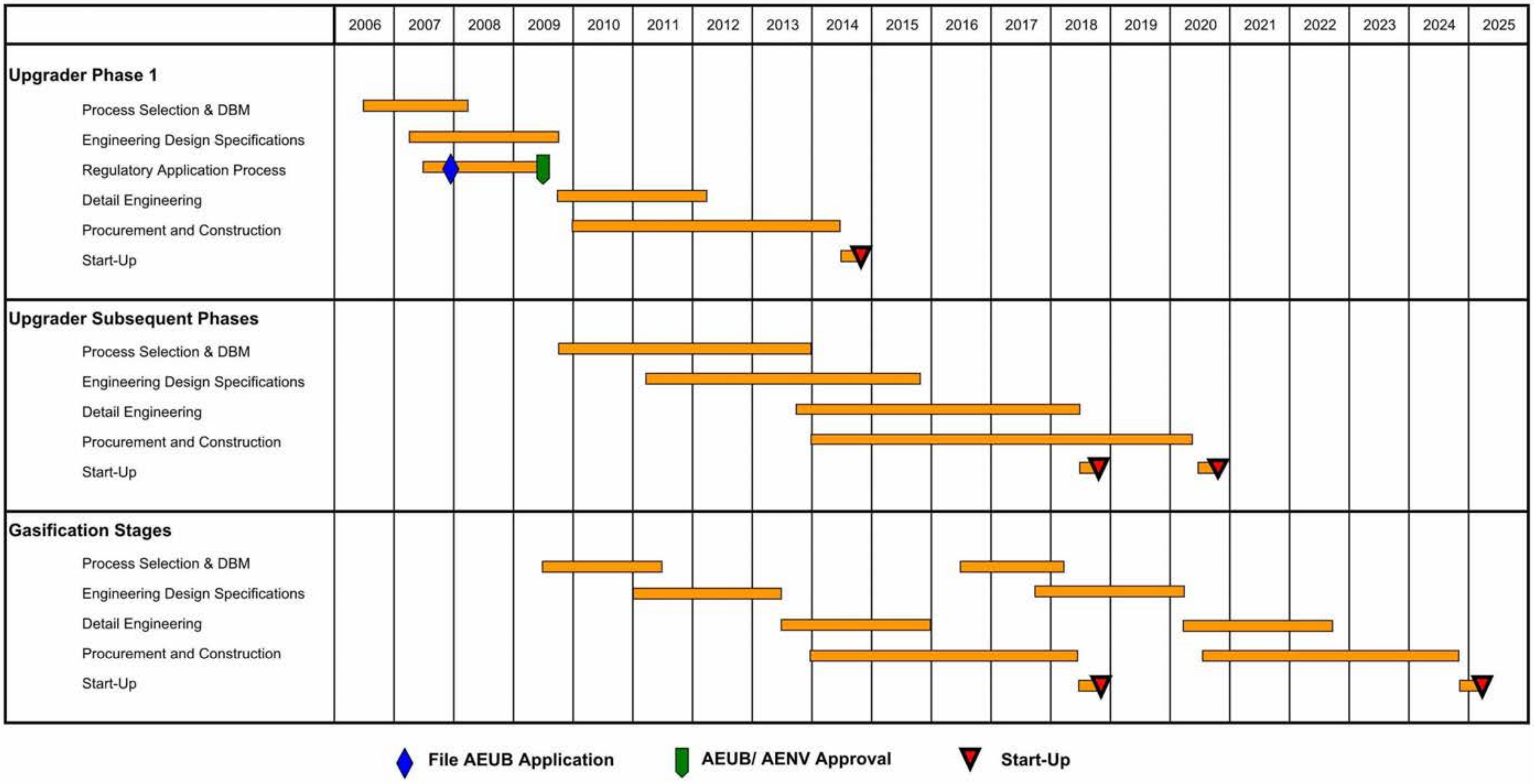
1.4-1



Project Schedule

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:

Revision Date:
Nov 20/07

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Figure 1.4-1 Project Schedule.doc

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1.5 Impact Assessment Approach

Preliminary work for the North American Upgrader Project was initiated in 2006 to evaluate Project alternatives, identify pertinent data sources, and define required data collection programs. Initial discussions were held with government authorities to scope Project requirements, application procedures and regulatory processes.

Consultation was conducted with local residents, government representatives, industry groups, and other stakeholders during this period to identify biophysical and socio-economic issues and confirm EIA study requirements (Volume 1, Section 10).

Field work was undertaken in 2006 and 2007 to enhance the quality and quantity of regional water, fish and fish habitat, soil, vegetation, wildlife, noise, light and historical resources information.

Potential environmental and socio-economic impacts for both the Upgrader Project alone and the Project's contribution to cumulative effects were identified and assessed using the following steps:

- Issues of greatest concern to stakeholders and regulators were identified, by each discipline, to focus the assessment.
- Ecological or socio-economic indicators (i.e., selected variables or parameters for in-depth analysis) were identified for each discipline to assist in quantification or evaluation of the potential effect of disturbances.
- The degree of spatial and temporal overlap was considered for each indicator and interaction to delineate Local Study Areas (LSAs) and Regional Study Areas (RSAs), as well as to define temporal boundaries for the assessment.
- Management methods including construction, design or scheduling principles were applied to prevent, minimize or mitigate adverse effects.
- Quantitative or qualitative assessments were made by comparing predicted residual effects (i.e., effects remaining after the application of management methods) to determine environmental or socio-economic consequence. Consequence and a final impact rating were defined based on established objectives or scientific criteria.
- Identification of monitoring or follow-up programs, if required.

1.5.1 Environmental and Socio-Economic Issues

Scoping is an accepted technique used to focus an EIA on issues of concern that have been identified by stakeholders including residents, federal, provincial and municipal governments, non-governmental organizations, as well as other agencies. Biophysical and socio-economic issues related to the construction, operations and decommissioning/reclamation of the Project, were identified through an examination of a number of sources including:

- consultation with local public, industry, and government (municipal, provincial and federal) representatives;
- TOR for the Project;

- other recent EIAs completed in the region;
- published literature on impact sources and effects; and
- professional knowledge of EIA team members.

1.5.2 Temporal Boundaries

The temporal scope of the EIA reflects the timing and nature of the Project phases as well as information available on other proposed projects. Project and cumulative effects are assessed for the construction, operation, decommissioning and reclamation, and closure phases of the Project. Each phase is assessed at the peak of project activity. The timing of project phases for the Upgrader project is presented in Volume 1, Section 1.4.

To establish a baseline timeframe, background conditions were assumed to be those that existed as of May 1, 2007. Baseline information includes both unpublished data and published data that is readily-available.

For this EIA, existing projects are defined as those that have been approved by the EUB and/or AENV. Planned developments include projects that have been publicly disclosed (but not approved) as of May 1, 2007. The projects and developments included within the scope of this assessment are listed in Table 1.5-1

Table 1.5-1 Existing and Planned Projects in the Upgrader Project Study Areas

	Operator	Facility
Existing and Approved Developments (Baseline Case)	Access Pipeline Inc.	Sturgeon Trim Blend Tank Terminal
	Agrium Products Inc.	Fort Saskatchewan Fertilizer Manufacturing Plant
	Agrium Products Inc.	Redwater Fertilizer Plant
	Air Liquide Canada Inc.	Scotford Cogeneration Power Plant
	ARC Resources Ltd. (formerly Imperial Oil)	Redwater Gas Conservation Plant
	ATCO Midstream Ltd.	Fort Saskatchewan Sour Gas Processing Plant
	Aux Sable Canada Ltd.	Heartland Off Gas Plant
	BA Energy Inc.	Heartland Oil Sands Processing Plant (Bitumen Upgrader)
	BP Canada Energy Company (formerly Amoco)	Fort Saskatchewan Fractionation Plant and Storage Facility
	Bunge Canada (formerly CanAmera Foods)	Fort Saskatchewan Oilseed Processing Plant
	Canexus Chemicals Limited Partnership	Bruderheim Sodium Chlorate Production Plant
	Capital Region	Wastewater Treatment Plant
	Celanese Canada Inc.	Edmonton Petrochemical Manufacturing Plant
	City of Edmonton	Gold Bar Wastewater Treatment Plant
	Degussa Canada Inc. (formerly DuPont)	Gibbons Hydrogen Peroxide Manufacturing Plant
	Dow Chemical Canada Inc.	Fort Saskatchewan Chemical Manufacturing Plant
	ERCO Worldwide (Albchem Industries)	Bruderheim Sodium Chlorate Manufacturing Plant
	Gulf Chemical and Metallurgical	Spent Catalyst Processing Facility
	Imperial Oil Ltd.	Strathcona Oil Refinery
	Keyera Energy Facilities Ltd., Chevron	Fort Saskatchewan Fractionation and Brine Storage Plant
	Marsulex Inc.	Fort Saskatchewan Chemical Manufacturing Plant
	Newalta Corporation	Redwater Disposal Facility
	North West Upgrading Inc.(1)	Bitumen Upgrader
	Petro-Canada	Edmonton Refinery
	Prospec Chemicals, Charles Tennant	Fort Saskatchewan Xanthate Chemical Manufacturing Plant
	Provident Energy Ltd., (formerly Novagas Clearinghouse/Williams Energy)	Redwater Fractionation and Storage Facility
	Redwater Water Disposal Company Limited	Redwater Waste Disposal Facility
	Shell Canada Limited	Scotford Complex (refinery & upgrader)
	Shell Chemicals Canada Limited	Scotford Styrene & MEG Plant
	Sherritt International Corporation	Fort Saskatchewan Fertilizer and Metal Manufacturing Plant
	TransAlta Cogeneration L.P.	Fort Saskatchewan. Cogeneration Facility
	TransCanada Energy Ltd.	Redwater Cogeneration Facility
	Umicore Canada Inc., Umex	Fort Saskatchewan Metal and Chemical Manufacturing Plant
The Project (Application Case)	**North American Oil Sands Corporation**	**North American Upgrader**
Planned Developments (Cumulative Case)	North West Upgrading Inc.(1)	Bitumen Upgrader
	Petro-Canada Oil Sands Inc. (PCOSI) (Fort Hills Energy L.P)	Sturgeon Upgrader
	Shell Canada Limited	Scotford Upgrader Expansion 1
	Shell Canada Limited	Scotford Upgrader 2
	Synenco Energy (Northern Lights Partnership)	Northern Lights Upgrader
	Total E & P Canada Ltd.(2)	Bitumen Upgrader

1 North West Upgrading is considered in the Air and Health sections as a planned development because the project was not approved at the time of air modelling. North West is included as baseline for the remaining disciplines.

2 Total E & P is included in the SEIA and light assessments based on available data at the time of the assessments. Data for the remaining disciplines were not available at the time of assessment.

1.5.3 Spatial Boundaries

The identification of appropriate study area boundaries is a critical component of an impact assessment. Study area boundaries are based on physical, biophysical or social considerations, and how far from the source (the Project) effects are expected to occur. However, it is not efficient or economically practical to assess and sample overly large study areas. Therefore, more detailed data are collected on those areas that are directly affected or influenced by the Project (LSA) and broader resolution data are collected for the extent of the RSA to capture regional indirect influences for the cumulative effects assessment.

For the Project, each biophysical and socio-economic study area was selected to reflect the anticipated zone of influence for each potential impact and pathway. Therefore, each study area boundary was defined as the largest zone of influence applicable to that component that best demonstrates the likely impact(s). For most disciplines, both a LSA and a RSA were delineated to analyze impacts caused by the Project. The LSA is used to evaluate areas that may be directly affected by the Project development. The RSA provides a larger geographical and ecological framework to evaluate impacts of the Project in combination with other existing and planned projects or land uses. Discipline study areas are presented in their relevant sections.

1.5.4 Indicators

There are numerous measurable parameters which may contribute to the environmental or socio-economic conditions and potential effects. Measuring and assessing all of the possible parameters and interactions is impractical. An accepted approach is to select key parameters or variables that are indicators for a broader group of parameters. Indicators are useful in quantifying or evaluating the effects of disturbances on ecological and socio-economic conditions. Selected indicators for each component are described in the applicable section.

1.5.5 Effects Criteria

Assessment criteria were used to describe and evaluate the predicted significance of project effects and the cumulative effects for various indicators.

The evaluation of Project effects includes a predictive assessment on the response of resources and/or indicators to project-specific activities. The evaluation of effects includes a predictive assessment on the response of resources and/or indicators to multiple stresses. Cumulative effects assessment (CEA) differs from project-specific environmental assessment by considering a larger geographic study area to include interactions between existing projects, developments and land uses with activities of the Project and nearby future projects, and foreseeable environmental changes.

Consistent with guidelines in the *Canadian Environmental Assessment Act* Responsible Authorities Guide (FEARO, 1994), Project-specific effects and cumulative effects were assessed using the following seven criteria. Where necessary, because of differences amongst the broad range of biophysical and social factors, the following criteria are further defined within relevant sections of the EIA.

- Direction;
- Extent;
- Magnitude;

- Duration;
- Frequency of Occurrence;
- Permanence; and,
- Prediction Confidence.

Direction describes if there is a net benefit, net loss or a net balance to the resource or affected party as result of the impact. The direction is classified as either a positive, neutral or negative effect.

Extent describes the area within which the effect occurs. It is classified as subregional (one watershed or natural subregion), regional (within the RSA), or extra-regional (effects extends beyond the RSA) effect. The classification of local is further defined and used in some sections of the EIA.

Magnitude describes the size and severity of the effect. Magnitude is classified as negligible (no discernible contribution), low (within acceptable protective standards and/or causes no detectable change to the resource), medium (within acceptable protective standards and/or causes a detectable change to the resource), or high (exceeds protective standards and/or causes a detectable change to the resource beyond the range of tolerance).

Duration describes how long the effect will occur. Duration is classified as short-term, medium-term or long-term. The time span of a duration will be defined as required by each discipline, for example, short-term (less than one year), medium-term (one to ten years), or long-term (greater than ten years) may be appropriate for some terrestrial disciplines but not appropriate for noise or air quality.

Frequency of occurrence describes how often an effect occurs within a set time period. It is classified as isolated (occurs at a specific time), occasional (intermittent and sporadic), regular (occurs recurrently during the assessment period), or continuous (occurs continually during the assessment period).

Permanence describes the potential for the recovery or reversibility of an effect. Permanence is classified as effects that are reversible in the short-term (within one year), reversible in the medium-term (one to ten years), reversible in the long-term (greater than ten years) or irreversible (permanent).

Prediction confidence describes the certainty of the effect assessment and considers data quality, rigor of the assessment/measurement approach, and/or the certainty of prescribed mitigation measures. Prediction confidence is classified as low (poor understanding of cause-effect relationships and poor quality data), medium (good understanding of cause-effect relationships and low quality data or high quality data but poor understanding of cause-effect relationships), or high (good understanding of cause-effect relationships and high quality data).

Conclusions for the project effects criteria are based on qualitative and quantitative assessments. Quantitative assessments include the results of measurable predictions or objective comparisons of residual project impacts with established limits (e.g., water quality guidelines, ambient air quality guidelines, environmental objectives.) Qualitative assessments are subjective and consider conclusions based on best professional judgment. This is important when environmental objectives are not available or quantitative predictions are not feasible.

The integration of the various effects criteria ratings result in a final impact rating for each potential Project effect. The possible final impact ratings are: no impact, negligible impact, low impact, medium impact or high impact. The result of combining objective and quantitative assessments with subjective evaluations and best professional judgment provides a conclusion for each predicted Project effect.

1.5.6 Cumulative Effects Analysis

Cumulative effects are the result of multiple stresses affecting the parts and functions of ecosystems. Ecosystems can change abruptly and unexpectedly in response to the incremental accumulation and interaction of these impacts, often responding to seemingly small changes (AENV, 2000). Assessments of cumulative effects often require innovative methods to predict changes to unique or site specific circumstances.

Cumulative Effects Assessment (CEA) differs from project-specific environmental assessment by considering a larger geographic study area to include interactions between existing projects, developments and land uses with activities of the Project and nearby future projects, and foreseeable environmental changes. General guidance to evaluate cumulative effects in Alberta is provided in CEAA (1999), EUB and NRCB (2000), AENV (2000) and AENV (1999).

In Alberta, Sections 47(d) and (e) of the *Alberta Environmental Assessment and Enhancement Act* state that EIAs required for oil sands development must include:

> "(d) a description of the potential positive and negative environmental, social, economic and cultural impacts of the proposed activity, including cumulative, regional, temporal and spatial considerations;
>
> (e) an analysis of the significance of the potential impacts identified under clause (d)."

There are inherent uncertainties in predicting future developments (CEARC, 1986; Sonntag et al., 1987; and AENV, 2000). Uncertainty such as the following can result in major limitations to the analysis of cumulative effects:

- Lack of site-specific data;
- Absence of defined resource use or ecological thresholds;
- Lack of availability of credible and defensible information on likely future development activities; and
- Difficulty in predicting synergistic, discontinuous or unanticipated resource and system effects.

1.5.6.1 CEA Methodology

Cumulative effects likely to result from the combination of the Project and other existing and proposed projects in the area and reasonably foreseeable environmental changes were considered and evaluated for each discipline using methods suitable to the discipline-specific issues. Environmental impacts in the LSA with a predicted magnitude of low or higher, that temporally and spatially overlap, and that could act cumulatively with other environmental pressures, were included in the CEA of the appropriate environmental component. Background information on the environmental setting, methodology and evaluations of potential project-related and cumulative effects are provided in each discipline section.

The complexity of the incremental accumulation of multiple stresses on an ecosystem makes it difficult to prescribe a set of standard methods for the analysis of cumulative effects. Instead, selection of appropriate approaches and methods depends on specific objectives and issues associated with the project (Cocklin et al., 1992a, 1992b; Shoemaker, 1994; Hegmann and Yarranton, 1995; Smit and Spaling, 1995; Hegmann et al., 1999; AENV, 2000). The scope and level of effort associated with an evaluation of cumulative environmental effects should be appropriate to the environmental setting, the nature of the project under assessment and its potential effects (AENV, 1999; AENV, 2000).

During early project notification and consultation, the key potential cumulative effects issues identified by the public, government representatives and the Project team were water use/disposal and air emissions.

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TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

2 AIR

2.1 Introduction

The Upgrader Project is in Strathcona County within Alberta's Industrial Heartland (AIH). The AIH includes a number of petroleum, petrochemical and chemical industries that are sources of air emissions. Emissions in the airshed come from these industrial sources, and from community and traffic sources (e.g., the City of Fort Saskatchewan). These emissions typically comprise small amounts of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter with aerodynamic diameters less than 2.5 um ($PM_{2.5}$), and other chemical substances. The Edmonton area is also a substantial source of industrial and urban emissions that can influence air quality in the AIH.

Many companies operating in AIH, including North American, are members of the Northeast Capital Industrial Association (NCIA), an Alberta group that aims to understand, reduce, and manage cumulative environmental effects due to member companies through collaborative efforts with the community and local government. Members from AIH area include Fort Saskatchewan, the towns of Lamont, Bruderheim, Redwater, Bon Accord and Gibbons, and rural residents. Other multi-stakeholder partnerships exist in the area, such as the Fort Air Partnership (FAP) that collects ambient air quality data in the Fort Saskatchewan area.

This section describes the effects of the Project on air quality within and downwind of AIH area. The overlapping effects of Project emissions were evaluated in the context of other facility and urban emissions. The air quality assessment was based on regional emission information obtained from the FAP and other sources, air quality data collected by FAP, and the application of air quality simulation models. Supporting documentation for the Air Quality assessment is presented in Appendices 2A through 2E.

2.2 Study Area

The effects of air emissions are seldom confined to the location where the emissions occur because winds transport the emissions away from the source locations. For example, southwesterly winds transport industrial and urban emissions from the Edmonton area to the AIH and then transport AIH emissions to the northeast. The CALPUFF transport and dispersion model (Appendix 2C) and the associated CALMET meteorology model (Appendix 2D) were the primary tools used to assess the air quality implications of the Project. The CALPUFF model was applied to a 100 km x 100 km area, and CALMET model was applied to a 125 km x 125 km area (Figure 2.2-1); both centred on the Project. These areas extend into Edmonton to provide an indication of community contributions to air quality near the Project.

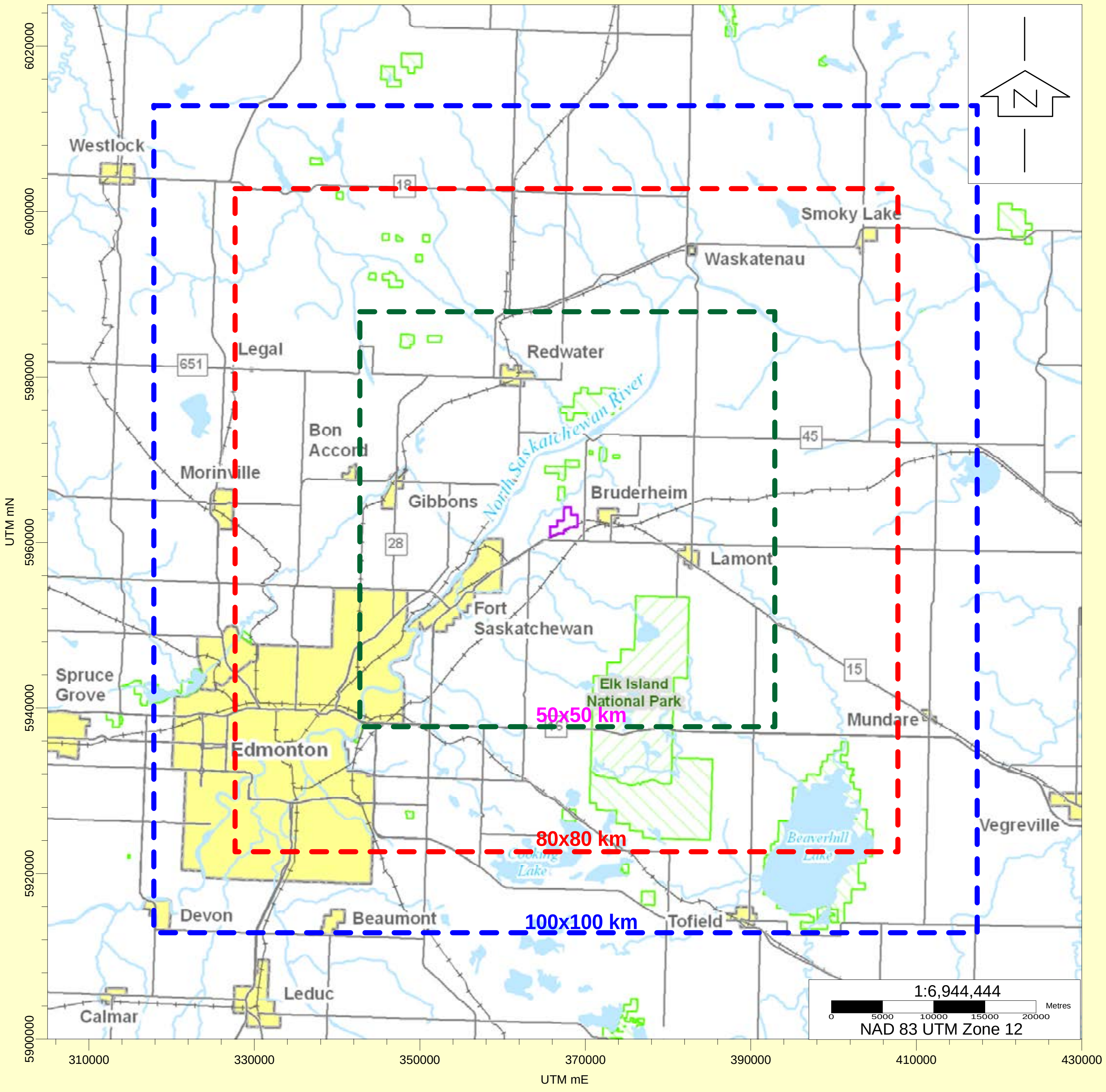
Based on the emission sources near the Project, the following smaller study areas were selected (Figure 2.2-1):

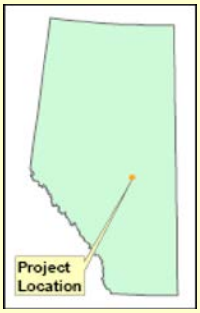
- **Local Study Area (LSA)**: For the Human Health Risk Assessment (HHRA), a number of sensitive receptors were identified, most of which are located within 5 km of the Project. The region defined by these receptor locations is the LSA.
- **Regional Study Area (RSA)**: The concentration predictions focused on a 50 km x 50 km area centred on the Project. The RSA includes industry emission sources from AIH area; the communities of Fort Saskatchewan, Bruderheim, Lamont, Redwater, Bon Accord and Gibbons, and Elk Island National Park.

- **Deposition Study Area (DSA)**: The deposition predictions are displayed for an 80 km x 80 km area centred on the Project. This area was chosen because the Potential Acid Input (PAI) isopleths of interest extend outside the RSA due to the future increase in SO_2 emissions.

The sizes of the RSA and DSA are consistent with other recently completed EIAs for projects in the region (e.g., Shell Canada Limited [2007], Petro-Canada Oil Sands Inc. [2006] and the DSA is larger than the earlier EIAs that have been submitted (e.g., North West Upgrading Inc. [2006]; Shell Canada Limited [2005a] and BA Energy Inc. [2004]). These latter EIAs focused on the smaller 50 km x 50 km study area. The RSA and DSA, being smaller than the 100 km x 100 km model domain, remove any computational “edge” effects associated with puffs that migrate in and out of the model domain. These smaller study areas also allow more details to be shown in the vicinities of the respective facilities where the concentration gradients are the greatest.

The study areas are bisected by the North Saskatchewan River (NSR), which has a southwest to northeast orientation. The higher terrain in the RSA is near Bon Accord (to the northwest of the Project) and Elk Island National Park (to the southeast of the Project) (Figure 2.2-1).





Legend

▭ Project Property Line
▭ Natural Area
▭ Community/Town
▭ RSA
▭ Model Domain
▭ DSA

Title:

AIR QUALITY STUDY AREA

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD

Revision Date: 09/10/2007

File:
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Drawn by: XC

Checked: MD

Fig. No.: **2.2-1**

2.3 Issues and Assessment Criteria

The Project is designed to process up to 1,610 m^3/h (or 243,000 bpsd) of bitumen and will include two stages of gasification. The air quality assessment is based on this proposed development. The Project will be a source of sulphur dioxide (SO_2), oxides of nitrogen (NOx), carbon monoxide (CO), volatile organic compound (VOC) and $PM_{2.5}$ emissions that result from combustion processes. Fugitive sources also produce VOC and reduced sulphur compound (RSC) emissions.

Potential air quality issues associated with the Project are evaluated in the context of Project emissions, other sources of emissions in the airshed, other users of the airshed and the regulatory framework. The Alberta regulatory framework identifies ambient air quality objectives for a number of chemicals and deposition target loading criteria for acid-forming emissions. In addition, Alberta Health requires assurance that resident heath will not be compromised by exposures to criteria and non-criteria air emissions. There is also a continuing provincial, national and international interest in documenting greenhouse gas (GHG) emissions.

2.3.1 Ambient Air Quality Criteria

Regulatory agencies have identified ambient air quality criteria. These criteria are based on a lowest observed level of effect and often incorporate a safety factor. Measured and predicted values are compared with these criteria.

2.3.1.1 Ambient Concentration Criteria

Table 2.3-1 provides the Alberta Ambient Air Quality Objectives (AAAQO) and the National Ambient Air Quality Objectives (NAAQO) for a number of substances, and the Canada-Wide Standards (CWS) for $PM_{2.5}$ and O_3. AENV (2005) states that the AAAQO are based on an evaluation of scientific, social, technical and economic factors. The substances identified in the table represent the expected substances emitted into the air from the Project and the substances that are routinely measured by FAP.

Although Alberta has a total suspended particulate (TSP) guideline, the CWS for $PM_{2.5}$ is deemed as more appropriate for ambient particulate matter in the air, since it is better correlated to potential health effects and is more restrictive than the AAAQO for TSP. The CWS for $PM_{2.5}$ is based on 30 ug/m^3 as a 24-hour average. Achievement is based on the average of monitors within an identified population centre, the 98th percentile for a year, averaged over three consecutive years. In determining compliance, natural sources or long-range transport contributions can be discounted. The Canadian Council of Ministers of the Environment (CCME) focuses on population centres over 100,000, whereas the Alberta Framework applies the CWS for $PM_{2.5}$ to all areas of the province. As shown in Table 2.3-1, three Alberta Framework action levels are identified:

- The **Exceedance Trigger** of 30 ug/m^3 requires a Mandatory Plan be developed to reduce $PM_{2.5}$ concentrations to below the CWS.
- The **Planning Trigger** of 20 ug/m^3 requires the development of a Management Plan by stakeholders to prevent an exceedance of the CWS.
- The **Surveillance Trigger** of 15 ug/m^3 is used to ensure that the appropriate monitoring is in place to assess the region's air quality. The FAP currently monitors $PM_{2.5}$ in the RSA.

A recent review by AENV (2007a) indicated that the surveillance trigger has been exceeded in the Edmonton Census Metropolitan Area (CMA). Specifically, a Surveillance Actions action level was assigned to the Edmonton CMA and to two FAP monitoring sites.

The CWS for O_3 is based on 65 ppb (127 ug/m^3) as an 8-hour average. Achievement is based on the fourth-highest value for a year, averaged over three consecutive years. In determining compliance, natural sources and long-range contributions can be discounted. The Alberta Framework identifies two action levels:

- The **Exceedance Trigger** of 65 ppb (127 ug/m^3) requires a Mandatory Plan be developed to reduce O_3 concentrations to below the CWS.

- The **Planning Trigger** of 58 ppb (113 ug/m^3) requires the development of a Management Plan by stakeholders to prevent an exceedance of the CWS.

A recent review by AENV (2007) indicated that the planning trigger has been exceeded in the Edmonton CMA. Specifically, a Management Plan action level was assigned to the Edmonton CMA and one FAP monitoring site; and Surveillance Actions action levels were assigned to two FAP monitoring sites. Surveillance Actions action levels were assigned in spite of no formal Surveillance Trigger for O_3.

The Alberta Action Triggers for $PM_{2.5}$ and O_3 are to be used for airshed management purposes; they are not intended to be applied as “point of impingement” concentration in relation to environmental approval limits (CASA 2003).

AENV (2003) recognizes that extreme, rare and transient meteorological conditions can affect model predictions of hourly average ambient air concentrations. To address this issue, AENV recommends the eight highest predicted hourly average concentrations in a year at a given location be considered outliers and disregarded. The ninth-highest hourly average value (equal to the 99.9th percentile) at a given location is therefore used as the basis for determining compliance with the hourly average AAAQO. The 99.9th percentile is referred to as the “maximum” value when referring to hourly average concentrations in this assessment.

2.3.1.2 Deposition Criteria

The PAI values are compared with the Clean Air Strategic Alliance (CASA)/AENV deposition loading criteria. These criteria (CASA and AENV, 1999) refer to PAI deposition averaged over a 1° longitude x 1° latitude grid cell. This grid cell corresponds to a region that is about 65 km x 112 km, with a total area of 7,280 km^2. For comparison, the air DSA has a nominal area of 6,400 km^2. The DSA average deposition can be compared to the 1° longitude x 1° latitude grid cell criteria to provide an indication of the regional PAI status. The CASA/AENV deposition criteria are shown in Table 2.3-2; the implications of exceeding these criteria are as follows:

- **Monitoring Load** – If a grid cell deposition exceeds the monitoring load, then AENV requires industry and non-industry stakeholders to discuss appropriate monitoring approaches. Monitoring loads are set below target loads to allow sufficient time for the development of a Management Plan before deposition levels reach target load levels.

- **Target Load** – Target loads are an environmental objective or regulatory instrument similar to the ambient air quality objectives. If a grid cell deposition exceeds the target load, then an Emission Reduction Plan will have to be developed.

Table 2.3-1 Canadian and Alberta Ambient Air Quality Objectives

Air Substances (ug/m^3)	**Averaging Period**	**Provincial**	**National** [b]			
			Canada Wide Standard CWS	**NAAQO**		
		Alberta AAAQO [a]		**Maximum Desirable**	**Maximum Acceptable**	**Maximum Tolerable**
Acetaldehyde	1-hour	90	-	-	-	-
Ammonia	1-hour	1,400	-	-	-	-
Benzene	1-hour	30	-	-	-	-
Carbon Disulphide	1-hour	30	-	-	-	-
Carbon Monoxide	1-hour	15,000	-	15,000	35,000	-
	8-hour	6,000	-	6,000	15,000	20,000
Ethylbenzene	1-hour	2,000	-	-	-	-
Formaldehyde	1-hour	65	-	-	-	-
Hydrogen Sulphide (H_2S)	1-hour	14	-	-	-	-
	24-hour	4	-	-	-	-
Nitrogen Dioxide (NO_2)	1-hour	400	-	-	400	1,000
	24-hour	200	-	-	200	300
	Annual	60	-	60	100	-
Ozone (O_3)	1-hour	160	-	100	160	300
	8-hour	-	127 [c]	-	-	-
	24-hour	-		30	50	-
	Annual	-	-	-	30	-
	8-hour	-	127	-	-	-
O_3 Exceedance Trigger	8-hour	127	-	-	-	-
O_3 Planning Trigger	8-hour	113	-	-	-	-
$PM_{2.5}$	24-hour	-	30 [c]	-	-	-
$PM_{2.5}$ Exceedance Trigger	24-hour	30	-	-	-	-
$PM_{2.5}$ Planning Trigger	24-hour	20	-	-	-	-
$PM_{2.5}$ Surveillance Trigger	24-hour	15	-	-	-	-
Styrene	1-hour	215	-	-	-	-
Sulphur Dioxide (SO_2)	1-hour	450	-	450	900	-
	24-hour	150	-	150	300	800
	Annual	30	-	30	60	-
Sulphuric Acid	1-hour	10	-	-	-	-
Total Suspended Particulates (TSP)	24-hour	100	-	-	120	400
	Annual	60	-	60	70	-
Toluene	1-hour	1,880	-	-	-	-
	24-hour	400	-	-	-	-
Xylenes	1-hour	2,300	-	-	-	-
	24-hour	700	-	-	-	-

SOURCES:

a Ambient Air Quality Objectives (AAAQO) (AENV 2005)
b National Ambient Air Quality Objectives. Government of Canada. (2004).
c Canada Wide Standards for Respirable Particulate Matter and Ozone, effective by 2010, CCME (2000).

NOTE: - Indicates data not available

- **Critical Load** – Critical loads identify a level of deposition that can lead to long-term harmful changes to the environment. Should a critical load be exceeded, an Emission Reduction Plan will have to be developed and implemented on an accelerated schedule. Exceeding a critical load, however, does not mean that environmental damage is imminent unless it is sustained over many years.

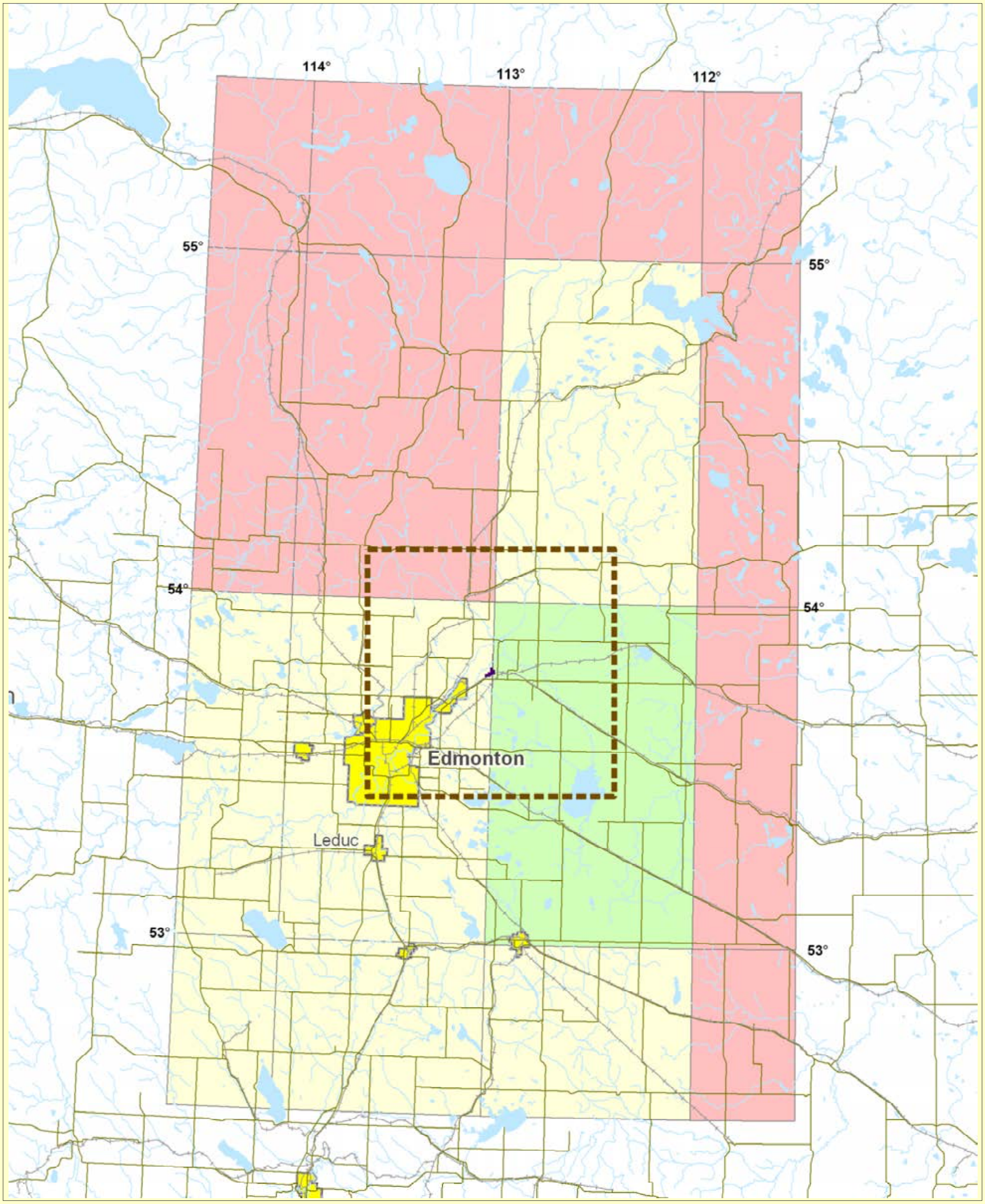
Figure 2.3-1 shows the grid cell sensitivity in the vicinity of the Project DSA on a 1° longitude x 1° latitude grid cell basis (from WBK & Associates 2006). Based on the information in the figure, the eastern half of the 80 km x 80 km DSA is mostly classified as a “sensitive” grid cell, and the western half is a “moderately sensitive” grid cell.

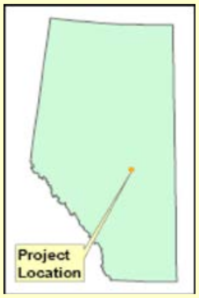
Although these loading criteria can be used as benchmarks on a local scale (i.e., for distance scales less than the 1° longitude x 1° latitude grid cell), the criteria are not intended to be applied on a local scale as environmental objectives or for determining the acceptability of an individual project. However, values exceeding criteria loadings on a local scale can be used to determine the need for management options, which could include monitoring or mitigation.

Table 2.3-2 Critical, Target and Monitoring Potential Acid Input Loads

Receptor Sensitivity	Deposition Load	Potential Acid Input (keq H^+/ha/y)
Low Sensitivity	Critical	1.00
	Target	0.90
	Monitoring	0.70
Moderately Sensitive	Critical	0.50
	Target	0.45
	Monitoring	0.35
Sensitive	Critical	0.25
	Target	0.22
	Monitoring	0.17

SOURCE: CASA and AENV (1999).





Legend

Grid Cell Sensitivity Class

- 🟩 Low Sensitivity
- 🟨 Moderately Sensitive
- 🟥 Sensitive
- ▭ 80 x 80 km Study Area
- ■ Project Area
- — Paved Access
- — Watercourse
- 🟨 Urban Area

Title:

Grid Cell Sensitivity to Acidification

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: MD	Revision Date: 03/12/2007

File:
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2.4 Methods

2.4.1 General Approach

A standard assessment approach was used to determine air quality for the three assessment cases. This approach, outlined in Table 2.4-1, includes the following tasks:

- identify and quantify atmospheric emission sources for each assessment case (i.e., Baseline, Application and Cumulative cases) (Task 1);
- review ambient air quality measurements in the region to provide an indication of existing conditions (Task 2);
- review regional and local meteorology to determine transport and dispersion patterns in the region (Task 3);
- review terrain elevations to account for influences on meteorology and land use information to account for deposition influences (Task 4);
- select and evaluate a dispersion model for the assessment (Task 5);
- apply the selected dispersion model to predict ambient concentrations and deposition patterns for each assessment case (Task 6); and
- compare the ambient monitoring measurements and air quality predictions to the ambient air quality and deposition criteria and identify the incremental air quality changes caused by the Project (Task 7).

The main features of this approach have been used for other air quality assessments in the region. Key enhancements associated with the approach used for the Project are the extension of the model domain to include more of Greater Edmonton Area and the use of 2002 MM5 meteorological data which allows the FAP surface data to be used. The first enhancement allows the effects of Edmonton emissions to be accounted for explicitly by the CALPUFF model, whereas the second enhancement should improve the meteorological representation.

2.4.2 Dispersion Model Selection

Dispersion model predictions provide a link between air emissions in a region and ambient air quality changes due to these emissions. The CALMET/CALPUFF model system was used for this assessment. It incorporates the following:

- The model system accounts for SO_X and NO_X chemistry and deposition processes, and can therefore be used to estimate PAI and nitrogen deposition.
- The treatment of the plume as a puff allows the predicted plume trajectory to vary as the wind varies, from hour to hour. Plumes can have realistic curvilinear paths that cannot be simulated by other straight-line models (e.g., AERMOD, ISC-PRIME).
- The meteorological parameters for any given hour can vary across the domain in response to terrain and other surface property influences.

The CALMET and CALPUFF models are described in Appendices 2C and 2D, respectively. This model system is a key assessment tool for predicting spatial concentration patterns from the Project and other regional emission sources. The CALMET/CALPUFF model system is approved by AENV (2003) for refined air quality assessments that are required for environmental impact assessments.

The ability of a model to predict ambient concentrations will depend on the accuracy of the source and emission inventory, the meteorology, and the assumptions used to represent the atmospheric physics and chemistry processes. There have been numerous model comparisons using different indicators. The U.S. Environmental Protection Agency (U.S. EPA, 2005) states: “models are reasonably reliable in estimating the magnitude of highest concentrations occurring sometime, somewhere within an area. For example, errors in highest estimated concentrations of ±10 to ±40% are found to be typical, i.e., certainly well within the often quoted factor-of-two accuracy that has long been recognized for these models.” In addition, they also state, “it is desirable to quantify the accuracy or uncertainty associated with concentration estimates used in decision-making. Communications between modellers and decision-makers must be fostered and further developed”. To address the latter statement, the CALPUFF/CALMET model system predictions associated with existing emissions were compared with FAP ambient measurements (Appendix D). This comparison provides an indication of the model confidence that is discussed on a substance-by-substance basis.

2.4.3 Assessment Cases

Because the Project is in an airshed with other emission sources, the assessment has to be cumulative, that is, overlapping effects of emissions with these other emission sources need to be considered. Figure 2.4-1 shows the location of the major industrial facilities in the DSA. The effects of the Project emissions on future air quality changes were assessed for three cases:

- Baseline Case
- Application Case
- Cumulative Case

For a description of these cases, see Volume 2, Section 1. A Project-only case was also considered to provide a direct indication of the Project contribution to air quality changes. The Project-only results are presented in Appendix 2E.

2.4.4 Substance Selection

A wide range of substances with varying magnitudes can be emitted from a facility such as the Project. The complexity of the emissions (i.e., the substances and the magnitude of the associated emission rates) increases when other industrial facilities are considered. Combustion emissions depend on the combustion device type, the fuel composition and the fuel consumption rate. Fugitive emissions depend on the type and composition of feedstock, intermediate and final product streams, and the associated methods of handling these streams.

Because the primary purpose of this assessment is to evaluate the Project, the emissions expected on the basis of the Project-specific design and operations formed the basis of selecting the substances for evaluation. Fuel gas flow rates were identified for all combustion related equipment, and appropriate engineering and emission factors were considered to determine the substance emission profile. Similarly, product streams were identified for the different process areas, and relevant emission factor information was used to estimate fugitive tank and process area emissions from the Project.

The expected substances that could be emitted were then reviewed and grouped to represent the specific regulatory criteria and potential effects on human health (Table 2.4-2). The air quality changes associated with these substances were assessed and displayed in a number of formats. Ambient SO_2, NO_2 and $PM_{2.5}$ concentrations are shown as contours superimposed over the RSA base map. Ambient PAI and nitrogen depositions are shown as contours superimposed over the DSA base map. Ambient concentrations of SO_2, NO_2, $PM_{2.5}$ and other substances (e.g., VOC and polycyclic aromatic hydrocarbons [PAH] for a total of 54 substance groups) are predicted for discrete locations that represent sensitive locations (i.e., individual residences, communities or recreation areas). For the air quality section, the discrete receptors were classified as:

- **Agricultural/Residential:** This includes all locations where a residence is assumed, and that the residents can potentially obtain some of their food from agricultural operations.
- **Residential/Community:** This includes all community and subdivision locations. Agricultural activities were not assumed to take place at these locations.
- **Public Access Area:** This includes all ambient monitoring locations and recreation areas where members of the public have access.
- **Commercial/Industrial:** This includes business and industrial facilities. These locations are within facility property lines.

Most of these discrete receptors are located within the 5 km radius of the LSA. If there was any uncertainty in classifying a potential receptor, it was classified as Agricultural. The receptors and their groupings were selected in consideration of the Human Health assessment (Volume 2, Section 4). Greenhouse gas emissions are discussed in terms of emissions only, ozone is discussed qualitatively, and visibility restrictions due to water vapour emissions are discussed quantitatively.

Table 2.4-1 Air Quality Impact Assessment Approach

Task	**Description**
1. Source Characterization	Because the Project is in an airshed shared by other sources, it is important to identify and characterize relevant emission sources. This task involved identifying industrial sources in the RSA (i.e., within a nominal 25 km radius) and community sources in the model domain. Information from recent EIAs and from the FAP database was used as a starting point to characterize industrial facilities. Additional industrial source information for the major east Edmonton facilities was included. Community and traffic sources, collectively referred to as urban sources, were obtained from the Environment Canada (EC) 2000 emission inventory, which is the most recent year available. Emissions were defined for the Baseline, Application and Cumulative cases (Appendix 2A).
2. Review of Ambient Air Quality Measurements	The FAP operates eight continuous ambient air quality stations and ten passive monitoring sites in the area. Continuous data for the 48-month period (January 2003 to December 2006), and passive data for the 18-month period (July 2005 to December 2006) were reviewed. Data collected from a VOC monitoring program conducted by FAP and Environment Canada (EC) (September 2004 to March 2006) were also reviewed. As precipitation chemistry and deposition information is not available for the region, data from AENV and EC monitoring programs outside the study area, and Western Canada model predictions undertaken by AENV were reviewed to determine existing levels. The detailed review of this information is presented in Appendix 2B.
3. Terrestrial Characterization	The airshed is bisected by a river valley with a southwest to northeast orientation. Higher terrain occurs in the areas of Elk Island National Park and Bon Accord. Digital terrain data were used to account for terrain elevation changes in the RSA. The nature of the surface will affect the deposition of pollutants. Land surface features were taken from satellite data. The nature of the surface was grouped according to the following land use classes: agricultural (80%), forested (6%), rangeland (7%), urban (4%) and water (3%) (based on the 125 km x 125 km CALMET domain). Detailed terrain information is presented in Appendix 2C.
4. Meteorological Characteristics	The CALMET meteorological model was used to generate three-dimensional meteorological fields for a 1-year (2002) period (Appendix 2C). The model used MM5 data processed by EC for a 12-km grid spacing and concurrent surface meteorological data from the FAP monitoring locations. Appendix 2C also provides a review of representative climate for the region.
5. Model Approach	The model selection and the associated assumptions about the model application are provided in Appendix 2D. The CALPUFF model was selected and model predictions are compared with FAP ambient air quality measurements to provide an indication of the model performance (Appendix 2D).
6. Model Application	The CALPUFF model was used to predict the transport, dispersion, chemical transformation and deposition from the emissions sources identified in Appendix 2A. The model predicted 1 hour, 24-hour and annual average concentration patterns (i.e., SO_2, NO_2, CO and $PM_{2.5}$) and annual potential acid input (i.e., PAI) and nitrogen deposition patterns. Model results for the Project only case are presented in Appendix 2E.
7. Air Assessment	The predicted concentrations and depositions are compared with respective ambient criteria in Section 2.3.

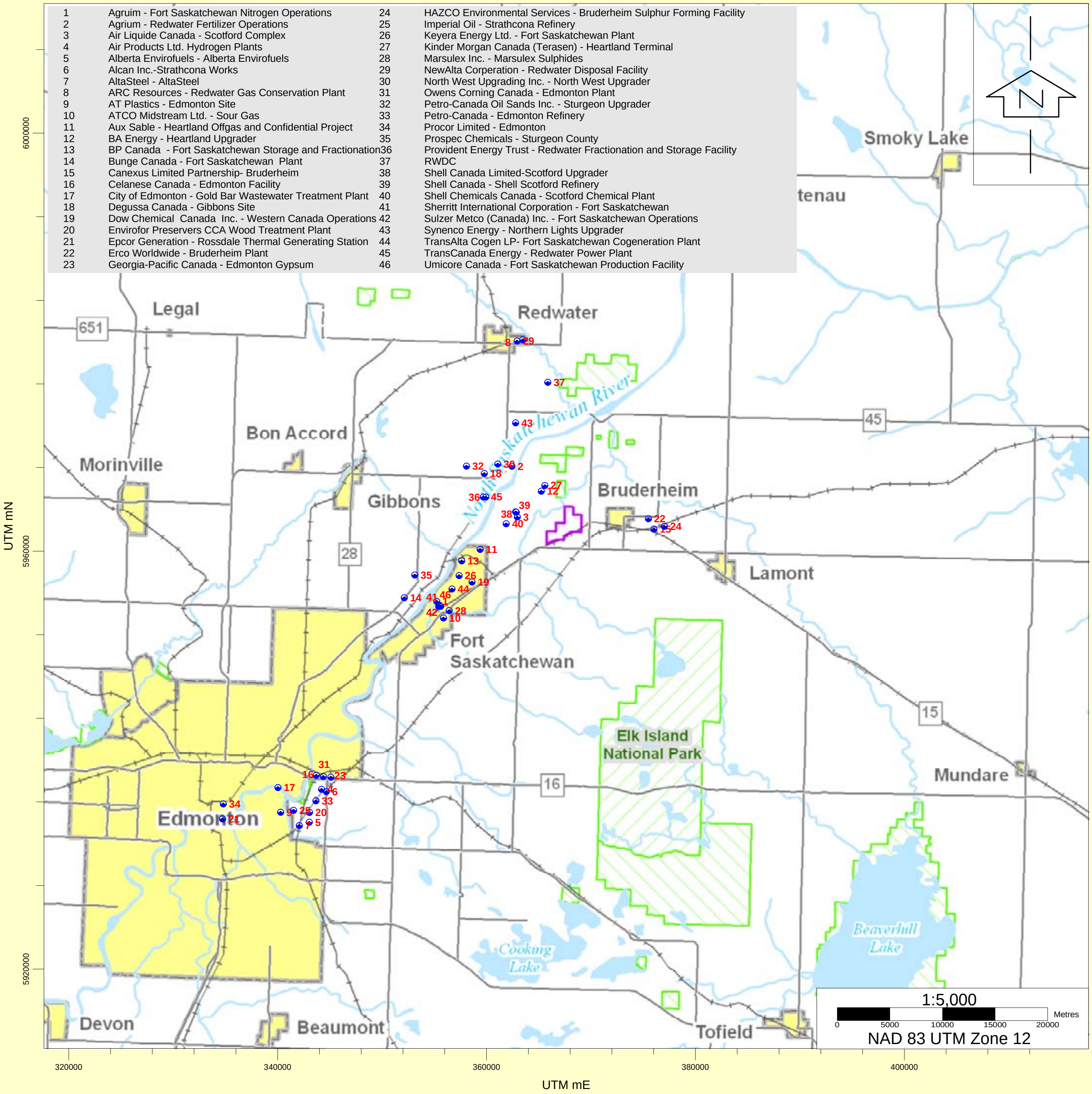
Table 2.4-2 Substances Evaluated for the Project

Substance	Substance Type	Assessment Format
SO_2	Other, Criteria	50 km x 50 km RSA, Discrete Receptor
NO_2	Other, Criteria	50 km x 50 km RSA, Discrete Receptor
$PM_{2.5}$	Other, Criteria	50 km x 50 km RSA, Discrete Receptor
PAI	Deposition	80 km x 80 km DSA
Nitrogen (N)	Deposition	80 km x 80 km DSA
Carbon Dioxide (CO_2)	GHG	Emission Only
Methane	GHG	Emission only
Water (H_2O)	Visibility	Fogging, height of visible plume
Ozone (O_3)	Other, Criteria	Qualitative
CO	Other, Criteria	Discrete Receptor
H_2S	RSC, Criteria	Discrete Receptor
CS_2	RSC, Criteria	Discrete Receptor
COS	RSC	Discrete Receptor
Mercaptan group	RSC	Discrete Receptor
Thiophene group	RSC	Discrete Receptor
1,3-butadiene	VOC	Discrete Receptor
2-chloronaphthalene	PAH	Discrete Receptor
2-methylnaphthalene	PAH	Discrete Receptor
Acenaphthene	PAH	Discrete Receptor
Acetaldehyde	VOC, Criteria	Discrete Receptor
Acrolein	VOC	Discrete Receptor
Aliphatic alcohols	VOC	Discrete Receptor
Aliphatic aldehydes	VOC	Discrete Receptor
Aliphatic ketones	VOC	Discrete Receptor
Ammonia	Other, Criteria	Discrete Receptor
Anthracene	PAH	Discrete Receptor
Benzaldehyde	VOC	Discrete Receptor
Benzene	VOC, Criteria	Discrete Receptor
Benzo(a)anthracene	PAH	Discrete Receptor
Benzo(a)pyrene	PAH	Discrete Receptor
Benzo(b)fluoranthene	PAH	Discrete Receptor
Benzo(e)pyrene	PAH	Discrete Receptor
Benzo(g,h,i)perylene	PAH	Discrete Receptor
Benzo(k)fluoranthene	PAH	Discrete Receptor
Biphenyl	VOC	Discrete Receptor
C_{17}+ aliphatic group	VOC	Discrete Receptor
C_{17}-C_{34} Aromatics	VOC	Discrete Receptor
C_5-C_8 aliphatics	VOC	Discrete Receptor
C_9-C_{16} Aromatics	VOC	Discrete Receptor
C_9-C_{18} aliphatics	VOC	Discrete Receptor
Chrysene	PAH	Discrete Receptor
Cyclohexane	VOC	Discrete Receptor
Dibenz(a,h)anthracene	PAH	Discrete Receptor
Dichlorobenzene	VOC	Discrete Receptor

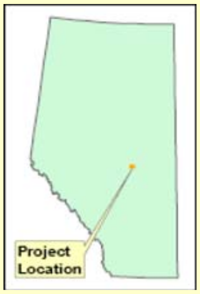
Substance	**Substance Type**	**Assessment Format**
Diethanolamine	VOC	Discrete Receptor
Ethylbenzene	VOC, Criteria	Discrete Receptor
Fluoranthene	PAH	Discrete Receptor
Fluorene	PAH	Discrete Receptor
Formaldehyde	VOC, Criteria	Discrete Receptor
Hexane	VOC	Discrete Receptor
Indeno(1,2,3-cd)pyrene	PAH	Discrete Receptor
Isopropylbenzene	VOC	Discrete Receptor
Methylene chloride	VOC	Discrete Receptor
Naphthalene	PAH	Discrete Receptor
Phenanthrene	PAH	Discrete Receptor
Propylene Oxide	VOC	Discrete Receptor
Pyrene	PAH	Discrete Receptor
Styrene	VOC, Criteria	Discrete Receptor
Toluene	VOC, Criteria	Discrete Receptor
Xylenes	VOC, Criteria	Discrete Receptor

Notes:

Criteria = substances for which there are AAAQO or CWS.
RSC = Reduced sulphur compound.
VOC = Volatile organic compound.
PAH = Polycyclic aromatic hydrocarbon.
GHG = Greenhouse gas.
Other = primarily inorganic and/or combustion related.



1	Agruim - Fort Saskatchewan Nitrogen Operations	24	HAZCO Environmental Services - Bruderheim Sulphur Forming Facility
2	Agrium - Redwater Fertilizer Operations	25	Imperial Oil - Strathcona Refinery
3	Air Liquide Canada - Scotford Complex	26	Keyera Energy Ltd. - Fort Saskatchewan Plant
4	Air Products Ltd. Hydrogen Plants	27	Kinder Morgan Canada (Terasen) - Heartland Terminal
5	Alberta Envirofuels - Alberta Envirofuels	28	Marsulex Inc. - Marsulex Sulphides
6	Alcan Inc.-Strathcona Works	29	NewAlta Corporation - Redwater Disposal Facility
7	AltaSteel - AltaSteel	30	North West Upgrading Inc. - North West Upgrader
8	ARC Resources - Redwater Gas Conservation Plant	31	Owens Corning Canada - Edmonton Plant
9	AT Plastics - Edmonton Site	32	Petro-Canada Oil Sands Inc. - Sturgeon Upgrader
10	ATCO Midstream Ltd. - Sour Gas	33	Petro-Canada - Edmonton Refinery
11	Aux Sable - Heartland Offgas and Confidential Project	34	Procor Limited - Edmonton
12	BA Energy - Heartland Upgrader	35	Prospec Chemicals - Sturgeon County
13	BP Canada - Fort Saskatchewan Storage and Fractionation	36	Provident Energy Trust - Redwater Fractionation and Storage Facility
14	Bunge Canada - Fort Saskatchewan Plant	37	RWDC
15	Canexus Limited Partnership- Bruderheim	38	Shell Canada Limited-Scotford Upgrader
16	Celanese Canada - Edmonton Facility	39	Shell Canada - Shell Scotford Refinery
17	City of Edmonton - Gold Bar Wastewater Treatment Plant	40	Shell Chemicals Canada - Scotford Chemical Plant
18	Degussa Canada - Gibbons Site	41	Sherritt International Corporation - Fort Saskatchewan
19	Dow Chemical Canada Inc. - Western Canada Operations	42	Sulzer Metco (Canada) Inc. - Fort Saskatchewan Operations
20	Envirofor Preservers CCA Wood Treatment Plant	43	Synenco Energy - Northern Lights Upgrader
21	Epcor Generation - Rossdale Thermal Generating Station	44	TransAlta Cogen LP- Fort Saskatchewan Cogeneration Plant
22	Erco Worldwide - Bruderheim Plant	45	TransCanada Energy - Redwater Power Plant
23	Georgia-Pacific Canada - Edmonton Gypsum	46	Umicore Canada - Fort Saskatchewan Production Facility



Legend

🟪 Project Property Line

● Industrial Facility

🟨 Community/Town

🟩 Natural Area

Title:

MAJOR INDUSTRIAL FACILITIES IN THE REGION

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 11/05/2007	
File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897 Other Emissions/Industrial inclusion_05Nov07.srf		
Drawn by: XC	Checked: MD	Fig. No.: 2.4-1

2.5 Existing Conditions

Relative to ambient air quality, meteorology determines the transport and dispersion processes in the atmosphere and ambient air quality measurements provide a direct indication of existing air quality.

2.5.1 Meteorology

Meteorology plays a major role in determining air quality levels downwind of industrial and non-industrial emission sources. Meteorological data from sites within and external to the RSA were reviewed, and the results were used for the CALMET meteorological model. The meteorological model was applied to the one year period January 1 to December 31, 2002. Upper-level meteorological data were obtained from EC based on the MM5 meso-scale model application to western Canada. Surface meteorological data were obtained from the FAP ambient air quality monitoring program. Appendix 2C provides identifies the data locations and the reviewed meteorological information. This information shows:

- A general tendency for regional winds (especially upper level) from the northwest. Depending on proximity to the NSR, which has a southwest to northeast orientation, there is also a tendency for winds from the southwest.
- Average wind speeds in the sheltered urban areas range from 2.0 m/s to 2.6 m/s (7 m/h to 9 m/h). In the more exposed rural areas, average wind speeds range from 3.2 m/s to 3.6 m/s (11 km/h to 13 km/h).
- Annual precipitation amounts appear to be relatively uniform over the region. Because of drought conditions, the 2002 precipitation was about one-half the longer-term average.
- The CALMET model predicted more frequent unstable conditions and less frequent stable conditions than would be expected, based on a traditional review of airport data. The CALMET model results were deemed to be representative, based on documented biases associated with the traditional approach.
- The predicted magnitude of the diurnal variation and the seasonal variation of the mixing heights using the CALMET model is consistent with the limited measurements in the region.

Details regarding the application of the CALMET model are provided in Appendix 2C. This meteorological model produced three-dimensional meteorological fields (e.g., winds, temperatures and turbulence) for the CALPUFF dispersion model.

2.5.2 Ambient Air Quality Measurements

Ambient air quality monitoring gives an indication of air quality levels from existing sources. This section provides an overview of the magnitude and trends derived from the ambient measurements.

2.5.2.1 Monitoring Locations

The FAP operates eight continuous ambient air quality stations in the region:

- three are located at or near communities (i.e., Fort Saskatchewan and Ross Creek Stations in Fort Saskatchewan and the Lamont Station near Lamont and Bruderheim);
- four are near industrial sources (i.e., the Station 401, Range Road 220, Scotford and Redwater Stations); and
- one is in a remote area (i.e., Elk Island National Park).

Ambient air quality data from these stations for the 48-month period January 1, 2003 to December 31, 2006 were reviewed to provide an indication of existing air quality in the region. Continuous ambient air quality measurements include those for SO_2, NO_2, $PM_{2.5}$, O_3, H_2S, ammonia (NH_3), CO and HC. Not all substances are measured at all stations. Passive SO_2, NO_2, and O_3 measurements were obtained from FAP for the 18-month period from July 2005 to December 2006. The passive samplers provide monthly average concentrations for each of the 18 months.

The FAP and EC carried out a VOC monitoring study where 24-hour air samples were collected once every six days from six locations in the region. The study was from September 12, 2004 to March 6, 2006 (19 months), and the air samples were analyzed for 150 VOC substances (EC, 2006).

The locations of these monitoring stations are shown in Figure 2.5-1.

2.5.2.2 Monitoring Summary

Ambient air quality exposures can vary widely with time due to the variability of the emissions and meteorological conditions. The continuous monitoring data, passive data, and VOC data were reviewed to determine maximum and mean values; and these values are summarized below. The monitoring data are presented in Appendix 2B.

SO_2 Concentrations

Elevated ambient 1-hour SO_2 concentrations have been measured near two stations (Redwater and Scotford). Exceedances of the 1-hour AAAQO (450 ug/m^3) were measured at both stations (forty-one at Redwater and one at Scotford), exceedances of the 24-hour AAAQO (150 ug/m^3) were measured at the Redwater station (four exceedances) and no annual exceedances were measured at any of the stations. The high ambient SO_2 concentrations were due to nearby industrial emissions and are very infrequent. The long-term average SO_2 concentrations at the two industry influenced stations were 6.8 and 8.6 ug/m^3. Long-term values at the other stations ranged from 1.4 ug/m^3 to 4.0 ug/m^3. The annual AAAQO is 30 ug/m^3.

NO_2 Concentrations

The highest NO_2 concentrations have been measured at the Ross Creek station, and these are attributed to traffic emissions. There were no exceedances of the 1-hour AAAQO (400 ug/m^3) at any stations, whereas one exceedance of the 24-hour AAAQO (200 ug/m^3) was measured at the Ross Creek station. The annual average NO_2 concentrations at the traffic influenced stations ranged from 20 ug/m^3 to 30 ug/m^3, and annual values at the other stations ranged from 6.5 ug/m^3 to 17.5 ug/m^3. The annual AAAQO is 60 ug/m^3.

$PM_{2.5}$ Concentrations

Elevated $PM_{2.5}$ concentrations (1-hour and 24-hour) have been observed in the region, at both industrial and rural areas. The long-term average $PM_{2.5}$ concentration ranged from 4.7 ug/m^3 at the Elk Island station to 8.2 ug/m^3 at the Redwater station. Rural-influenced site annual $PM_{2.5}$ values tend to range from 4.5 ug/m^3 to 11.48 ug/m^3 (Cheng et al. 2000).

The 98th percentile 24-hour $PM_{2.5}$ measurements are below the Surveillance Trigger of 15 ug/m^3 at the Elk Island station, but not at the other stations. In addition, 98th percentile 24-hour $PM_{2.5}$ measurements are below the Planning Trigger of 20 ug/m^3 at all but the Lamont station. The $PM_{2.5}$ measurements at all stations are less than the CWS of 30 ug/m^3. This review did not exclude natural sources and long-range transport contributions, and therefore may overstate the exceedances.

Alberta Environment (2006, 2007) reviewed $PM_{2.5}$ concentrations across Alberta and assigned a Surveillance Actions action level to the Edmonton CMA, and to the Fort Saskatchewan and Elk Island monitoring stations. No CMAs or individual stations were assigned a Management Plan action level. The Alberta Environment reviews excluded natural sources and long-range transport contributions.

O_3 Concentrations

A review of 17 years of O_3 data from the Fort Saskatchewan station shows that one year (1996) was above the 3-year CWS (127 ug/m^3). A review of 4 years of O_3 data from the Lamont and Elk Island monitoring stations provides values for 2005 and 2006 that can be compared to the 3-year CWS. The 3-year CWS was not exceeded at either site for either year. The Planning Trigger of 113 ug/m^3, however, has been exceeded at all three stations. This review did not exclude natural sources and long-range transport contributions, and therefore may overstate the exceedances.

Alberta Environment (2006, 2007) reviewed O_3 concentrations across Alberta and assigned a Management Plan action level to the Edmonton CMA and to the Fort Saskatchewan monitoring station. The Lamont and Elk Island monitoring stations were assigned a Surveillance Actions action level even though there is no surveillance trigger for O_3. The AENV reviews excluded natural sources and long-range transport contributions.

H_2S Concentrations

Exceedances of the 1-hour AAAQO (14 ug/m^3) have been measured at the Scotford (five) and Lamont (one) stations. Exceedances of the 24-hour AAAQO (4 ug/m^3) were measured at the Scotford (one) and Fort Saskatchewan (one) stations. The ambient H_2S concentrations are associated with fugitive industrial emission sources.

NH_3 Concentrations

The highest 1-hour average values at each site ranged from 279 ug/m^3 to 1,267 ug/m^3. The highest ambient NH_3 concentrations have been measured near the fertilizer manufacturing facilities. There were no exceedances of the 1-hour AAAQO (1,400 ug/m^3) for NH_3. The long-term average near the fertilizer facilities was 9.6 ug/m^3, whereas the long-term averages for the other sites ranged from 0.3 ug/m^3 to 3.3 ug/m^3.

CO Concentrations

Ambient CO concentrations are only measured at the Fort Saskatchewan station. The maximum measured 1-hour value (3,663 ug/m^3) is less than the 1-hour AAAQO (15,000 ug/m^3) for CO. The maximum measured 8-hour value (2,432 ug/m^3) is less than the 8-hour AAAQO (6,000 ug/m^3) for CO.

VOC Substances

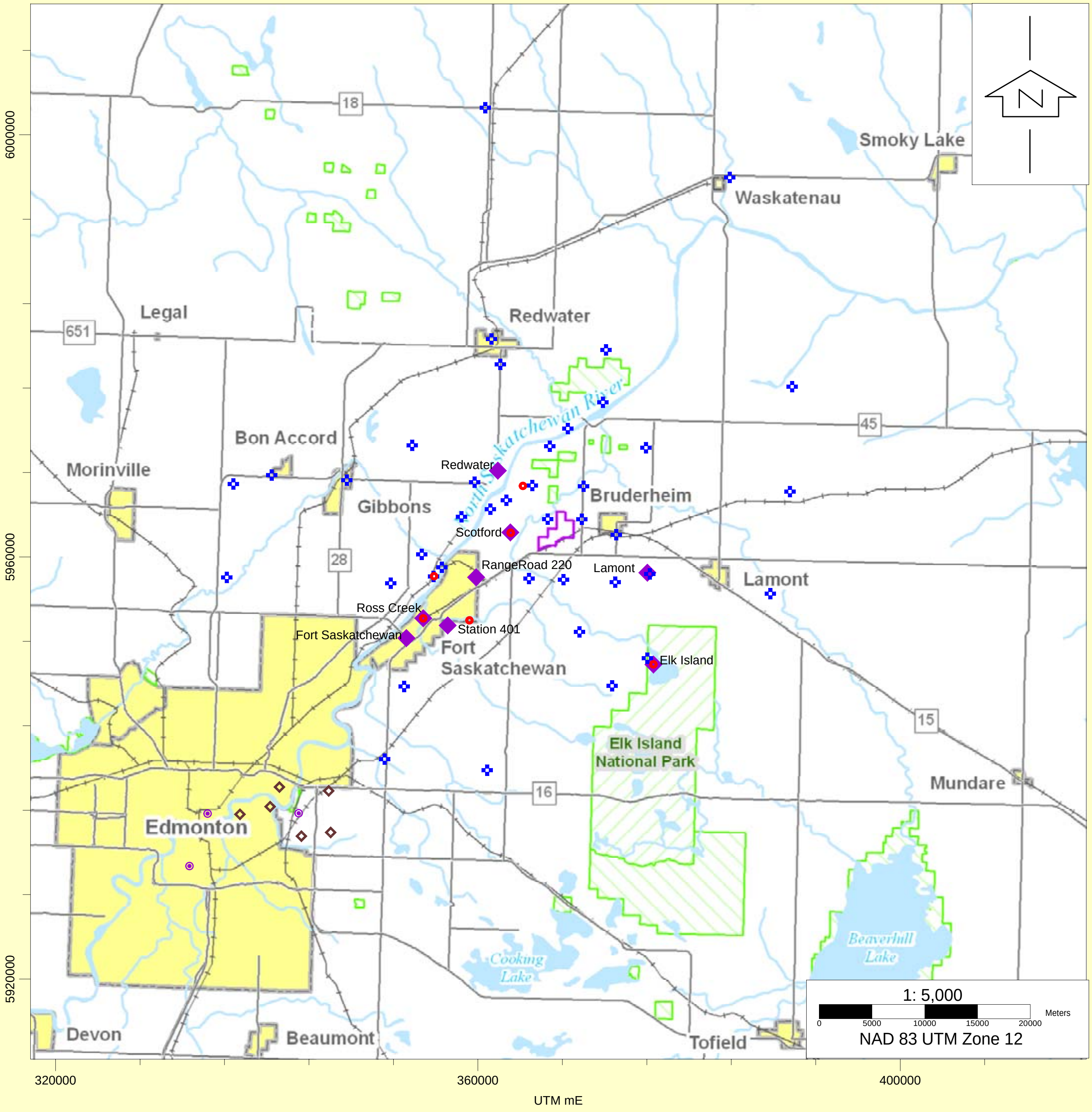
The 150 substances were summarized into 14 groups based on expected project emissions and associated human health responses. Some of the highest concentration groups (i.e., 1,3-butadiene, C_5-C8 aliphatics, dichlorobenzene, hexane, C_3-C_5, and xylenes) were associated with traffic influenced sites, whereas others (e.g., benzene, ethylbenzene, and styrene) were associated with industry influenced sites. In general, the lowest concentrations were measured at the remote Elk Island site. The maximum toluene and xylene concentrations are well below the respective AAAQO. There are no 24-hour AAAQO for the other VOC substances that were measured.

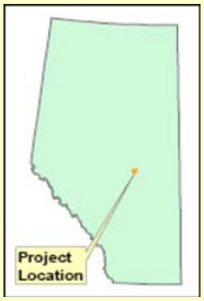
PAI Deposition

There are challenges in determining a representative PAI value for the region. Given the absence of representative measurements for the area, measurements external to the region and model predictions (i.e., RELAD) for western Canada were used to infer a value for the area. Regional average estimates based on measurements and the AENV regional scale RELAD model predictions indicate a representative existing PAI of about 0.19 keq H^+/ha/y. The predictions include the neutralizing effect of base cations (wet plus dry), which is estimated to be about 0.14 keq H^+/ha/y (Chaikowsky, 2001).

Ambient Air Quality Summary

In summary, the air quality in the Fort Saskatchewan area is consistent with the local influences of industrial and urban emissions. The area has a comprehensive monitoring program that can be used to identify current conditions and track changes over time.





Legend

- ◇ Strathcona Industrial Association
- ◆ FAP Continuous
- ✚ FAP Passive
- ○ FAP VOC
- ◉ Edmonton Monitoring

Title:

AIR QUALITY MONITORING SITES IN THE REGION

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 11/05/07

File:
H:/AQ/Shared/1018897 NAOSC Matrix/
N8897 Coordinates/receptors/
monitoring station_05Nov07.srf

Drawn by: XC	Checked: MD	Fig. No.: **2.5-1**

2.6 Mitigation and Project/Regional Emissions

2.6.1 Mitigation Measures

2.6.1.1 Construction Emission Control

During construction, any cleared vegetation will be mulched rather than burned to reduce smoke emissions. Also, to reduce the potential for wind-blown dust under dry, windy conditions, the following mitigation measures will be used:

- Wet suppression will be used to control open dust sources.
- Temporary access routes and parking lots within the site will be constructed to reduce emissions. Gravel roadways and parking lots will reduce PM emissions relative to bare soil surfaces. Fugitive dust emissions can be further reduced by chemical stabilization for semi-permanent or relatively long-term unpaved roads or parking lots.
- The early paving of permanent access roads will also reduce fugitive dust emissions.
- Bus transport will be made available to construction workers to reduce emissions associated with the use of individual vehicles to reduce commuting emissions. A no-idling policy will be introduced to control bus and vehicle emissions.
- Track-out controls will be implemented to prevent soil and mud from being spread onto public roadways by trucks and other vehicles entering and leaving the Project site.

2.6.1.2 Operations Emission Control

A number of mitigation measures will be implemented to control emissions to the atmosphere during operations:

- The SRUs for the Project are designed for a sulphur recovery efficiency of 99.9% with an expected annual average recovery of 99.8%. On a quarterly basis, the expected minimum sulphur recovery for each SRU/TGTU complex is 99.5%.
- The heaters and furnaces will be fired with plant fuel gas and supplemented with natural gas when necessary. The sulphur content of the plant fuel gas will be 25 ppm (as H_2S equivalent) or less.
- The furnaces and combustion turbine units will be designed to be more stringent than the CCME guidelines for NO_X and CO emissions. That is, low-NO_X burners will be used to reduce flue gas NO_x emissions, and, where technically feasible, the Project will use ultra-low NO_X burners.
- Storage tanks carrying a sour product will be tied into a vapour recovery system or pressurized storage to reduce fugitive emissions associated with the handling and storage of intermediate and final product. A vapour control efficiency of 95% was assumed for tanks with vapour recovery.
- A Leak Detection and Repair (LDAR) Program will be implemented to identify and reduce fugitive emissions.

- Operations will be managed to control the duration and frequency of major upset flaring events. A detailed flare management plan will be prepared after commissioning to reflect actual operating conditions. Mitigation features will include limiting duration and adding supplementary natural gas.

Although ambient air monitoring is not a mitigation measure, feedback from ambient monitoring programs will provide valuable feedback for improving emission performance.

2.6.1.3 Greenhouse Gas Emission Control

Controls specific to the management of GHG emissions will include:

- Pre-heating combustion air to increase combustion efficiency;
- Insulating of transport pipelines and hot process vessels to conserve energy;
- Installing of thermally efficient heaters, furnaces and boilers; and
- Implementing an LDAR program to control and reduce fugitive methane emissions.

During operations, the Project will continue to explore ways to reduce GHG emissions. With appropriate regulatory and fiscal regimes in place, there is the potential to capture and sequester CO_2 from this Project when the gasification units are commissioned. A Greenhouse Gas Management Plan will be developed to meet regulatory requirements (EC, 2007).

2.6.2 Project Emissions

2.6.2.1 Construction Emissions

Dust emissions from construction activities could have a temporary effect on local air quality. These emissions are associated with land clearing, ground excavation, cut and fill operations and equipment traffic on the site. Generally, fugitive dust emissions are: (1) proportional to the disturbed land area and the level of construction activity; (2) limited to periods of the day and week when the construction activities take place; and (3) can vary substantially from day to day with varying meteorological conditions. Under dry, windy conditions, wet suppression can be used to control these fugitive dust sources.

TSP emissions from construction activities (based on a medium level of activity and semi arid conditions) can be estimated from (U.S. EPA, 1995):

$$\text{TSP (t/d)} = 2.69 \times A / 30$$

where A is the area (ha) of the activity. This relationship is based on one set of field studies and therefore has a large level of uncertainty and conservativeness associated with it. The TSP emission rate is 0.18 t/d based on a 1 ha area of active construction over a nominal daytime (i.e., 12 hour) period.

TSP includes all size fractions. Particles larger than 100 um in diameter are likely to fall out within 6 m to 9 m from the point of emission. Particles between 30 um and 100 um in diameter are likely to fall out within 60 m of the point of emission. The U.S. EPA (1995) indicates that there are no factors for the indicated emission equation that can relate the TSP emission estimation to a $PM_{2.5}$ emission. Application of the U.S. EPA section on unpaved road emissions for industrial roads, however, indicates about 30% of the TSP can be expected to be in the PM_{10} size fraction, and about 3% of the TSP can be expected to be in the $PM_{2.5}$ size fraction. On this basis, the respective PM_{10} and $PM_{2.5}$ emission rates are 0.054 t/d and 0.005 t/d, respectively.

Vehicles on the Project site are also sources of exhaust emissions. Construction activities such as welding, use of solvents, sand blasting and painting can also affect air quality in the construction area. These emissions are considered minimal.

During the construction period, a proposed concrete batch plant will be direct (i.e., fugitive dust emissions) and indirect (i.e., truck emissions) sources of on-site emissions. Given the need for concrete at the site, the net on-site and off-site emissions associated with the delivery of concrete are expected to be reduced due to reduced trucking needs, assuming aggregate and cement are brought to the site by rail.

2.6.2.2 Operation Emissions

The Project will be serviced by 27 conventional stacks and 11 flares. Fugitive emissions will result from 28 storage tanks and ancillary facilities, and from 13 identified process areas. One of the identified process areas will include sulphur handling facilities comprised of sulphur forming, pastille storage and loading components. The Project will also be serviced by one cooling tower. Table 2.6-1 provides a summary of the emissions from the Project, and more detailed information is provided in Appendix 2A (Section 2A.4). The following general comments can be made with respect to the emissions.

Sulphur Dioxide Emissions

The main source of SO_2 emissions are the five SRU/TGTU incinerator stacks. The SO_2 emissions will vary with the sulphur recovery efficiency for each SRU/TGTU complex. The AAAQO for SO_2 are specified for annual, 24-hour and 1-hour averaging periods. To provide a realistic estimate of Project SO_2 emissions on ambient air quality, it is desirable to select SO_2 emission rates that are appropriate for each averaging period. For a facility serviced by a single SRU/TGTU complex, the maximum 24-hour SO_2 emission rate is typically derived from a 99.5% sulphur recovery (i.e., a 0.3% decrease for a quarterly sulphur recovery). Similarly, the maximum 1-hour SO_2 emission rate is typically based on the 24-hour rate times 1.4.

However, for a facility that is serviced by five independent SRU/TGTU complexes, adopting this approach for all complexes is viewed as unrealistic as it is unlikely that all five complexes will simultaneously experience abnormal operating conditions. Table 2.6-2 shows the estimated SO_2 emissions for the following cases:

- Based on the AENV/EUB ID 2001-3 guidelines, the maximum annual and 24-hour average SO_2 emissions would be 43.48 t/d and 54.25 t/d, respectively. This is based on overall sulphur recovery efficiencies of 98.79% and 98.49%, respectively.
- Based on the Upgrader design, the annual average SO_2 emissions are expected to be 7.18 t/d, based on a sulphur recovery efficiency of 99.8%.
- SO_2 emission rates were calculated for a number of abnormal cases based on the application of the 0.3% sulphur recovery difference and the 1.4 factor to some of the complexes. The corresponding SO_2 emission rates range from 7.18 t/d to 17.98 t/d (Table 2.6-2), depending on the assumption for each individual SRU/TGTU complex.

- Given the variability in the SO_2 emission depending on the assumed SRU/TGTU sulphur recovery efficiency, the following SO_2 emission rates were selected to provide an indication of the Project impact on ambient air quality:

- For the purposes of estimating annual average SO_2 concentrations and PAI deposition, the annual average SO_2 emission rate is based on the 99.8% sulphur recovery assumption. The corresponding SO_2 emission rate from the five SRU/TGTU facilities operating at this rate is 7.18 t/d. The total Project SO_2 emissions for this case are 7.34 t/d.

- For the purposes of estimating 24-hour and 1-hour average SO_2 concentrations, the 24-hour and 1-hour average SO_2 emission rates are based on the 99.5% sulphur recovery assumption. The corresponding SO_2 emission rate from the five SRU/TGTU facilities operating at this rate is 17.98 t/d. This is viewed as conservative (i.e., overstating the SO_2 emissions) as it is unlikely that all SRU/TGTU complexes will simultaneously be operating as low as 99.5%. The total Project SO_2 emissions for this case are 18.14 t/d.

The preceding discussion focuses solely on the SO_2 emissions from the SRU/TGTU incinerator stacks and is not applicable to the sulphur content of the fuel used to fire the various heaters, furnaces and boilers. The SO_2 emission from these units will overlap with the SO_2 emissions from the five SRU/TGTU incinerator stacks.

Other Emissions

Comments with respect to other emissions associated with the Project include:

- The NO_x emissions are projected to be 3.45 t/d. Most of the NO_x emissions result from the various process heaters and furnaces.

- The CO emissions are projected to be 2.48 t/d. Most of the CO emissions result from the various process heaters and furnaces.

- The $PM_{2.5}$ emissions are projected to be 0.42 t/d. Virtually all the $PM_{2.5}$ emissions result from the various process heaters and furnaces.

- The VOC/PAH emissions for the substances of interest (Table 2.4-2) are projected to be 0.90 t/d. Most of these VOC/PAH emissions result from storage tank and fugitive process area sources. The total C2+ hydrocarbon emissions for the Project are projected to be 1.53 t/d.

- The H_2S emissions are projected to be 0.26 t/d. About 77% of the H_2S emissions result from the thermal oxidizer stacks, and the others are from fugitive sources.

- The RSC emissions are projected to be 0.77 t/d. About 88% of the RSC emissions result from the thermal oxidizer stacks, and the others are from fugitive sources.

- The water vapour emissions are projected to be 12,406 t/d; with 67% resulting from the cooling tower and the remaining 33% from the combustion sources.

- The CO_2 equivalent (CO_2e) emissions are projected to be 8,181 t/d. This emission rate assumes CO_2 capture on the gasification units. Virtually all the CO_2e emissions result from combustion sources.

Short-term flaring events can result in large volumes of SO_2 being discharged to the atmosphere. The largest volumes are associated with the hydrocarbon flare stacks. The major events are infrequent (i.e., once every two years) and of short duration (i.e., less than 30 minutes). Equivalent 1-hour average SO_2 emission rates can range from 0.002 to 25.66 t/h for these flaring events.

2.6.3 Regional Emissions

Tables 2.6-3, 2.6-4 and 2.6-5 summarize the Regional emissions from a 100 km x 100 km area centred on the project site for the Baseline, Application and Cumulative Case development scenarios, respectively.

2.6.3.1 Baseline Case

The Baseline Case includes the approved but not yet operating BA Energy Heartland Oil Sands Bitumen Upgrader and the Shell Canada Scotford Upgrader Expansion 1. The following comments can be made with respect to the Baseline Case emissions (Table 2.6-3):

- The long-term Baseline Case SO_2 emissions due to Fort Saskatchewan industrial facilities are 61.11 t/d. As the BA Energy Heartland Oil Sands Bitumen Upgrader is not operating, and the current Scotford Upgrader emissions are more typically 18.95 t/d on a long-term basis (based on 1995 NPRI), the existing industrial SO_2 emissions in Fort Saskatchewan are therefore about 29.3 t/d. For the Baseline Case, industry is the main source of SO_2 emissions, with 61.11 t/d and 31.8 t/d from Fort Saskatchewan and Edmonton facilities, respectively. Industry accounts for about 95% of the regional emissions.

- The long-term Baseline Case NO_x emissions due to Fort Saskatchewan industrial facilities are 44.95 t/d. As the BA Energy Heartland Oil Sands Bitumen Upgrader is not operating, and the current Scotford Upgrader emissions are more typically 2.54 t/d on a long-term basis (based on 1995 NPRI), the existing industrial NO_x emissions in Fort Saskatchewan are about 33.6 t/d. Baseline Case Fort Saskatchewan and Edmonton industry NO_x emissions are 44.95 t/d and 26.7 t/d, respectively. Industry accounts for about 29% of the regional emissions, with the rest originating from urban sources (71%).

- The CO, $PM_{2.5}$ and VOC/PAH emissions are similar to the NOx emissions in that most of the emissions originate from urban sources (93% for CO, 63% for $PM_{2.5}$, and 93% for VOC/PAH). All the H_2S emissions were assumed to originate from Fort Saskatchewan upgrader sources.

2.6.3.2 Application Case

Relative to the Baseline Case, the Application Case will increase the emissions due to the Project into the airshed as follows (Table 2.6-4):

- Depending on the averaging time period, the Project is expected to increase regional SO_2 emissions from 103 to 121 t/d (short-term basis) and from 98 t/d to 106 t/d (long-term basis).

- The Project is expected to increase regional NO_x, CO, $PM_{2.5}$ and VOC/PAH emissions between 0.3% and 2.2%, depending on substance.

- The Project is expected to increase Fort Saskatchewan industrial H_2S emissions from 0.7 t/d to 1.0 t/d. Out of the three upgraders for which H_2S emission information is available, the Project accounts for 27% of the H_2S emissions.

2.6.3.3 Cumulative Case

The main additional emission sources for the Cumulative Case include the North West Bitumen Upgrader, the Synenco Northern Lights Upgrader, the Petro-Canada Oil Sands Inc. Sturgeon Upgrader, and the Shell Canada Scotford Upgrader 2. Relative to the Baseline Case, the Cumulative Case will increase emissions into the airshed as follows (Table 2.6-5):

- Depending on the averaging period considered, the future projects are expected to increase regional SO_2 emissions by 103 t/d to 201 t/d (short-term basis), and from 98 t/d to 170 t/d (long-term basis). The long-term Cumulative Case SO_2 emission rates are likely overstated since some of the proposed upgrader applications appear to be using higher SO_2 emission rates to evaluate annual average concentrations and depositions in order to be conservative.

- The future projects are expected to increase regional NO_x, CO, $PM_{2.5}$ and VOC/PAH emissions between 5% and 17%, depending on substance.

- The future projects are expected to increase Fort Saskatchewan industrial H_2S emissions from 0.7 t/d to 1.4 t/d.

In summary, the Project and the other proposed upgraders will have an influence on regional Cumulative Case SO_2 and H_2S emissions. Urban NO_x, CO, $PM_{2.5}$ and VOC/PAH emissions are presently larger, and will continue to be larger, than the corresponding industrial emissions.

Table 2.6-1 Summary of Operational Emissions Associated with the Project

Substance (t/d)	Conventional Stacks	Flare Stacks	Sub-total Stacks	Storage Tanks	Process Areas	Sub-total Fugitive	Cooling Tower	Total
Common Air Contaminants								
SO_2 (1-h and 24-h) (t/d)	18.13	0.0008	18.13	0	0.009	0.009	0	18.14
SO_2 (Annual average) (t/d)	7.34	0.0008	7.34	0	0.0003	0.0003	0	7.34
NO_x (t/d)	2.99	0.03	3.02	0	0.428	0.428	0	3.45
CO (t/d)	2.33	0.03	2.36	0	0.127	0.127	0	2.48
$PM_{2.5}$ (t/d)	0.41	0.0006	0.41	0	0.013	0.013	0	0.42
HC and RSC Substances								
VOC/PAH substances (t/d)	0.19	0.06	0.25	0.39	0.26	0.65	0	0.90
H_2S (t/d)	0.20	0	0.20	0.020	0.043	0.063	0	0.26
RSC (t/d)	0.68	0	0.68	0.027	0.060	0.087	0	0.77
Water Vapour								
H_2O (t/d)	4,019	26.65	4046	0	0	0	8360	12406
Greenhouse Gas Emissions								
CO_2 (t/d)	8,035	46.87	8082	0	30.88	30.88	0	8,113
Methane (t/d)	0.16	0.0009	0.16	0.060	0.95	1.01	0	1.17
N_2O (t/d)	0.14	0.0008	0.14	0	0.0004	0.0004	0	0.14
CO_{2e} (t/d)	8,082	47.1	8129	1.3	51.0	52.2	0	8,181

Note:
Emissions from Process areas include the sulphur handling area emissions.

Table 2.6-2 Sensitivity of Project SO_2 Emission Rates to Sulphur Recovery Efficiencies

Case	SRU/TGTU SO_2 Emission Rate (t/d)						Scenario Description
	UP1	UP2	UP3	GAS1	GAS2	All	
A	1.89	1.89	1.89	0.76	0.76	7.18	Annual Project Case = 99.8%
B	1.89	1.89	1.89	*1.91*	0.76	8.34	*1 GAS = 99.5%,* others = 99.8%
C	1.89	1.89	1.89	*2.67*	0.76	9.10	*1 GAS = 99.5%x1.4,* others = 99.8%
D	*4.72*	1.89	1.89	0.76	0.76	10.02	*1 UP = 99.5%*, others = 99.8%
E	*4.72*	1.89	1.89	*1.91*	0.76	11.17	*1 UP and 1 GAS = 99.5%*, others = 99.8%
F	*6.60*	1.89	1.89	0.76	0.76	11.90	*1 UP = 99.5%x1.4*, others = 99.8%
G	*6.60*	1.89	1.89	*2.67*	0.76	13.81	*1 UP and 1 GAS = 99.5%x1.4*, others = 99.8%
H	4.72	4.72	4.72	1.91	1.91	17.98	1-h and 24-h Project Case = 99.5%
I	11.42	11.42	11.42	4.61	4.61	43.48	EUB 2003, Everything = 98.79% (Long-term)
J	14.25	14.25	14.25	5.75	5.75	54.25	EUB 2003, Everything = 98.49% (Quarterly)

Notes:
The three upgrader SRU/TGTU complexes are referred to as UP1, UP2 and UP3.
The two gasifier SRU/TGTU complexes are referred to as GAS1 and GAS2.
Case A assumes all SRU/TGTU complexes are operating at 99.8% and is used to represent the Project when calculating annual average SO_2 concentrations and PAI deposition.
Case H assumes all SRU/TGTU complexes are operating at 99.5% and is used to represent the Project when calculating 1-hour and 24-hour average SO_2 concentrations.

Table 2.6-3 Summary of Emissions (t/d) associated with Baseline Case Sources

Operator	Facility	Emission Rate (t/d)						
		SO_2 (short term)	SO_2 (long term)	NO_x	CO	$PM_{2.5}$	VOC/PAH	H_2S
Agrium Products	Fort Saskatchewan Fertilizer Plant	0.0045	0.0045	3.1680	0.6999	0.0169	0.0443	0.0000
Agrium Products	Redwater Fertilizer Plant	7.6580	4.1299	5.1060	1.2613	0.3847	0.3005	0.0000
Air Liquide Canada	Scotford Cogeneration Power Plant	0.0000	0.0000	0.4658	0.1476	0.0154	0.0209	0.0000
ARC Resources	Redwater Gas Conservation Plant	0.8001	0.8001	2.5759	1.8290	0.0280	0.0403	0.0000
ATCO Midstream	Fort Saskatchewan Sour Gas Plant	0.0007	0.0070	0.0174	0.0030	0.0013	0.0010	0.0000
Aux Sable	Heartland Off Gas Plant	0.0000	0.0000	0.1770	0.1490	0.0120	0.0097	0.0000
BA Energy	Heartland Oil Sands Bitumen Upgrader	19.4400	19.4400	4.6656	1.5600	0.4700	0.2566	0.4700
BP Canada Energy	Fort Saskatchewan Storage and Fractionation	1.0410	0.1294	0.2941	0.2474	0.0055	0.0162	0.0000
Canexus Limited Partnership	Bruderheim Sodium Chlorate Plant	0.0000	0.0000	0.0380	0.0030	0.0156	0.0021	0.0000
Degussa Canada (formerly DuPont)	Gibbons Hydrogen Peroxide Plant	0.0004	0.0004	0.0580	0.0480	0.0040	0.0032	0.0000
Dow Chemical Canada Inc.	Fort Saskatchewan Chemical Plant	0.1342	0.1342	5.5283	6.2630	0.8900	0.1865	0.0000
ERCO Worldwide	Bruderheim Sodium Chlorate Plant	0.0000	0.0000	0.0116	0.0098	0.0010	0.0006	0.0000
Keyera Energy Ltd.	Fort Saskatchewan Fractionation and Storage Plant	2.4000	2.4000	0.8350	0.0260	0.0250	0.0107	0.0000
Marsulex Inc.	Fort Saskatchewan Chemical Plant	0.6420	0.6420	0.0040	0.0030	0.0002	0.0060	0.0000
Newalta Corporation	Redwater Disposal Facility	0.0000	0.0000	0.0200	0.0170	0.0020	0.0011	0.0000
Prospec Chemicals	Fort Saskatchewan Xanthate Plant	0.0818	0.0818	0.0034	0.0500	0.0000	0.0002	0.0000
Provident Energy Trust	Redwater Fractionation and Storage Facility	0.7143	0.7143	0.2530	0.0580	0.0191	0.0139	0.0000
Redwater Water Disposal Company	Redwater Waste Disposal Facility	0.2740	0.2740	0.0000	0.0000	0.0000	0.0000	0.0000
Shell Canada Ltd.	Scotford Upgrader	31.2990	31.2990	9.2645	9.1941	0.8226	0.5095	0.1927
Shell Canada Ltd.	Scotford Refinery	0.0040	0.0040	1.4320	1.0121	0.1970	0.0975	0.0000
Shell Chemicals Canada	Scotford Styrene & MEG Plant	0.1168	0.1168	2.7336	1.1970	0.3496	0.1503	0.0000
Sherritt International Corporation	Fort Saskatchewan Fertilizer and Metal Plant	0.9044	0.9044	7.6667	0.5913	0.0280	0.2579	0.0000
TransAlta Cogeneration LP	Fort Saskatchewan Cogeneration Plant	0.0300	0.0300	0.2900	0.2600	0.0200	0.0200	0.0000
TransCanada Energy	Redwater Cogeneration Facility	0.0000	0.0000	0.3451	0.1200	0.0100	0.0081	0.0000
Umicore Canada	Fort Saskatchewan Metal & Chemical Manufacturing Plant	0.0000	0.0000	0.0000	0.0000	0.0300	0.0000	0.0000
FAP Industrial Fugitive Emissions	All	0.0000	0.0000	0.0000	0.0000	0.039	3.262	0.0307
Sub-Total FAP (t/d)		**65.55**	**61.11**	**44.95**	**24.75**	**3.39**	**5.22**	**0.69**
Edmonton Industrial Sources	All (See Appendix 2A, Section 2A.6)	31.80	31.80	26.70	38.10	3.72	-	-
Sub-Total FAP and Edmonton Industrial (t/d)		**97.35**	**92.91**	**71.65**	**62.85**	**7.11**	**5.22**	**0.69**
Urban Sources	Traffic and Heating	5.25	5.25	177.40	916.10	12.10	73.3	0.0
Baseline Case Total (FAP and Edmonton Industrial and Urban Sources) (t/d)		**102.60**	**98.16**	**249.05**	**978.95**	**19.21**	**78.52**	**0.69**

Notes:
This table does not include the North West Bitumen Upgrader that became conditionally approved since the assessment was undertaken.
Short term = SO_2 emission rates used to evaluate 1-hour and 24-hour concentrations.
Long term = SO_2 emission rates used to evaluate annual average concentrations and deposition.

Table 2.6-4 Summary of Emissions (t/d) Associated with Application Case Sources

Operator	Facility	Emission Rate (t/d)						
		SO_2 (short term)	SO_2 (long term)	NO_x	CO	$PM_{2.5}$	VOC/PAH	H_2S
Agrium Products	Fort Saskatchewan Fertilizer Plant	0.0045	0.0045	3.1680	0.6999	0.0169	0.0443	0.0000
Agrium Products	Redwater Fertilizer Plant	7.6580	4.1299	5.1060	1.2613	0.3847	0.3005	0.0000
Air Liquide Canada	Scotford Cogeneration Power Plant	0.0000	0.0000	0.4658	0.1476	0.0154	0.0209	0.0000
ARC Resources	Redwater Gas Conservation Plant	0.8001	0.8001	2.5759	1.8290	0.0280	0.0403	0.0000
ATCO Midstream	Fort Saskatchewan Sour Gas Plant	0.0007	0.0070	0.0174	0.0030	0.0013	0.0010	0.0000
Aux Sable	Heartland Off Gas Plant	0.0000	0.0000	0.1770	0.1490	0.0120	0.0097	0.0000
BA Energy	Heartland Oil Sands Bitumen Upgrader	19.4400	19.4400	4.6656	1.5600	0.4700	0.2566	0.4700
BP Canada Energy	Fort Saskatchewan Storage and Fractionation	1.0410	0.1294	0.2941	0.2474	0.0055	0.0162	0.0000
Canexus Limited Partnership	Bruderheim Sodium Chlorate Plant	0.0000	0.0000	0.0380	0.0030	0.0156	0.0021	0.0000
Degussa Canada (formerly DuPont)	Gibbons Hydrogen Peroxide Plant	0.0004	0.0004	0.0580	0.0480	0.0040	0.0032	0.0000
Dow Chemical Canada Inc.	Fort Saskatchewan Chemical Plant	0.1342	0.1342	5.5283	6.2630	0.8900	0.1865	0.0000
ERCO Worldwide	Bruderheim Sodium Chlorate Plant	0.0000	0.0000	0.0116	0.0098	0.0010	0.0006	0.0000
Keyera Energy Ltd.	Fort Saskatchewan Fractionation and Storage Plant	2.4000	2.4000	0.8350	0.0260	0.0250	0.0107	0.0000
Marsulex Inc.	Fort Saskatchewan Chemical Plant	0.6420	0.6420	0.0040	0.0030	0.0002	0.0060	0.0000
Newalta Corporation	Redwater Disposal Facility	0.0000	0.0000	0.0200	0.0170	0.0020	0.0011	0.0000
North American Oil Sands	***Project (stack emissions)***	***18.13***	***7.34***	***3.02***	***2.36***	***0.41***	***0.25***	***0.20***
	Project (fugitive emissions)	***0.009***	***0.0003***	***0.428***	***0.127***	***0.013***	***0.65***	***0.063***
Prospec Chemicals	Fort Saskatchewan Xanthate Plant	0.0818	0.0818	0.0034	0.0500	0.0000	0.0002	0.0000
Provident Energy Trust	Redwater Fractionation and Storage Facility	0.7143	0.7143	0.2530	0.0580	0.0191	0.0139	0.0000
Redwater Water Disposal Company	Redwater Waste Disposal Facility	0.2740	0.2740	0.0000	0.0000	0.0000	0.0000	0.0000
Shell Canada Ltd.	Scotford Upgrader	31.2990	31.2990	9.2645	9.1941	0.8226	0.5095	0.1927
Shell Canada Ltd.	Scotford Refinery	0.0040	0.0040	1.4320	1.0121	0.1970	0.0975	0.0000
Shell Chemicals Canada	Scotford Styrene & MEG Plant	0.1168	0.1168	2.7336	1.1970	0.3496	0.1503	0.0000
Sherritt International Corporation	Fort Saskatchewan Fertilizer and Metal Plant	0.9044	0.9044	7.6667	0.5913	0.0280	0.2579	0.0000
TransAlta Cogeneration LP	Fort Saskatchewan Cogeneration Plant	0.0300	0.0300	0.2900	0.2600	0.0200	0.0200	0.0000
TransCanada Energy	Redwater Cogeneration Facility	0.0000	0.0000	0.3451	0.1200	0.0100	0.0081	0.0000
Umicore Canada	Fort Saskatchewan Metal & Chemical Manufacturing Plant	0.0000	0.0000	0.0000	0.0000	0.0300	0.0000	0.0000
FAP Industrial Fugitive Emissions	All without Project	0.0000	0.0000	0.0000	0.0000	0.039	3.262	0.0307
Sub-Total FAP (t/d)		**83.68**	**68.45**	**48.40**	**27.24**	**3.81**	**5.78**	**0.98**

Operator	**Facility**	**Emission Rate (t/d)**						
		SO_2 (short term)	**SO_2 (long term)**	**NO_x**	**CO**	**$PM_{2.5}$**	**VOC/PAH**	**H_2S**
Edmonton Industrial Sources	All (Appendix 2A, Section 2A.6)	31.80	31.80	26.70	38.10	3.72	-	-
Sub-Total FAP and Edmonton Industrial (t/d)		**115.48**	**100.25**	**75.10**	**65.34**	**7.53**	**6.12**	**0.96**
Urban Sources	Traffic and Heating	5.25	5.25	177.40	916.10	12.10	73.30	-
Application Case Total (FAP and Edmonton Industrial and Urban Sources) (t/d)		**120.73**	**105.50**	**252.50**	**981.44**	**19.63**	**79.42**	**0.96**
Baseline Case Total (FAP and Edmonton Industrial and Urban Sources) (t/d)		**102.60**	**98.16**	**249.05**	**978.95**	**19.21**	**78.52**	**0.69**
Increase Relative to Baseline Case (%)		18	7.5	1.4	0.3	2.2	1.1	39

Notes:
This table does not include the North West Bitumen Upgrader that became conditionally approved since the assessment was undertaken.
Short term = SO_2 emission rates used to evaluate 1-hour and 24-hour concentrations.
Long term = SO_2 emission rates used to evaluate annual average concentrations and deposition.
Project emissions are shown in ***bold face, italic*** font.

Table 2.6-5 Summary of Emissions Associated with Cumulative Case Sources

Operator	Facility	Emission Rate (t/d)						
		SO$_2$ (short term)	SO$_2$ (long term)	NO$_x$	CO	PM$_{2.5}$	VOC/PAH	H$_2$S
Agrium Products	Fort Saskatchewan Fertilizer Plant	0.0045	0.0045	3.1680	0.6999	0.0169	0.0443	0.0000
Agrium Products	Redwater Fertilizer Plant	7.6580	4.1299	5.1060	1.2613	0.3847	0.3005	0.0000
Air Liquide Canada	Scotford Cogeneration Power Plant	0.0000	0.0000	0.4658	0.1476	0.0154	0.0209	0.0000
ARC Resources	Redwater Gas Conservation Plant	0.8001	0.8001	2.5759	1.8290	0.0280	0.0403	0.0062
ATCO Midstream	Fort Saskatchewan Sour Gas Plant	0.0007	0.0070	0.0174	0.0030	0.0013	0.0010	0.0000
Aux Sable	*Confidential Project*	*0.0000*	*0.0000*	*2.1870*	*1.8380*	*0.1480*	*0.1203*	*0.0000*
Aux Sable	Heartland Off Gas Plant	0.0000	0.0000	0.1770	0.1490	0.0120	0.0097	0.0000
BA Energy	Heartland Oil Sands Bitumen Upgrader	19.4400	19.4400	4.6656	1.5600	0.4700	0.2566	0.4700
BP Canada Energy	Fort Saskatchewan Storage and Fractionation	1.0400	0.1294	0.2941	0.2474	0.0055	0.0162	0.0000
Canexus Limited Partnership	Bruderheim Sodium Chlorate Plant	0.0000	0.0000	0.0380	0.0030	0.0156	0.0021	0.0000
Degussa Canada (formerly Dupont)	Gibbons Hydrogen Peroxide Plant	0.0004	0.0004	0.0580	0.0480	0.0040	0.0032	0.0000
Dow Chemical Canada Inc.	Fort Saskatchewan Chemical Plant	0.1342	0.1342	5.5283	6.2620	0.8900	0.1865	0.0000
ERCO Worldwide	Bruderheim Sodium Chlorate Plant	0.0000	0.0000	0.0116	0.0098	0.0010	0.0006	0.0000
HAZCO Environmental	Bruderheim Sulphur Forming Facility	0.0000	0.0000	0.0090	0.0110	0.0190	0.0005	0.0000
Keyera Energy Ltd.	Fort Saskatchewan Fractionation and Storage Plant	2.4000	2.4000	0.8350	0.3450	0.0250	0.0107	0.0002
Marsulex Inc.	Fort Saskatchewan Chemical Plant	0.6420	0.6420	0.0040	0.0030	0.0002	0.0060	0.0000
Newalta Corporation	Redwater Disposal Facility	0.0000	0.0000	0.0200	0.0170	0.0020	0.0011	0.0000
North American Oil Sands	***Project (stack emissions)***	***18.13***	***7.34***	***3.02***	***2.36***	***0.41***	***0.25***	***0.20***
	Project (fugitive emissions)	***0.009***	***0.0003***	***0.428***	***0.127***	***0.013***	***0.65***	***0.063***
North West Upgrading Inc.	*North West Bitumen Upgrader*	*19.5505*	*17.7000*	*2.1090*	*17.5507*	*0.1769*	*0.5877*	*0.0000*
Petro Canada Oil Sands Inc. (Fort Hills)	*Sturgeon Upgrader*	*23.7191*	*10.1191*	*14.3766*	*9.5073*	*0.4397*	*0.9966*	*0.1540*
Prospec Chemicals	Fort Saskatchewan Xanthate Plant	0.0818	0.0818	0.0034	0.0500	0.0000	0.0002	0.0000
Provident Energy Trust	Redwater Fractionation and Storage	0.7143	0.7143	0.2530	0.0580	0.0191	0.0139	0.0000
Redwater Water Disposal Company	Redwater Waste Disposal Facility	0.2740	0.2740	0.0000	0.0000	0.0000	0.0000	0.0000
Shell Canada Ltd.	*Scotford Upgrader (Base+SE1+SU2)*	*39.1894*	*39.1894*	*25.6593*	*19.1473*	*1.7618*	*1.4113*	*0.4905*
Shell Canada	Scotford Refinery	0.0040	0.0040	1.4320	1.0121	0.1970	0.0975	0.0000
Shell Chemicals Canada	Scotford Styrene & MEG Plant	0.1168	0.1168	2.7336	1.1970	0.3496	0.1503	0.0000
Sherritt International Corp.	Fort Saskatchewan Fertilizer and Metal Plant	0.9044	0.9044	7.6667	0.5913	0.0280	0.2579	0.0000
Synenco Energy	*Northern Lights Upgrader*	*28.8501*	*28.8501*	*3.1109*	*4.5600*	*0.2075*	*0.2986*	*0.0000*

Operator	**Facility**	**Emission Rate (t/d)**						
		SO_2 (short term)	**SO_2 (long term)**	**NO_x**	**CO**	**$PM_{2.5}$**	**VOC/PAH**	**H_2S**
TransAlta Cogeneration LP	Fort Saskatchewan Cogeneration Plant	0.0300	0.0300	0.2900	0.2600	0.0200	0.0200	0.0000
TransCanada Energy	Redwater Cogeneration Facility	0.0000	0.0000	0.3451	0.1200	0.0100	0.0081	0.0000
Umicore Canada	Fort Saskatchewan Metal & Chemical Manufacturing Plant	0.0000	0.0000	0.0000	0.0000	0.0300	0.0000	0.0000
FAP Industrial Fugitive Emissions	All without Project	0.0000	0.0000	0.0000	0.0000	0.039	3.262	0.0307
Sub-total FAP Industrial (t/d)		**163.69**	**133.01**	**86.59**	**70.97**	**5.74**	**9.03**	**1.41**
Edmonton Industrial Sources	All (See Appendix 2A, Section 2A.6)	31.80	31.80	26.70	38.10	3.72	-	-
Sub-total FAP and Edmonton Industrial (t/d)		**195.49**	**164.81**	**113.29**	**109.07**	**9.46**	**9.03**	**1.41**
Urban Sources	Traffic and Heating	5.25	5.25	177.40	916.10	12.10	73.3	-
Cumulative Case Total (FAP and Edmonton Industrial and Urban Sources) (t/d)		**200.74**	**170.06**	**290.69**	**1,025.17**	**21.56**	**82.33**	**1.41**
Baseline Case Total (FAP and Edmonton Industrial and Urban Sources) (t/d)		**102.60**	**98.16**	**249.05**	**978.95**	**19.21**	**78.52**	**0.69**
Increase Relative to Baseline Case (%)		96	73	17	5	12	5	104

Notes:
This table does not include the proposed Total E&P Canada Upgrader as emissions were not available at the time of the assessment.
Short term = SO_2 emission rates used to evaluate 1-hour and 24-hour concentrations.
Long term = SO_2 emission rates used to evaluate annual average concentrations and deposition.
Project emissions are shown in ***bold face, italic*** font and other planned emissions are shown in *italic* font.

2.7 Impact Assessment

The CALPUFF dispersion model, as described in Appendix 2D, was used to predict ambient concentrations for the Project-only, Baseline, Application and Cumulative cases. The model predictions are discussed on a substance-by-substance basis.

2.7.1 Sulphur Dioxide Concentrations

2.7.1.1 SO_2 Emission Profiles

Ambient SO_2 concentrations are directly related to the number of sources that emit SO_2 and the associated SO_2 emission rates. Table 2.7-1 shows the SO_2 emission rate dependence with the averaging times. Peak values (short-term) were used to represent the 1-hour and 24-hour predictions; lower annual average emission rates (long-term) were used to represent the annual averaging period. The SO_2 emission rates shown represent the normal range of emission rates.

Table 2.7-1 SO_2 Emission Rates – Assessment Cases

Assessment Case	SO_2 Emission (t/d)		
	Short-term		Long-term
	1-Hour	24-Hour	Annual
Project-Only Case	18.14	18.14	7.34
Baseline Case	102.60	102.60	98.16
Application Case	120.73	120.73	105.50
Cumulative Case	200.74	200.74	170.06

Short-term abnormal SO_2 emission rates greater than the values represented in the table can occur under emergency conditions. These extreme emergency cases, which involve the flaring of large volumes of gas, are of short-duration (typically less than 1 hour) and intermittent (once every few years). SO_2 emissions due to upset or emergency events from facilities other than the Project were not evaluated.

2.7.1.2 1-Hour Average SO_2 Predictions

Project-Only Case (1-Hour Predictions)

Normal Scenarios

Table 2.7-2 shows the sensitivity of the maximum predicted 1-hour SO_2 concentrations to the various SO_2 emission rates that depend on the individual SRU/TGTU sulphur recovery efficiencies. The following are noted:

- If all five SRU/TGTU units are operating simultaneously at the 99.8% sulphur recovery (Case A), then the maximum 1-hour SO_2 concentration is about 50% of the 1-hour AAAQO.

- If one Upgrader (UP1) SRU/TGTU unit and one gasifier (GAS1) SRU/TGTU unit are operating at 99.5% sulphur recovery, and the remaining SRU/TGTU units are operating at 99.8% (Case E), then the maximum 1-hour SO_2 concentration is about 82% of the1-hour AAAQO.

- If all SRU/TGTU units are operating simultaneously at the 99.5% sulphur recovery rate, (Case H), then the maximum 1-hour SO_2 concentration SO_2 concentration is predicted to exceed the 1-hour AAAQO.

- Two hypothetical SO_2 emission rate cases based on meeting the EUB sulphur recovery guideline (Cases J and K) are show, In these cases, the 1-hour AAAQO is predicted to be exceeded by a factor of about three.

Normal Project SO_2 emissions are expected to be represented by Case A. As one moves down the table towards Case K, the SO_2 emission rate and the associated SO_2 concentration predictions become less probable.

Upset Scenarios

Fifteen upset/ emergency flaring scenarios were identified for the Project and the air quality implications of these scenarios are presented in Appendix 2E. Five of these scenarios could potentially occur for up to 24 hours, two for 12 hours and the remaining eight scenarios are expected to be in the 15 minute to 20 minute duration range. The frequencies of the individual flaring scenarios range from once every 2 years to once every 25 years. For all scenarios, the addition of fuel gas and effect of varying the flaring durations were evaluated. The maximum SO_2 concentrations associated with most scenarios were less than the 1-hour AAAQO. The 1-hour AAAQO was predicted to be exceeded for two cases, both associated with a blower failure.

North American's goal is to reduce the duration and frequency of these flaring scenarios. In the event that flaring has to occur for safety reasons, North American plans to manage all flaring scenarios such that the maximum 1-hour SO_2 concentration associated with Project flaring will be less than the 1-hour AAAQO. Detailed flare management plans will evolve with more advanced Project design.

Overlapping Cases (1-Hour SO_2 Predictions)

Table 2.7-3 provides a summary of the predicted maximum 1-hour SO_2 concentrations and compares these concentrations to the SO_2 1-hour AAAQO. The predictions in the table are based on the higher short-term SO_2 emissions. A comparison of using the lower, long-term SO_2 emissions is provided in Table 2.7-4. The model predictions in the tables are at the property lines for the major SO_2 emitting facilities. The predictions are also provided for each discrete receptor grouping (e.g., agricultural/residential).

The predicted SO_2 concentration spatial patterns for the three primary assessment cases are presented in Figures 2.7-1 to 2.7-3 as contours superimposed over the 50 km x 50 km RSA base map. These are based on the short-term SO_2 emission rates to represent the 1-hour averaging period. Corresponding Project-only plots are presented in Appendix 2E.

Baseline Case

Table 2.7-3 and Figure 2.7-1 show the predictions based on the higher short-term emissions (102.60 t/d). High hourly SO_2 concentrations are predicted to occur near the existing Agrium Redwater Fertilizer Plant, the existing Shell Canada Scotford Complex, and the approved BA Energy Heartland Oil Sands Bitumen Upgrader. The predicted SO_2 concentration maxima of 466 ug/m^3 (Redwater) and 851 ug/m^3 (Scotford) exceed the AAAQO. The maximum number of predicted 1-hour exceedances in one year are two (Redwater) and nine (Scotford).

High concentrations are also predicted at one commercial/industrial location, this being the Scotford Complex (851 ug/m^3) location, with up to thirty-seven 1-hour exceedances in a year. The AAAQO is not applicable within industrial facilities. The highest concentrations predicted at the agricultural/residential and residential/community locations are 181 ug/m^3 and 79 ug/m^3, respectively. These predicted values are less than the 1-hour AAAQO.

Table 2.7-4 shows the predictions based on the lower long-term emissions (98.16 t/d). Smaller predictions near the Agrium Redwater Fertilizer Plant are noted due to the smaller long-term emissions from this facility. The change near the Scotford Complex is not much smaller, as lower long-term SO_2 emissions were not assumed for this facility. If the Scotford predictions are scaled according to 2005 NPRI SO_2 emissions (18.95 t/d), then the corresponding maximum predicted value is 512 ug/m^3 (i.e., 846x18.95/31.30 = 512). The highest concentrations predicted at the agricultural/residential and residential/community locations are 173 ug/m^3 and 72 ug/m^3, respectively. These predicted values are less than the 1-hour AAAQO.

Application Case

Table 2.7-3 and Figure 2.7-2 show the predictions based on the higher short-term emissions (120.73 t/d). High SO_2 concentrations are predicted to occur near the previously mentioned plants. The SO_2 concentration maxima are 481 ug/m^3 (Redwater), 851 ug/m^3 (Scotford) and 451 ug/m^3 (Heartland Upgrader). The respective changes due to Project emissions range from +0.0% +3.2%. These maximum predicted concentrations exceed the 1-hour AAAQO. The maximum number of predicted 1-hour exceedances in one year range from three (Redwater) to eleven (Heartland Upgrader). The Project emissions increase the exceedance frequencies by up to 1 hour in a year, depending on location. The maximum predicted value at or outside the project property line (PPL) is 586 ug/m^3. Eight predicted 1-hour exceedances in one year are predicted at or outside the PPL.

High concentrations are still predicted at the Scotford Complex industrial location (851 ug/m^3); the Project contribution being +0.01% (Table 2.7-3). The AAAQO is not applicable within industrial facilities. The highest concentrations predicted at the agricultural/residential and residential/community locations are 246 ug/m^3 and 149 ug/m^3, respectively. These predicted values are less than the AAAQO.

Table 2.7-4 shows the predictions based on the lower long-term emissions (105.50 t/d). Smaller predictions near the Agrium Redwater Fertilizer Plant are noted due to the smaller long-term emissions from this facility. The change near the Scotford Complex is not much smaller as lower long-term SO_2 emissions were not assumed for this facility. The effect of the Project emissions at these locations is small. The maximum predicted value at or outside the PPL is 256 ug/m^3, which is less than the AAAQO. The highest concentrations predicted at the agricultural/residential and residential/community locations are 181 ug/m^3 and 91 ug/m^3, respectively. These predicted values are less than the AAAQO.

Cumulative Case

Table 2.7-3 and Figure 2.7-3 show the predictions based on the higher short-term emissions (200.74 t/d). High SO_2 concentrations are predicted to occur near existing and proposed plants. The respective SO_2 concentration maxima are 666 ug/m^3 (Redwater), 731 ug/m^3 (Scotford), 524 ug/m^3 (Heartland Upgrader), 632 ug/m^3 (Project), 634 ug/m^3 (North West) and 656 ug/m^3 (Northern Lights), and 387 ug/m^3 (Sturgeon). The respective changes range from -20.4% to +399%, depending on location. The predicted decrease at the Scotford Complex is due to the larger development area associated with the proposed Scotford 2 upgrader. The maximum predicted concentrations exceed the 1-hour AAAQO. The maximum number of predicted 1-hour exceedances in one year range from zero (Sturgeon) to eleven (Redwater and Scotford).

Relative to the Baseline case, the proposed projects increase the frequency of an exceedance by up to 10 hours in a year.

High concentrations are still predicted at the Scotford Complex (859 ug/m^3); the proposed projects' contribution being +0.94%. The AAAQO is not applicable within industrial facilities. The highest concentrations predicted at the agricultural/residential and residential/community locations are 318 ug/m^3 and 225 ug/m^3, respectively. These predicted values are less than the AAAQO.

Table 2.7-4 shows the predictions based on the lower long-term emissions (170.06 t/d). Smaller predictions near the Agrium Redwater Fertilizer Plant are noted due to the smaller long-term emissions from this facility. The change near the Scotford Upgrader is not much smaller as lower long-term SO_2 emissions were not assumed for this facility. The effect of the Project emissions at these locations is small. The maximum predicted value at or outside the PPL 278 ug/m^3, which is less than the AAAQO. The highest concentrations predicted at the agricultural/residential and residential/community locations are 264 ug/m^3 and 166 ug/m^3, respectively. These predicted values are less than the 1-hour AAAQO.

Table 2.7-2 Project-Only Case Sensitivity of Predicted SO_2 Concentrations to the Various SO_2 Emission Rates

Case	SRU/TGTU SO_2 Emission Rate (t/d)	Predicted SO_2 Concentration (ug/m^3)						Scenario Description
		1-hour		24-hour		Annual		
		PPL	Outside PPL	PPL	Outside PPL	PPL	Outside PPL	
A	7.18	229	224	61	60	2.0	2.0	Annual Project Case = 99.8%
B	8.34	319	297	87	85	2.4	2.4	*1 GAS = 99.5%,* others = 99.8%
C	9.10	394	374	104	101	2.86	2.86	*1 GAS = 99.5%x1.4,* others = 99.8%
D	10.02	366	354	77	72	2.74	2.72	*1 UP = 99.5%*, others = 99.8%
E	11.17	374	369	105	103	3.04	3.01	*1 UP and 1 GAS = 99.5%*, others = 99.8%
F	11.90	**467**	440	96	80	3.22	3.20	*1 UP = 99.5%x1.4*, others = 99.8%
G	13.81	**475**	444	125	121	3.74	3.70	*1 UP and 1 GAS = 99.5%x1.4*, others = 99.8%
H	17.98	**559**	**548**	**152**	150	4.81	4.80	1-h and 24-h Project Case = 99.5%
I	43.48	**1341**	**1314**	**367**	**360**	11.4	11.4	EUB 2003, Everything = 98.79% (Long-term)
J	54.25	**1674**	**1640**	**458**	**450**	14.24	14.2	EUB 2003, Everything = 98.49% (Quarterly)
AAAQO		450		150		30		

Notes:
GAS = one of the two Gasifier SRU/TGTU complexes
UP = one of the three upgrader SRU/TGTU complexes
Case A assumes all SRU/TGTU complexes are operating at 99.8% and is used to represent the Project when calculating annual average SO_2 concentrations.
Case H assumes all SRU/TGTU complexes are operating at 99.5% and is used to represent the Project when calculating 1-hour and 24-hour average SO_2 concentrations and depositions.
AAAQO = Alberta Ambient Air Quality Objective
Exceedances are shown in **bold face** font.
For these sensitivity studies, chemical and deposition processes were not assumed; therefore the predicted SO_2 concentrations could be overstated by about 10%.
PPL = Project property line

Table 2.7-3 Predicted 1-Hour Average SO_2 Concentrations for Baseline, Application and Cumulative Cases based on Short-term SO_2 Emissions

Location	**Maximum SO_2 Concentration (ug/m^3)**			**Number of Exceedances (h/y)**		
	Baseline (102.60 t/d)	**Application** (120.73 t/d)	**Cumulative** (200.74 t/d)	**Baseline**	**Application**	**Cumulative**
Agrium Redwater Fertilizer Plant PL	**466**	**481** (+3.2)	**666** (+43)	2	3	11
Shell Canada Scotford Complex PL	**851**	**851** (0.00)	**731** (-20)	9	9	11
BA Energy Heartland Oil Sands Bitumen Upgrader PL	443	**451** (+1.7)	**524** (+18)	0	1	5
Project Upgrader - Inside PPL	122	903 (+642)	930 (+664)	0	18	19
Project Upgrader - Outside PPL	127	**586** (+363)	**632** (+399)	0	8	9
North West Bitumen Upgrader PL	423	432 (+2.2)	**634** (+50)	0	0	10
Synenco Northern Lights Upgrader PL	176	187 (+6.4)	**656** (+272)	0	0	8
Petro-Canada Oil Sands Inc. Sturgeon Upgrader PL	281	284 (+1.8)	387 (+38)	0	0	0
Discrete Receptor Group						
Agricultural/Residential	181	246 (+36)	318 (+76)	0	0	0
Residential/Community	79	149 (+88)	225 (+183)	0	0	0
Public Access Area	157	199 (+27)	294 (+87)	0	0	0
Commercial/Industrial Area	**851**	**851** (+0.01)	**859** (+0.94)	37	37	47
AAAQO	**450**	**450**	**450**	N/A	N/A	N/A

Notes:

SO_2 emission rates for each Assessment Case are shown.
PL = property line
PPL = Project Property Line
AAAQO are not applicable in the PL or the PPL.
Predictions exceeding the AAAQO are shown in **bold face** font.
The values in the parentheses represent the % change with respect to the Baseline Case.
The numbers of predicted hourly exceedances are consistent with the interpretation of the Alberta Air Model Guideline.
N/A = no AAAQO

Table 2.7-4 Predicted 1-Hour Average SO_2 Concentrations for Baseline, Application and Cumulative Cases based on Long-term SO_2 Emissions

Location	**Maximum SO_2 Concentration (ug/m^3)**			**Number of Exceedances (h/y)**		
	Baseline	**Application**	**Cumulative**	**Baseline**	**Application**	**Cumulative**
	(98.16 t/d)	(105.50 t/d)	(170.06 t/d)	**-**	**-**	**-**
Agrium Redwater Fertilizer Plant PL	233	235 (+0.9)	**661** (+183)	0	0	10
Shell Canada Scotford Complex PL	**846**	**846** (+0.00)	**704** (-22)	9	9	10
BA Energy Heartland Oil Sands Bitumen Upgrader PL	441	444 (+0.7)	**492** (+12)	0	0	3
Project Upgrader - Inside PPL	121	381 (+215)	395 (+227)	0	0	0
Project Upgrader - Outside PPL	123	256 (+108)	278 (+126)	0	0	0
North West Bitumen Upgrader PL	215	220 (+2.3)	**550** (+155)	0	0	6
Synenco Northern Lights Upgrader PL	116	123 (+6.6)	**652** (+463)	0	0	7
Petro-Canada Oil Sands Inc. Sturgeon Upgrader PL	264	265 (+0.50)	282 (+6.7)	0	0	0
Discrete Receptor Group						
Agricultural/Residential	173	181 (+4.8)	264 (+53)	0	0	0
Residential/Community	72	91 (+26)	166 (+130)	0	0	0
Public Access Area	142	159 (+12)	250 (+76)	0	0	0
Commercial/Industrial Area	**765**	**765** (+0.01)	**561** (-27)	8	9	5
AAAQO	**450**	**450**	**450**	N/A	N/A	N/A

Notes:

SO_2 emission rates for each Assessment Case are shown.
PL = property line
PPL = Project Property Line
AAAQO are not applicable in the PL or the PPL.
Predictions exceeding the AAAQO are shown in **bold face** font.
The values in the parentheses represent the % change with respect to the Baseline Case.
The numbers of predicted hourly exceedances are consistent with the interpretation of the Alberta Air Model Guideline.
N/A = no AAAQO

2.7.1.3 Maximum 24-Hour Average SO_2 Predictions

Project-Only Case (24-Hour Predictions)

Normal Scenarios

Table 2.7-2 shows the sensitivity of the maximum predicted 24-hour SO_2 concentrations to the various SO_2 emission rates that depend on the individual SRU/TGTU sulphur recovery efficiencies. The following are noted:

- If all five SRU/TGTU units are operating simultaneously at the 99.8% sulphur recovery rate (Case A), then the 24-hour SO_2 concentration is about 40% of the 24-hour AAAQO.
- If one Upgrader (UP1) SRU/TGTU unit and one Gasifier (GAS1) SRU/TGTU unit are operating at 99.5% sulphur recovery, and the remaining SRU/TGTU units are operating at 99.8% (Case E), then the maximum 24-hour SO_2 concentration is about 69% of the 24-hour AAAQO.
- If all SRU/TGTU units are operating simultaneously at the 99.5% sulphur recovery rate, (Case H), then the maximum 24-hour SO_2 concentration is predicted to marginally exceed the 24-hour AAAQO.
- Two hypothetical SO_2 emission rate cases based on meeting the EUB sulphur recovery guideline (Cases I and J) are shown. In these cases, the 24-hour AAAQO is predicted to be exceeded by a factor of about three.

The normal Project SO_2 emissions are expected to be represented by Case A. As one moves down the table towards Case J, the SO_2 emission rate and the associated SO_2 concentration predictions become less probable.

Upset Scenarios

Fifteen upset/emergency flaring scenarios were identified for the Project and the air quality implications of these scenarios are presented in Appendix 2E. Only five of these scenarios could potentially occur for up to 24-hours; the estimated frequencies being once every 2 years. The 24-hour AAAQO was predicted to be exceeded for two scenarios, both associated with a blower failure.

North American's goal is to reduce the duration and frequency of these flaring events. In the event that flaring has to occur for safety reasons, North American plans to manage all flaring events such that the maximum 1-hour SO_2 concentration associated with Project flaring events will be less than the 1-hour AAAQO. If the scenarios are managed to meet the 1-hour AAAQO, they will meet the 24-hour AAAQO. Detailed flare management plans will evolve with more advanced Project design.

Overlapping Cases (24-Hour Predictions)

Table 2.7-5 provides a summary of the predicted maximum 24-hour SO_2 concentrations and compares these concentrations to the SO_2 24-hour AAAQO. The predictions in the table are based on the higher short-term SO_2 emissions. A comparison of using the lower, long-term SO_2 emissions is provided in Table 2.7-6. The model predictions in the tables are provided at the property lines of major SO_2 emitting facilities. The predictions are also provided for each discrete receptor grouping (e.g., agricultural/ residential).

The predicted SO_2 concentration spatial patterns for the three primary assessment cases are presented in Figures 2.7-4 to 2.7-6 as contours superimposed over the 50 km x 50 km RSA base map. These are based on the short-term SO_2 emission rates to represent the 24-hour averaging period. Corresponding Project-only plots are presented in Appendix 2E.

Baseline Case

Table 2.7-5 and Figure 2.7-4 show the predictions based on the higher short-term emissions (102.60 t/d). High hourly SO_2 concentrations are predicted to occur near the existing Agrium Redwater Fertilizer Plant, the existing Shell Canada Scotford Upgrader, and the approved BA Energy Heartland Oil Sands Bitumen Upgrader. The predicted SO_2 concentration maximum of 327 ug/m^3 (Scotford) exceeds the AAAQO. The maximum number of predicted 24-hour exceedances in one year is two (Scotford).

High concentrations are also predicted at one commercial/industrial location, this being the Scotford Complex (238 ug/m^3) location. The AAAQO is not applicable within industrial facilities. The highest concentrations predicted at the agricultural/residential and residential/community locations are 62.3 ug/m^3 and 32.8 ug/m^3, respectively. These predicted values are less than the 24-hour AAAQO.

Table 2.7-6 shows the predictions based on the lower long-term emissions (98.16 t/d). Smaller predictions near the Agrium Redwater Fertilizer Plant are noted due to the smaller long-term emissions from this facility. The change near the Scotford Upgrader is not much smaller, as lower long-term SO_2 emissions were not assumed for this facility. If the Scotford predictions are scaled according to 2005 NPRI SO_2 emissions (18.95 t/d), then the maximum predicted value is 196 ug/m^3 (i.e., 323x18.95/31.30 = 196). The highest concentrations predicted at the agricultural/residential and residential/community locations are 61.4 ug/m^3 and 29.7 ug/m^3, respectively. These predicted values are less than the 24-hour AAAQO.

Application Case

Table 2.7-5 and Figure 2.7-6 show the predictions based on the higher short-term emissions (120.73 t/d). High SO_2 concentrations are predicted to occur near the previously mentioned plants. The SO_2 concentration maxima are 152 ug/m^3 (Redwater), 334 ug/m^3 (Scotford) and 149 ug/m^3 (Heartland Upgrader). The respective changes due to Project emissions range from +2.2% to +13.9%. Some of the maximum predicted concentrations are larger than the 24-hour AAAQO. Three 24-hour exceedances in one year are predicted: one at Redwater and two at Scotford. The Project emissions increase these frequencies by up to one day in a year. The maximum predicted value at or outside the PPL is 177 ug/m^3; only one AAAQO exceedance is predicted at or outside the Project PPL.

High concentrations are still predicted at the previously indicated commercial/industrial location (245 ug/m^3); the Project contribution being +3.14%. The AAAQO is not applicable within industrial facilities. The highest concentrations predicted at the agricultural/residential and residential/community locations are 87 ug/m^3 and 49 ug/m^3, respectively. These predicted values are less than the AAAQO.

Table 2.7-6 shows the predictions based on the lower long-term emissions (105.50 t/d). Smaller predictions near the Agrium Redwater Fertilizer Plant are noted due to the smaller long-term emissions from this facility. The change near the Scotford Upgrader is not much smaller as lower long-term SO_2 emissions were not assumed for this facility. The effect of the Project emissions at these locations is small. The maximum predicted value at or outside the PPL is 87 ug/m^3, which is less than the AAAQO. The highest concentrations predicted at the agricultural/residential and residential/community locations are 62.1 ug/m^3 and 36.3 ug/m^3, respectively. These predicted values are less than the 24-hour AAAQO.

Cumulative Case

Table 2.7-5 and Figure 2.7-7 show the predictions based on the higher short-term emissions (200.74 t/d). High SO_2 concentrations are predicted to occur near existing and proposed plants. The SO_2 concentration maxima are 190 ug/m^3 (Redwater), 294 ug/m^3 (Scotford), 209 ug/m^3 (Heartland Upgrader), 204 ug/m^3 (Project), 174 ug/m^3 (North West) and 154 ug/m^3 (Northern Lights), and 159 ug/m^3 (Sturgeon). The respective changes resulting from the proposed facilities range from -18.2% to +309%. The predicted decrease at the Scotford Complex is due to the larger development area associated with the proposed Scotford 2 upgrader. Maximum predicted concentrations exceed the 24-hour AAAQO. The maximum number of predicted 24-hour exceedances in one year are one (Redwater), three (Scotford), two (Heartland Upgrader), one (Project), one (North West), one (Northern Lights), and zero (Sturgeon). Relative to the Baseline Case, the proposed projects increase the frequencies by up to one to four days a year.

High concentrations are predicted at the Scotford Complex (234 ug/m^3); the proposed projects' contributions being +0.94%. The AAAQO is not applicable within industrial facilities. The highest concentrations predicted at the agricultural/residential and residential/community locations are 142 ug/m^3 and 106 ug/m^3, respectively. These predicted values are less than the AAAQO.

Table 2.7-6 shows the predictions based on the lower long-term emissions (170.06 t/d). Smaller predictions near the Agrium Redwater Fertilizer Plant are noted due to the smaller long-term emissions from this facility. The change near the Scotford Upgrader is not much smaller as lower long-term SO_2 emissions were not assumed for this facility. The effect of the Project emissions at these locations is small. The maximum predicted value at or outside the PPL is 113 ug/m^3, which is less than the AAAQO. The highest concentrations predicted at the agricultural/residential and residential/community locations are 115 ug/m^3 and 80.8 ug/m^3, respectively. These predicted values are less than the 24-hour AAAQO.

Table 2.7-5 Predicted 24-Hour Average SO_2 Concentrations for Baseline, Application and Cumulative Cases based on short-term SO_2 emissions

Location	**Maximum SO_2 Concentration (ug/m^3)**			**Number of Exceedances (d/y)**		
	Baseline	**Application**	**Cumulative**	**Baseline**	**Application**	**Cumulative**
	(102.60 t/d)	(120.73 t/d)	(200.74 t/d)	**-**	**-**	**-**
Agrium Redwater Fertilizer Plant PL	146	**152** (+3.5)	**190** (+30)	0	1	1
Shell Canada Scotford Complex PL	327	**334** (+2.2)	**294** (-18)	2	2	3
BA Energy Heartland Oil Sands Bitumen Upgrader PL	131	149 (+14)	**209** (+60)	0	0	2
Project Upgrader - Inside PPL	49.8	247 (+396)	254 (+410)	0	3	4
Project Upgrader - Outside PPL	49.9	**177** (+255)	**204** (+309)	0	1	1
North West Bitumen Upgrader PL	121	124 (+2.7)	**174** (+44)	0	0	1
Synenco Northern Lights Upgrader PL	56.0	57.1 (+1.9)	**154** (+174)	0	0	1
Petro-Canada Oil Sands Inc. Sturgeon Upgrader PL	85.4	98.5 (+15)	**159** (+86)	0	0	1
Discrete Receptor Group						
Agricultural/Residential	62.3	87.0 (+40)	142 (+128)	0	0	0
Residential/Community	32.8	49.0 (+50)	106 (+225)	0	0	0
Public Access Area	53.1	66.8 (+26)	116 (+119)	0	0	0
Commercial/Industrial Area	238	**245** (+3.1)	**234** (-1.6)	2	4	5
AAAQO	**150**	**150**	**150**	N/A	N/A	N/A

Notes:
SO_2 emission rates for each Assessment Case are shown.
PL = property line
PPL = Project Property Line
AAAQO are not applicable in the PL or the PPL.
Predictions exceeding the AAAQO are shown in **bold face** font.
The values in the parentheses represent the % change with respect to the Baseline Case.
N/A = no AAAQO

Table 2.7-6 Predicted 24-Hour Average SO_2 Concentrations for Baseline, Application and Cumulative Cases based on Long-Term SO_2 Emissions

Location	**Maximum SO_2 Concentration (ug/m³)**			**Number of Exceedances (d/y)**		
	Baseline	**Application**	**Cumulative**	**Baseline**	**Application**	**Cumulative**
	(98.16 t/d)	(105.50 t/d)	(170.06 t/d)	**-**	**-**	**-**
Agrium Redwater Fertilizer Plant PL	85.9	87.9 (+2.4)	135 (+58)	0	0	0
Shell Canada Scotford Complex PL	**323**	**326** (+0.9)	**284** (-21)	2	2	3
BA Energy Heartland Oil Sands Bitumen Upgrader PL	126	133 (+5.8)	**186** (+48)	0	0	1
Project Upgrader - Inside PPL	42.9	107 (+150)	118 (+176)	0	0	0
Project Upgrader - Outside PPL	42.9	87.0 (+102)	113 (+163)	0	0	0
North West Bitumen Upgrader PL	65.6	67.4 (+2.8)	144 (+120)	0	0	0
Synenco Northern Lights Upgrader PL	42.9	44.0 (+2.50)	143 (+234)	0	0	0
Petro-Canada Oil Sands Inc. Sturgeon Upgrader PL	83.3	88.3 (+6.0)	137 (+64)	0	0	0
Discrete Receptor Group						
Agricultural/Residential	61.4	62.1 (+1.0)	115 (+87)	0	0	0
Residential/Community	29.7	36.3 (+22)	80.8 (+172)	0	0	0
Public Access Area	50.2	51.6 (+2.8)	92.8 (+85)	0	0	0
Commercial/Industrial Area	**234**	**237** (+1.3)	**224 (**-4.3)	2	2	1
AAAQO	**150**	**150**	**150**	N/A	N/A	N/A

Notes:
SO_2 emission rates for each Assessment Case are shown.
PL = property line.
PPL = Project Property Line.
AAAQO are not applicable in the PL or the PPL..
Predictions exceeding the AAAQO are shown in **bold face** font.
The values in the parentheses represent the % change with respect to the Baseline Case.
N/A = no AAAQO.

2.7.1.4 Annual Average SO_2 Predictions

Project-Only Case (Annual Predictions)

Normal Scenarios

Table 2.7-7 shows the sensitivity of the maximum predicted annual SO_2 concentrations to the various SO_2 emission rates that depend on the individual SRU/TGTU sulphur recovery efficiencies. The following conditions are noted:

- If all five SRU/TGTU units are operating simultaneously at the 99.8% sulphur recovery (Case A), then the maximum annual SO_2 concentration is about 7% of the annual AAAQO.
- If one Upgrader (UP1) SRU/TGTU unit and one Gasifier (GAS1) SRU/TGTU unit are operating at 99.5% sulphur recovery, and the remaining SRU/TGTU units are operating at 99.8% (Case E), then the maximum annual SO_2 concentration is about 10% of the annual AAAQO.
- If all SRU/TGTU units are operating simultaneously at the 99.5% sulphur recovery (Case H), then the maximum annual SO_2 concentration is about 16% of the annual AAAQO.
- Two hypothetical SO_2 emission rate cases based on meeting the EUB sulphur recovery guideline (Cases I and J) are shown. For these cases, the maximum annual SO_2 concentration is about 50% of the annual AAAQO.

The Project SO_2 emissions are expected to be represented by the Case A and Case B scenarios. As one moves down the table towards Case J, the SO_2 emission rate and the associated SO_2 concentration predictions become less probable.

Upset Scenarios

As the duration of each upset/emergency flaring scenario is typically less than one hour or in the extreme up to 24 hours, the flaring will not have a meaningful contribution to the annual average SO_2 concentrations.

Overlapping Cases (Annual Predictions)

Table 2.7-7 provides a summary of the predicted annual SO_2 concentrations and compares these concentrations to the SO_2 annual AAAQO. The predictions in the table are based on the long-term SO_2 emissions. The model predictions in the tables are provided at the property lines of major SO_2 emitting facilities. The predictions are also provided for each discrete receptor grouping (e.g., agricultural/residential).

The predicted SO_2 concentration spatial patterns for the three primary assessment cases are presented in Figures 2.7-7 to 2.7-9 as contours superimposed over the 50 km x 50 km RSA base map. These are based on the long-term SO_2 emission rates to represent the annual averaging period. Corresponding Project-only plots are presented in Appendix 2E.

Baseline Case

Table 2.7-7 and Figure 2.7-7 show the predictions based on the lower long-term emissions (98.16 t/d). High hourly SO_2 concentrations are predicted to occur near the existing Agrium

Redwater Fertilizer Plant, the existing Shell Canada Scotford Upgrader, and the approved BA Energy Heartland Oil Sands Bitumen Upgrader. All predicted SO_2 concentration maxima are less than the AAAQO.

The highest concentrations predicted at the agricultural/residential and residential/community locations are 7.04 ug/m^3 and 4.25 ug/m^3, respectively. These predicted values are less than the annual AAAQO.

Application Case

Table 2.7-7 and Figure 2.7-8 show the predictions based on the lower long-term emissions (105.50 t/d). High SO_2 concentrations are predicted to occur near the previously mentioned plants. The respective changes due to Project emissions range from +3.37% and +6.06%. The maximum predicted value at or outside the PPL is 7.38 ug/m^3. All predicted concentrations are less than the annual AAAQO.

The highest concentrations predicted at the agricultural/residential and residential/community locations are 7.51 ug/m^3 and 5.05 ug/m^3, respectively. These predicted values are less than the AAAQO.

Cumulative Case

Table 2.7-7 and Figure 2.7-9 show the predictions based on the lower long-term emissions (170.06 t/d). High SO_2 concentrations are predicted to occur near existing and proposed projects. Relative to the Baseline Case, the respective SO_2 concentration changes resulting from the proposed projects range from +56.6% to +162%. All the predicted concentrations are less than the annual AAAQO.

The highest concentrations predicted at the agricultural/residential and residential/community locations are13.3 ug/m^3 and 9.11 ug/m^3, respectively. These predicted values are less than the AAAQO.

Table 2.7-7 Predicted Annual Average SO_2 Concentrations for Baseline, Application and Cumulative Cases

Location	Annual SO_2 Concentration (ug/m³)		
	Baseline (98.16 t/d)	Application (105.50 t/d)	Cumulative (170.06 t/d)
Agrium Redwater Fertilizer Plant PL	8.00	8.29 (+3.6)	14.1 (+76)
Shell Canada Scotford Complex PL	9.82	10.2 (+3.4)	17.0 (+73)
BA Energy Heartland Oil Sands Bitumen Upgrader PL	8.11	8.60 (+6.1)	16.7 (+105)
Project Upgrader - Inside PPL	6.46	7.55 (+17)	13.3 (+105)
Project Upgrader - Outside PPL	6.47	7.38 (+14)	13.3 (+105)
North West Bitumen Upgrader PL	6.15	6.40 (+4.2)	11.6 (+90)
Synenco Northern Lights Upgrader PL	3.99	4.28 (+7.4)	10.5 (+162)
Petro-Canada Oil Sands Inc. Sturgeon Upgrader PL	5.61	5.91 (+5.4)	8.78 (+57)

Location	Annual SO_2 Concentration (ug/m³)		
	Baseline (98.16 t/d)	Application (105.50 t/d)	Cumulative (170.06 t/d)
Discrete Receptor Group			
Agricultural/Residential	7.04	7.51 (+6.8)	13.3 (+89)
Residential/Community	4.25	5.05 (+19)	9.11 (+115)
Public Access Area	6.46	6.97 (+7.9)	13.5 (+110)
Commercial/Industrial Area	9.39	9.69 (+3.3)	15.0 (+60)
AAAQO	**30**	**30**	**30**

Notes:
SO_2 emission rates for each Assessment Case are shown.
PL = property line.
PPL = Project Property Line.
AAAQO are not applicable in the PL or the PPL.
Predictions exceeding the AAAQO are shown in **bold face** font.
The values in the parentheses represent the % change with respect to the Baseline Case.
N/A = no AAAQO.

2.7.1.5 SO_2 Summary

The SO_2 concentration patterns in the region are dominated by the primary SO_2 emitting facilities. The Project and other proposed upgraders will increase SO_2 emissions in the area. The SO_2 emissions are directly related to the sulphur recovery efficiencies that can vary with time. The model is predicting elevated SO_2 concentration levels near major approved and proposed SO_2 emitting facilities, with decreasing concentrations associated with increasing distances from these sources. The model predictions show a potential for SO_2 concentrations to exceed the 1-hour and 24-hour AAAQO values near each respective operation; these exceedances are predicted to occur near the respective plant property lines. There are no predicted annual AAAQO exceedances, on- or off-site.

The highest 1-hour and 24-hour offsite concentrations due to the Project are predicted along the southern and northeastern plant boundaries. There are predicted exceedances of the AAAQO along these areas; these being based on assuming the simultaneous occurrence of high SO_2 emissions and poor dispersion conditions. There are no predicted exceedances of the annual AAAQO at any locations. For the Baseline, Application and Cumulative cases, no AAAQO exceedances are predicted at either agricultural/residential or residential/community locations.

The human health and environmental consequences of these predicted SO_2 concentrations are discussed in Volume 2, Section 4 - Human Health and in Volume 4, Section 10 - Vegetation.

2.7.1.6 Prediction Confidence

The prediction confidence relates to the uncertainty associated with the emission estimates and assumptions, and to the uncertainty associated with the model's ability to predict ambient concentrations. The comparison between predictions and measurements (Appendix 2D) accounts for both uncertainties. Based on the comparison, the 99th percentile 1-hour concentrations at each station, on average are overpredicted by 5%. The maximum 24-hour concentrations, on average, are underpredicted by 49%. The annual concentrations, on average, are overpredicted by 9%.

In general, the model predicted high concentrations where high concentrations are measured and low concentrations where low concentrations are measured. The model can be viewed as an appropriate “best estimate” tool.

2.7.2 Nitrogen Dioxide Concentrations

2.7.2.1 NO_x Emission Profiles

Ambient nitrogen dioxide (NO_2) concentrations are directly related to the number of sources that emit oxides of nitrogen (NO_x) and their associated NO_x emission rates. Table 2.7-8 shows the NO_x emission rates that are used to represent all averaging periods. The industry NO_x emissions may be overstated in that all fired equipment, whether on continuous or standby duty, are assumed to be operating simultaneously.

Table 2.7-8 NO_x Emission Rates – Assessment Case

Assessment Case	NOx Emission (t/d)
Project-Only Case	3.45
Baseline Case	249.1
Application Case	252.5
Cumulative Case	290.7

2.7.2.2 1-Hour Average NO_2 Predictions

Project-Only Case (1-Hour Predictions)

Normal Scenarios

Table 2.7-9 shows the maximum predicted 1-hour NO_2 concentrations due to the Project operating in isolation. All fired equipment is assumed to be operating simultaneously at 100% of design capacity. The maximum predicted NO_2 concentrations along and outside the PPL are less that the 1-hour AAAQO for NO_2.

Table 2.7-9 Maximum Predicted NO_2 Concentrations Associated with Project-Only Case

Averaging Period	NO_x Emission Rate (t/d)	Maximum Concentration (ug/m^3)			AAAQO (ug/m^3)
		Inside PPL	PPL	Outside PPL	
1-hour	3.43	585	168	159	400
24-hour	3.43	325	111	110	200
Annual	3.43	18.1	3.1	2.9	60

Overlapping Cases (1-Hour NO_2 Predictions)

Table 2.7-10 provides a summary of the predicted maximum NO_2 concentrations and compares these concentrations to the NO_2 1-hour AAAQO. The model predictions in the tables are provided for the same locations as used for the SO_2 evaluation (i.e., at the respective plant property lines). The predictions are also provided for each discrete receptor grouping (e.g., agricultural/residential).

The predicted NO_2 concentration spatial patterns for the three primary assessment cases are presented in Figures 2.7-10 to 2.7-12 as contours superimposed over the 50 km x 50 km RSA base map. Corresponding Project-only plots are presented in Appendix 2E.

Baseline Case

Table 2.7-10 and Figure 2.7-10 show the predicted concentrations for the Baseline Case (249.1 t/d NO_x emission). The maximum predicted NO_2 concentration maxima at the indicated locations range from 100 ug/m^3 to 135 ug/m^3; these values are all less than the 1-hour AAAQO. Higher concentration values are predicted in the Edmonton area.

Application Case

Table 2.7-10 and Figure 2.7-11 show the predicted concentrations for the Application Case (252.5 t/d NO_x emission). High NO_2 concentrations (588 ug/m^3) are predicted to occur within the PPL, decreasing to 171 ug/m^3 at the PPL. The relative change at the PPL due to the Project is +71.8%. Relative changes at other locations due to the Project are +6.85% or less. All predicted values are less than 1-hour AAAQO.

Cumulative Case

Table 2.7-10 and Figure 2.7-12 show the predicted concentrations for the Cumulative Case (290.7 t/d NO_x emission). High NO_2 concentrations (591 ug/m^3) are predicted to occur within the PPL, decreasing to 172 ug/m^3 at the PPL. The relative change at the PPL due to the proposed projects is +72.5%. Relative changes at other locations due to the proposed projects are +28.6% or less. All predicted values are less than 1-hour AAAQO.

Table 2.7-10 Predicted 1-Hour Average NO_2 Concentrations for Baseline, Application and Cumulative Cases

Location	**Maximum NO_2 Concentration (ug/m³)**			**Number of Exceedances (h/y)**		
	Baseline (249.05 t/d)	**Application** (252.51 t/d)	**Cumulative** (290.70 t/d)	**Baseline**	**Application**	**Cumulative**
Agrium Redwater Fertilizer Plant PL	115	116 (+0.48)	147 (+28)	0	0	0
Shell Canada Scotford Complex PL	116	116 (+0.09)	149 (+29)	0	0	0
BA Energy Heartland Oil Sands Bitumen Upgrader PL	106	106 (+0.00)	123 (+17)	0	0	0
Project Upgrader - Inside PPL	100	588 (+489)	591 (+492)	0	47	47
Project Upgrader - Outside PPL	100	171 (+72)	172 (+73)	0	0	0
North West Bitumen Upgrader PL	109	112 (+2.9)	118 (+8.9)	0	0	0
Synenco Northern Lights Upgrader PL	105	105 (+0.00)	106 (+1.4)	0	0	0
Petro-Canada Oil Sands Inc. Sturgeon Upgrader PL	107	107 (+0.49)	119 (+12)	0	0	0
Discrete Receptor Group						
Agricultural/Residential	102	109 (+6.9)	112 (+9.9)	0	0	0
Residential/Community	118	118 (+0.00)	118 (+0.00)	0	0	0
Public Access Area	135	135 (+0.00)	136 (+0.28)	0	0	0
Commercial/Industrial Area	121	121 (+0.17)	134 (+11)	0	0	0
AAAQO	**400**	**400**	**400**	N/A	N/A	N/A

Notes:
NO_x emission rates for each Assessment Case are shown.
PL = property line.
PPL = Project Property Line.
AAAQO are not applicable in the PL or the PPL..
Predictions exceeding the AAAQO are shown in **bold face** font.
The values in the parentheses represent the % change with respect to the Baseline Case.
The numbers of predicted hourly exceedances are consistent with the interpretation of the Alberta Air Model Guideline.
N/A = no AAAQO.

2.7.2.3 Maximum 24-Hour Average NO_2 Predictions

Project-Only Case (24-Hour Predictions)

Table 2.7-9 shows the maximum predicted 24-hour NO_2 concentrations due to the Project operating in isolation. All fired equipment is assumed to be operating simultaneously at 100% capacity. The maximum predicted NO_2 concentrations along and outside the PPL are less that the 24-hour AAAQO for NO_2.

Overlapping Cases (24-Hour Predictions)

Table 2.7-11 provides a summary of the predicted maximum NO_2 concentrations and compares these concentrations to the NO_2 24-hour AAAQO. The model predictions in the tables are provided for the same locations as used for the SO_2 evaluation (i.e., at the respective plant property lines). The predictions are also provided for each discrete receptor grouping (e.g., agricultural/residential).

The predicted NO_2 concentration spatial patterns for the three primary assessment cases are presented in Figures 2.7-13 to 2.7-15 as contours superimposed over the 50 km x 50 km RSA base map. Corresponding Project-only plots are presented in Appendix 2E.

Baseline Case

Table 2.7-11 and Figure 2.7-13 show the predicted concentrations for the Baseline Case (249.1 t/d NO_x emission). The maximum predicted NO_2 concentration maxima at the indicated locations range from 54.9 ug/m^3 to 87 ug/m^3; these values are all less than the 24-hour AAAQO. Higher concentration values are predicted in the City of Edmonton and the City of Fort Saskatchewan areas.

Application Case

Table 2.7-11 and Figure 2.7-14 show the predicted concentrations for the Application Case (252.5 t/d NO_x emission). Higher NO_2 concentrations (326 ug/m^3) are predicted to occur within the PPL, decreasing to 117 ug/m^3 at the PPL. The relative change outside the PPL due to the Project is +114%. Relative changes at other locations due to the Project are +25% or less. All predicted values are less than 24-hour AAAQO.

Cumulative Case

Table 2.7-11 and Figure 2.7-15 show the predicted concentrations for the Cumulative Case (290.7 t/d NO_x emission). High NO_2 concentrations (326 ug/m^3) are predicted to occur within the PPL, decreasing to 118 ug/m^3 at the PPL. The relative change at the PPL due to the proposed projects is +114%. Relative changes at other locations due to the proposed projects are +48.1% or less. All predicted values are less than 24-hour AAAQO.

Table 2.7-11 Predicted 24-Hour Average NO_2 Concentrations for Baseline, Application and Cumulative Cases

Location	Maximum NO_2 Concentration (ug/m³)			Number of Exceedances (d/y)		
	Baseline (249.1 t/d)	**Application** (252.5 t/d)	**Cumulative** (290.7 t/d)	**Baseline**	**Application**	**Cumulative**
Agrium Redwater Fertilizer Plant PL	80.2	80.2 (+0.00)	119 (+48)	0	0	0
Shell Canada Scotford Complex PL	68.5	68.5 (+0.00)	82.7 (+21)	0	0	0
BA Energy Heartland Oil Sands Bitumen Upgrader PL	60.1	60.1 (+0.00)	82.5 (+37)	0	0	0
Project Upgrader - Inside PPL	54.9	326 (+495)	326 (+495)	0	7	7
Project Upgrader - Outside PPL	54.9	117 (+113)	118 (+114)	0	0	0
North West Bitumen Upgrader PL	56.6	56.6 (+0.00)	62.3 (+9.9)	0	0	0
Synenco Northern Lights Upgrader PL	57.3	57.4 (+0.07)	79.1 (+38)	0	0	0
Petro-Canada Oil Sands Inc. Sturgeon Upgrader PL	56.6	56.6 (+0.00)	68.8 (+22)	0	0	0
Discrete Receptor Group						
Agricultural/Residential	58.2	72.9 (+25)	75.2 (+29)	0	0	0
Residential/Community	79.5	79.7 (+0.26)	81.3 (+2.3)	0	0	0
Public Access Area	87.0	87.0 (+0.00)	87.0 (+0.00)	0	0	0
Commercial/Industrial Area	83.9	83.9 (+0.01)	86.3 (+2.9)	0	0	0
AAAQO	**200**	**200**	**200**	N/A	N/A	N/A

Notes:
NO_x emission rates for each Assessment Case are shown.
PL = property line.
PPL = Project Property Line.
AAAQO are not applicable in the PL or the PPL..
Predictions exceeding the AAAQO are shown in **bold face** font.
The values in the parentheses represent the % change with respect to the Baseline Case.
N/A = no AAAQO.

2.7.2.4 Annual Average NO_2 Predictions

Project-Only Case (Annual Predictions)

Table 2.7-9 shows the maximum predicted annual NO_2 concentrations due to the Project operating in isolation. All fired equipment was assumed to be operating simultaneously at 100% capacity. The maximum predicted NO_2 concentrations are less than the annual AAAQO for NO_2.

Overlapping Cases (Annual Predictions)

Table 2.7-12 provides a summary of the predicted maximum NO_2 concentrations and compares these concentrations to the NO_2 annual AAAQO. The model predictions in the tables are provided for the same locations as used for the SO_2 evaluation (i.e., at the respective plant property lines). The predictions are also provided for each discrete receptor grouping (e.g., agricultural/residential).

The predicted NO_2 concentration spatial patterns for the three primary assessment cases are presented in Figures 2.7-16 to 2.7-18 as contours superimposed over the 50 km x 50 km RSA base map. Corresponding Project-only plots are presented in Appendix 2E.

Baseline Case

Table 2.7-12 and Figure 2.7-16 show the predicted concentrations for the Baseline Case (249.1 t/d NO_x emission). The maximum predicted NO_2 concentrations at the indicated locations range from 9.8 ug/m^3 to 22.2 ug/m^3; these values are all less than the annual AAAQO. Higher concentration values are predicted in the City of Edmonton and City of Fort Saskatchewan areas.

Application Case

Table 2.7-12 and Figure 2.7-17 show the predicted concentrations for the Application Case (252.5 t/d NO_x emission). Higher NO_2 concentrations (28.8 ug/m^3) are predicted to occur within the PPL, decreasing to 15.8 ug/m^3 at the PPL. The relative change outside the PPL due to the Project is +11%. Relative changes at other locations due to the Project range from 0.22% to +4.3%. All predicted values are less than annual AAAQO.

Cumulative Case

Table 2.7-12 and Figure 2.7-18 show the predicted concentrations for the Cumulative Case (252.5 t/d NO_x emission). Higher NO_2 concentrations (33.5 ug/m^3) are predicted to occur within the PPL, decreasing to 21.2 ug/m^3 at the PPL. The relative change at the PPL due to proposed projects is +49%. Relative changes at other locations due to proposed projects range from +4.1% to +89%. All predicted values are less than annual AAAQO.

Table 2.7-12 Predicted Annual Average NO_2 Concentrations for Baseline, Application and Cumulative Cases

Location	Annual NO_2 Concentration (ug/m³)		
	Baseline (249.1 t/d)	**Application** (252.5 t/d)	**Cumulative** (290.7 t/d)
Agrium Redwater Fertilizer Plant PL	17.9	18.1 (+0.9)	23.6 (+32)
Shell Canada Scotford Complex PL	17.6	17.9 (+1.3)	25.1 (+42)
BA Energy Heartland Oil Sands Bitumen Upgrader PL	14.1	14.3 (+1.9)	22.4 (+59)
Project Upgrader - Inside PPL	14.2	28.8 (+103)	33.5 (+136)
Project Upgrader - Outside PPL	14.2	15.8 (+11)	21.2 (+49)
North West Bitumen Upgrader PL	12.9	13.1 (+1.1)	20.3 (+60)
Synenco Northern Lights Upgrader PL	9.8	10.0 (+1.8)	14.6 (+49)
Petro-Canada Oil Sands Inc. Sturgeon Upgrader PL	12.8	13.0 (+1.3)	18.4 (+44)
Discrete Receptor Group			
Agricultural/Residential	15.7	16.3 (+4.3)	22.1 (+41)
Residential/Community	15.4	15.6 (+0.80)	17.6 (+14)
Public Access Area	22.2	22.2 (+0.22)	23.1 (+4.1)
Commercial/Industrial Area	16.1	16.3 (+1.3)	20.7 (+29)
AAAQO	**60**	**60**	**60**

Notes:
NO_x emission rates for each Assessment Case are shown.
PL = property line
PPL = Project Property Line
AAAQO are not applicable in the PL or the PPL.
Predictions exceeding the AAAQO are shown in **bold face** font.
The values in the parentheses represent the % change with respect to the Baseline Case.
N/A = no AAAQO

2.7.2.5 NO_2 Summary

The Project and other proposed upgraders will increase NO_x emissions in the area. The NO_x emissions from these sources are less than those from Edmonton urban traffic and residential heating sources. The NO_2 concentration patterns in the region are dominated by the urban sources. While high NO_2 concentrations are predicted within the PPL, the maximum predicted values at all locations outside the PPL for the three assessment cases are less than the AAAQOs for NO_2.

The human health and environmental consequences of these predicted NO_2 concentrations are discussed in Volume 2, Section 4 - Human Health and in Volume 4, Section 10 - Vegetation.

2.7.2.6 Prediction Confidence

The prediction confidence relates to the uncertainty associated with the emission estimates and assumptions, and to the uncertainty associated with the model's ability to predict ambient concentrations. The comparison between predictions and measurements (Appendix 2D) accounts for both uncertainties. Based on the comparison, the 99th percentile 1-hour concentrations at each station, on average are overpredicted by 12%. The maximum 24-hour concentrations, on average, are underpredicted by 31%. The annual concentrations, on average, are overpredicted by 51%.

In general, the model predicted high concentrations where high concentrations are measured and low concentrations where low concentrations are measured. The model can be viewed as an appropriate "best estimate" tool.

2.7.3 Particulate Matter Concentrations

The particulate matter (PM) concentration predictions include combustion source contributions (referred to as primary) and sulphate and nitrate contributions from SO_2 and NO_x emissions (referred to as secondary). For the purposes of estimating the secondary PM contribution, sulphate and nitrate were assumed to be in the form of ammonium sulphate and ammonium nitrate, respectively. In addition, all primary and secondary PM was assumed to be in the fine fraction (i.e., that is all PM was assumed to have aerodynamic diameters less than 2.5 um in diameter ($PM_{2.5}$).

2.7.3.1 $PM_{2.5}$ Emission Profiles

Ambient $PM_{2.5}$ concentrations due to primary emission sources are directly related to the number of sources that emit $PM_{2.5}$ and the magnitude of the associated $PM_{2.5}$ emission rates. Table 2.7-13 shows the $PM_{2.5}$ emission rates that were examined and the values in the table represent the range of emission rates that can be described as normal. About 60% of the $PM_{2.5}$ emissions (i.e., 12.1 t/d) result from urban sources. Short-term abnormal $PM_{2.5}$ emissions that are greater than the values represented in Table 2.7-12 might occur under plant upset conditions, or might be associated with biogenic (e.g., biomass burning) or community sources. These events were not considered for this assessment.

Table 2.7-13 $PM_{2.5}$ Emission Rates – Assessment Cases

Assessment Case	$PM_{2.5}$ Emission (t/d)
Project-Only Case	0.42
Baseline Case	19.21
Application Case	19.63
Cumulative Case	21.56

2.7.3.2 24-hour Average $PM_{2.5}$ Predictions

Project-Only Case (24-hour Predictions)

Normal Scenarios

Table 2.7-14 shows the maximum predicted 24-hour $PM_{2.5}$ concentrations due to the Project operating in isolation. All fired equipment was assumed to be operating simultaneously at 100% of design capacity. The maximum predicted $PM_{2.5}$ concentrations along and outside the PPL are less that the 24-hour CWS for $PM_{2.5}$.

Table 2.7-14 Maximum Predicted $PM_{2.5}$ Concentrations Associated with Project-Only Case

Averaging Period	$PM_{2.5}$ Emission Rate (t/d)	Maximum Concentration (ug/m^3)			CWS (ug/m^3)
		Inside PPL	PPL	Outside PPL	
24-hour (98th percentile)	0.42	43.6	10.7	10.1	30
Annual	0.42	16.6	1.9	1.7	N/A

Construction Scenarios

During construction, there is the potential for fugitive dust emissions. Maximum expected TSP, PM_{10} and $PM_{2.5}$ concentrations 500 m and 1,000 m downwind of a 1 ha area of construction activity are provided in Table 2.7-15. The predictions are based on the assumptions given in Section 2.6.2.1 and assume that the 12-hour emission rates are applicable to a full 24-hour period. The predicted values are provided for neutral atmospheric conditions with wind speeds of 1 m/s and 3 m/s. Neutral conditions were selected to account for the daytime bias for construction activities.

The predicted values in Table 2.7-15 indicate lower concentrations with higher wind speeds. There is the potential for high TSP levels downwind of the construction area, indicating the need for dust suppression when meteorological conditions conducive to forming dust occur. The predicted $PM_{2.5}$ levels, however, are less than the associated CWS metric.

Table 2.7-15 Maximum Predicted $PM_{2.5}$ Concentrations Associated with Project-Only Construction Activity

24-hour Averaging Period	Wind Speed (m/s)	Maximum Concentration (ug/m^3)		
		TSP	PM_{10}	$PM_{2.5}$
Emission Rate (t/d)	-	0.18	0.054	0.005
500 m downwind	1	369	111	11
1,000 m downwind	1	134	40	4
500 m downwind	3	123	37	4
1,000 m downwind	3	45	14	1.4
AAAQO or CWS	-	**100**	**N/A**	**30**

Notes:
N/A = no AAAQO or CWS

2.7.3.3 Overlapping Cases (24-Hour Predictions)

Table 2.7-16 provides a summary of the maximum predicted 98th percentile $PM_{2.5}$ concentrations for the 24-hour averaging period and compares these concentrations to the CWS for $PM_{2.5}$. The 98th percentile concentrations that are provided correspond to the 8th highest daily value at any single location out of the one-year simulation period. The model predictions in the table are provided for the same locations as used for the SO_2 evaluation (i.e., at the respective plant property lines). The predictions are also provided for each discrete receptor grouping (e.g., agricultural/residential).

The predicted $PM_{2.5}$ concentration spatial patterns for the three primary assessment cases are presented in Figures 2.7-19 to 2.7-21 as contours superimposed over the 50 km x 50 km RSA base map. Corresponding Project-only plots are presented in Appendix 2E.

Baseline Case

Table 2.7-16 and Figure 2.7-19 show the predicted concentrations for the Baseline Case (19.21 t/d $PM_{2.5}$ emission). The maximum predicted $PM_{2.5}$ concentration maxima at the indicated locations range from 11.7 ug/m^3 to 22.2 ug/m^3; these values are all less than the 24-hour CWS. Higher concentration values that are greater than the CWS are predicted in the Edmonton area.

Application Case

Table 2.7-16 and Figure 2.7-20 show the predicted concentrations for the Application Case (19.63 t/d $PM_{2.5}$ emission). High $PM_{2.5}$ concentrations are predicted to occur at the PPL 20.4 ug/m^3. The maximum predicted concentrations at other (offsite) locations due to the Project range from 11.8 ug/m^3 to 23.0 ug/m^3. All predicted offsite values are less than CWS.

Cumulative Case

Table 2.7-16 and Figure 2.7-21 show the predicted concentrations for the Cumulative Case (21.56 t/d $PM_{2.5}$ emission). Higher $PM_{2.5}$ concentrations (25.3 ug/m^3) are predicted to occur at the PPL. The maximum predicted concentrations at other (offsite) locations due to the Project range from 16.2 ug/m^3 to 25.3 ug/m^3. All predicted offsite values are less than CWS.

Table 2.7-16 Predicted (98th Percentile) 24-Hour Average $PM_{2.5}$ Concentrations for Baseline, Application and Cumulative Cases

Location	**Maximum $PM_{2.5}$ Concentration (ug/m³)**			**Number of Exceedances (d/y)**		
	Baseline (19.21 t/d)	**Application (19.63 t/d)**	**Cumulative (21.56 t/d)**	**Baseline**	**Application**	**Cumulative**
Agrium Redwater Fertilizer Plant PL	14.1	14.9 (+5.9)	20.9 (+49)	0	0	0
Shell Canada Scotford Complex PL	18.1	18.9 (+4.5)	24.8 (+37)	0	0	0
BA Energy Heartland Oil Sands Bitumen Upgrader PL	15.5	16.1 (+3.4)	22.9 (+47)	0	0	0
Project Upgrader - Inside PPL	15.6	54.3 (+249)	56.9 (+265)	0	0	0
Project Upgrader - Outside PPL	15.6	20.4 (+31)	25.3 (+62)	0	0	0
North West Bitumen Upgrader PL	14.5	14.6 (+0.67)	20.9 (+44)	0	0	0
Synenco Northern Lights Upgrader PL	11.7	11.8 (+0.92)	16.2 (+39)	0	0	0
Petro-Canada Oil Sands Inc. Sturgeon Upgrader PL	17.3	17.5 (+1.1)	22.1 (+17)	0	0	0
Discrete Receptor Group						
Agricultural/Residential	15.6	16.8 (+7.6)	23.6 (+52)	0	0	0
Residential/Community	21.0	21.0 (+0.33)	22.4 (+6.6)	0	0	0
Public Access Area	22.2	23.0 (+3.3)	24.0 (+8.1)	0	0	0
Commercial/Industrial Area	18.2	18.9 (+4.0)	24.0 (+32)	0	0	0
CWS	**30**	**30**	**30**	N/A	N/A	N/A

Notes:
$PM_{2.5}$ emission rates for each Assessment Case are shown.
PL = property line
PPL = Project Property Line
CWS are not applicable in the PL or the PPL.
Predictions exceeding the CWS are shown in **bold face** font.
The values in the parentheses represent the % change with respect to the Baseline Case.
N/A = no CWS

2.7.3.4 Annual Average Predictions

Project-Only Case (Annual Predictions)

Table 2.7-14 shows the predicted annual $PM_{2.5}$ concentrations due to the Project operating in isolation. All fired equipment is assumed to be operating simultaneously at 100% capacity. There are no AAAQO or CWS for annual $PM_{2.5}$ concentrations. Project-only concentration plots are presented in Appendix 2E.

Overlapping Cases (Annual Predictions)

Table 2.7-17 provides a summary of the predicted maximum $PM_{2.5}$ concentrations. The model predictions in the tables are provided for the same locations as used for the SO_2 evaluation (i.e., at the respective plant property lines). The predictions are also provided for each discrete receptor grouping (e.g., agricultural/residential).

The predicted $PM_{2.5}$ concentration spatial patterns for the three primary assessment cases are presented in Figures 2.7-22 to 2.7-24 as contours superimposed over the 50 km x 50 km RSA base map.

Baseline Case

Table 2.7-17 and Figure 2.7-22 show the predicted concentrations for the Baseline Case (19.21 t/d $PM_{2.5}$ emission). The predicted annual average $PM_{2.5}$ concentrations at the indicated locations range from 2.4 ug/m^3 to 4.89 ug/m^3. Higher concentration values (i.e., greater than 30 ug/m^3) are predicted in the Edmonton area.

Cheng et al. (2000) indicated that annual average $PM_{2.5}$ concentrations in the 1.7 ug/m^3 to 3.8 ug/m^3 range are representative of “rural-remote” sites; annual average $PM_{2.5}$ concentrations in the 4.5 ug/m^3 to 11.48 ug/m^3 range are representative of “rural-influenced” sites; and annual average $PM_{2.5}$ concentrations in the 14 ug/m^3 to 24 ug/m^3 range are representative of “rural industrial” sites.

Application Case

Table 2.7-17 and Figure 2.7-23 show the predicted concentrations for the Application Case (19.63 t/d $PM_{2.5}$ emission). Annual average $PM_{2.5}$ concentrations inside and outside the PPL are 4.36 ug/m^3 and 3.82 ug/m^3, respectively. The relative change outside the PPL due to the Project is +15.2%. Relative changes due at other locations to the Project range from +0.50 to +2.62%.

Cumulative Case

Table 2.7-17 and Figure 2.7-24 show the predicted concentrations for the Cumulative Case (21.56 t/d $PM_{2.5}$ emission). Annual average $PM_{2.5}$ concentrations inside and outside the PPL are 5.29 ug/m^3 and 4.73 ug/m^3, respectively. The relative change outside the PPL due to the proposed projects is +43%. Relative changes at other locations due to the proposed projects range from +7.4 to +460%.

Table 2.7-17 Predicted Annual Average $PM_{2.5}$ Concentrations for Baseline, Application and Cumulative Cases

Location	Annual $PM_{2.5}$ Concentration (ug/m³)		
	Baseline (19.21 t/d)	**Application (19.63 t/d)**	**Cumulative (21.56 t/d)**
Agrium Redwater Fertilizer Plant PL	3.92	3.97 (+1.1)	4.92 (+26)
Shell Canada Scotford Complex PL	4.13	4.20 (+1.9)	5.85 (+42)
BA Energy Heartland Oil Sands Bitumen Upgrader PL	3.34	3.43 (+2.6)	4.88 (+46)
Project Upgrader - Inside PPL	3.30	4.36 (+32)	5.29 (+60)
Project Upgrader - Outside PPL	3.31	3.82 (+15)	4.73 (+43)
North West Bitumen Upgrader PL	3.25	3.29 (+1.2)	4.32(+33)
Synenco Northern Lights Upgrader PL	2.40	2.45 (+2.1)	3.24 (+35)
Petro-Canada Oil Sands Inc. Sturgeon Upgrader PL	3.19	3.24 (+1.5)	4.04 (+27)
Discrete Receptor Group			
Agricultural/Residential	3.49	3.55 (+1.9)	4.66 (+33)
Residential/Community	3.57	3.62 (+1.2)	4.10 (+15)
Public Access Area	4.89	4.92 (+0.50)	5.25 (+7.4)
Commercial/Industrial Area	4.21	4.27 (+1.5)	5.20 (+234)
CWS	**N/A**	**N/A**	**N/A**

Notes:
$PM_{2.5}$ emission rates for each Assessment Case are shown.
PL = property line.
PPL = Project Property Line.
CWS are not applicable in the PL or the PPL.
Predictions exceeding the AAAQO are shown in **bold face** font.
The values in the parentheses represent the % change with respect to the Baseline Case.
N/A = no CWS.

2.7.3.5 Key Findings

The Project and other proposed upgraders will increase $PM_{2.5}$ emissions in the area. The Edmonton and Fort Saskatchewan urban areas are the major sources of $PM_{2.5}$; the $PM_{2.5}$ concentration patterns are therefore dominated by urban emission sources in the region. Specifically, the model is predicting elevated $PM_{2.5}$ concentration levels near the urban areas with decreasing concentrations associated with increasing distances from these areas.

Higher 24-hour average $PM_{2.5}$ concentrations are predicted in the Edmonton area. The maximum predicted 24-hour $PM_{2.5}$ concentrations near the Project area is about one-half the CWS. The 98th percentile $PM_{2.5}$ concentrations at locations near the Project are predicted to meet the CWS for the Baseline, Application and Cumulative cases.

The human health consequences of these predicted $PM_{2.5}$ concentrations are discussed in Volume 2, Section 4 - Human Health.

2.7.3.6 Prediction Confidence

The prediction confidence relates to the uncertainty associated with the emission estimates and assumptions, and to the uncertainty associated with the model's ability to predict ambient concentrations. The comparison between predictions and measurements (Appendix 2D) accounts for both uncertainties. The comparison showed that the model is predicting reasonable 1-hour $PM_{2.5}$ concentrations at the rural stations, and overpredicting 1-hour $PM_{2.5}$ concentrations at the urban stations. There is a tendency to overpredict 24-hour and annual average $PM_{2.5}$ concentrations at the urban sites (Appendix 2B).

2.7.4 PAI Deposition

PAI deposition is a result of SO_2 and NO_x emissions and is expressed as keq H^+/ha/y. The PAI predictions are discussed on a local scale and on a DSA average scale. The DSA averages are more comparable to the AENV/CASA target loading values that are referenced to a 1º longitude x 1º longitude grid cell.

2.7.4.1 SO_2 and NO_x Emission Profiles

The PAI is directly related to the SO_2 and NO_x emission rates. Table 2.7-18 shows the SO_2 and NO_x emission rates that were used to represent the annual averaging period.

Though intermittent sources (i.e., flaring events) can represent a considerable SO_2 emission source for a short-term period, they are relatively small contributors when considered over an annual period. For example, over the period July to December 2003 that followed the Shell Canada Scotford Upgrader commissioning phase, the Scotford Upgrader SO_2 emissions from intermittent flaring and continuous incinerator stack emissions were 144 t and 5,339 t, respectively. The intermittent flaring therefore accounted for 2.6% of the total SO_2 emissions during post-commissioning (Shell Canada, 2005a). On this basis, the intermittent source contribution to the total PAI would be expected to be much smaller than the contribution from the continuous sources.

Table 2.7-18 Comparison of SO_2 and NO_x Emission Rates

Assessment Case	SO_2 Annual (Long-term) Emission (t/d)	NO_x Annual Emission (t/d)
Project-Only Case	7.34	3.45
Baseline Case	98.16	249.1
Application Case	105.50	252.5
Cumulative Case	170.06	290.7

2.7.4.2 Local-Scale Predictions

Table 2.7-19 provides a summary of the maximum predicted PAI deposition on a local scale. The values are based on the sum of predicted individual hourly depositions that accumulates over the one-year simulation period. The model predictions in the tables are provided for the same locations as used for the SO_2 evaluation (i.e., at the respective plant property lines). The predictions are also provided for each discrete receptor grouping (e.g., agricultural/residential).

The predicted spatial PAI deposition patterns for four assessment cases are presented as contours -superimposed over the 80 km x 80 km DSA base map (Figures 2.7.25 to 2.7-27). The Project-only plots are presented in Appendix 2E.

Baseline Case

Table 2.7-19 and Figure 2.7-25 show the predicted PAI deposition for the Baseline Case. Figure 2.7-25 shows that while the Edmonton and Fort Saskatchewan urban emissions play a major role in determining the spatial PAI deposition pattern in the study area, the influences of the main SO_2 emission sources can also be seen. The maximum predicted values in the Edmonton and Fort Saskatchewan areas are greater than 1.0 keq H^+/ha/y. The maximum values near the approved SO_2 emission sources range from 0.61 keq H^+/ha/y to 0.81 keq H^+/ha/y. The maximum value predicted in Elk Island National Park is 0.31 keq H^+/ha/y.

Application Case

Table 2.7-19 and Figure 2.7-26 show the predicted PAI deposition for the Application Case. The maximum values near the approved SO_2 emission sources range from 0.64 keq H^+/ha/y to 0.83 keq H^+/ha/y (i.e., the changes range from 1.9% to 4.4%). The maximum value at the PPL is 0.443 keq H^+/ha/y, which represents an increase of +20%. The maximum value predicted in Elk Island National Park is 0.32 keq H^+/ha/y (i.e., an increase of 3.5%).

Cumulative Case

Table 2.7-19 and Figure 2.7-27 show the predicted PAI deposition for the Cumulative Case. The maximum values near the approved and proposed SO_2 emission sources range from 0.62 keq H^+/ha/y to 1.22 keq H^+/ha/y (i.e., the changes range from +50% to +131%, relative to the Baseline Case). The maximum value predicted in Elk Island National Park is 0.41 keq H^+/ha/y (i.e., an increase of 30%, relative to the Baseline Case).

2.7.4.3 DSA-Average Predictions

Table 2.7-20 provides a summary of the average PAI deposition for the 80 km x 80 km DSA. The area of the DSA is similar to that of a 1° latitude x 1°□longitude grid cell. The average values for the DSA can therefore be compared to the target loads given in the table. The applicability of a given target load will depend on the grid cell receptor sensitivity. The western half of the DSA is classified being “Moderately Sensitive”, and the eastern half is classified as having a “Low Sensitivity”.

Baseline Case

Table 2.7-20 shows the predicted DSA-average PAI deposition for the Baseline Case. The DSA-average PAI deposition (0.14 keq H^+/ha/y) is less than the target loads, regardless of the assumed DSA sensitivity.

Application Case

Table 2.7-19 shows the predicted DSA-average PAI deposition for the Application Case. The DSA-average PAI deposition (0.15 keq H^+/ha/y) is less than the target load, regardless of the assumed DSA sensitivity. The Project emissions increase the DSA-average PAI by +2.9%.

Cumulative Case

Table 2.7-19 shows the predicted DSA-average PAI deposition for the Cumulative Case. The DSA-average PAI deposition (0.18 keq H^+/ha/y) is less than the target load, regardless of the assumed DSA sensitivity. The Cumulative Case emissions increase the DSA-average PAI by +30%, relative to the Baseline Case.

2.7.4.4 Key Findings

There are two primary areas where relatively high PAI values from existing sources are predicted to occur: near the urban areas of Edmonton and Fort Saskatchewan (because of NO_x emissions) and near the existing primary SO_2 emissions sources (because of SO_2 emissions). The local scale peak values are predicted to increase substantially near the proposed upgraders, with the relative increases decreasing with increasing distances from these facilities. The Project is predicted to increase the maximum PAI deposition in Elk Island National Park by about +3.5%. For the Cumulative Case, the predicted increase in the Park is +30%.

The AENV Target Load criteria are to be applied on a 1º latitude x 1º longitude grid basis. In the study area, this grid corresponds to an area that is about 7,326 km^2 (i.e., about 111 km x 66 km). As the DSA has a similar area of 6,400 km^2 (i.e., 80 km x 80 km), the DSA-average PAI deposition can be compared to the target load values. The DSA-average PAI for the Baseline, Application and Cumulative (with Project) cases are 0.14 keq H^+/ha/y, 0.15 keq H^+/ha/y and 0.18 keq H^+/ha/y, respectively. The Project contributes about 3% to the DSA-average relative to the Baseline Case. The DSA-average values are currently less that the target loading for Low Sensitivity, Moderately Sensitive and Sensitive receptors.

The environmental consequences of the predicted PAI deposition are discussed in Volume 3, Section 7 - Surface Water Quality, Volume 4, Section 9 - Soils, and Volume 4, Section 10 - Vegetation.

2.7.4.5 Prediction Confidence

The prediction confidence relates to the uncertainty associated with the emission estimates, to the uncertainty associated with the dispersion model's ability to predict ambient concentrations, and to the uncertainty associated with the model's ability to represent deposition processes. As there are no PAI deposition measurements in the Fort Saskatchewan area, the prediction confidence has to be inferred indirectly.

Specifically, the deposition is related to the annual average sulphur and nitrogen substance concentrations. The model tends to overpredict annual average SO_2 and NO_2 concentrations. This can lead to a corresponding overprediction of the dry PAI deposition. However, the 2002 simulation year was a drought year (267 mm based on Edmonton International Airport), and the wet SO_2 and NO_2 deposition might be underestimated. A comparison of predicted total PAI deposition using more representative 2006 precipitation (476 mm) data and 2006 meteorological data indicated that while the 2002 wet deposition was underestimated, the 2002 dry deposition was overestimated (relative to the 2006 predictions). The net effect being that the predicted 2002 DSA-average PAI deposition was within 2% of the predicted 2006 DSA-average PAI deposition (PCOSI, 2007).

In terms of predicting PAI deposition, the approach that was adopted can be regarded as a best estimate practice, and results provided are more comprehensive than what has been undertaken for the area to date. For this reason, the predicted PAI deposition is given a high confidence rating as a relative indicator, and an undetermined confidence rating as an absolute indicator.

Table 2.7-19 Predicted Annual PAI Deposition for the Baseline, Application and Cumulative Cases

Location	Annual PAI Deposition ($keq\ H^+/ha/y$)		
	Baseline	**Application**	**Cumulative**
Agrium Redwater Fertilizer Plant PL	0.65	0.66 (+2.5)	1.10 (+71)
Shell Canada Scotford Complex PL	0.81	0.83 (+1.9)	1.22 (+50)
BA Energy Heartland Oil Sands Bitumen Upgrader PL	0.61	0.64 (+4.4)	1.13 (+86)
Project Upgrader – Inside PPL	0.37	0.68 (+85)	0.92 (+151)
Project Upgrader – Outside PPL	0.37	0.44 (+20)	0.69 (+88)
North West Bitumen Upgrader PL	0.38	0.40 (+3.4)	0.88 (+131)
Synenco Northern Lights Upgrader PL	0.20	0.22 (+6.8)	0.62 (+208)
Petro-Canada Oil Sands Inc. Sturgeon Upgrader PL	0.34	0.35 (+3.3)	0.64 (+86)
Discrete Receptor Group			
Agricultural/Residential	0.40	0.44 (+8.2)	0.74 (+83)
Residential/Community	0.25	0.28 (+9.8)	0.45 (+79)
Public Access Area	0.50	0.51 (+1.0)	0.69 (+37)
Commercial/Industrial Area	0.87	0.88 (+1.7)	1.07 (+24)
Elk Island National Park	0.31	0.32 (+3.5)	0.41 (+30)
Target Load	**N/A**	**N/A**	**N/A**

Notes:
The values in the parentheses represent the % change with respect to the Baseline Case.
The values include an adjustment of -0.08 keq H^+/ha/y to account for contributions external to the DSA and for base cations.
PL = property line.
PPL = Project property line.
N/A = no target load.

Table 2.7-20 Predicted Average DSA PAI Deposition for the Baseline, Application and Cumulative Cases.

	Annual PAI Deposition ($keq\ H^+/ha/y$)		
	Baseline	**Application**	**Cumulative**
DSA Average	0.14	0.15 (+2.9)	0.18 (+30)
Target Load	Low sensitivity	0.90 (Applicable to eastern portion of DSA)	
	Moderately sensitive	0.45 (Applicable to western portion of DSA)	
	Sensitive	0.22	

Notes:
The values in the parentheses represent the % change with respect to the Baseline Case.
The values include an adjustment of -0.08 keq H^+/ha/y to account for contributions external to the DSA and for base cations.
Target Load values are discussed in Section 2.3.1.2 and are given in Table 2.3-2.

2.7.5 Nitrogen Deposition

Nitrogen deposition is a result of NO_x emissions and the nitrogen predictions are discussed for the local scale.

2.7.5.1 NO_x Emission Profiles

Nitrogen deposition is directly related to the NO_x emission rates. Table 2.7-21 shows the annual average NO_x emission rates that were used to represent the annual averaging period.

Table 2.7-21 Comparison of NO_x Emission Rates

Assessment Case	**NO_x Annual Emission** (t/d)
Project-Only Case	3.45
Baseline Case	249.1
Application Case	252.5
Cumulative Case	290.7

2.7.5.2 Nitrogen Deposition Predictions

Table 2.7-22 provides a summary of the maximum predicted nitrogen deposition. The values are based on the sum of the predicted individual hourly depositions that accumulates over the one-year simulation period. The model predictions in the tables are provided for the same locations as used for the SO_2 evaluation (i.e., at the respective plant property lines). The predictions are also provided for each discrete receptor grouping (e.g., agricultural/residential).

The predicted spatial nitrogen deposition patterns for three assessment cases are presented as contours superimposed over the 80 km x 80 km DSA base map (Figures 2.7-28 to 2.7-30). The Project-only plots are presented in Appendix 2E.

Baseline Case

Table 2.7-22 and Figure 2.7-28 show the predicted nitrogen deposition for the Baseline Case. Figure 2.7-28 shows that the Edmonton and Fort Saskatchewan urban emissions play a major role in determining the nitrogen deposition pattern in the study area. The maximum predicted values in the City of Edmonton and the City of Fort Saskatchewan areas are greater than 10 kg N/ha/y.

The maximum values near the approved upgraders range from 4.5 kg N/ha/y to 6.6 kg N/ha/y, and the maximum values near the Project site is 3.7 kg N/ha/y. The maximum value predicted in Elk Island National Park is 4.4 kg N/ha/y.

Application Case

Table 2.7-22 and Figure 2.7-29 show the predicted nitrogen deposition for the Application Case. The maximum values near the approved SO_2 emission sources range from 4.7 kg N/ha/y to 6.7 kg N/ha/y (i.e., changes range from 1.1% to 4.7%), the maximum value outside the PPL is 4.3 kg N/ha/y, which represents a change of +15.7% due to the Project). The maximum value predicted in Elk Island National Park is 4.4 kg N/ha/y, which represents a change of +1.3% due to the Project.

Cumulative Case

Table 2.7-22 and Figure 2.7-30 show the predicted nitrogen deposition for the Cumulative Case. The maximum values near the approved and proposed SO_2 emission sources range from 4.2 kg N/ha/y to 10 kg N/ha/y (i.e., changes are in the +43% to +86% range). The maximum value outside the PPL is 6.21 kg N/ha/y, which represents a change of +69% due to the proposed projects). The maximum value predicted in Elk Island National Park National Park is 5.0 kg N/ha/y, which represents a change of 153% due to the proposed projects).

2.7.5.3 Key Findings

Relatively high (i.e., larger than 10 kg N/ha/y) nitrogen deposition values are predicted to occur in the Edmonton and Fort Saskatchewan urban area because of NOx emissions. The Project is predicted to change the maximum nitrogen deposition in Elk Island National Park by about +1.3%. For the Cumulative Case, the change relative to the Baseline Case is +15% (from 4.4 kg N/ha/y to 5.0 kg N/ha/y).

The environmental consequences of the predicted nitrogen deposition are discussed in Volume 3, Section 7 - Surface Water Quality, Volume 4, Section 9 - Soils, and Volume 4, Section 10 - Vegetation.

2.7.5.4 Prediction Confidence

The prediction confidence relates to the uncertainty associated with the emission estimates, to the uncertainty associated with the dispersion model's ability to predict ambient concentrations and to the uncertainty associated with the model's ability to represent deposition processes. There are no PAI deposition measurements in the Fort Saskatchewan area and, therefore, the prediction confidence has to be inferred indirectly.

Specifically, the deposition will be closely related to the annual average nitrogen substance concentrations. Similar comments regarding the prediction of PAI deposition can be made relative to the prediction of nitrogen deposition. With respect to 2002 being a drought year, the predicted 2002 DSA-average nitrogen deposition was within 2% of the predicted 2006 DSA-average nitrogen deposition (PCOSI, 2007).

In terms of predicting nitrogen deposition, the approach that was adopted can be regarded as a best estimate practice, and results provided are more comprehensive than what has been undertaken for the area to date. For this reason, the predicted nitrogen deposition is given a high confidence rating as a relative indicator, and an undetermined confidence rating as an absolute indicator.

Table 2.7-22 Predicted Annual Average Nitrogen Deposition for Baseline, Application and Cumulative Cases

Location	Annual N Deposition (kg/ha/y)		
	Baseline	**Application**	**Cumulative**
Agrium Redwater Fertilizer Plant PL	6.6	6.7 (+1.1)	9.4 (+43)
Shell Canada Scotford Complex PL	6.0	6.1 (+1.3)	10.1 (+68)
BA Energy Heartland Oil Sands Bitumen Upgrader PL	4.5	4.7 (+3.3)	8.4 (+86)
Project Upgrader - Inside PPL	3.7	7.7 (+109)	9.5 (+159)
Project Upgrader - Outside PPL	3.7	4.3 (+16)	6.2 (+699)
North West Bitumen Upgrader PL	3.8	3.9 (+1.6)	6.8 (+79)
Synenco Northern Lights Upgrader PL	2.4	2.5 (+2.8)	4.2 (+74)
Petro-Canada Oil Sands Inc. Sturgeon Upgrader PL	3.4	3.5 (+1.5)	5.9 (+73)
Discrete Receptor Group			
Agricultural/Residential	3.9	4.1 (+3.5)	6.6 (+68)
Residential/Community	3.8	3.9 (+1.0)	4.4 (+16)
Public Access Area	7.2	7.2 (+0.3)	7.6 (+5.0)
Commercial/Industrial Area	6.5	6.5 (+1.1)	9.1 (+41)
Elk Island Monitoring Station	4.4	4.4 (+1.3)	5.0 (+15)
Target Load	**NA**	**NA**	**NA**

Notes:
The values in the parentheses represent the % change with respect to the Baseline Case.
PL = property line
PPL = Project property line
N/A = no target load

2.7.6 Ozone Concentrations

2.7.6.1 Background

Ambient O_3 concentrations in the region can be attributed to a number of different naturally occurring causes. In addition, there is a potential for O_3 formation resulting from precursor NO_x and VOC emissions, with the appropriate meteorological conditions (i.e., strong solar radiation, high temperatures and low wind speeds). In the presence of NO_x emission sources, O_3 concentrations decrease because of the NO to NO_2 conversion reaction. Photochemical production of O_3 tends to occur at greater downwind distances. From a Fort Saskatchewan perspective, the potential for photochemical production would have to account for precursor emission sources that extend beyond the selected regional study area (i.e., to include Edmonton CMA emissions).

2.7.6.2 Precursor Emissions

Table 2.7-23 compares the precursor NO_X and VOC emissions for the 100 km x 100 km area centred on the Project site (i.e., the CALPUFF model domain). This area includes a significant portion of the Edmonton urban emissions. The Project contributions to the NO_x and VOC emissions relative to the Baseline Case are +1.4% and +2.4%, respectively. For the Cumulative Case, the proposed NO_x and VOC precursor emissions change by +17% and +6.1%, respectively. Relative to the Edmonton Census Division (CD), the Project contributions to the NO_x and VOC emissions are 0.8 and 0.5%, respectively.

The Project NO_X emissions would decrease ambient O_3 concentrations near the site. Further downwind, given the low NO_X and VOC emissions caused by the Project relative to the larger area, the potential for measurable contribution to photochemical O_3 formation is small.

2.7.6.3 Environment Canada Studies

EC has conducted two assessments relative to ozone formation downwind of the Edmonton CMA. One involved the application of the Community Multiscale Air Quality (CMAQ) model to evaluate the potential effect of industrial development in Fort Saskatchewan area on ozone formation. The second study involved an intensive monitoring program coupled with modelling; this project is referred to as PrAIRie 2005.

As part of a submission at the North West Bitumen Upgrader hearing, EC (2007) provided CMAQ model predictions showing the effect of additional AIH upgraders on ozone concentrations downwind of the source region. The EC modelling was based on the 3-month period, June 1 to August 31, 2002, when the potential for ozone formation was expected to be the greatest; and on additional NO_x emissions of 39 t/d and additional VOC emissions of 9 t/d.

Table 2.7-23 indicates that Cumulative Case NO_x emissions are 41.65 t/d more than Baseline case emissions. This increase is consistent with the EC projection of 39 t/d. Table 2.7-23 indicates Cumulative Case VOC emissions are 5.44 t/d more than Baseline Case emissions. This is less than the EC projection of 9 t/d, and is likely attributable to the VOC emission estimates in Table 2.6-5 focusing on hydrocarbons that have a human health focus rather than a photochemical O_3 production focus. Specifically, the VOC projections in Table 2.7-23 are likely understated as not all facility projections include the C_2 to C_4 component, which comprises a large portion of the VOC emissions.

The EC model findings are expressed in terms of the 4th highest 8-hour prediction to be consistent with the CWS, and they may be summarized as:

- In the City of Edmonton, the ozone concentration changes are less than +0.1%.
- To the east of Edmonton, the ozone concentration changes are about +1.1%.
- In the FAP area, the ozone concentration changes are in the +2.9% to +4.8% range.
- The overall maximum increase that appears to be located to the east of the Edmonton CMA is 8.6%.

An associated detailed report relating to this and additional ozone modelling is expected to be completed in November 2007.

Project PrAIRie2005 included surface and aircraft field measurements and photochemical modelling. Although the findings and conclusions of the program have not been officially released, the program has been discussed at conferences (e.g., Makar, 2006). The model simulations show that O_3 is removed over urban and other areas with high NO_x emissions, and that ozone production was found to occur several hundred kilometres downwind of the source region. Formal reports describing the findings are expected to be available in the first half of 2008 (Kellerhals, pers. comm.)

Table 2.7-23 Comparison of Precursor NO_x and VOC Emissions

Region	Case	NO_x (t/d)	VOC (t/d)
CALPUFF model area (100 km x 100 km)	Project Only	3.45	1.53 (C2+)
	Baseline Case	249.1	78.52
	Application Case	252.5 (+1.4)	80.05 (+1.9)
	Cumulative Case	290.7 (+17)	83.96 (+1.8)
Comparison to Edmonton Census Division (CD)	Project Only	3.45	1.53
	Edmonton CD 2010	445 (0.8)	366 (0.4)

Notes:

For the CALPUFF model area emissions, the values in the parentheses represent the percent change with respect to the Baseline Case.

For the Edmonton CD emissions, the values in the parentheses represent the Project contribution (%) with respect to the Edmonton CD emissions.

VOC values for the CALPUFF model area also include small amounts of PAH.

Edmonton CD 2010 emissions from ChemInfo (2002) include all of Edmonton, Fort Saskatchewan and the Wabamun area.

2.7.6.4 Key Findings

While the Project ozone precursor emissions are relatively minor compared to the Edmonton CMA emissions, modelling has indicated that collectively, the proposed upgraders could contribute to increased ozone concentrations. In the City of Edmonton, this increase is virtually negligible; in the FAP area it is in the 3% to 5% range. The overall maximum increase is predicted to be 8.6%. The EC assessment, which is essentially a Cumulative Case, indicates the future maximum ozone concentrations are predicted to be in the 107 ug/m^3 to 137 ug/m^3 range. For the purposes of comparison, the CWS is 127 ug/m^3.

2.7.6.5 Prediction Confidence

The prediction confidence relates to the uncertainty associated with the emission estimates, to the uncertainty associated with the dispersion model's ability to predict ambient concentrations and to the uncertainty associated with the model's ability to represent photochemical processes. The project PrAIRie 2005 findings may provide an indication of the confidence associated with the CMAQ predictions.

2.7.7 Health and Odour Related Concentrations

To obtain an indication of how air quality changes could affect human health, maximum concentrations for 54 different substances and substance groups were predicted at 178 discrete locations to represent potentially sensitive receptor locations. Most of the receptors are located within 5 km of the Project (Figure 2.7-31), as the maximum air quality changes occur within this region. The predicted concentrations were calculated for averaging periods ranging from ten minutes to one year. For most substances, maximum 1-hour, 24-hour and annual average concentrations were predicted. The assessment considered the Baseline, Application and Cumulative cases.

2.7.7.1 Key Findings

Table 2.7-24 provides a summary of the maximum predicted concentrations for the substances that have associated ambient air quality objectives. The summary is provided for the respective averaging period, and the maximum values are provided for each discrete receptor group. The results indicate:

- The maximum predicted acetaldehyde, ethylbenzene, styrene, toluene and xylene concentrations at agricultural/residential and residential/community locations are all low. That is, they range between 0.7% to 8.7% of the respective AAAQO, depending on the substance.

- The maximum predicted benzene concentration at agricultural/residential and residential/community locations for the Application Case is 23% of the AAAQO. The Project contribution at this worst case location is +0.21%. The corresponding maximum predicted benzene concentration for the Cumulative Case is 38% of the AAAQO, with the Cumulative Case contribution at this worst case location being +65%.

- The maximum predicted carbon disulphide concentration at agricultural/residential and residential/community locations for the Application and Cumulative Cases is about 13% of the AAAQO.

- The maximum predicted carbon monoxide concentrations at agricultural/residential and residential/community locations for the Application and Cumulative Cases are about 16% (1-hour) and 37% (8-hour) of the respective AAAQOs. The Project contribution to these predicted maximum values is negligible.

- The maximum predicted formaldehyde concentration at agricultural/residential and residential/ community locations for the Application Case is 9% of the AAAQO. The Project contribution is negligible. The corresponding maximum concentration for the Cumulative Case is 75% of the AAAQO.

- For the Application Case, the maximum predicted H_2S concentrations due to the Project exceed both the 1-hour AAAQO at 10 agricultural/residential locations and 24-hour AAAQO at two agricultural/residential locations. This closest residential location is about 300 m to the west of the PPL, and at this location, there are 115 hours and 119 hours of predicted exceedances of the 1-hour AAAQO for the Application and Future Cases, respectively. The predicted exceedance levels indicate that there is a potential for odours to occur near the Project site due to the operation of the Project based on the emission profiles assumed for the assessment.

The results indicate that the predicted concentrations are less than the respective AAAQO for all residential (i.e., agricultural/residential and residential/community) receptor locations, except for H_2S concentrations. The model predictions emphasize the need for the management of fugitive H_2S emissions, both at the detailed engineering design stage and during the operation. The HHRA provides a systematic review of the predictions for these and the other substance groups relative to potential human health and odour responses. The HHRA is provided in Volume 2, Section 4 - Human Health.

2.7.7.2 Prediction Confidence

The confidence for predicted SO_2 concentrations (Section 2.7.1.6) showed reasonable model predictions. Ideally, one would like to assume that the same level of confidence can be extended to other substance groups. Although this assumption can be made relative to the transport and dispersion components of the assessment approach, it cannot be extended to the emission inventory component. For many of the substances evaluated, reliance is made on emission factors that have been extrapolated from other facilities to estimate potential Project and other facility emissions. In addition, the emissions for these substances might be highly variable given the intermittent nature of fugitive emission sources.

Table 2.7-25 compares the measured and predicted 24-hour average concentrations based on the measurements at the Scotford monitoring station (EC 2005). The measured maximum and 95th percentile values are shown. The comparison indicates:

- There can be a considerable difference between the measured maximum and 95th percentile values, indicating the variability that can occur.
- For a number of substances (i.e., benzene, C9-C16 aromatics, hexane, naphthalene, toluene, and xylenes), the predicted values fall between the maximum and the 95th percentile measurements, indicating reasonable agreement.
- For a number of substances (i.e., C5-C8 aliphatics, cyclohexane, ethylbenzene, and styrene), the predicted values are less than the 95th percentile measurements, but still reasonable.
- 1,3-butadiene predicted concentrations are consistent with the measurements.
- There is one large underprediction case: the dichlorobenzene concentrations are significantly underpredicted. It is likely that regional dichlorbenzene emission sources were not fully characterized.

Given the natural variability of the fugitive emissions and ambient concentrations, the comparison in Table 2.7-25 indicates that the model is predicting reasonable concentration for a number of the substance groups. Although there might be uncertainties for a specific substance and or for a specific facility, the overall consideration of 54 different substance groups should be viewed as providing a first order estimate of exposures.

Table 2.7-24 Maximum Predicted Concentrations for the Baseline, Application, and Cumulative Cases

Assessment Case	Maximum Concentration (ug/m³)		
	Baseline	Application	Cumulative
Acetaldehyde 1-hour (AAAQO = 90 ug/m^3)			
Agricultural/Residential	7.5	7.5 (+0.0%)	7.5 (+0.0%)
Residential/Community	7.8	7.8 (+0.0%)	7.8 (+0.0%)
Public Access Area	10.0	10.0 (+0.0%)	10.0 (+0.0%)
Commercial/Industrial Area	6.0	6.0 (+1.0%)	6.0 (+1.0%)
Benzene 1-hour (AAAQO = 30 ug/m^3)			
Agricultural/Residential	7.0	7.0(+0.2%)	11.5 (+65%)
Residential/Community	6.2	6.2 (+0.0%)	6.2 (+0.0%)
Public Access Area	8.0	8.0 (+0.0%)	8.0(+0.0%)
Commercial/Industrial Area	12.1	12.3 (+1.6%)	14.3 (+18%)
Carbon Disulphide 1-hour (AAAQO = 30 ug/m^3)			
Agricultural/Residential	0.19	3.8 (+1884%)	3.8 (+1884%)
Residential/Community	0.11	0.5 (+391%)	0.8 (+635%)
Public Access Area	0.28	1.1 (+290%)	1.2 (+314%)
Commercial/Industrial Area	0.13	5.3 (+4032%)	8.1 (+6221)
Carbon Monoxide 1-hour (AAAQO = 15,000 ug/m^3)			
Agricultural/Residential	2,320	2,320 (+0.0%)	2,320 (+0.0%)
Residential/Community	2,428	2,428 (+0.0%)	2,428 (+0.0%)
Public Access Area	3,118	3,118 (+0.0%)	3,118 (+0.0%)

Assessment Case	Maximum Concentration (ug/m^3)		
	Baseline	Application	Cumulative
Commercial/Industrial Area	1,868	1,868 (+0.0%)	1,868 (+0.0%)
Carbon Monoxide 8-hour (AAAQO = 6,000 ug/m^3)			
Agricultural/Residential	2,121	2,121 (+0.0%)	2,121 (+0.00%)
Residential/Community	2,240	2,240 (+0.0%)	2,240 (+0.0%)
Public Access Area	2,748	2,749 (+0.02%)	2,762 (+0.5%)
Commercial/Industrial Area	1,657	1,663 (+0.3%)	1,664 (+0.4%)
Ethylbenzene 1-hour (AAAQO = 2,000 ug/m^3)			
Agricultural/Residential	4.2	4.2 (+0.0%)	4.8 (+14%)
Residential/Community	2.2	2.2 (+0.0%)	2.2 (+0.0%)
Public Access Area	2. 8	2.8 (+0.00%)	2.9 (+5.0%)
Commercial/Industrial Area	1.7	2.1 (+25%)	2.3 (+35%)
Formaldehyde 1-hour (AAAQO = 65 ug/m^3)			
Agricultural/Residential	5.6	5.6 (+0.0%)	49 (+762%)
Residential/Community	5.9	5.9 (+0.0%)	7.0 (+20%)
Public Access Area	7.5	7.5 (+0.0%)	16 (+113%)
Commercial/Industrial Area	5.1	5.1 (+0.0%)	37 (+624%)
Hydrogen Sulphide 1-hour (AAAQO = 14 ug/m^3)			
Agricultural/Residential	3.0	**30.4** (+909%)	**30.4** (+910%)
Residential/Community	1.3	4.6 (+228%)	4.7 (+229%)
Public Access Area	3.9	9.8 (+151%)	10.1 (+157%)
Commercial/Industrial Area	11.6	38.1 (+256%)	38.2 (+268%)
Hydrogen Sulphide 24-hour (AAAQO = 4 ug/m^3)			
Agricultural/Residential	1.5	**21.6** (+1301%)	**21.8** (+1317%)
Residential/Community	0.4	1.7 (+314%)	1.8 (+340%)
Public Access Area	1.3	3.1 (+136%)	3.6 (+175%)
Commercial/Industrial Area	6.9	14.6 (+111%)	14.8 (+115%)
Styrene 1-hour (AAAQO = 215 ug/m^3)			
Agricultural/Residential	8.2	8.2 (+0.00%)	8.2 (+0.00%)
Residential/Community	1.0	1.0 (+0.00%)	1.0 (+0.00%)
Public Access Area	3.1	3.1 (+0.00%)	3.1 (+0.00%)
Commercial/Industrial Area	14.1	14.1 (+0.00%)	14.1 (+0.00%)
Toluene 1-hour (AAAQO = 1,880 ug/m^3)			
Agricultural/Residential	14.8	14.8 (+0.2%)	20.9 (+42%)
Residential/Community	15.4	15.4 (+0.0%)	15.4 (+0.00%)
Public Access Area	19.7	19.7 (+0.01%)	19.7 (+0.09%)
Commercial/Industrial Area	21.1	21.3 (+0.8%)	56.5 (+168%)
Toluene 24-hour (AAAQO = 400 ug/m^3)			
Agricultural/Residential	6.5	9.1 (+38.3%)	12.5 (+91%)
Residential/Community	6.5	6.5 (+0.0%)	6.5 (+0.07%)
Public Access Area	8.4	8.5 (+0.8%)	8.6 (+2.1%)
Commercial/Industrial Area	9.6	9.8 (+1.6%)	29.6 (+208%)
Xylenes 1-hour (AAAQO = 2,300 ug/m^3)			
Agricultural/Residential	8.5	8.46 (+0.0%)	15.5 (+84%)
Residential/Community	8.8	8.82 (+0.0%)	8.8 (+0.0%)
Public Access Area	25.3	25.6 (+1.0%)	27.2 (+7.3%)
Commercial/Industrial Area	11.3	11.3 (+0.0%)	11.3 (+0.0%)
Xylenes 24-hour (AAAQO = 700 ug/m^3)			
Agricultural/Residential	3.7	5.0 (+33%)	9.0 (+139%)
Residential/Community	3.7	3.7 (+0.0%)	3.7 (+0.1%)
Public Access Area	4.8	4.8 (+0.6%)	5.5 (+15%)
Commercial/Industrial Area	10.0	10.0 (+0.7%)	14.1 (+42%)

Notes:

Exceedances of an AAAQO are shown in **bold face** font.
The AAAQO are not applicable within industrial areas.

Table 2.7-25 Comparison of Measured and Predicted for Selected VOC Substances Based on the Scotford Monitoring Station Site

Substance Group	Measured 24-hour Average		Predicted 24-hour Average
	Maximum	95th percentile	
1,3-butadiene	0.28	0.13	0.30
Benzene	16.4	2.34	2.48
C_5-C_8 Aliphatics	59	24	20
C_9-C_{16} Aliphatics	3.0	1.1	5.40
C_9-C_{16} Aromatics	3.09	1.2	2.96
Cyclohexane	0.85	0.46	0.27
Dichlorobenzene	0.06	0.03	0.002
Ethylbenzene	6.49	1.42	0.85
Hexane	3.96	2.09	3.88
Naphthalene	0.29	0.11	0.14
Styrene	14.06	1.31	0.64
Toluene	24.75	3.45	5.52
Xylenes	7.36	0.04	3.25

Notes:
The measured values are based on the FAP/EC values (94 24-hour samples) obtained from September 2004 to April 2005. Appendix 2B provides more details.
The predicted values are for the Baseline Case.

2.7.8 Greenhouse Gas Emissions and Climate Change

2.7.8.1 Introduction

Climate change issues related to the Project include the Project's contributions to GHG emissions, and to changes in climate parameters that could occur over the lifetime of the Project. The GHG emissions are primarily a result of carbon dioxide (CO_2) emissions associated with the combustion of fossil fuels (i.e., natural gas and plant gas) and fugitive hydrocarbon gas leaks containing methane (CH_4). The long-term climate change relates to potential adverse influences on the operation of the Project.

2.7.8.2 Project GHG Emissions

The GHG emissions from the Project consist of CO_2, CH_4, and nitrous oxide (N_2O). Total GHG emissions are expressed as equivalent carbon dioxide (CO_2e), which reflects the higher contributing potential to a GHG effect by CH_4 and N_2O.

Project Construction and Decommissioning Emissions

GHG emissions at the Project site will directly result from construction activities, and these emissions will be mainly from the operation of construction equipment and other vehicles, with smaller amounts due to land use/land coverage changes. Decommissioning activities, to some extent, will be similar to construction related emissions. On-site GHG emissions for decommissioning could typically be 50% of construction values.

GHG emissions during construction and decommissioning are a small portion of the GHG emissions estimated for Project operations. For example, others have estimated that the direct GHG emission rates from the construction and decommissioning phases are typically 1% or less than those associated with the operations phase (Shell, 2007). As they are considered inconsequential, these GHG emissions were not assessed further in terms of the potential effects of the Project on climate. The offsetting of carbon following reclamation will compensate for the carbon release during construction and decommissioning.

Project Operating Emissions

During Project operations, GHG emissions result from combustion of fuels and the release of fugitive emissions. Fuel used for heat generation, hydrogen production, petcoke gasification and fugitive emissions will be the largest contributors to GHG emissions during Project operations. A summary of Project these emissions during operations is provided in Table 2.7-26. The CO_{2e} emissions associated with the Project fuel combustion conservatively assume that all the combustion sources are operating at full fired capacity for the full year. Petcoke gasification produces the largest contribution of GHG emissions in the form of a CO_2 vent gas from the acid gas recovery units. If and when gasification is implemented, North American plans to target this vent gas for recovery and sequestration. As a result, these emissions have not been included in the air quality impact assessment for the Project.

2.7.8.3 Contribution to Alberta/Canada Total

Fossil fuel combustion for industrial, energy industry and power generation purposes accounts for the largest portion of global GHG emission totals. Regulation of GHG emissions reporting has only recently begun. Governments have been cooperating on the reporting of many other emissions since the 1970s. Many large GHG emitters began reporting their emissions through the Voluntary Challenge and Registry (VCR) early in the 1990s. Other sources of indirect GHG data, including energy consumption, are also available. Therefore, Canada has been able to develop relatively accurate annual GHG emission values; and Table 2.7-27 provides GHG emissions from these inventories for 1990 to 2000, with projections for the years 2005-2020, are presented in Natural Resources Canada (NRCan; 2005a; 2005b).

Nationally, GHG emissions have increased almost every year since 1990, growing by 24% from 1990 to 2003, and growing by 3% from 2002 to 2003. The predicted 2015 Canada and Alberta totals are 718,000 kt CO_2e/y and 254,000 kt CO_2e/y, respectively. The overall GHG emission estimate associated with Project operations can be placed in context with the provincial and federal emissions totals:

- CO_2 emissions of 2,962 kt CO_2e/y represent 1.2% of the projected 2015 provincial total.
- CO_2 emissions of 2,962 kt CO_2e/y represent 0.4% of the projected 2015 national total.

These comparisons are based the Project CO_2 emissions with CO_2 recovery from gasification.

Table 2.7-26 Estimated Operations GHG Emissions for the Project

Project Case and Source	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
Case 1: Without CO_2 recovery from gasification				
Fuel combustion (t/d)	8,082	0.16	0.14	8,129
Fugitive emissions (t/d)	31	1.00	0.00	52
Petcoke gasification vents (t/d)	16,083	0.00	0.00	16,083
Emission Rate (t/d)	24,196	1.16	0.14	24,197
Annual Emission Rate (kt/y)	8,832	0.42	0.05	8,832
Case 2: With CO_2 recovery from gasification				
Fuel combustion (t/d)	8,082	0.16	0.14	8,129
Fugitive emissions (t/d)	31	1.00	0.00	52
Petcoke gasification vents (t/d)	0	0.00	0.00	0
Emission Rate (t/d)	8,113	1.16	0.14	8,114
Annual Emission Rate (kt/y)	2961	0.42	0.05	2,962

Table 2.7-27 Greenhouse Gas Emissions for Canada and Alberta

Year	**Canadian Total (kt CO_2e/y)**	**Alberta Total (kt CO_2e/y)**
2015	718,000	254,000
2010	669,000	233,000
2005	728,000	222,000
2000	720,000	221,000
1995	646,000	197,000
1990	596,000	168,000
SOURCES: NRCan (2005a; 2005b; 2005c).		

2.7.8.4 GHG Intensity

The GHG emission intensity during Project operations is based on the annual direct GHG emissions divided by the annual number of barrels of bitumen processed through the Upgrader. As North American plans to build two stages of gasification to produce hydrogen and SNG they are categorized as a high intensity upgrader. However, as these plans are anticipated to be accompanied by CO_2 recovery the net result places North American on the low end of the scale for low intensity upgraders. The North American Project is designed to process 243,000 bpsd of bitumen and produce 222,800 bpsd of synthetic crude oil (SCO). The corresponding CO_{2e} emission intensities for the Project, assuming CO_2 recovery with gasification, are 33.4 kg CO_{2e}/bbl of bitumen processed and 36.4 kg CO_{2e}/bbl of SCO produced. Should North American decide not to implement Gasification, hydrogen for the full Project capacity would be supplied by additional steam methane reforming (SMR) of natural gas. The additional emissions from the SMR would raise the GHG emissions and the CO_{2e} intensity, but the Upgrader would still fall into the low intensity category

McCulloch et al. (2006) compare the GHG emission intensity for typical low- and high-intensity upgrader operations. Typically, a value of 52 kg CO_{2e}/bbl of synthetic crude oil (SCO) was associated with a low-intensity upgrader, and a value of 79 kg CO_{2e}/bbl of SCO was associated with a high-intensity upgrader. A low-intensity upgrader is associated with the use natural gas as a fuel and a feedstock for hydrogen production. A high-intensity upgrader is associated with gasification technology to produce hydrogen and syngas for energy supply purposes. Assuming

CO_2 recovery with gasification, the North American Project CO_{2e} emission intensity is less than the “typical” low intensity value of 52 kg CO_{2e}/bbl of SCO.

A comparison of the Project’s GHG emissions with emissions of other upgrader projects is in Table 2.7-28. Because the technologies differ, there are considerable differences between the emission intensities in the table.

Table 2.7-28 Estimated GHG Emission Intensities

Source	Bitumen Capacity (bbl/d)	GHG Emissions (kt/y)	Intensity (kg CO_{2e}/bbl)
North American Project (with CO_2 recovery from gasification)	**243,000**	**2,962**	**33.4**
Shell Canada Scotford Upgrader 2	400,000	8,888	60.9
Shell Canada Scotford Base + Approved Expansion	290,000	3,482	32.9
Shell Canada Scotford Base Plant	155,000	1,901	33.6
Petro-Canada Oil Sands Inc. Sturgeon Upgrader Phase 1	165,000	2,448	40.6
Petro-Canada Oil Sands Inc. Sturgeon Upgrader Phase 2/3	340,000	7,769	62.6
BA Energy Heartland Oil Sands Bitumen Upgrader	260,400	1,331	14.0
North West Bitumen Upgrader	150,000	5,081	92.8

SOURCES: Shell (2007), PCOSI (2007), North West Upgrading (2006) and BA Energy (2005).

2.7.9 Project Sensitivity to Climate Change

2.7.9.1 Background

The Canadian Environmental Assessment Agency provides guidance on how to incorporate climate change considerations into an EIA (CEA Agency, 2003). The Third Assessment Report of the IPCC, as established by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) (IPCC, 2001), is also helpful as it presents an understanding of the general magnitude of climate parameter changes from Global Climate Models (GCM). Of direct interest are the regional interpretations of this GCM guidance. Such regional interpretation might be found in various published works, including Government of Canada (2004).

A number of GCM scenarios were done by IPCC to the year 2100. The IPCC predicts an increased incidence of extreme weather events, higher maximum temperatures, lower minimum temperatures, more intense precipitation events, increases in tropical cyclone peak wind intensities and a global mean sea level rise over the 100-year period to 2100. Their GCM predictions include scenarios, among many others, where GHG (CO_2e) emissions are tripled by the year 2050. The IPCC states that globally averaged surface temperature is projected to increase by 1.4 to 5.8 °C, for the full range of scenarios based on a number of climate models.

2.7.9.2 Alberta Climate Change

Alberta Environment has commissioned a number of climate change studies for Alberta (e.g., Barrow and Yu, 2005; Khandekar, 2002; Khandekar, 2000; Chaikowsky, 2000; Shen, 1999). In addition, NRCan has commissioned studies on Canadian climate change (e.g., Lemmen and Warren, 2004; Geological Survey of Canada, 2001). The studies have examined historical climate parameter changes and future projections based on GCM predictions.

Historically, Alberta winters have warmed by 1°C to 3°C, summers have cooled slightly and the fall season has cooled by 1°C to 2°C. The overall warming over the last 50 years is because recent winters have been warmer than earlier winters. Summer "hot spells" might also be declining (Khandakar 2002). Mean annual temperatures are predicted to increase between 3°C and 5°C by 2050; the Edmonton area increase is 3°C. Similar changes are expected for the minimum and maximum temperatures with slightly greater increases in the minimum temperatures (Barrow and Yu, 2005). The enhanced increased minimum temperatures might be related to increased cloud cover at night (Chaikowsky, 2000).

Precipitation amounts have increased over the last couple of years. Mean annual precipitation changes for 2050 are predicted to vary from -10% to +15%; for the Edmonton area, the increase is +5% (Barrow and Yu, 2005). The increases tend to be associated with the winter and spring, and decreases with the summer and fall (Geological Survey of Canada, 2001). There are different interpretations on what this means in terms of soil moisture content (Lemmen and Warren, 2004). Although precipitation is projected to increase, the increases will not be sufficient to offset the increased moisture losses through higher temperatures and evapotranspiration rates. Lemmen and Warren indicate others have projected that the moisture levels in the top 120 cm would be the same or higher than today.

Water availability varies with the changing seasons and with year and, as a consequence, the Prairie Provinces have experienced droughts and floods. The snowpack and the glaciers in the Rocky Mountains are important sources of water for the prairies, and climate changes can have an influence on the viability of these sources. Increased temperatures could lead to a more rapid snowmelt leading to lower summer river flows (Lemmen and Warren, 2004)

2.7.9.3 Climate Influences on the Project

Following CEA Agency guidance (CEA Agency, 2003), the effect of potential climate change on the Project were assessed qualitatively and the various phases of the Project were ranked according to direct and indirect climate influences. Direct effects include the influence of climate parameters such as temperature, precipitation and wind extremes. Indirect effects include other influences that could be affected by climate change, including changes in groundwater and stream flow availability. Project sensitivities to climate influences are listed below and in Table 2.7-29:

- **Construction Phase:** Individual sensitivities for the construction phase are ranked as nil to low. The low rankings recognize that weather conditions can influence the transportation of materials and construction activities. Overall, sensitivity for this phase is ranked as nil because the construction phase is of limited duration.

- **Operations Phase:** Individual sensitivities for the operations phase are ranked as nil to medium. The direct influences are all ranked as nil since the Project has been constructed to meet extreme weather criteria. The only moderate ranking recognizes the importance of potential reduced availability of water from the NSR through climate change. Overall, the Project sensitivity for the operations phase is ranked as low.

- **Decommissioning Phase:** Individual sensitivities for the decommissioning phase are ranked as nil to low. The low rankings assume the plant site will be remediated to a non-industrial land use following the life of the Upgrader, and that the nature and the success of site re-vegetation activities will depend on prevailing climate conditions at that time. Overall the Project sensitivity for the decommissioning phase is ranked as low.

The Project will be designed to accommodate potential direct and indirect climate influences.

Table 2.7-29 Project Sensitivities to Direct and Indirect Climate Influences

Climate Influences	Project Phase		
	Construction	Operations	Decommissioning
Direct			
Mean temperature	Nil	Nil	Nil
Extreme temperature	Low	Nil	Low
Mean rainfall	Nil	Nil	Low
Mean snowfall	Nil	Nil	Nil
Extreme precipitation	Low	Nil	Low
Extreme winds	Low	Nil	Nil
Indirect			
NSR flow	Nil	Moderate	Nil
Soil moisture and groundwater	Nil	Nil	Low
Evaporation rate	Nil	Nil	Low
Extreme weather events	Nil	Nil	Nil
Overall ranking	Nil	Low	Low

2.7.10 Visibility

2.7.10.1 Assessment Focus

Under normal operating conditions, only the process equipment and the associated stacks will be visible from a distance. Most of the process stacks are 30 to 61 m tall, the SRU/TGTU stacks are 90 m tall, and the flare stacks are16 m to 152 m tall. The final height selection of the flare stacks are to be determined when a more detailed flare management plan is prepared. Under normal conditions, the emissions from these stacks will not be visible; however, there might be exceptions:

- Small flames might be visible at the flare stack tips because of the flare pilot or when small, unwanted volumes of waste gas are discharged to the flare system. Under these conditions, the flame lengths would typically be a few metres.

- Larger flames at the flare tips will occur when large volumes of gas are directed to the flare under upset or emergency conditions. Although these cases tend to occur infrequently and are of limited duration, the flame length can be several tens of metres.

- Under low temperature or high humidity conditions, the water vapour in the stack plumes will condense to form visible plumes. Though these plumes will be visible at large distances, they will not result in ground-level visibility restrictions.

- Under low temperature or high humidity conditions, the water vapour in the cooling tower plumes will also condense to form visible plumes. Depending on the prevailing meteorological conditions, these plumes might result in ground-level visibility restrictions.

Given that the largest visibility issues are associated with water vapour emissions, the occurrence and extent of these plumes was evaluated. The water vapour emissions from the Project (for stacks and cooling towers) were calculated, and the CALPUFF model was used to predict the occurrence of elevated visible plumes, and the occurrence of visible plumes at ground level near the Project area.

2.7.10.2 H_2O Emission Profiles

Water (H_2O) vapour emissions result from combustion sources and from the cooling tower. Table 2.7-30 compares the Project only H_2O emissions from these source types. About two-thirds of the water vapour emissions result from the cooling tower.

Table 2.7-30 Comparison of H_2O Emission Rates

Project-Only Case	**H_2O Emission** (t/d)
Stacks	8,360
Cooling Tower	4,046
Project Total	12,406

2.7.10.3 Plume Height

Visible plumes would only be expected during low temperature conditions, which for the most part would be associated with stable conditions during the night and early mornings and near neutral conditions during the day. The height of a visible plume will be determined by several factors:

- the final rise of a plume;
- relative humidity; and
- ambient temperature.

Figures 2.7-32 and 2.7-33 show the frequency of the plume heights predicted using the CALPUFF model for all hours of the day and for day-time hours only. The results show that:

- When all hours of the day are considered, the most frequent visible plume heights are less than 75 m or between 100 m and 250 m. Visible plumes are least frequent in the summer and most frequent in the winter.
- When only day-time hours are considered, the most frequent visible plume heights are in the 150 m to 250 m range. Visible plumes are least frequent in the summer and most frequent in the winter.

The CALPUFF model predictions indicate that visible plume heights are expected to be typically in the 150 m to 250 m range.

2.7.10.4 Roadway Visibility Restrictions

Figure 2.7-34 shows the predicted frequencies of fogging for a 18 km x 18 km area centred on the Project. The predicted values are due to the operation of the proposed Project cooling tower. Only the cooling tower was evaluated as it is associated with plume heights that are less than those associated with stacks. The figure also shows the location of Highway 15 that has an east-west orientation to the south of the Project area, and the location of Highway 830 that has a north-south orientation to the east of the Project. The model predictions indicate a potential for fogging to occur for approximately 10 hours per year along the Highway 830 segment and 12 hours per year along the Highway 15 segment.

Figure 2.7-35 indicates most of the predicted visibility restrictions are associated with the winter period (specifically January to March). These predictions are based on 2002 meteorological data, when December, January and February were warmer than the long-term average, and March and April were cooler than the long-term average (Appendix 2B).

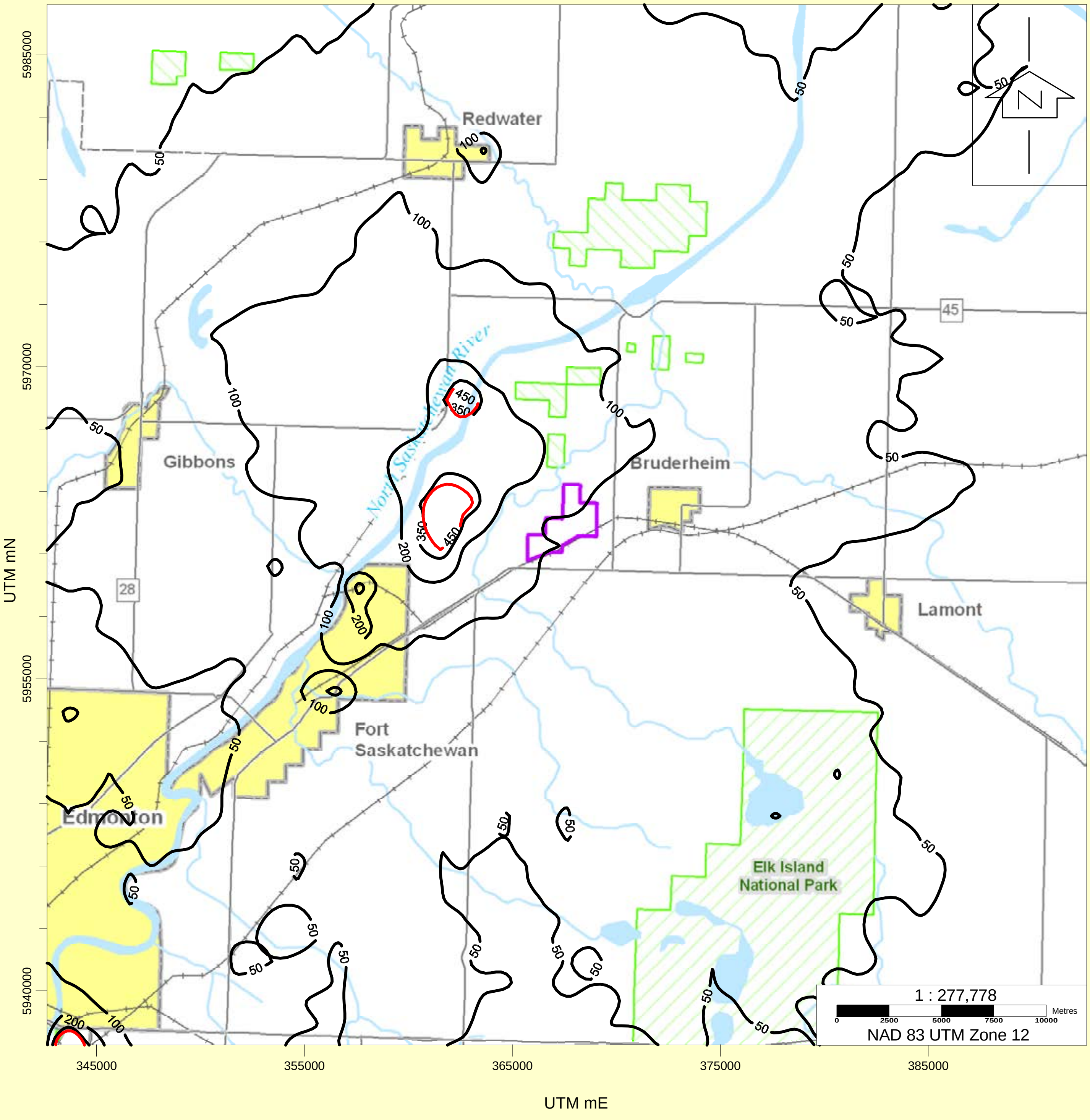
Long-term records from Namao Airport indicate visibility restrictions less than 1 km occur, on average, 94 hours in a year. These visibility restrictions tend to be most frequent in the November to March period (each month with more than 10 hours per month). The predictions therefore indicate that the Project cooling tower emissions could increase reduced visibility (i.e., fogging) occurrences by about 13%.

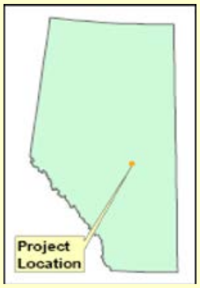
2.7.10.5 Mitigation

There are no mitigation measures that can be used to preclude the occurrence of elevated visible plumes from the cooling towers or from the combustion sources under low temperature, high humidity periods. While improved energy efficiency will reduce fuel consumption and decrease the associated water vapour emissions, there will still be sufficient water vapour emissions to produce elevated visible plumes. Given the uncertainties associated with the fog assessment, monitoring the occurrence of fog coupled with the use of warning signage along the highway is recommended.

2.7.10.6 Prediction Confidence

The heights of the visible plumes provided are reasonable. The predicted frequencies of the visible plume heights and the predicted frequencies of fog occurring along nearby highways are less certain because of the limited documentation provided with the CALPUFF model and the lack of confirming field study comparisons.





Legend

▭ Project Property Line

▭ Community/Town

▭ Natural Area

AAAQO: 450 ug/m^3

Title:

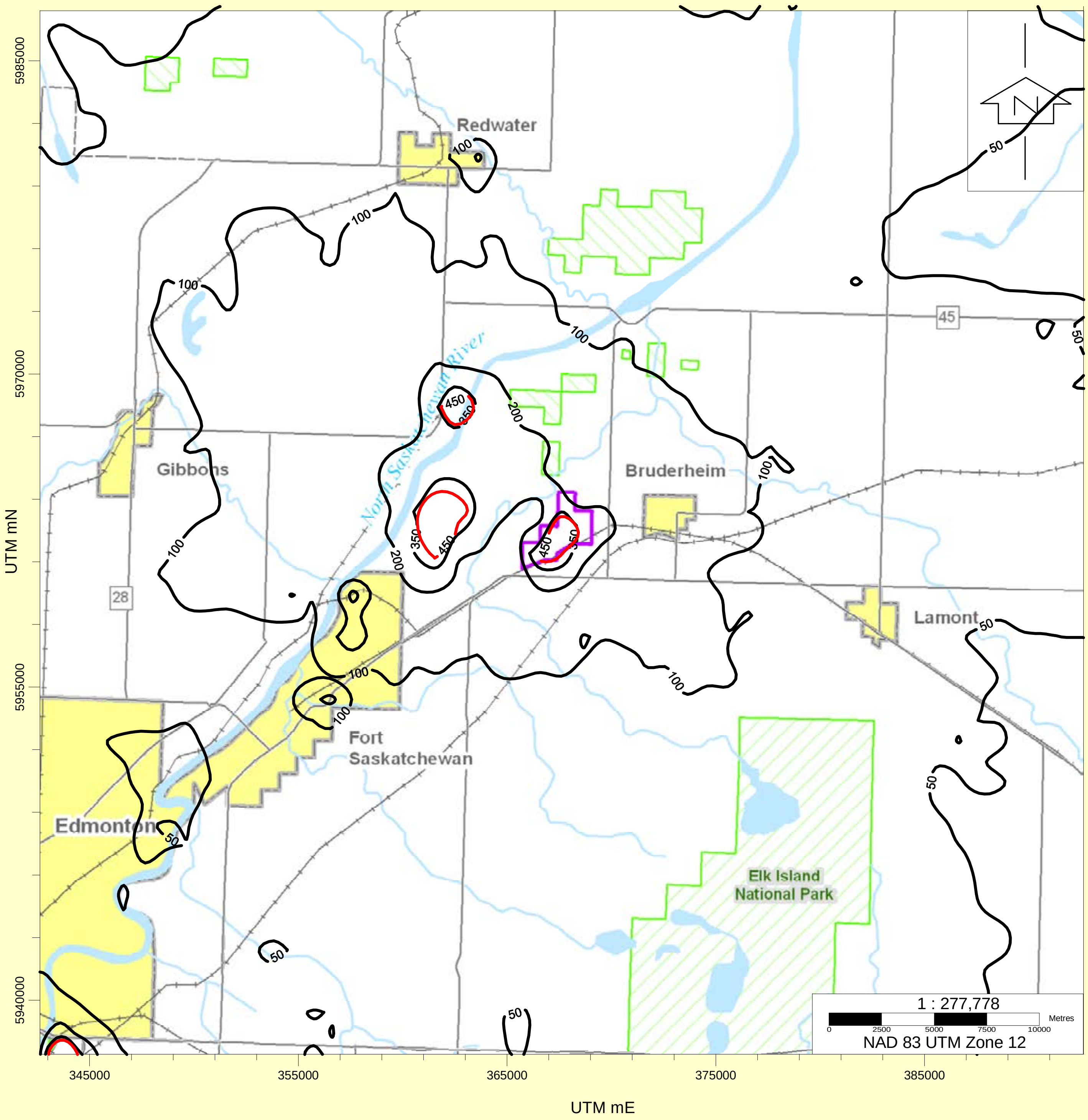
1-HOUR SO$_2$ CONCENTRATION (BASELINE CASE)

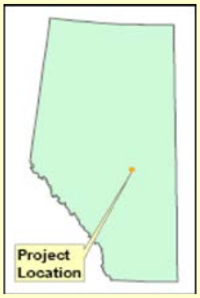
NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:
MD	05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/ Case 13 Base/Con_Base 50km_05Nov07.srf

Drawn by:	Checked:	Fig. No.:
XC	MD	**2.7-1**





Legend

▭	Project Property Line
▭	Community/Town
▭	Natural Area

AAAQO: 450 ug/m³

Title:

1- HOUR SO$_2$CONCENTRATION (APPLICATION CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER /Case 14 Application/05Nov07/SO2_h.srf

Drawn by:	Checked:	Fig. No.:
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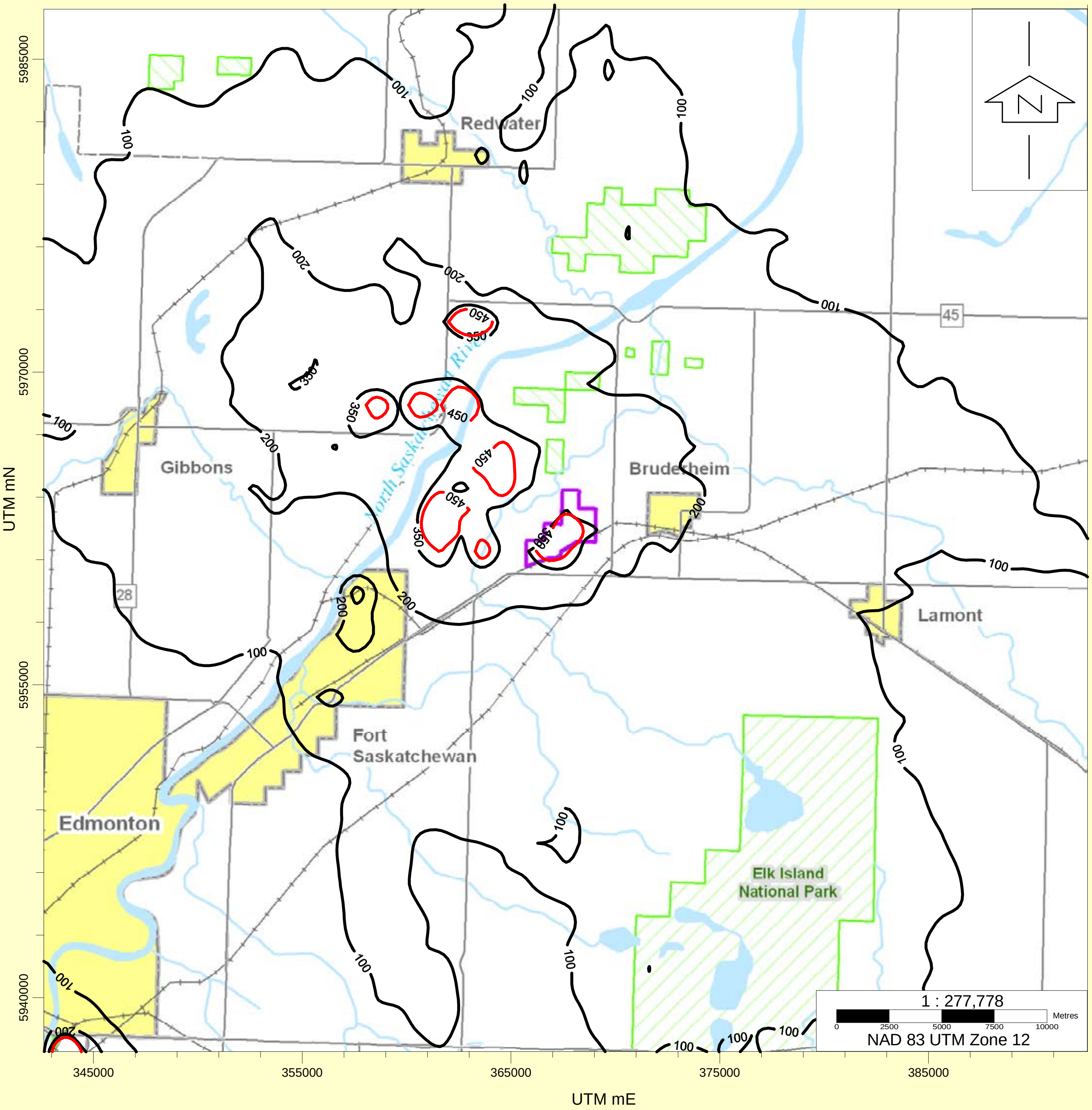

Legend

🟪 Project Property Line

🟨 Community/Town

🟩 Natural Area

AAAQO: 450 ug/m³

Title:

1-HOUR SO$_2$ CONCENTRATION (CUMULATIVE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:
MD	05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/ Case 15 future/05Nov07/SO2_h.srf

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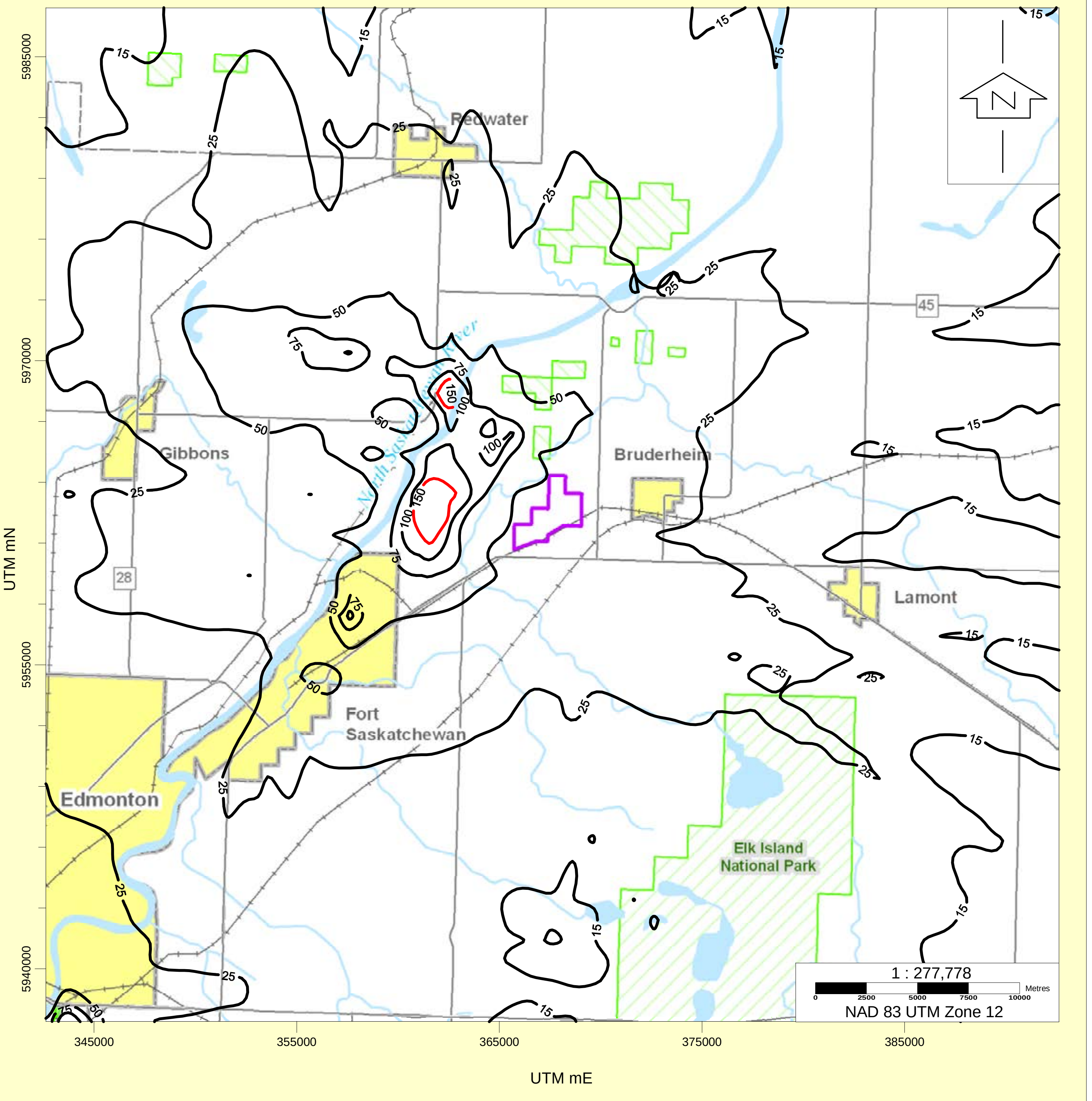

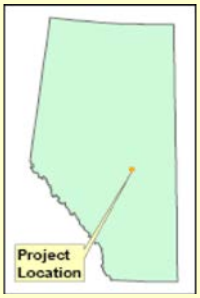

Legend

▭ Project Property Line

▨ Community/Town

▭ Natural Area

AAAQO: 150 ug/m³

Title:

24-HOUR SO$_2$ CONCENTRATION (BASELINE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:
MD	05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/Case 13 Base/SO2_d.srf

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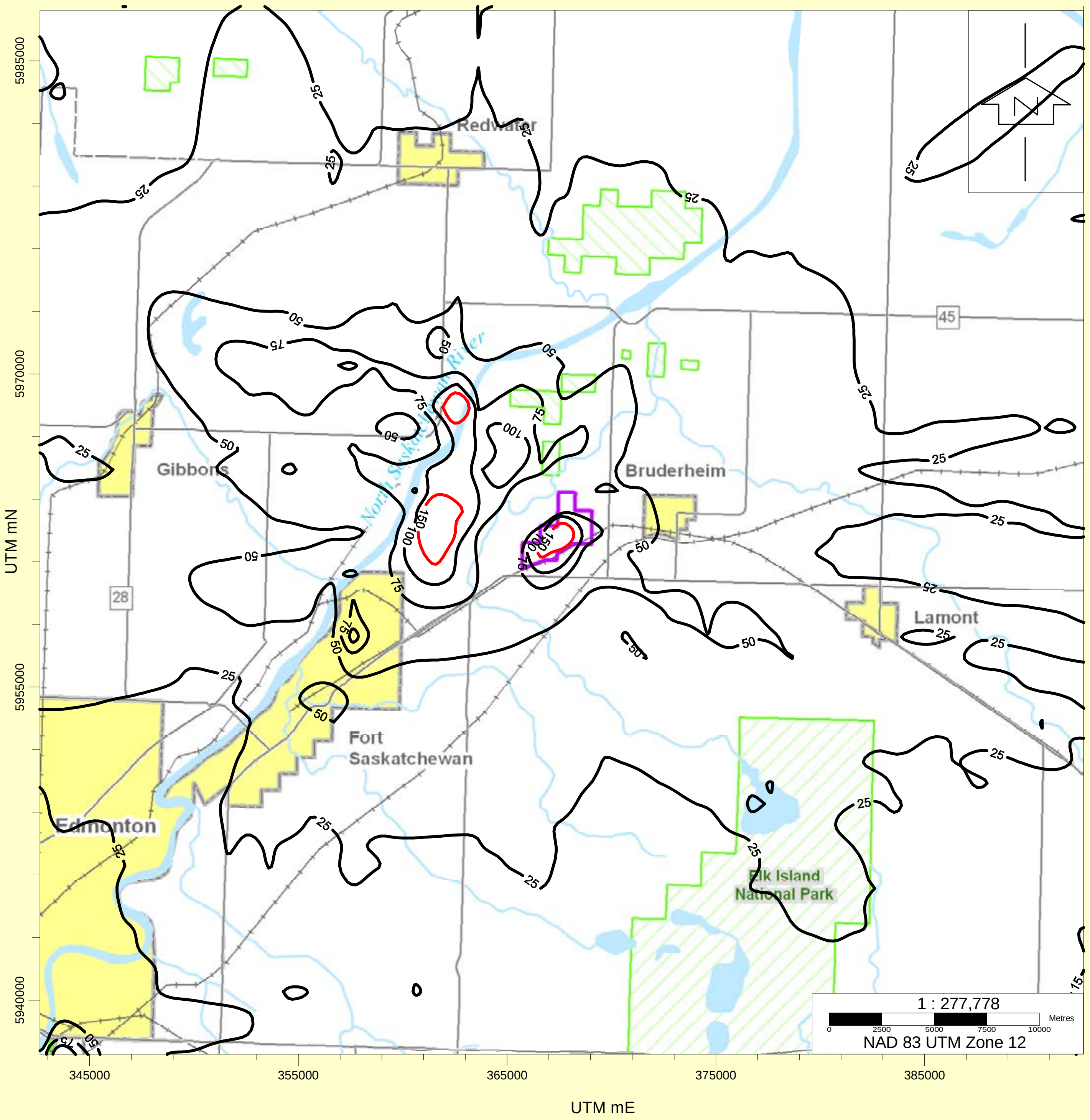

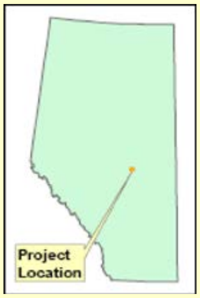

Legend

🟪 Project Property Line

🟨 Community/Town

🟩 Natural Area

AAAQO: 150 ug/m³

Title:

24-HOUR SO_2 CONCENTRATION (APPLICATION CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER /Case 14 Application/05Nov07/SO2_d.srf

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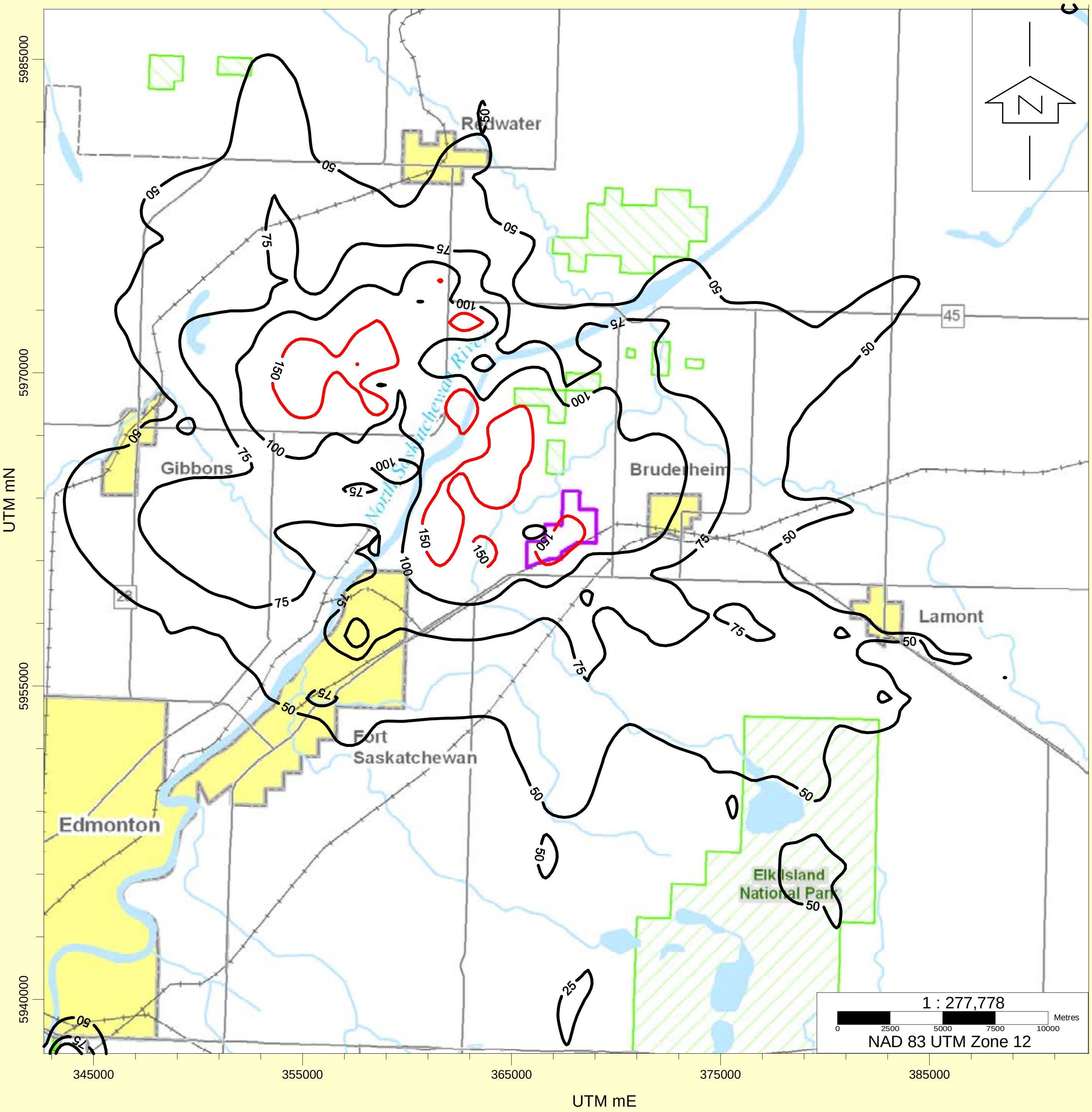

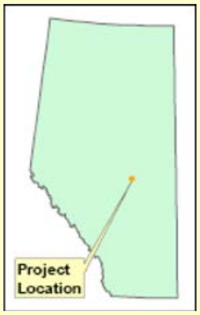

Legend

▭ Project Property Line

🟨 Community/Town

▭ Natural Area

AAAQO: 150 ug/m³

Title:

24-HOUR SO$_2$ CONCENTRATION (CUMULATIVE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:
MD	05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/ Case 15 future/05Nov07/SO2_d.srf

Drawn by:	Checked:	Fig. No.:
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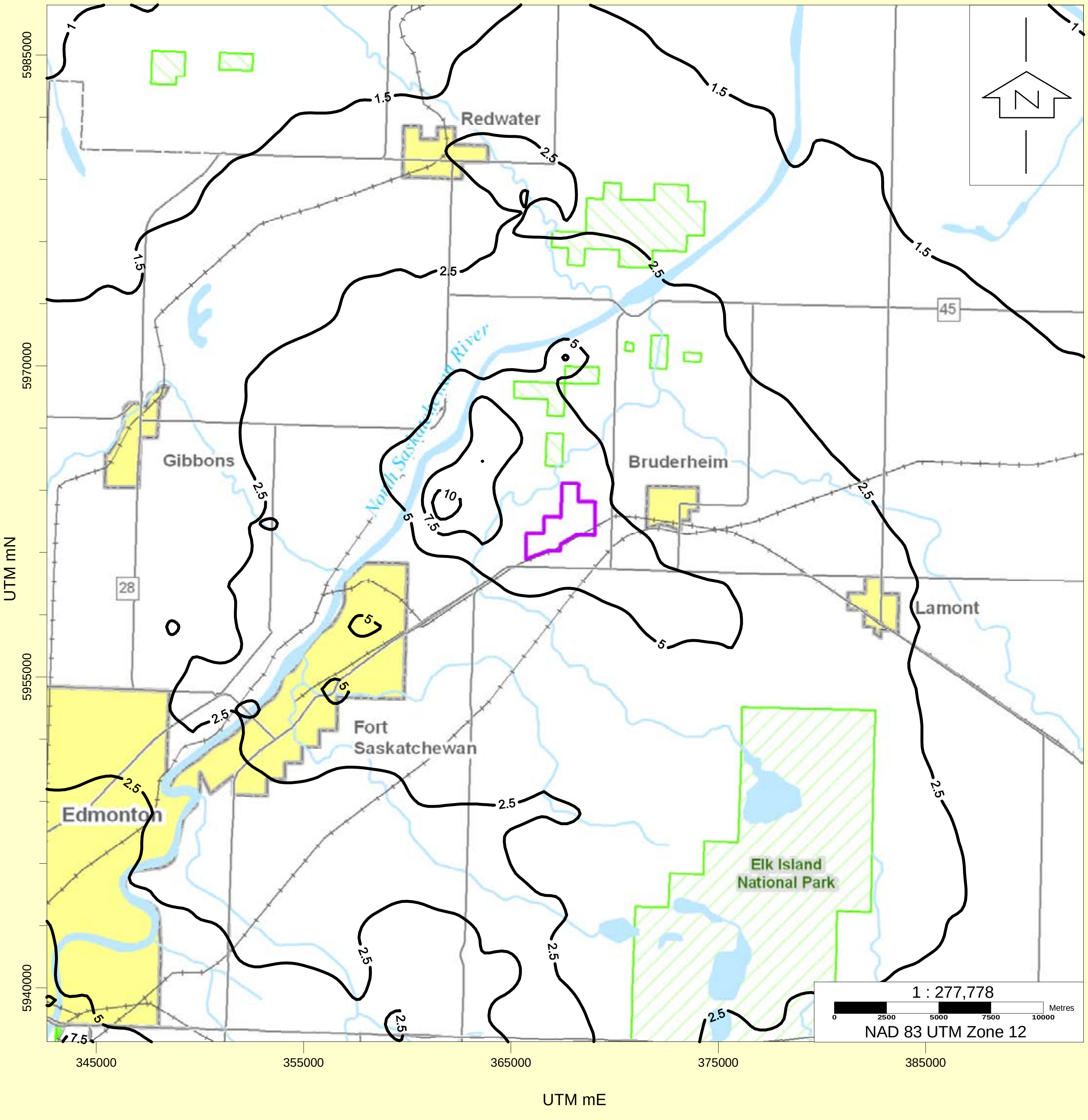

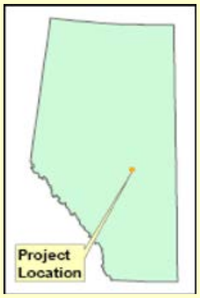

Legend

▭ Project Property Line

🟨 Community/Town

▭ Natural Area

AAAQO: 30 ug/m³

Title:

ANNUAL SO_2 CONCENTRATION (BASELINE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/Case 13 Base/SO2_a.srf

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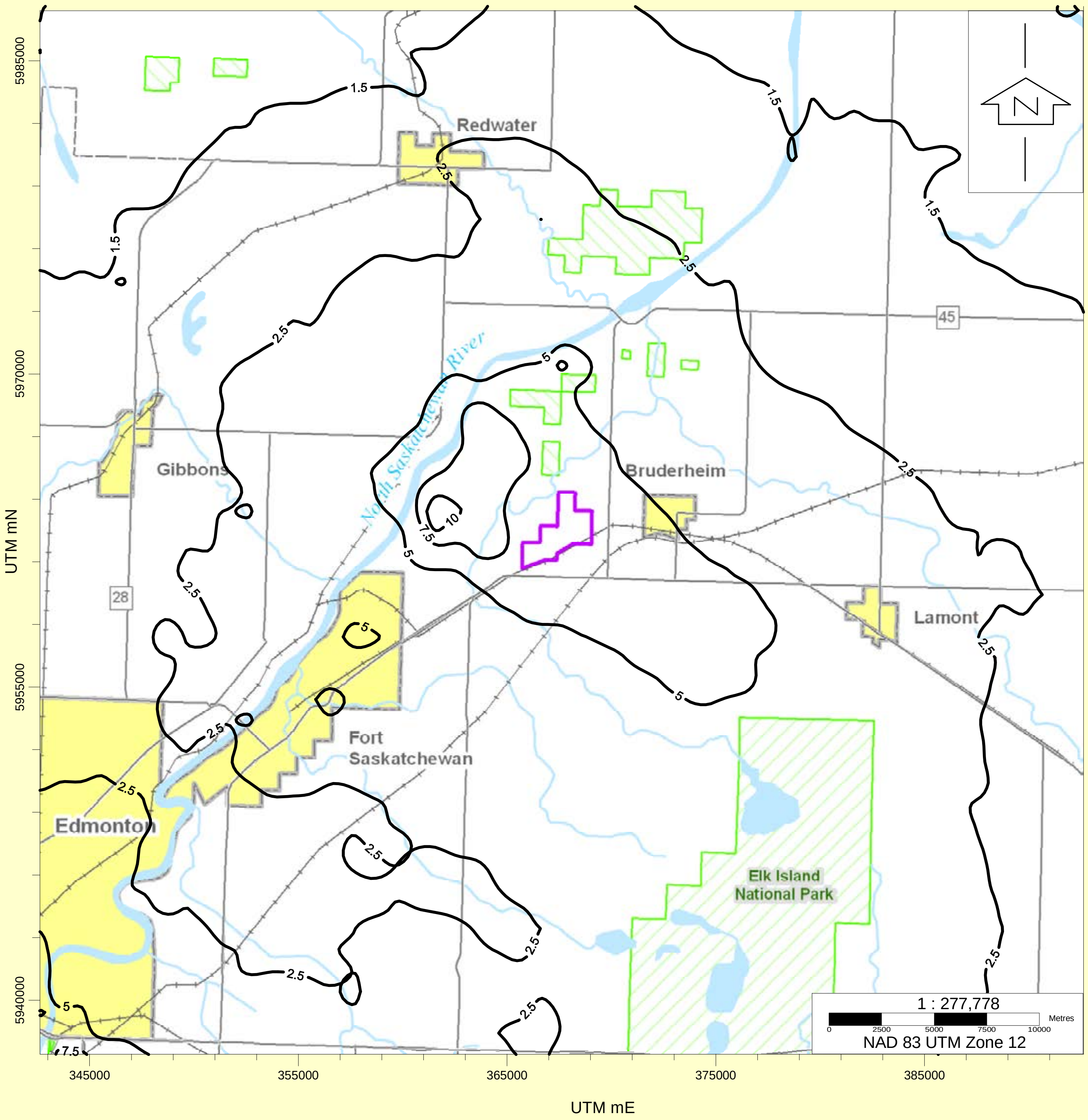

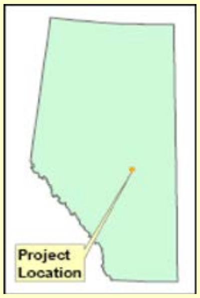

Legend

▭ Project Property Line

🟨 Community/Town

▭ Natural Area

AAAQO: 30 ug/m^3

Title:

ANNUAL SO_2 CONCENTRATION (APPLICATION CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER /Case 14 Application/05Nov07/SO2_a.srf

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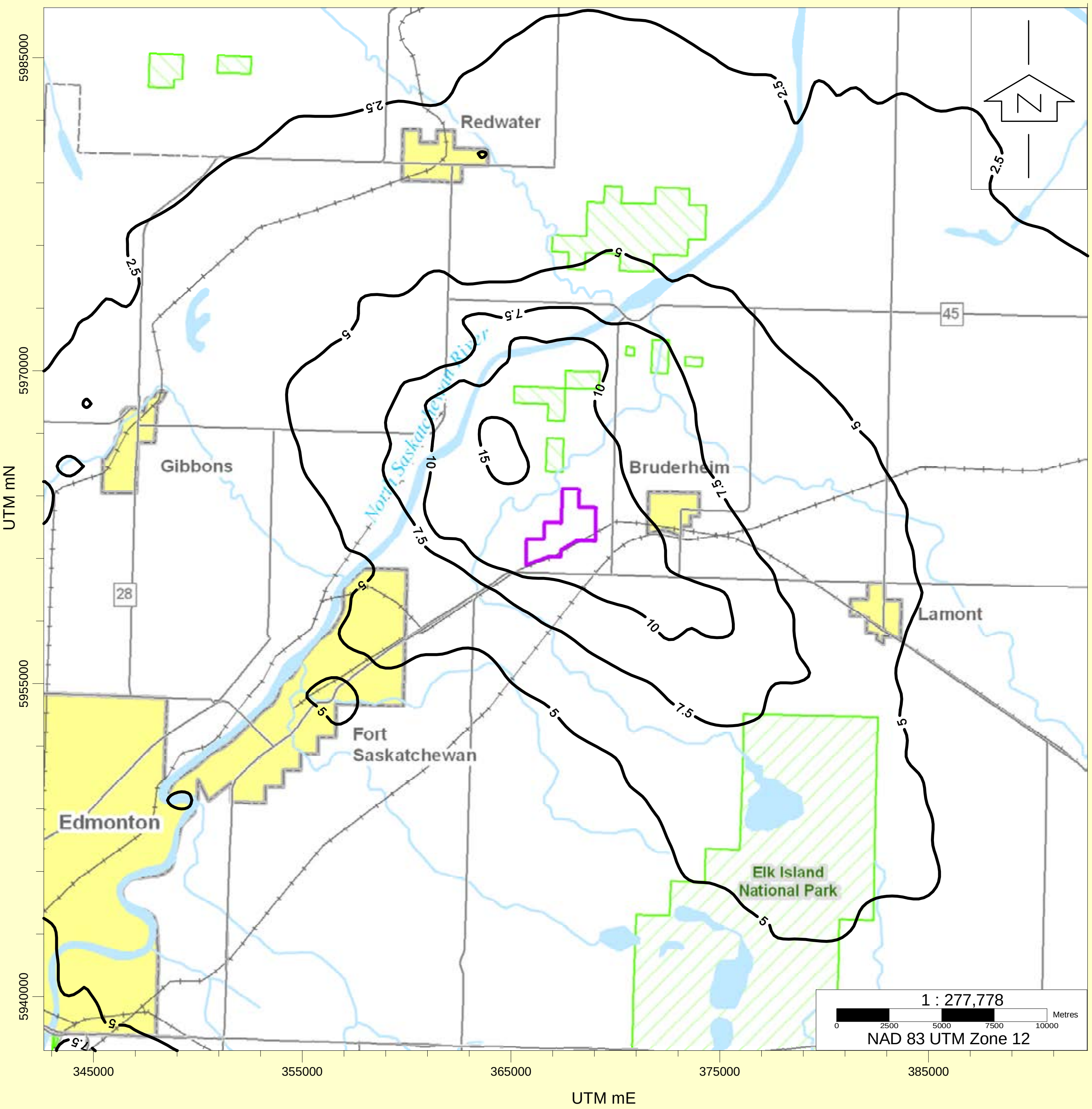

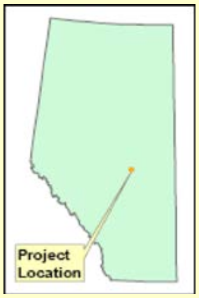

Legend

▭ Project Property Line

🟨 Community/Town

▭ Natural Area

AAAQO: 30 ug/m³

Title:

ANNUAL SO$_2$ CONCENTRATION (CUMULATIVE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/Case 15 future/05Nov07/SO2_a.srf

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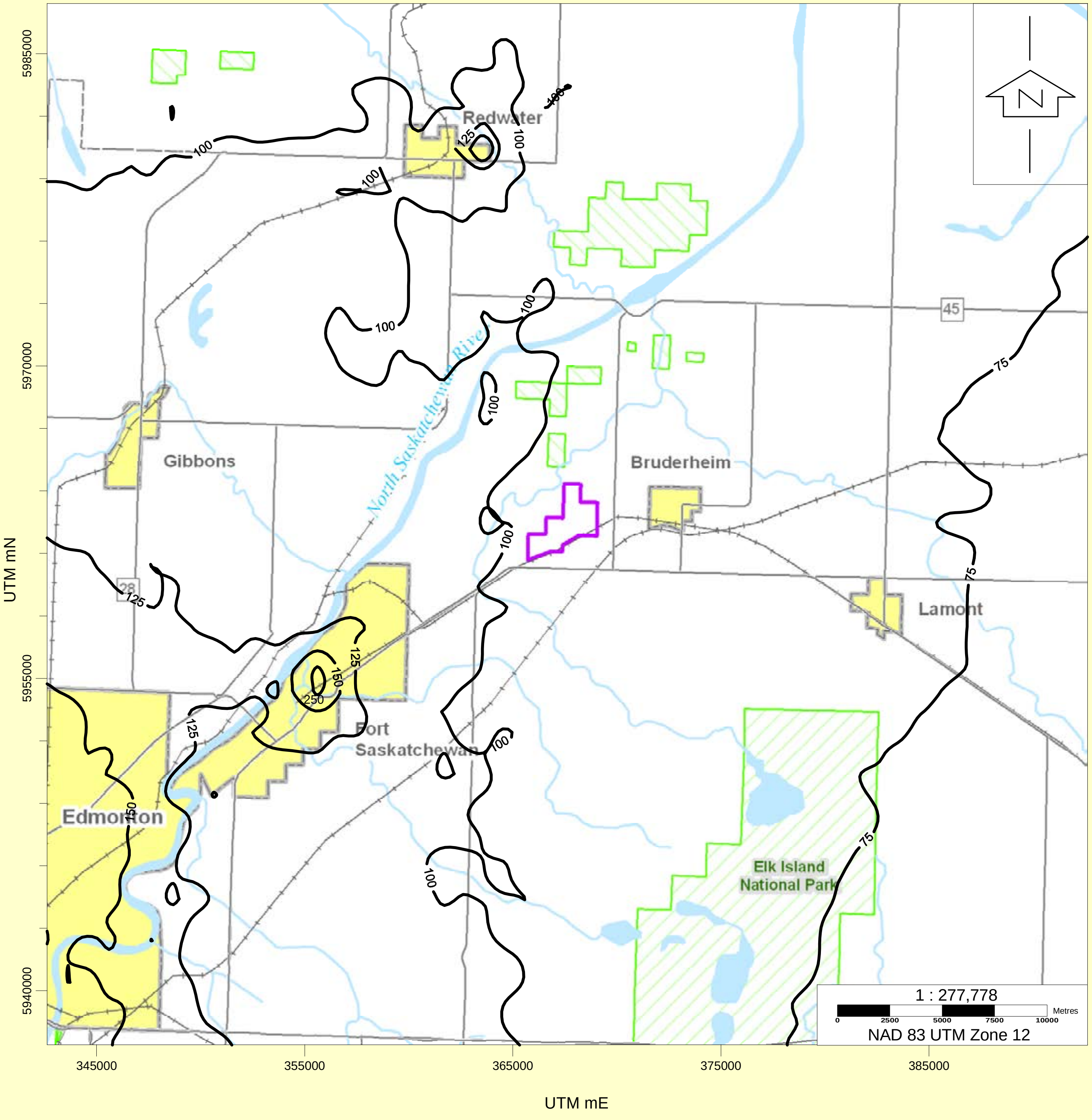

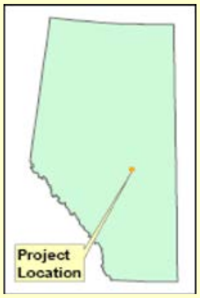

Legend

▭ Project Property Line

🟨 Community/Town

🟩 Natural Area

AAAQO: 400 ug/m^3

Title:

1-HOUR NO$_2$ CONCENTRATION
(BASELINE CASE)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007	
File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/ Case 13 Base/05Nov07/NO2_h.srf		
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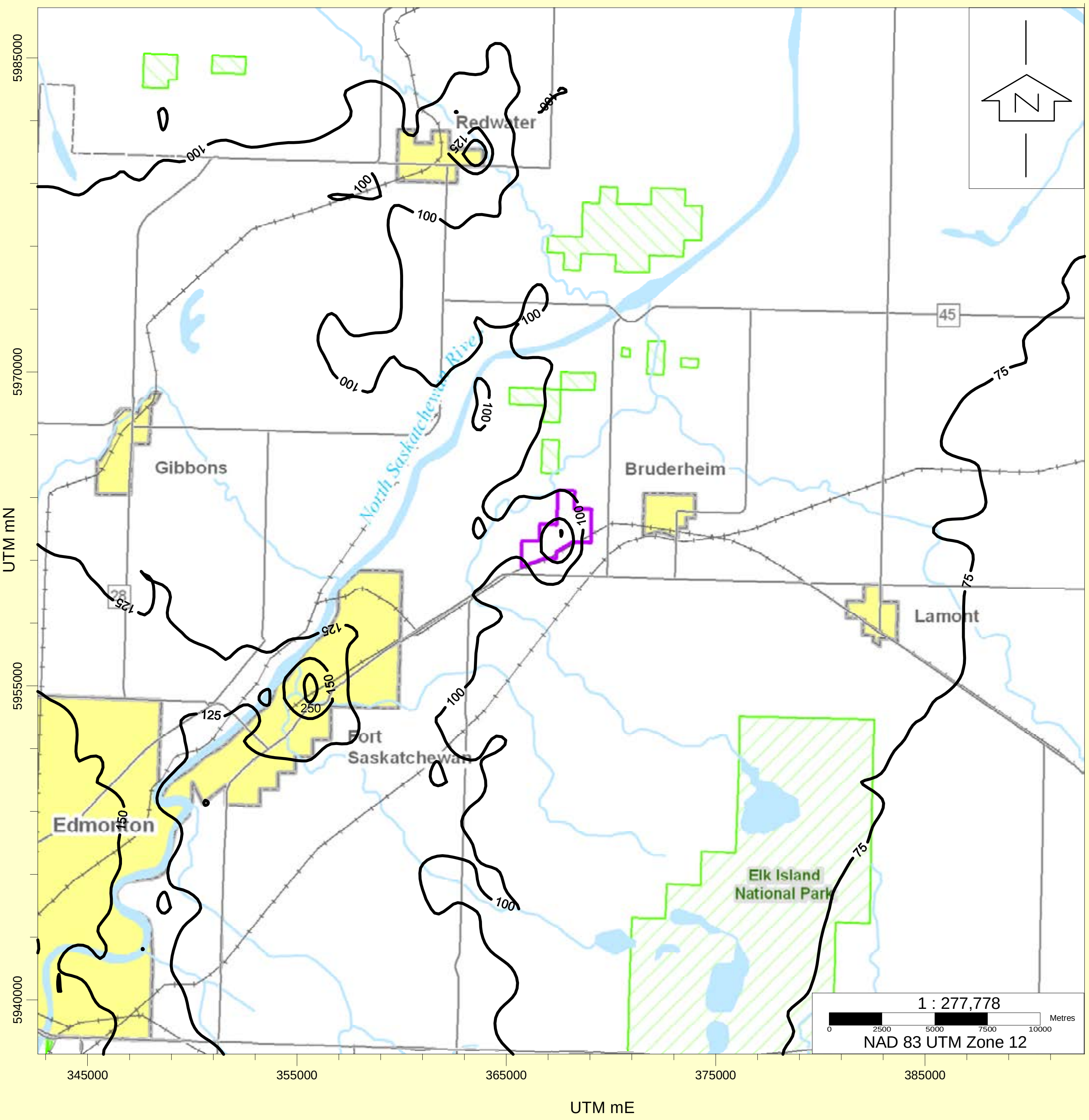

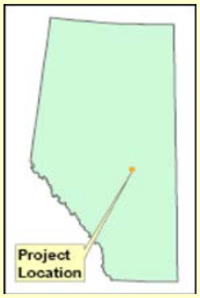

Legend

▭ Project Property Line

▨ Community/Town

▭ Natural Area

AAAQO: 400 ug/m³

Title:

1-HOUR NO$_2$ CONCENTRATION (APPLICATION CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER /Case 14 Application/05Nov07/NO2_h.srf

Drawn by:	Checked:	Fig. No.:
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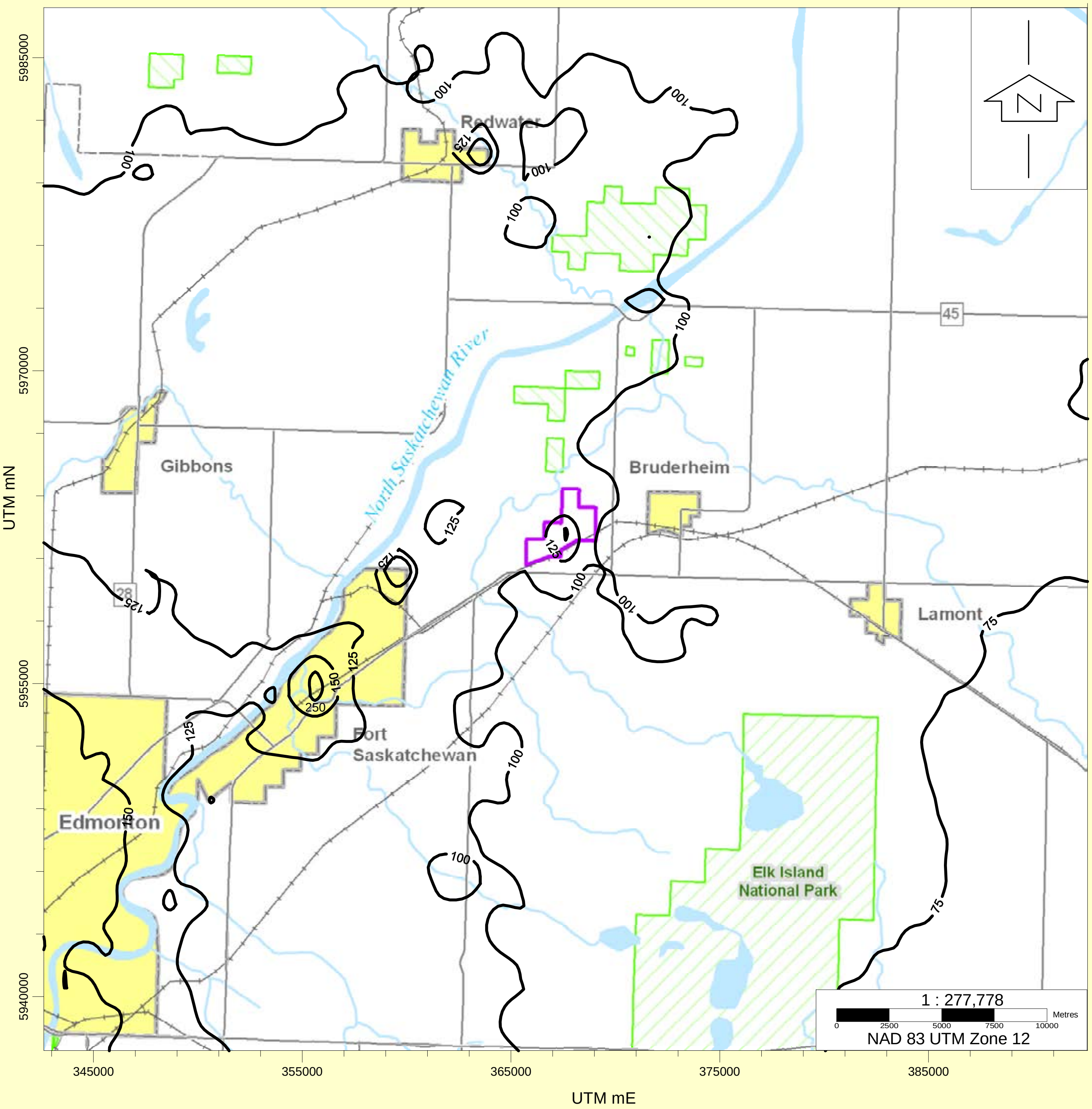

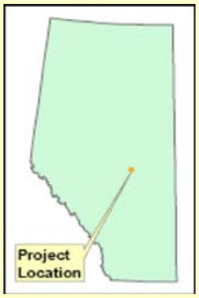

Legend

▭ Project Property Line

🟨 Community/Town

🟩 Natural Area

AAAQO: 400 ug/m³

Title:

1-HOUR NO_2 CONCENTRATION (CUMULATIVE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/Case 15 future/05Nov07/NO2_h.srf

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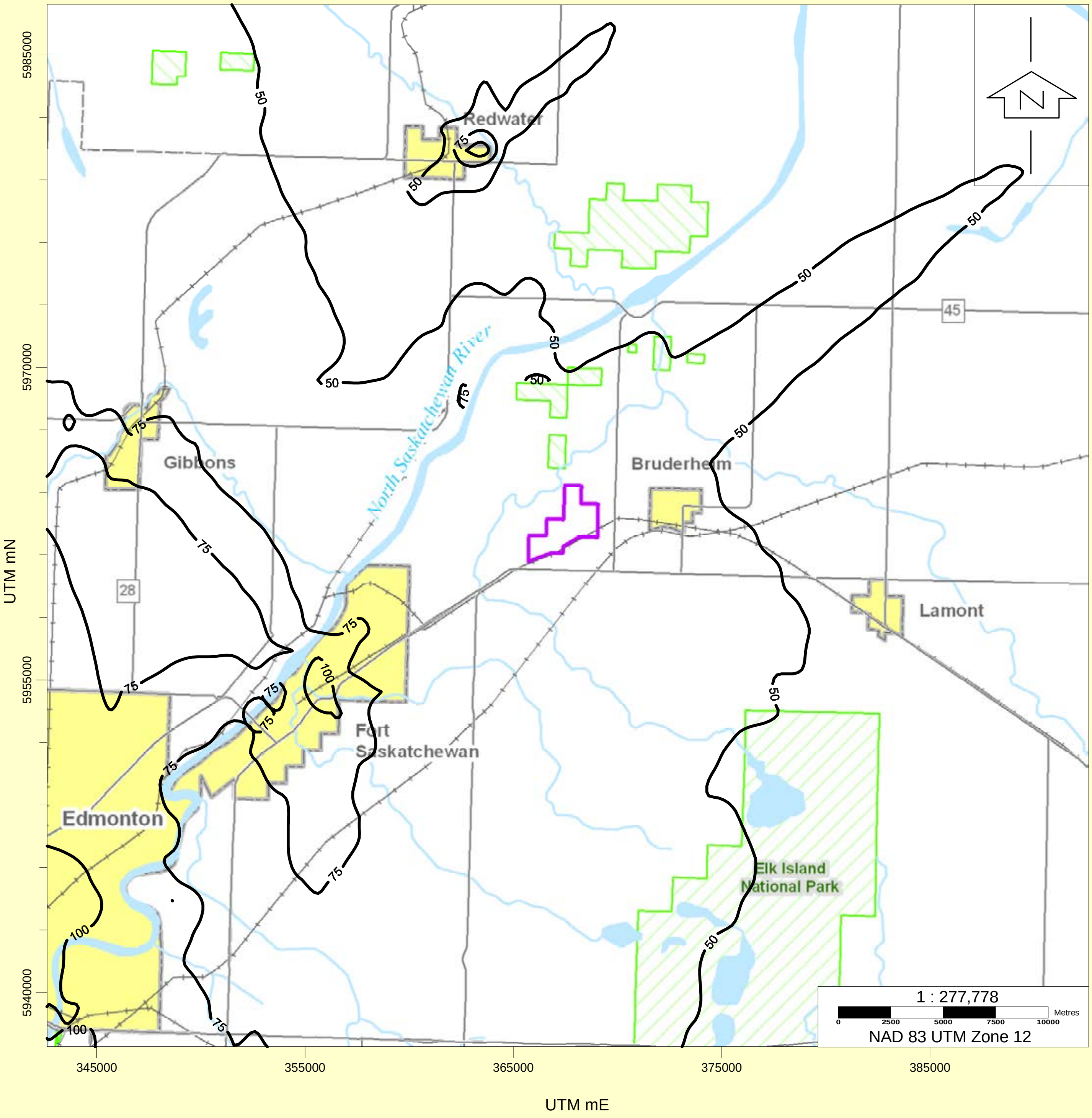

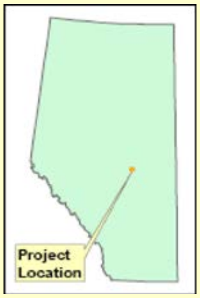

Legend

▭ Project Property Line

▨ Community/Town

🟩 Natural Area

AAAQO: 200 ug/m³

Title:

24-HOUR NO$_2$ CONCENTRATION (BASELINE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/ Case 13 Base/05Nov07/NO2_d.srf

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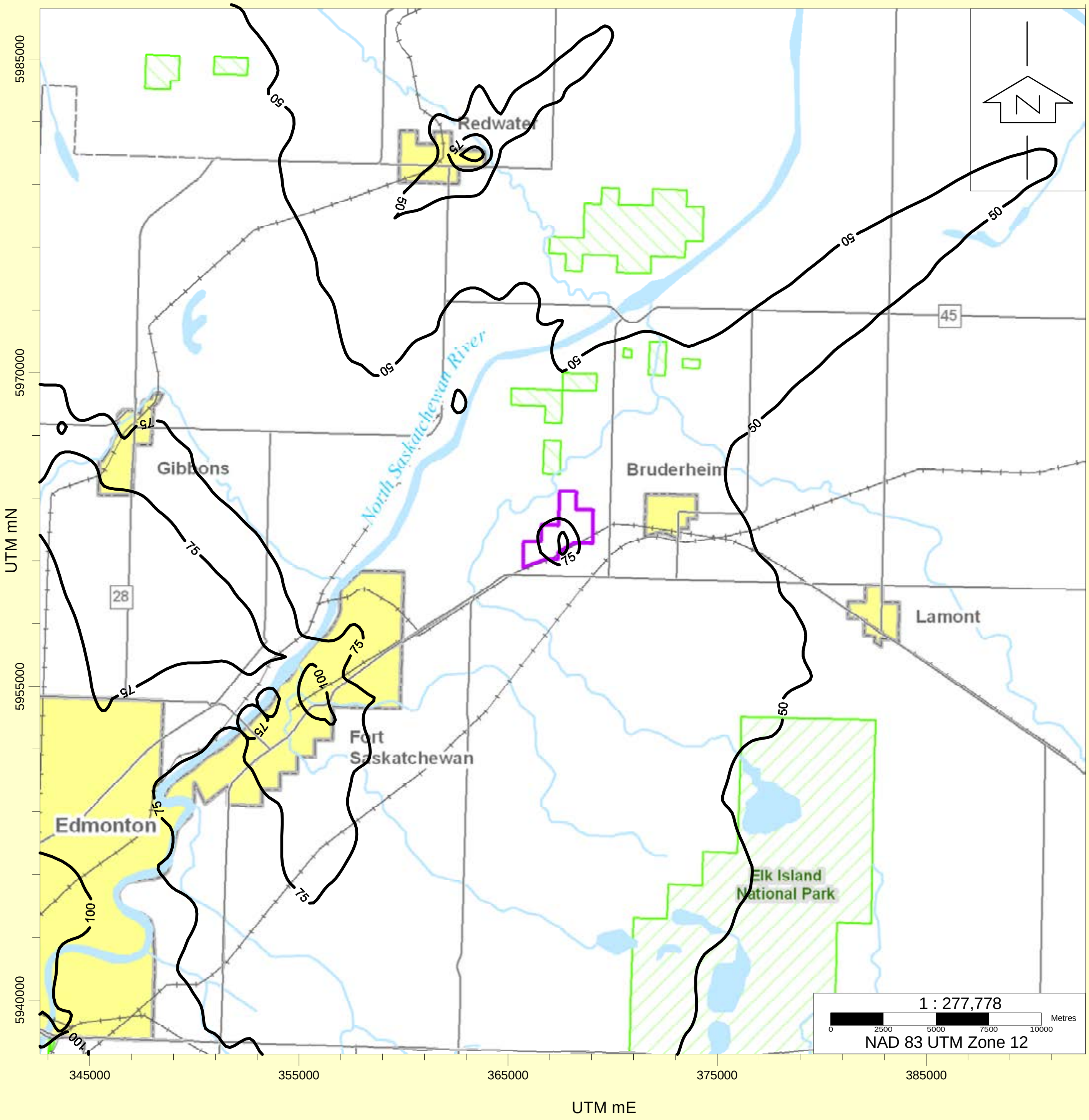

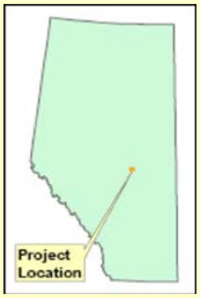

Legend

🟪 Project Property Line

🟨 Community/Town

🟩 Natural Area

AAAQO: 200 ug/m³

Title:

24-HOUR NO$_2$ CONCENTRATION (APPLICATION CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:
MD	05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER /Case 14 Application/05Nov07/NO2_d.srf

Drawn by:	Checked:	Fig. No.:
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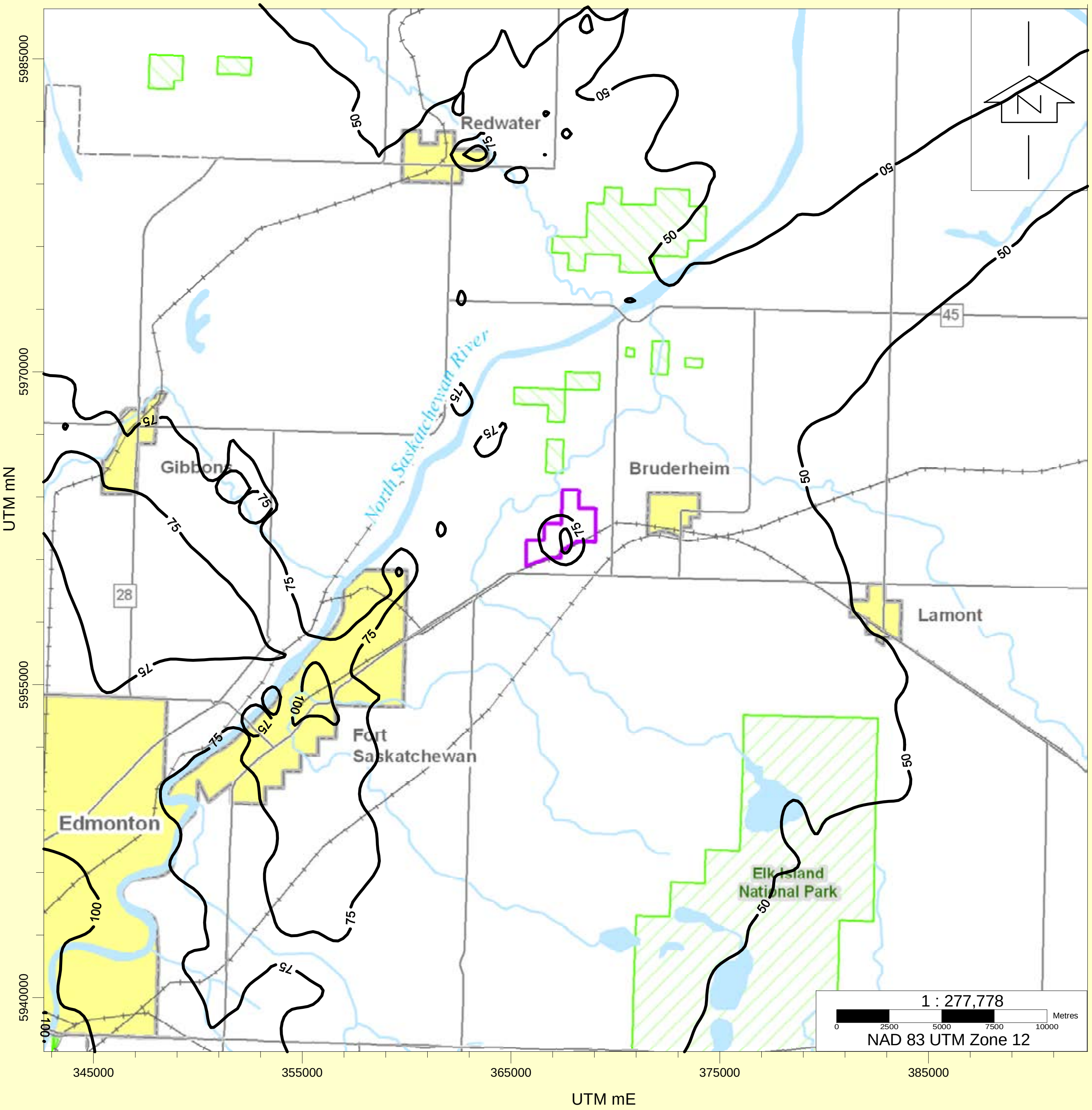

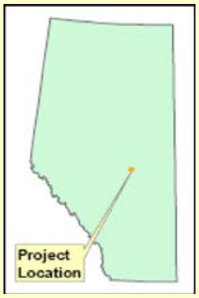

Legend

▭ Project Property Line

▭ Community/Town

▭ Natural Area

AAAQO: 200 ug/m^3

Title:

24-HOUR NO$_2$ CONCENTRATION (CUMULATIVE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/ Case 15 future/05Nov07/NO2_d.srf

Drawn by:	Checked:	Fig. No.:
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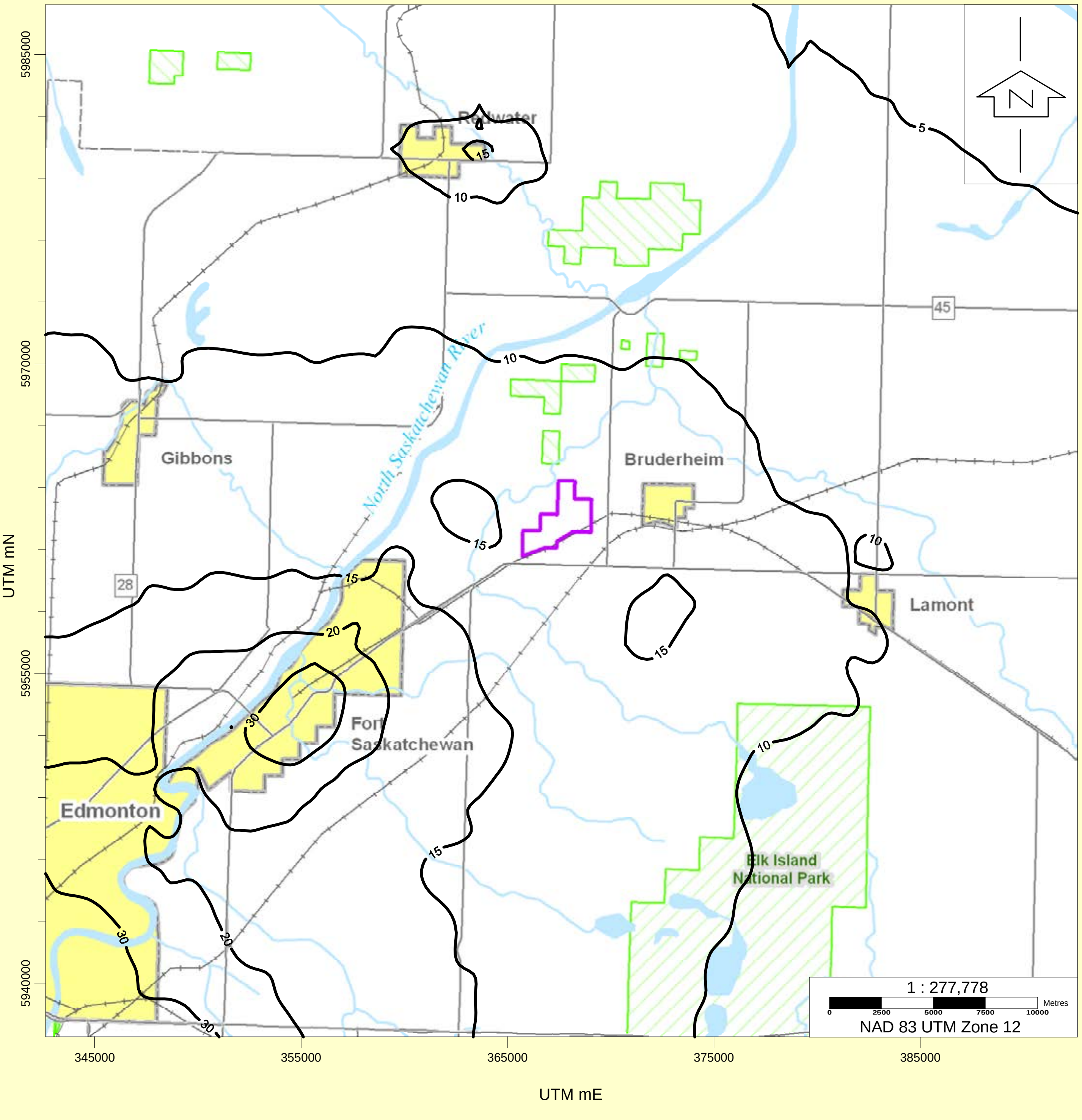
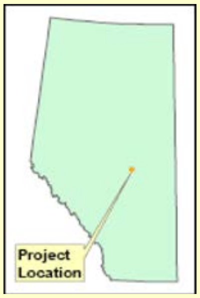




Legend

▭	Project Property Line
▨	Community/Town
▭	Natural Area

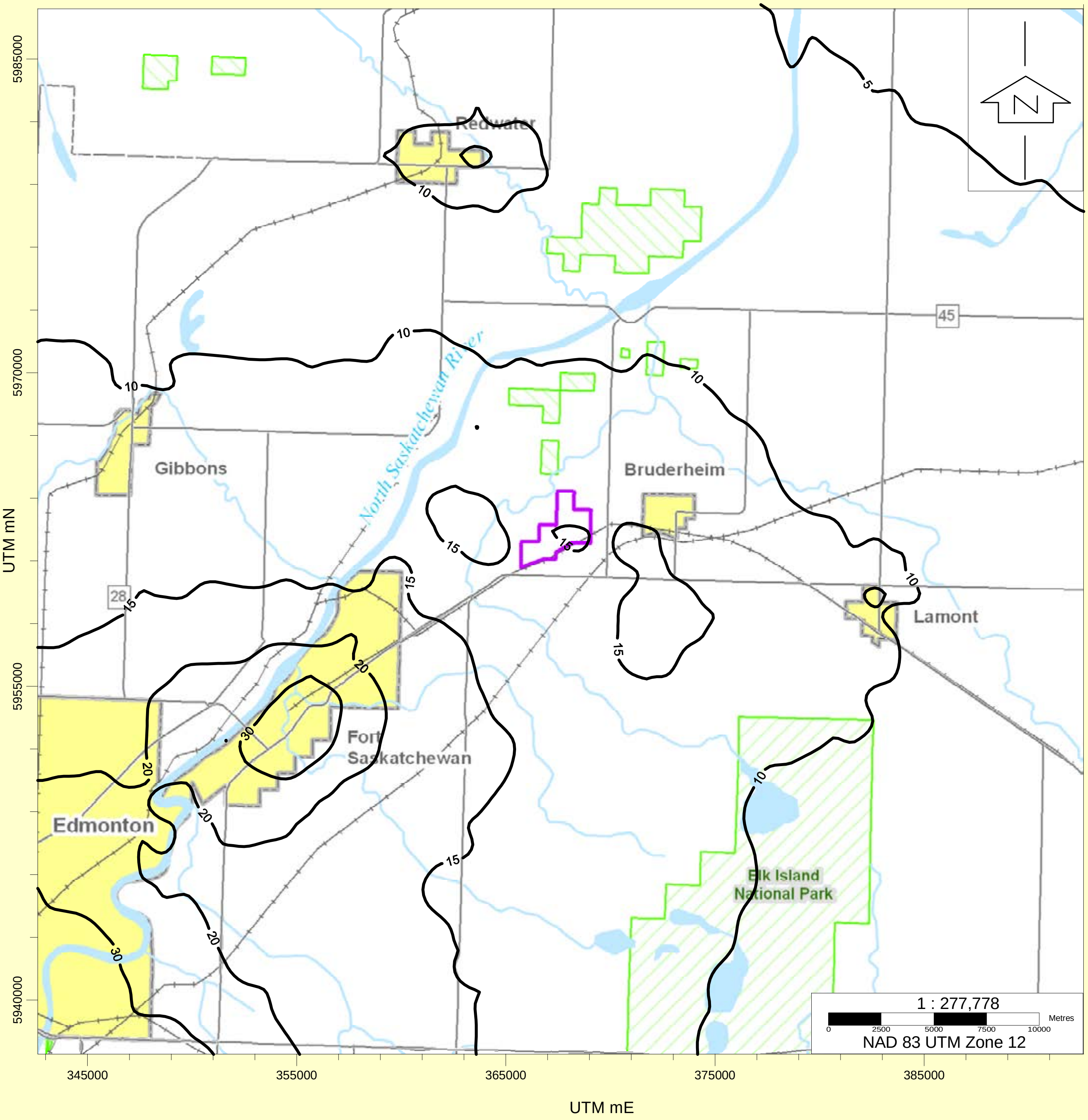
AAAQO: 60 ug/m³

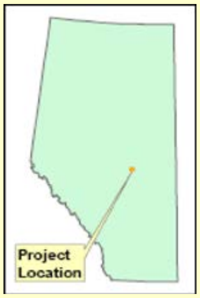
Title:

ANNUAL NO_2 CONCENTRATION (BASELINE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007	
File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/ Case 13 Base/05Nov07/NO2_a.srf		
Drawn by: XC	Checked: MD	Fig. No.: **2.7-16**





Legend

🟪 Project Property Line

🟨 Community/Town

🟩 Natural Area

AAAQO: 60 ug/m³

Title:

ANNUAL NO $_2$ CONCENTRATION (APPLICATION CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD

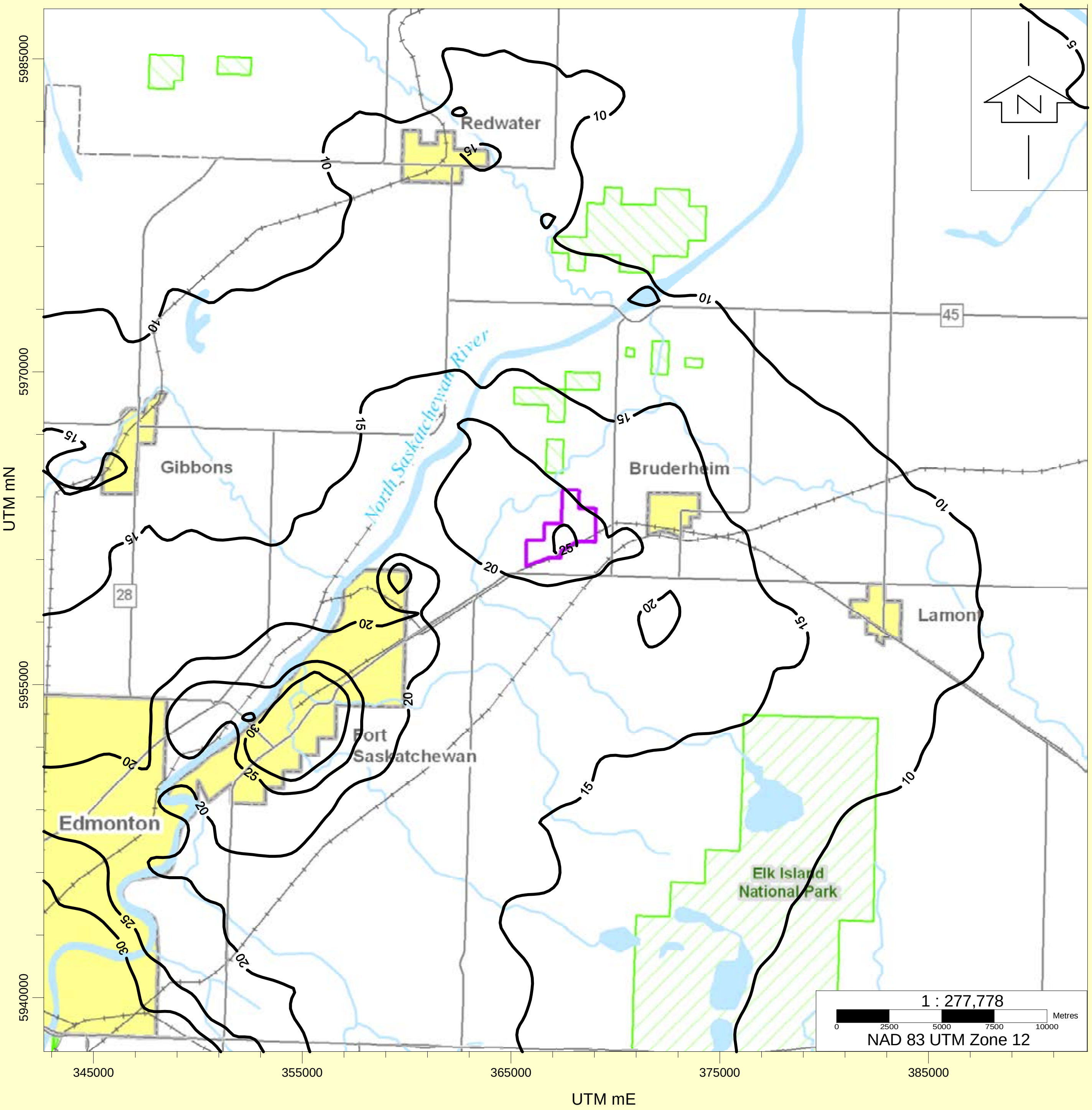
Revision Date: 05/10/2007

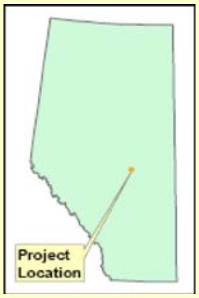
File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER /Case 14 Application/05Nov07/NO2_a.srf

Drawn by: XC

Checked: MD

Fig. No.: 2.7-17





Legend

▭ Project Property Line

▨ Community/Town

▭ Natural Area

AAAQO: 60 ug/m^3

Title:

ANNUAL NO$_2$ CONCENTRATION (CUMULATIVE CASE)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/ Case 15 future/05Nov07/NO2_a.srf

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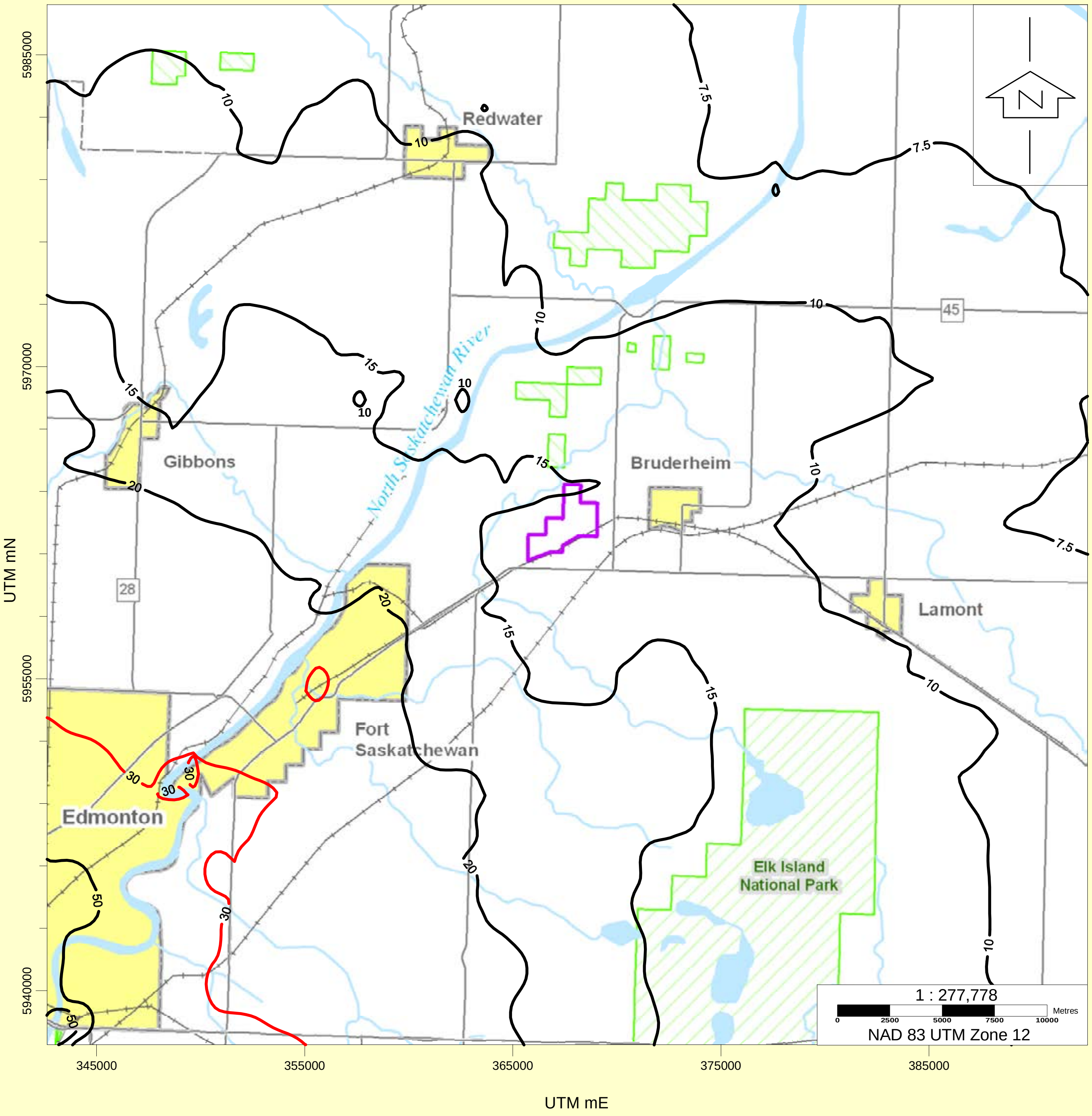

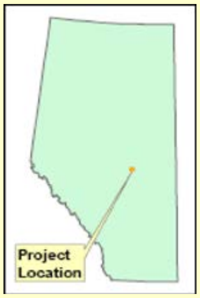

Legend

🟪	Project Property Line
🟨	Community/Town
🟩	Natural Area

CWS: 30 ug/m³

Title:

24-HOUR $PM_{2.5}$ CONCENTRATION (BASELINE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:
MD	05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/ Case 13 Base/05Nov07/PM2.5_d.srf

Drawn by:	Checked:	Fig. No.:
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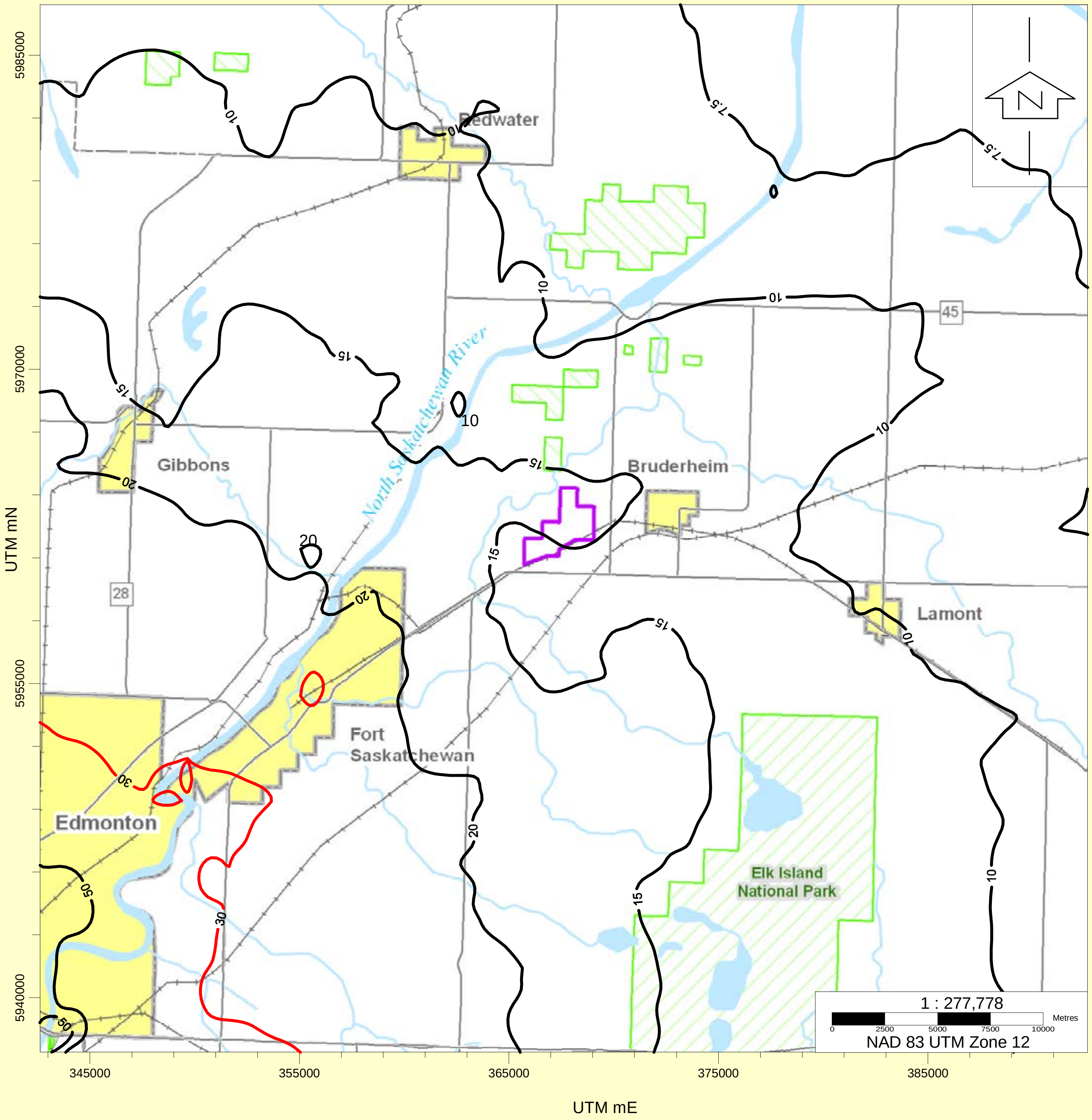

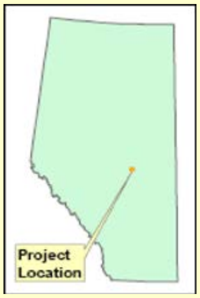

Legend

▭ Project Property Line

▨ Community/Town

▭ Natural Area

CWS: 30 ug/m³

Title:

24-HOUR PM$_{2.5}$ CONCENTRATION (APPLICATION CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:
MD	05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER /Case 14 Application/05Nov07/PM2.5_d.srf

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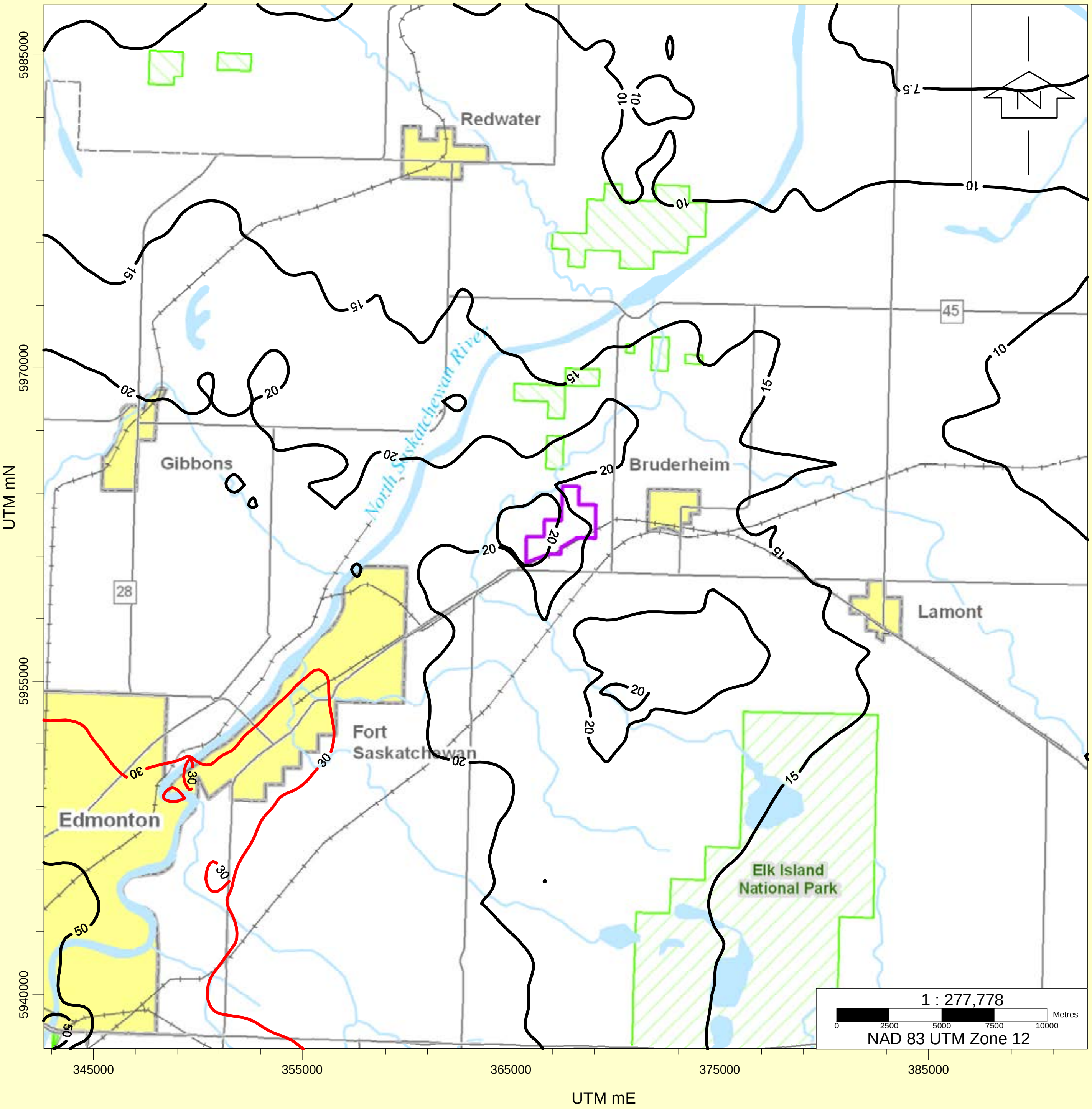

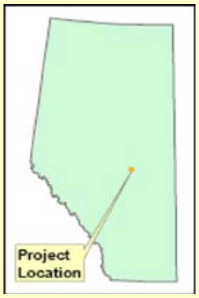

Legend

▭ Project Property Line

🟨 Community/Town ▭ Natural Area

CWS: 30 ug/m³

Title: **24-HOUR PM$_{2.5}$ CONCENTRATION (CUMULATIVE CASE)**	NORTH AMERICAN OIL SANDS CORPORATION
Approved: MD	Revision Date: 05/10/2007
File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/Case 15 future/05Nov07/PM2.5_d.srf	
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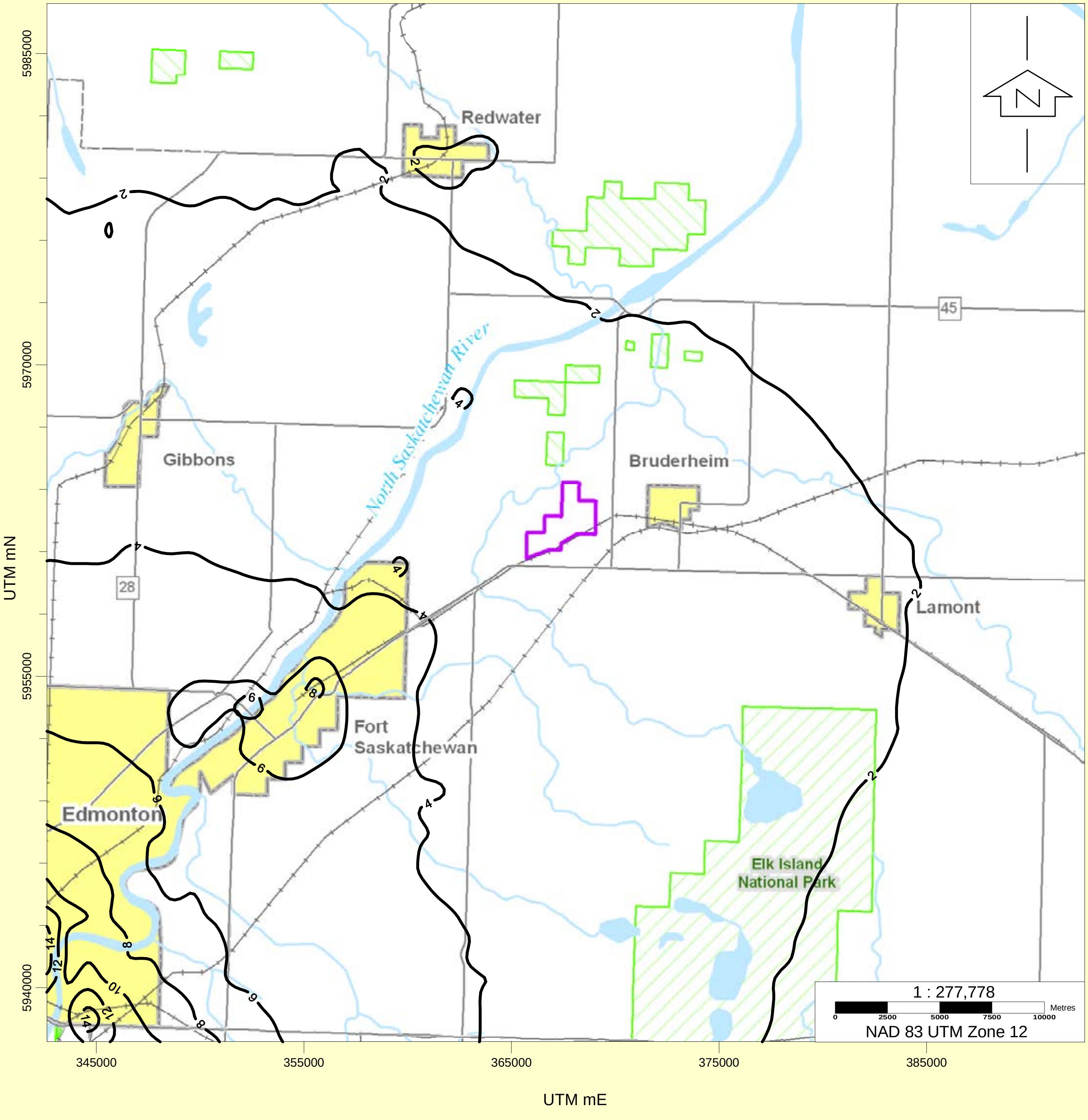
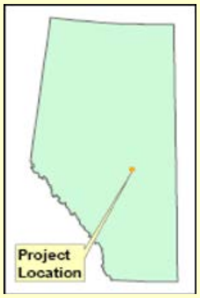
Fig. No.: **2.7-21**	





Legend

▭ Project Property Line

▨ Community/Town 🟩 Natural Area

Title:

ANNUAL $PM_{2.5}$ CONCENTRATION (BASELINE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:
MD	05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/ Case 13 Base/05Nov07/PM2.5_a.srf

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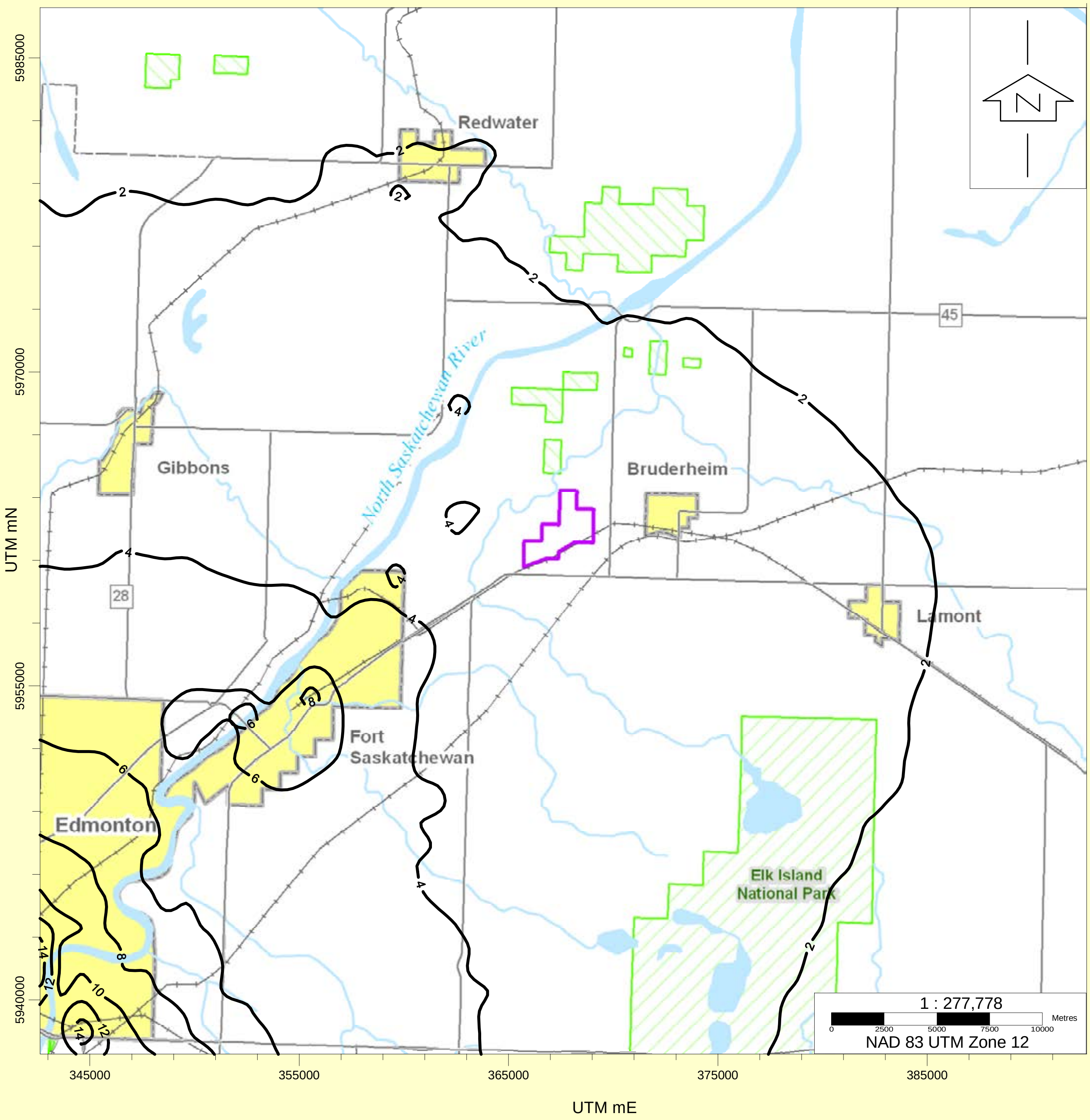

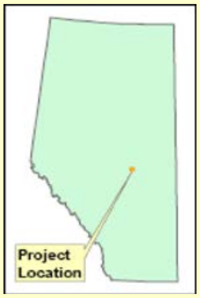

Legend

▭ Project Property Line

▭ Community/Town

▭ Natural Area

Title:

ANNUAL $PM_{2.5}$ CONCENTRATION (APPLICATION CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER /Case 14 Application/05Nov07/PM2.5_a.srf

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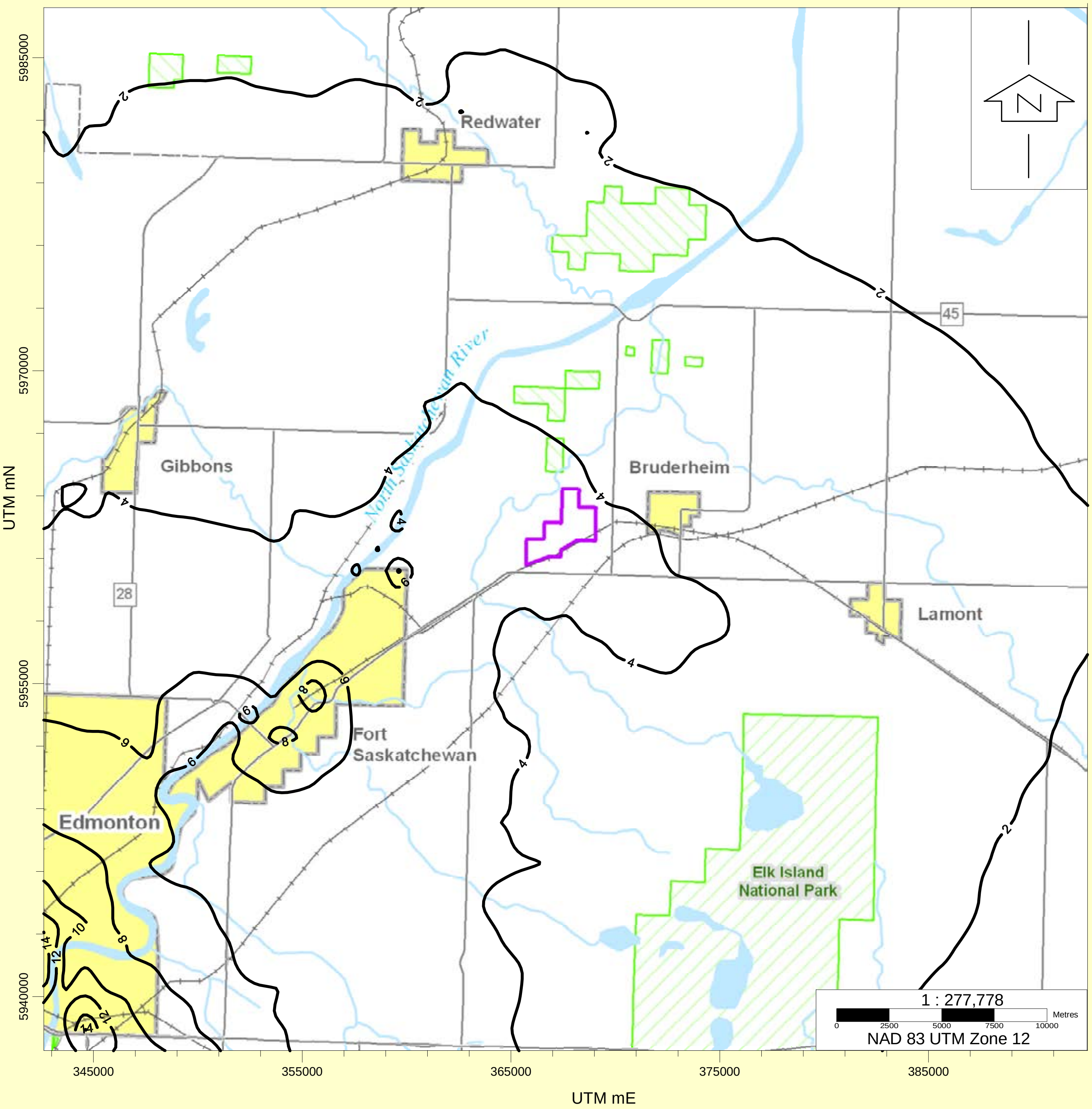

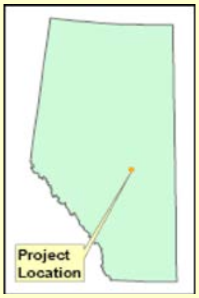

Legend

▭ Project Property Line

▭ Community/Town

▭ Natural Area

Title:

ANNUAL $PM_{2.5}$ CONCENTRATION (CUMULATIVE CASE)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date:
MD	05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/Case 15 future/05Nov07/PM2.5_a.srf

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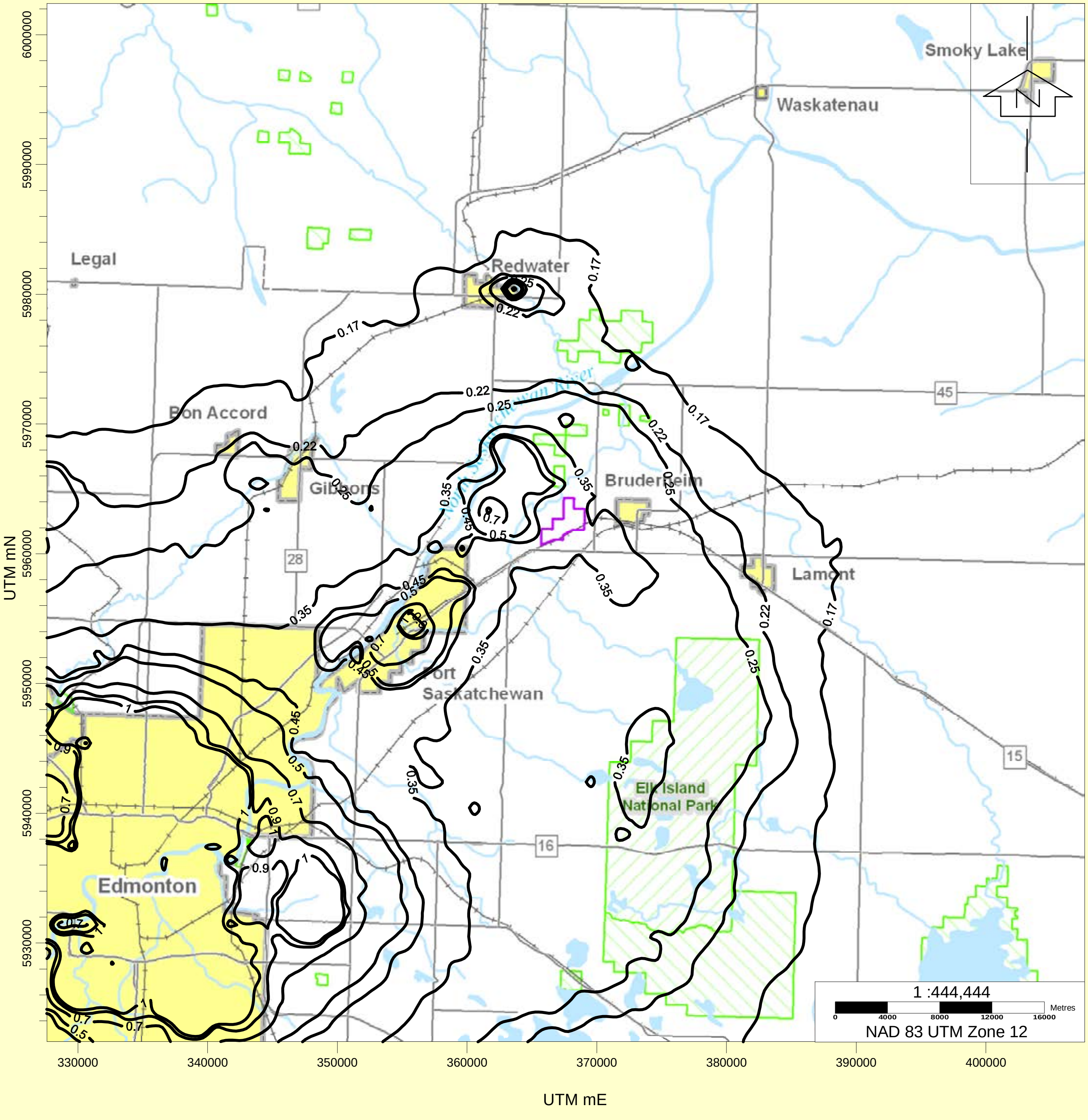

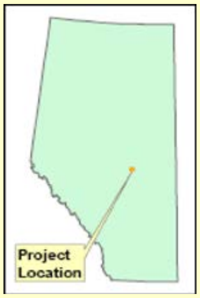

Legend

🟪	Project Property Line
🟨	Community/Town
🟩	Natural Area

Title:

PAI Deposition
(keq H⁺ /ha/y)
(BASELINE CASE)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/ Case 13 Base/05Nov07/PAI_a.srf

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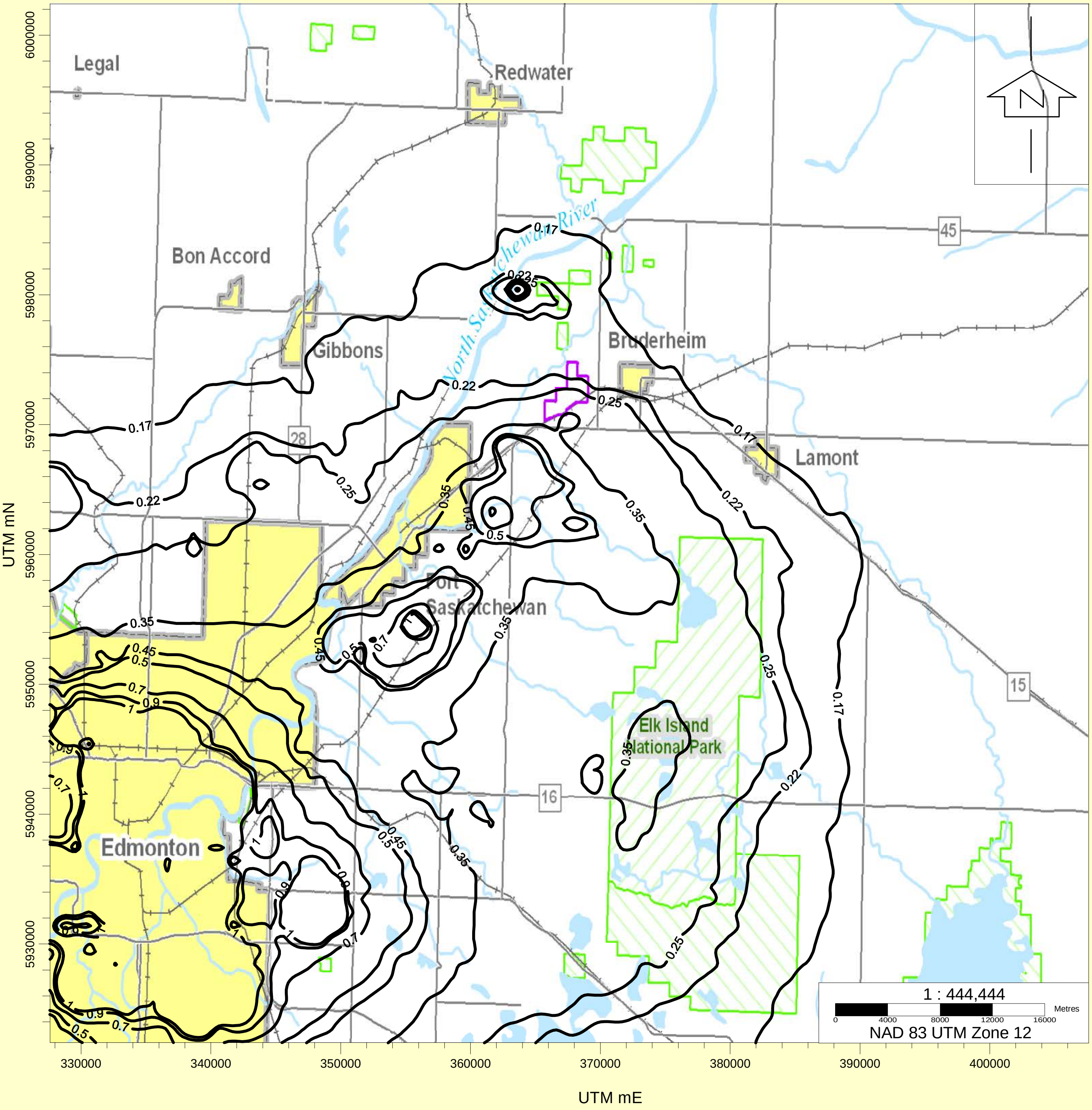

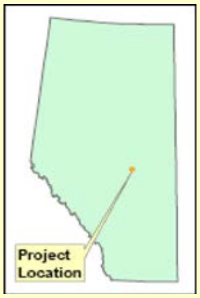

Legend

🟪 Project Property Line

🟨 Community/Town

🟩 Natural Area

Title:

PAI Deposition
(keq H⁺ /ha/y)
(APPLICATION CASE)

Approved: MD	Revision Date: 05/10/2007
File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER /Case 14 Application/05Nov07/PAI_a.srf	

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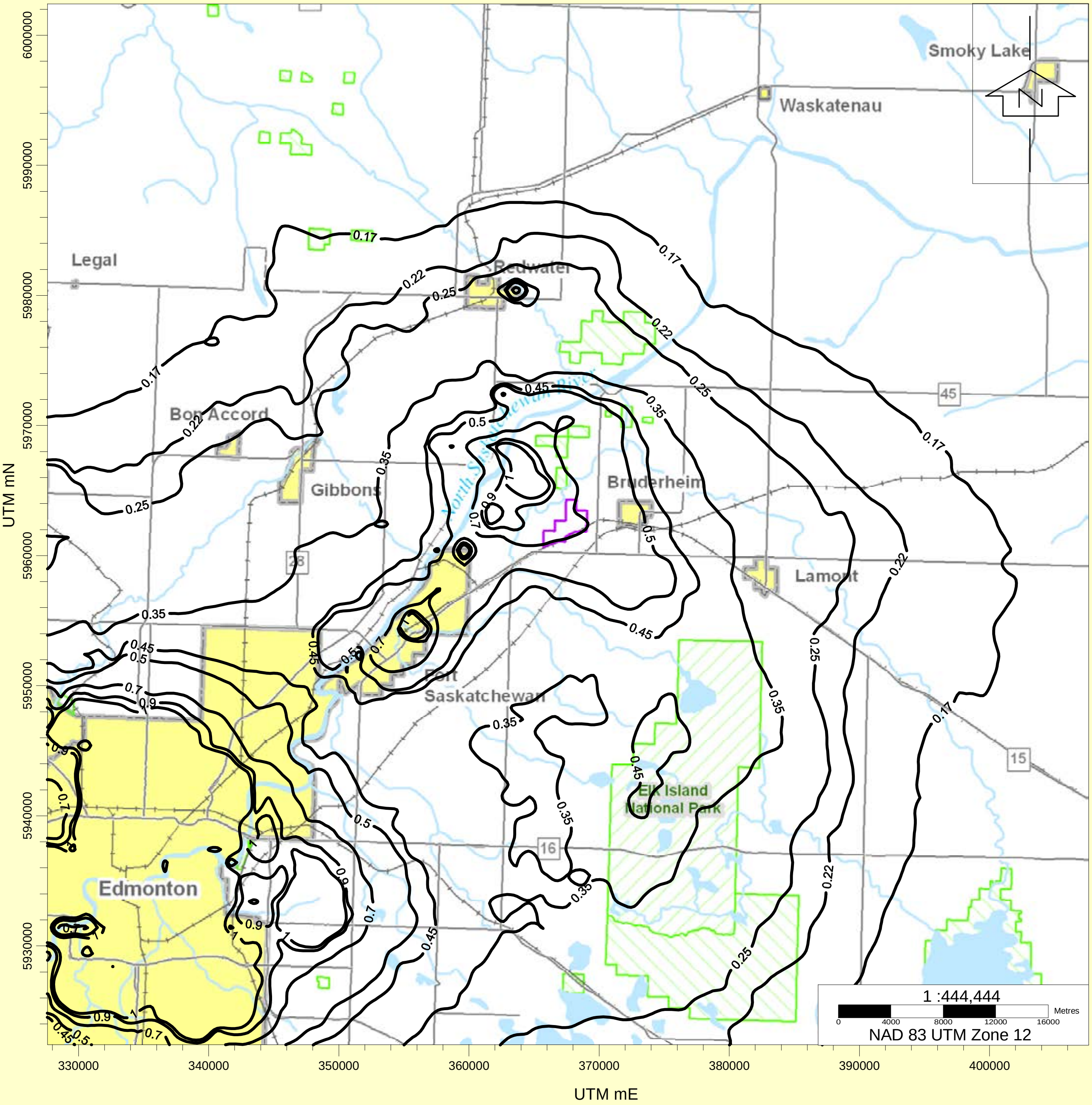

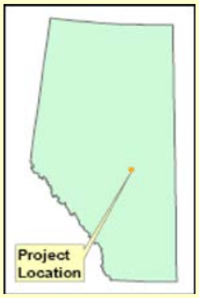

Legend

▭ Project Property Line

🟨 Community/Town

▭ Natural Area

Title:

PAI Deposition
(keq H^+ /ha/y)
(CUMULATIVE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:
MD	05/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/Case 15 future/05Nov07/PAI_a.srf

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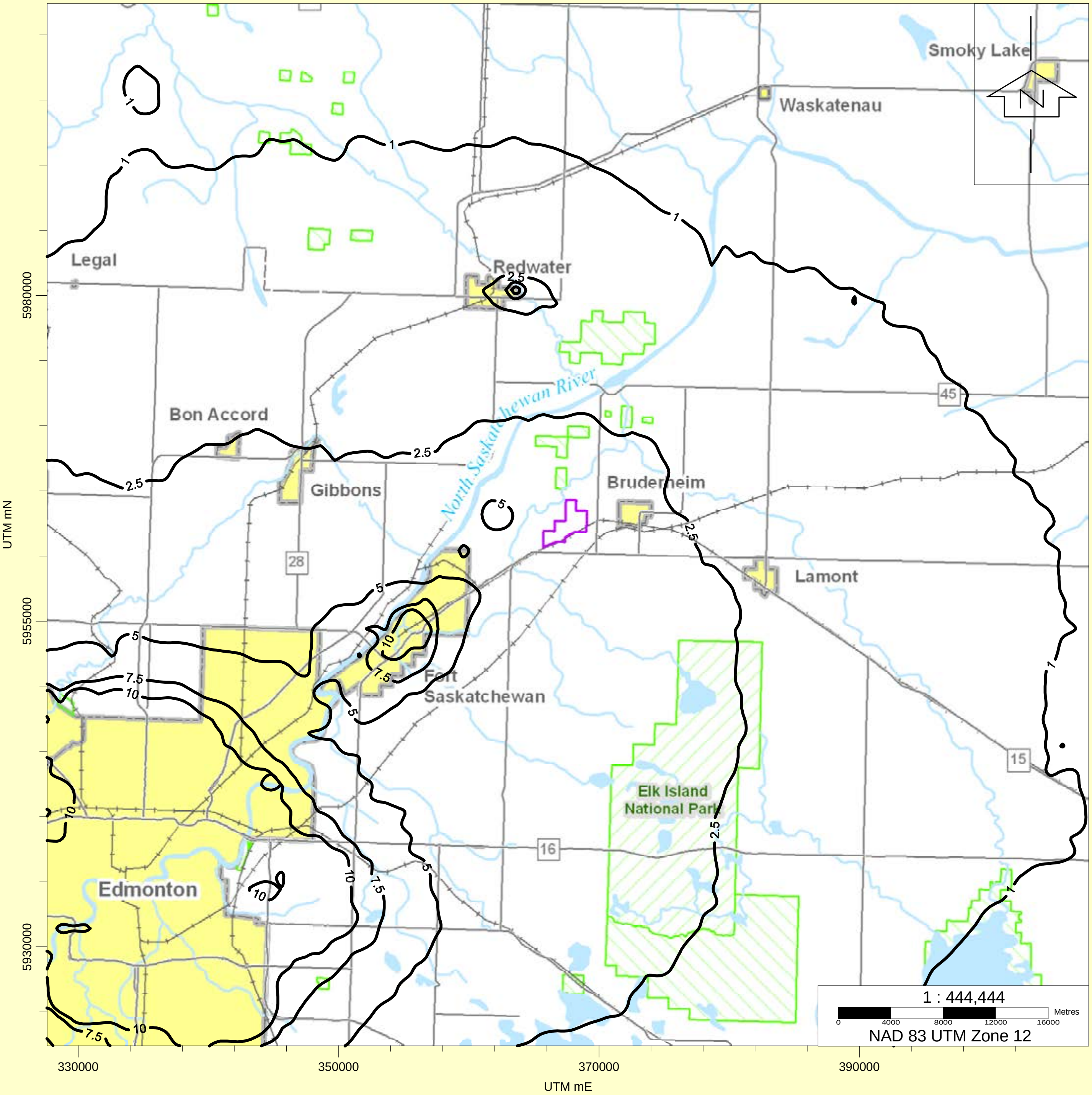
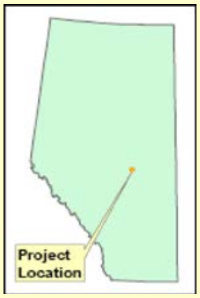
XC	MD	**2.7-27**





Legend

▭ Project Property Line

▨ Community/Town

▭ Natural Area

Title:

NITROGEN DEPOSITION
(kg N/ha/y)
(BASELINE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 09/10/2007
File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/ Case 13 Base/NDEP_a.srf	

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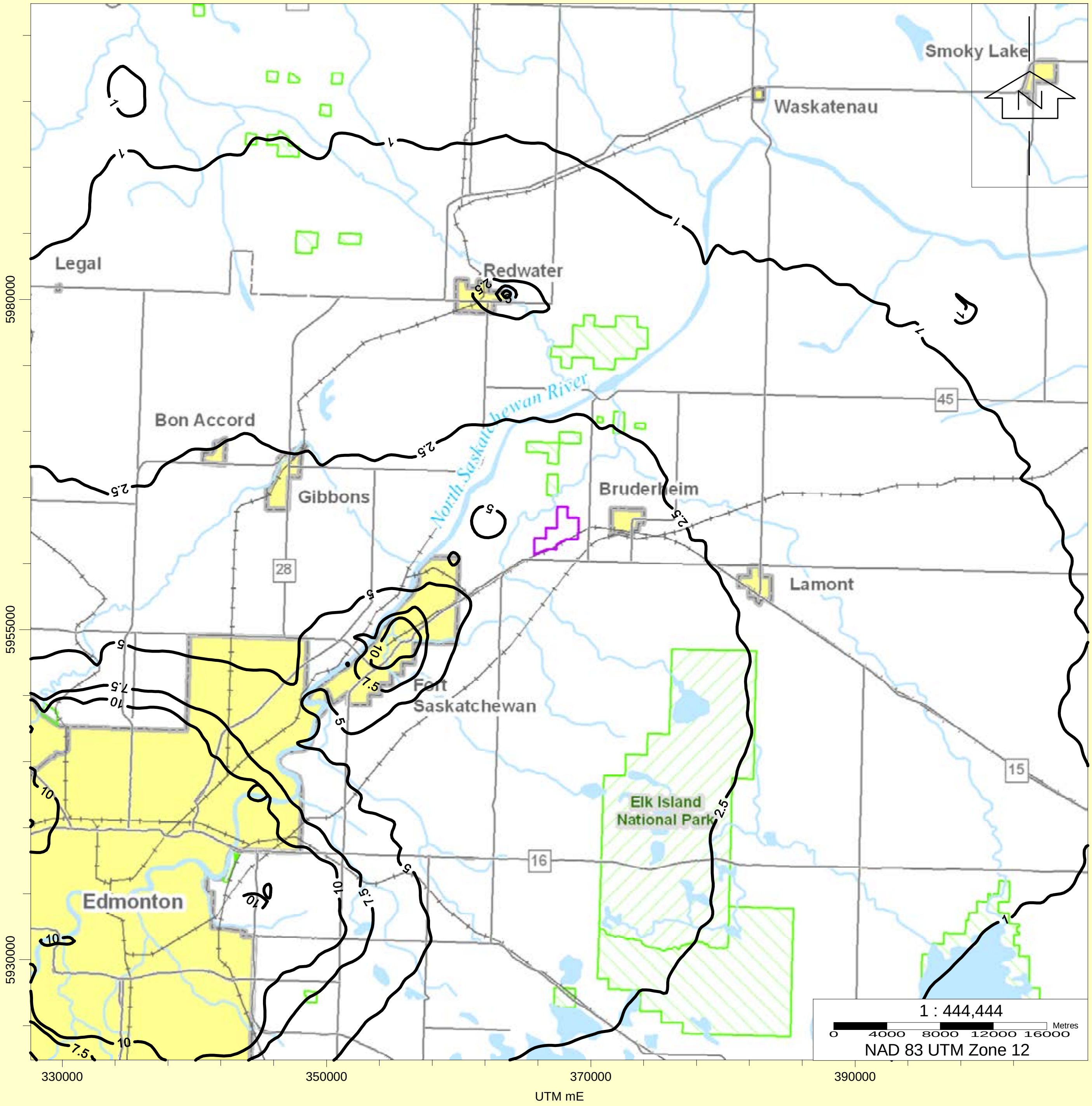

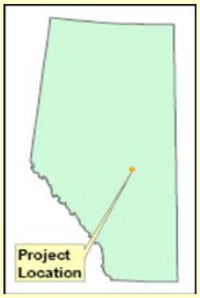

Legend

🟪	Project Property Line
🟨	Community/Town
🟩	Natural Area

Title:

NITROGEN DEPOSITION
(kg N/ha/y)
(APPLICATION CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 09/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER /Case 14 Application/05Nov07/NDEP_a.srf

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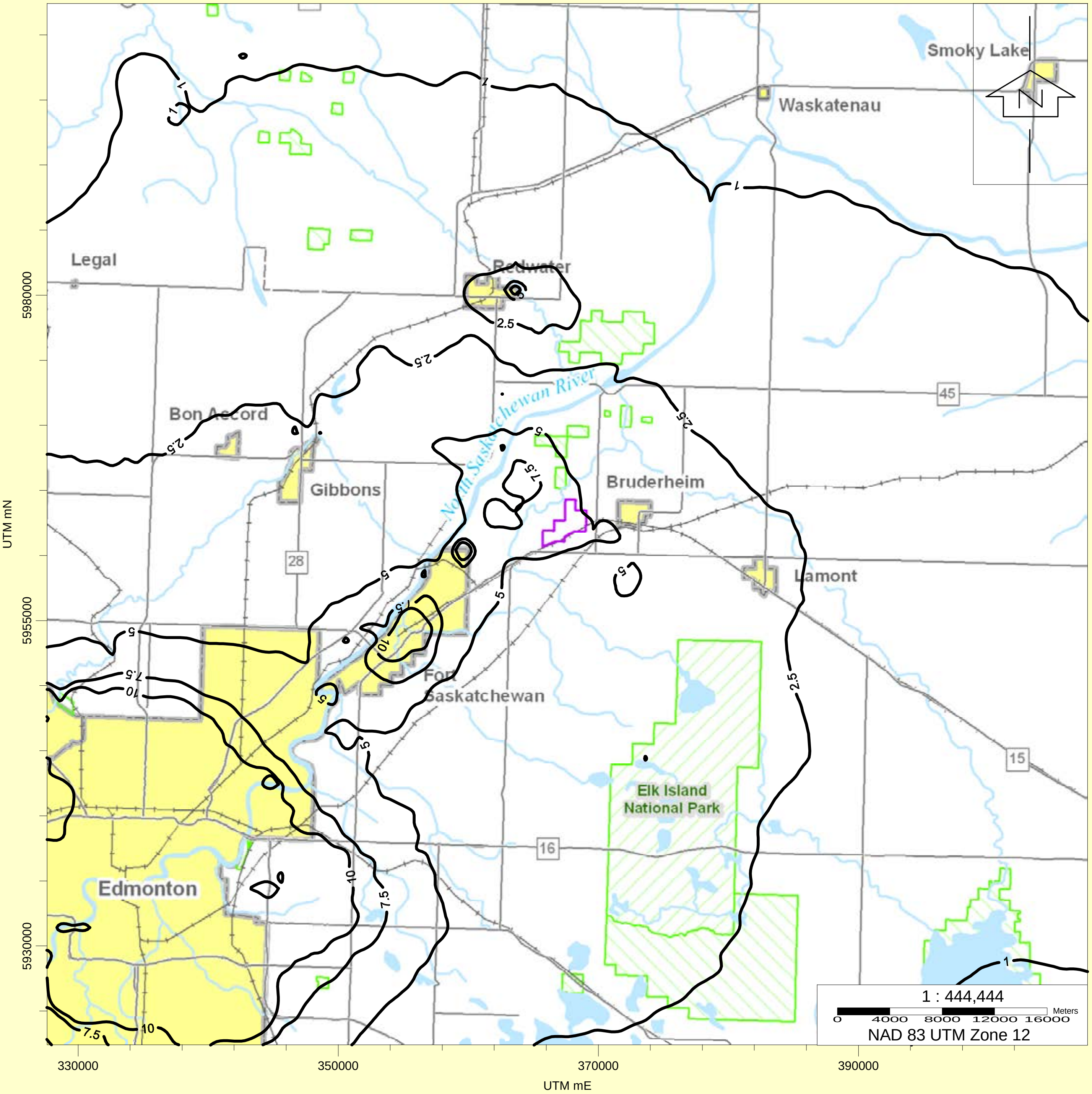

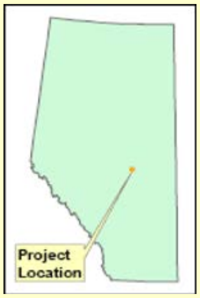

Legend

🟪 Project Property Line

🟨 Community/Town

🟩 Natural Area

Title:

NITROGEN DEPOSITION
(kg N/ha/y)
(CUMULATIVE CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:	
MD	09/10/2007	

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/Case 15 future/05Nov07/NDEP_a.srf

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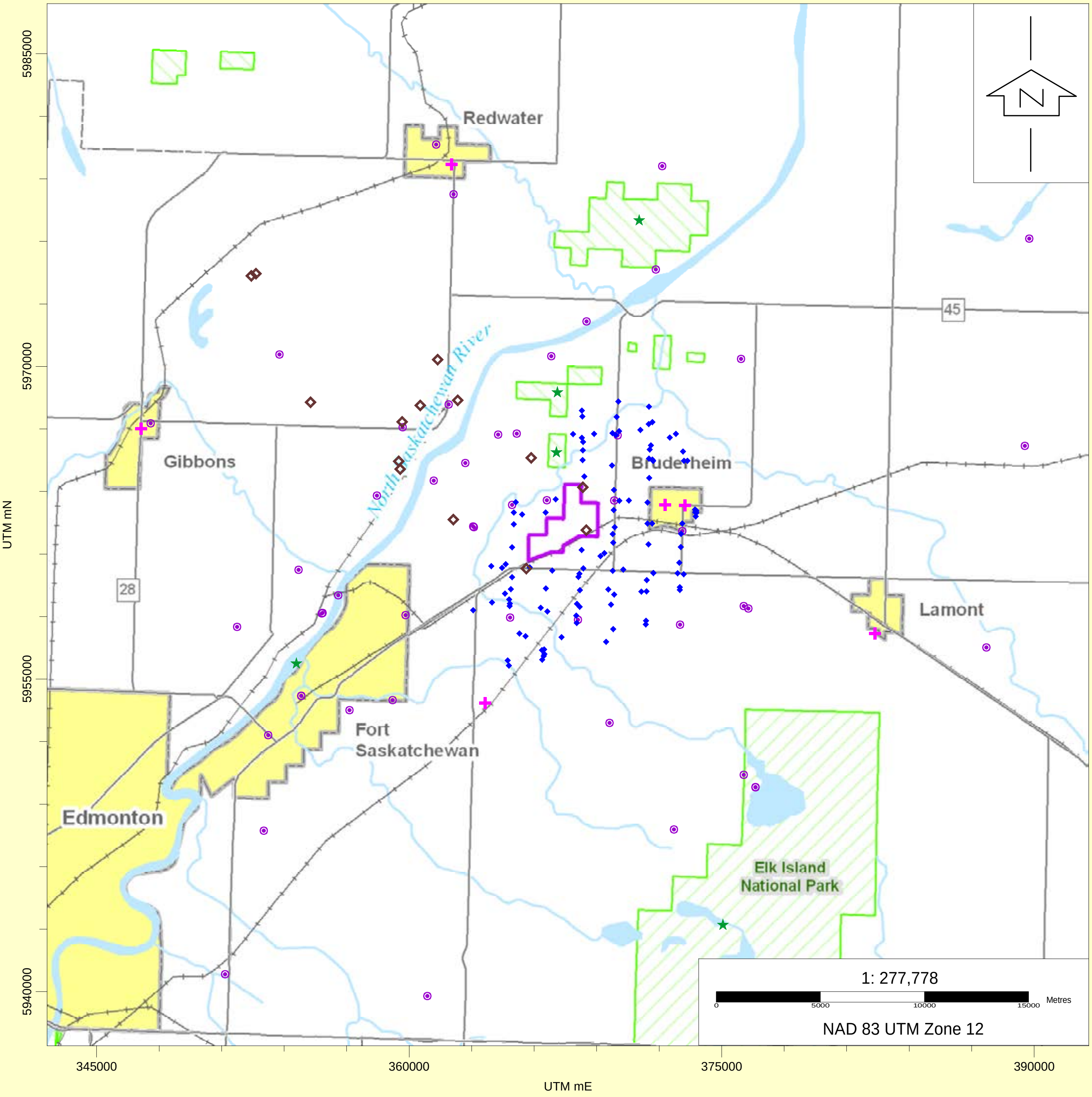
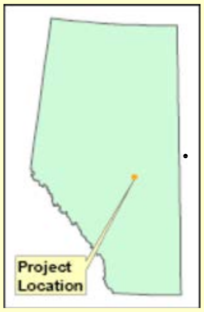
XC	MD	2.7-30





Legend

- ◆ Agriculture/Residential
- ✚ Residential/Community
- ◇ Commercial/Industrial Area
- ★ Public Access Area
- ◉ FAP Monitoring Stations

Title:

LOCATION OF DISCRETE RECEPTORS

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 09/10/2007
File: H:/AQ/Shared/1018897 NAOSC Matrix/ N8897 Coordinates/receptors/ Figure 2.7-30.srf	

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XC	MD	**2.7-31**

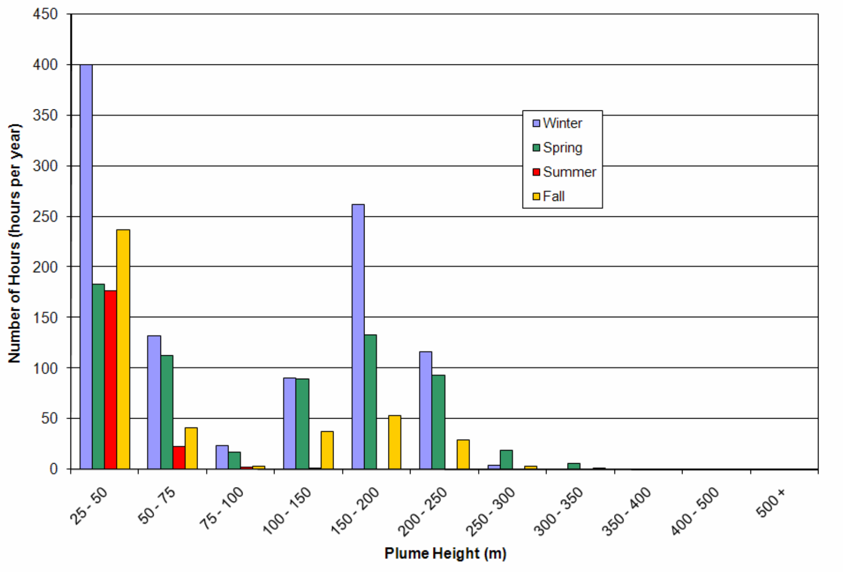


Figure 2.7-32 **Predicted Frequencies of Visible Plume Heights for All Hours of the Day due to Project Stack and Cooling Tower Emissions**

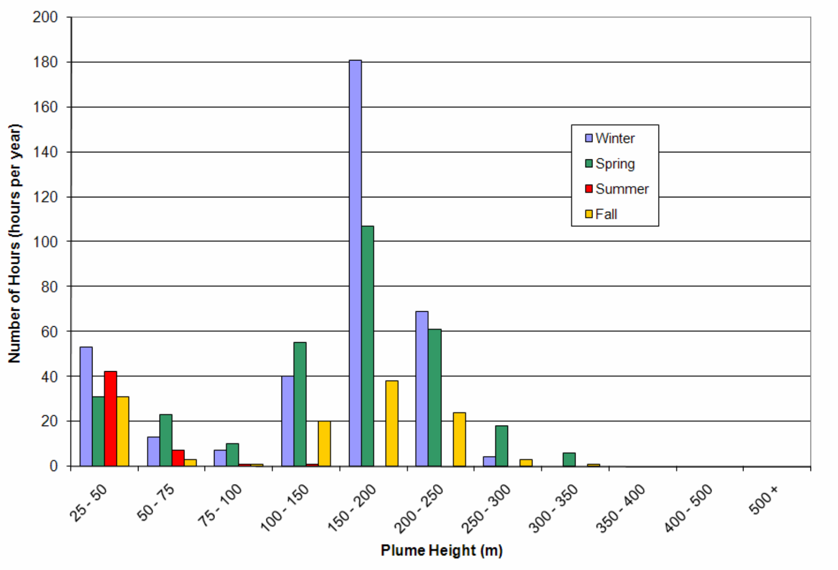
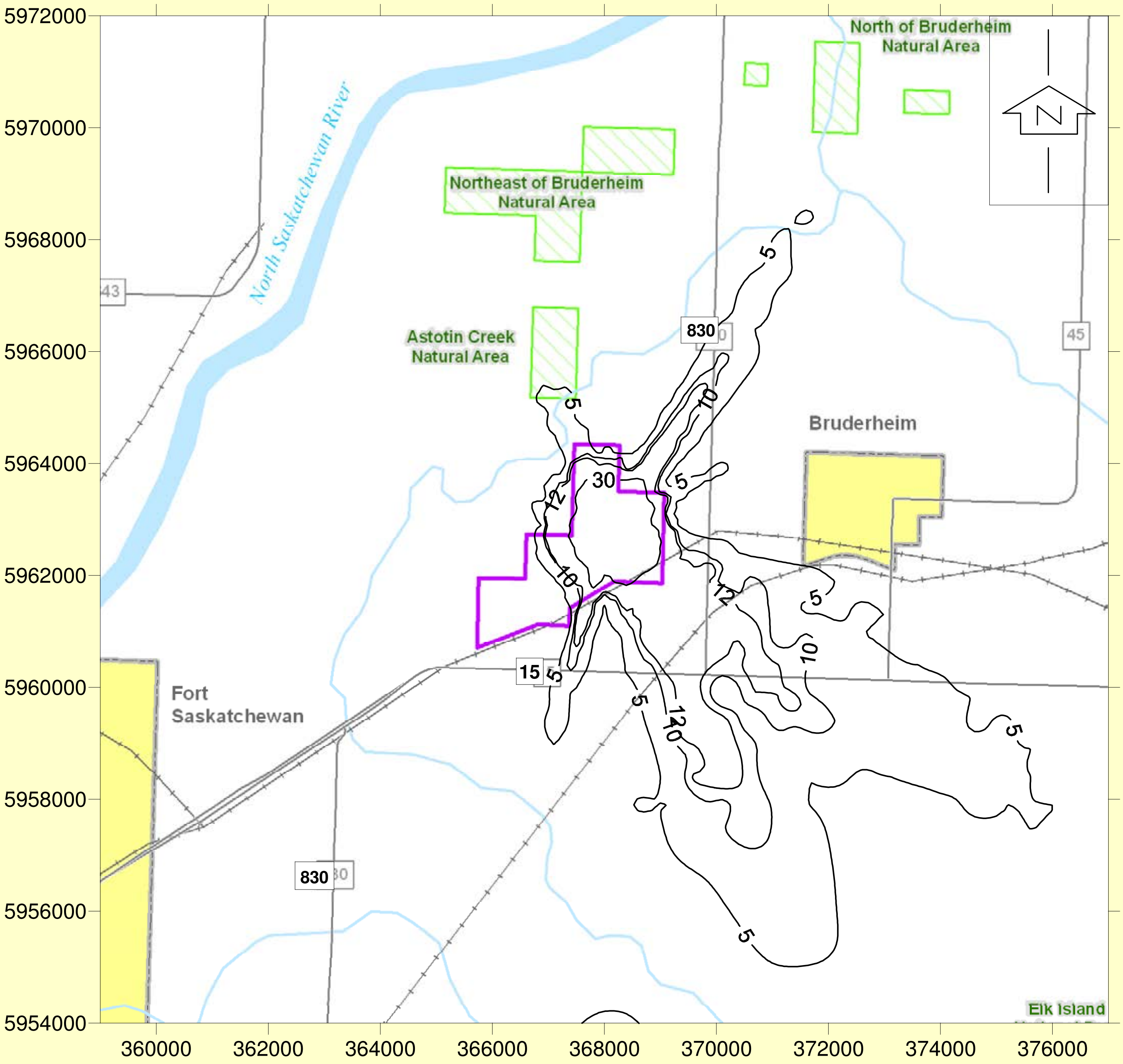
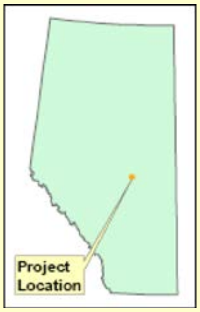


Figure 2.7-33 **Predicted Frequencies of Visible Plume Heights for Daytime Hours due to Project Stack and Cooling Tower Emissions**





Legend

🟨	Community/Town
▭	Project Property Line

Title:

Predicted Fog Occurrence (h/y) due to Project Cooling Tower

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date: 03/12/2007	
File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897FOG/ Fog Isopleth Dec 3.srf		
Drawn by: YS	Checked: MD	Fig. No.: 2.7-34

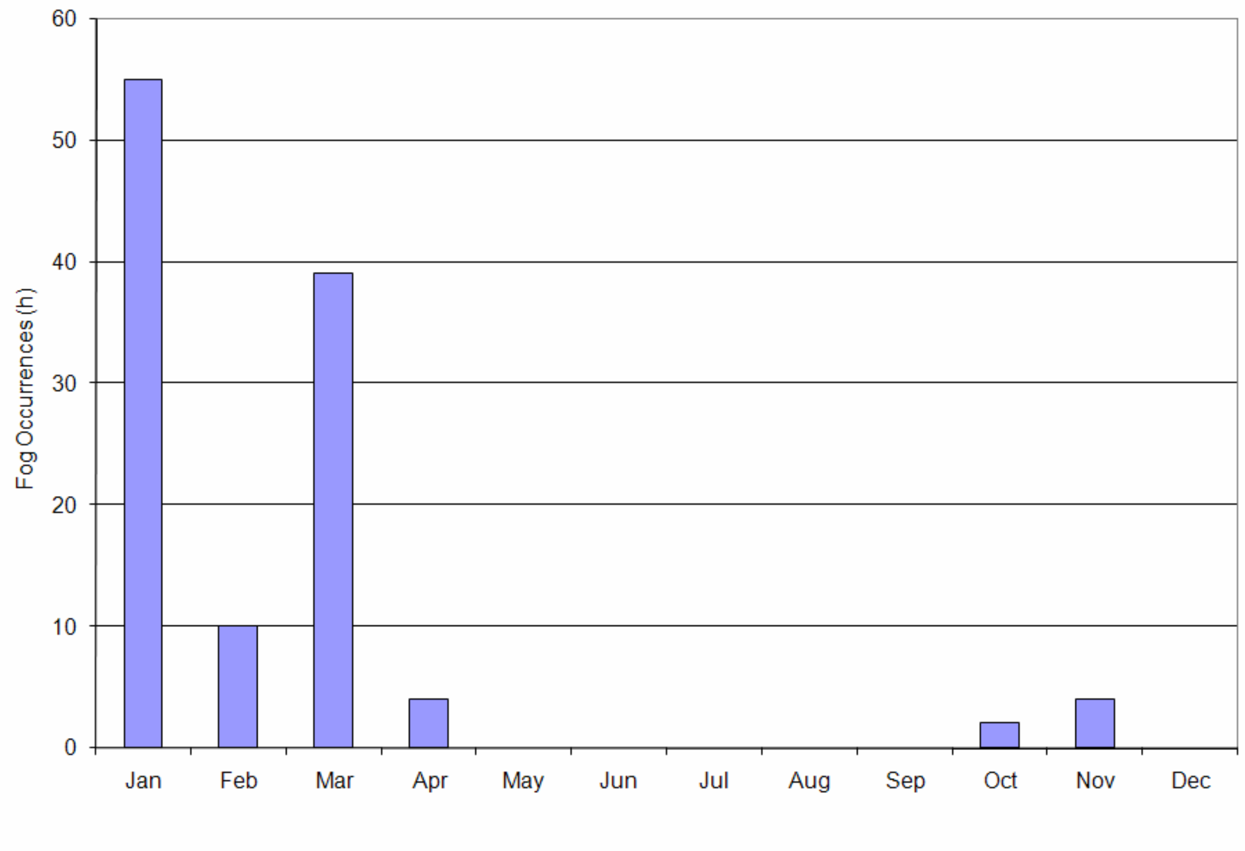


Figure 2.7-35 **Predicted Fog Occurrence Frequency Dependence on Time of Year due to Project Cooling Tower Emissions**

2.8 Follow-up and Monitoring

The environmental approvals issued under the Alberta *Environmental Protection and Enhancement Act* (EPEA) for upgraders require emission source and ambient air quality monitoring with associated reporting. North American expects to have similar requirements associated with their approval. The Alberta *Climate Change and Emissions Management Act* (CCEMA) requires that GHG emissions be reported on an annual basis; the calculation can require monitoring or other indirect measures. The EUB will also require the reporting of emission information relating to sulphur substances.

North American will also submit the required annual report to the federal government on estimated substance emissions to meet the National Pollutant Reporting Inventory (NPRI) requirements under the *Canadian Environmental Protection Act* (CEPA). North American will also meet CEPA’s requirement for GHG reporting by meeting the Alberta CCEMA reporting requirements.

2.8.1 Source Monitoring

The following emission source monitoring and ambient air quality monitoring will be undertaken in accordance with the respective AENV environmental approval.

2.8.1.1 SO_2/RSC Source Monitoring

Since the SRU/TGTU stacks represent the largest continuous SO_2 emission sources, continuous stack emission monitors will be used to measure key stack parameters. The monitoring will be undertaken in accordance with the Alberta continuous stack emission monitoring procedures. This will be complemented by manual stack surveys that will be conducted in accordance with the Alberta Stack Sampling Code. The RSC content of the SRU/TGTU flue gas will be determined as part of the manual stack surveys. The interval for this monitoring will be reviewed after the initial measurements have been obtained.

The sulphur content of the plant fuel gas and the plant fuel gas consumption will be monitored to allow for the calculation of Project-wide SO_2 emissions from the other continuous combustion sources.

A flare management plan will be developed to identify potential flaring scenarios based on refined engineering operations. SO_2 emissions from the flare stacks will be calculated on a daily basis. Flow rates to the flare stacks will be continuously monitored. Representative gas stream compositions will be measured and used to estimate SO_2 emissions. Flaring events will be documented and reviewed on an ongoing basis to examine opportunities to reduce the frequency, duration, and magnitude of flaring.

The monitoring results will be reported in accordance with the terms and conditions identified in the EPEA approval. In addition, the sulphur balance and sulphur recovery efficiencies will be reported to the EUB.

2.8.1.2 NO_x Source Monitoring

The steam methane reformer stack (Stack 7) represents the largest continuous NOx emission source. The next largest NO_x emission sources are the delayed coking heater stacks (Stacks 2, 3, 19 and 20). Continuous stack emission monitors will be used to measure key stack parameters on a continuous basis. The frequency and approach used will be the same as for SO_2/RSC monitoring.

For the smaller NO_x emissions stacks, one manual stack survey per year will be conducted for these stacks, and the interval for continued monitoring will be reviewed after the first few surveys.

The fuel use rate will be monitored to allow plant-wide NO_x emissions to be calculated for inventory reporting purposes. The results of the continuous monitoring and stack surveys will be reported in accordance with the terms and conditions identified in the EPEA approval.

2.8.1.3 Other Source Monitoring/Reporting

North American will implement an LDAR program, which is typically specified in the EPEA approval. As an addition to its NO_x monitoring commitment, North American will measure trace VOC and PAH emissions, and compare these to the values provided in the assessment. The measurements will also be used to support the NPRI reporting needs. NPRI and the GHG reporting requirements will be met by a combination of monitoring or direct measurements, mass balance, process specific emission factors or engineering estimates.

2.8.2 Ambient Monitoring

Ambient monitoring in the region is conducted by the FAP to meet various stakeholder (i.e., the public, regulatory and industry) needs. North American intends to actively participate in this regional monitoring organization. Based on this assessment, North American has identified a number of ambient air quality monitoring programs for consideration by FAP:

- Given the proximity to the community of Bruderheim, North American sees the benefit for an ambient air quality monitoring station to be located between the project and the community. A preferred location would be near the western boundary of the community. This station could be instrumented in similar fashion as the existing FAP Lamont station (i.e., SO_2, H_2S, NO_2, O_3, $PM_{2.5}$ and NMHC, winds and temperature). Monitoring should be commenced prior to operation to obtain an understanding of pre-operation ambient air quality. North American will work with AENV and the FAP to address this issue.

- While on an individual plant basis, the contribution to the predicted PAI in Elk Island National Park is relatively small, the combined SO_2 emissions, in conjunction with the Edmonton urban area NO_x emissions, lead to the need for acidification measurements at this location. These measurements should take the form of wet deposition sample collection, and the calculation of dry deposition similar to that undertaken in the Wood Buffalo Environmental Association airshed (e.g., EPCM, 2002).

- To enhance the usefulness of the Elk Island National Park measurements, the measurements need to be placed in the context with a reference site not influenced by the Fort Saskatchewan industrial or the Edmonton urban sources. This reference site could be located to the north of Edmonton.

- The EC model predictions and their associated recommendations call for an additional ozone monitoring station to be located in a region where the model is predicting high ozone concentrations due to precursor Edmonton Census Division emissions. The need for such a site should be confirmed, and the selection of a site should be undertaken after the more detailed EC information becomes available.

- Water vapour emissions from the operation, in extreme conditions, may result in the reduction in ground-level visibility. North American will monitor this situation relative to their emissions to determine the need for mitigation such as warning signs.

North American plans to work with FAP stakeholders to determine monitoring priorities and implementation with respect to these considerations. Over the long-term North American will participate and support the multi-stakeholder FAP and proactively support any future regional monitoring initiatives.

2.9 Summary

Three primary assessment cases (i.e., Baseline, Application and Cumulative) were selected to determine the effect of the Project on ambient air quality. For the most part, the effect has been determined by comparing maximum ambient concentrations associated with each assessment case. Ambient concentrations will increase with increasing emission rates, decrease with increasing distance from an emission source, and vary with the prevailing meteorological conditions. Ambient concentrations do and will therefore vary considerably with location and time. This assessment focused on worst case situations, which for the most part assumed worst case meteorological conditions and worst case locations. The latter of which tended to be at the facility property lines. A summary of key air quality findings relating to the Project emissions follows.

2.9.1 SO_2 Concentrations

The Project will increase regional Baseline Case, short-term SO_2 emissions from 102.60 t/d to 120.73 t/d; this is an increase of 18.14 t/d, which corresponds to a +18% increase in SO_2 emissions. Corresponding Baseline Case and Application Case long-term SO_2 emissions are 98.16 t/d and 105.50 t/d; with the Project value of 7.34 t/d representing a +7.5% increase.

The maximum SO_2 concentrations due to the Project are predicted to occur in the immediate vicinity of the Project, that is, along the PPL. The simultaneous occurrence of low 1-hour sulphur recovery (i.e., SO_2 emissions rate based on a 99.5% sulphur recovery with a 1.4 factor) and poor dispersion conditions, which is a very unlikely occurrence, indicate a potential to exceed the AAAQO at the PPL. This finding is consistent with measurements and with predictions for other facilities and predictions from other EIA applications. The model predictions reinforce the benefit of operating the SRU/TGTU complexes near the design value of 98% sulphur recovery.

Fifteen upset/emergency flaring events associated with the Project were evaluated. The benefit of adding supplemental natural gas and reducing the flaring duration for each event was noted. Two flaring scenarios indicated a potential to exceed the 1-hour AAAQO. This reinforces the need to develop a flare management plan to ensure that these flaring events can be managed to meet the 1-hour AAAQO.

The predicted SO_2 concentrations decrease significantly with increasing distance from the Project site. There are no predicted AAAQO exceedances at agricultural/residential or at residential/community locations for any of the three assessment cases.

2.9.2 NO_2 Concentrations

The Project will increase regional Baseline Case NO_x emissions from 249.1 t/d to 252.5 t/d; this is an increase of 3.45 t/d, which represents a 1.4% increase in NO_x emissions.

The maximum NO_2 concentrations resulting from the Project are predicted to occur along the PPL. Along and outside the PPL, the predicted NO_2 concentrations do not exceed the 1-hour, 24-hour or annual AAAQO. The regional NO_2 concentration pattern is dominated by Edmonton urban sources.

There are no predicted AAAQO exceedances at agricultural/residential, residential/community, public access area, or commercial/industrial area locations for any of the three assessment cases.

2.9.3 $PM_{2.5}$ Concentrations

The Project will increase regional $PM_{2.5}$ emissions from 19.21 t/d (Baseline Case) to 19.63 t/d (Application Case); this is an increase of 0.42 t/d, which represents a 2.2% increase in $PM_{2.5}$ emissions.

The maximum $PM_{2.5}$ concentrations resulting from the Project are predicted along the PPL. Along and outside the PPL, the predicted $PM_{2.5}$ concentrations do not exceed the 24-hour CWS. High intensity construction activities can result in PM emissions, and ambient PM concentrations of 134 ug/m^3 could occur 1 km downwind. This indicates the benefit of the construction mitigation measures identified in Section 2.6.1.1. The regional $PM_{2.5}$ concentration pattern is dominated by Edmonton urban sources.

There are no predicted CWS exceedances at agricultural/residential, residential/community, or public access area locations for any of the three assessment cases.

2.9.4 PAI Deposition

The Project will increase the PAI precursor SO_2 and NO_x emissions: the regional Baseline Case annual SO_2 emissions increase from 98.16 to 105.50 t/d (i.e., a +7.5% increase in SO_2 emissions); the regional Baseline Case, annual NO_x emissions increase from 249.1 t/d to 252.5 t/d (i.e., a +1.4% increase in NO_x emissions).

The urban areas provide a large contribution to the regional PAI because of the associated NO_x emissions. The approved and proposed upgraders provide a large PAI contribution because of the associated SO_2 emissions. The maximum PAI deposition resulting from the Project is predicted to occur in the immediate vicinity of the Project.

The maximum predicted PAI depositions in Elk Island National Park are 0.31 keq H^+/ha/y, 0.32 keq H^+/ha/y and 0.41 keq H^+/ha/y for the Baseline, Application and Cumulative Cases, respectively. The Project contribution to the Application Case is 3.51%.

The 80 km x 80 km DSA average for the Baseline, Application and Cumulative Cases are 0.14 keq H^+/ha/y, 0.15 keq H^+/ha/y and 0.18 keq H^+/ha/y, respectively. This is less than the Target Load criteria of 0.22 keq H^+/ha/y, 0.45 keq H^+/ha/y and 0.90 keq H^+/ha/y for “Sensitive”, “Moderately Sensitive” and “Low Sensitivity” grid cells. The western portion of the DSA is a “Moderately Sensitive” area, and the eastern portion of the DSA is a “Low Sensitivity” area.

2.9.5 Nitrogen Deposition

The Project will increase the nitrogen precursor NOx emissions. The regional Baseline Case, annual NO_x emissions are predicted to increase from 249.1 t/d to 252.5 t/d (i.e., a +1.4% increase in NO_x emissions).

The urban sources dominate the nitrogen deposition due their high NO_x emissions. Values in excess of 10 kg N/ha/y are predicted in the Edmonton and Fort Saskatchewan areas because of these urban emissions. The maximum nitrogen deposition resulting from the Project is predicted to occur in the immediate vicinity of the Project.

The predicted nitrogen depositions in Elk Island National Park are 4.4 kg N/ha/y, 4.4 kg N/ha/y and 5.0 kg N/ha/y for the Baseline, Application, Cumulative Cases, respectively. The Project contribution to the Application Case is 1.3%.

2.9.6 Ozone Concentrations

The potential for the secondary photochemical formation of O_3 is related to precursor NOx and VOC emissions. The Project NO_x emission of 3.43 t/d represents 0.8% of the projected 2010 Edmonton area NO_x emissions. The Project VOC emission of 1.53 t/d represents 0.4% of the projected 2010 Edmonton area VOC emissions. The Project contribution to ambient O_3 concentrations is expected to be low because of the low Project precursor NO_x and VOC emissions relative to the Edmonton airshed. In the immediate Edmonton area and in industrial areas with high NO_x emissions, ambient O_3 concentrations are expected to decrease.

Notwithstanding the precursor emission comparison, the EC model predictions indicate that future upgraders could potentially increase the peak ozone concentrations between 3% and 5% in the FAP region, and by as much as 8.6% to the east of the FAP region.

2.9.7 Human Health and Odours

Ambient concentrations for 54 substance groups that could be emitted from the Project were predicted at 178 human health related locations; most of these were within 5 km of the Project. The predictions were made for averaging periods ranging from 10 minutes to 1 year for the three assessment cases. Potential human health effects are discussed in a systematic manner in Volume 2, Section 4 - Human Health.

2.9.8 Greenhouse Gas Emissions and Climate

The Project will be a source of GHG emissions, resulting primarily from combustion sources. North American has incorporated a number of design features to minimize GHG emissions on a per barrel of bitumen processed basis. North American plans to continue to seek ways to further reduce GHG emissions during the detailed engineering and operation phases of the Project.

A review of potential climate changes in the future was undertaken to determine potential influences on the Project. The indirect climate effect on the NSR water flows was seen as being the most significant potential influences.

2.9.9 Visibility

Combustion and cooling tower sources will be a source of water vapour emissions. Under low-temperature, high-humidity conditions, plumes from these sources will be clearly visible, and their heights are expected to be typically in the 100 m to 250 m range. The plumes from the cooling towers could have the potential reduce ground-level visibility on nearby highways by up to 12 hour per year, which represents an approximate 13% increase over background levels.

2.9.10 Closing

The air quality assessment focused on identifying the effects of Project emissions on the ambient air concentrations and comparing these concentrations to relevant air quality criteria. Four areas flagged for attention are:

- Operate the SRU/TGTU at the high sulphur recovery efficiencies to preclude the occurrence of high 1-hour average SO_2 concentrations at the PPL.
- Develop a flare management plan consistent with EUB Directive 060 to preclude high 1-hour average SO_2 concentrations when upset/emergency flaring is required.
- Design and operate the coker area to minimize and control fugitive RSC emissions to prevent off-site odours.
- Monitor fog formation from the cooling tower to determine the need for Highway signage.

The human health and environmental consequences of these predictions are discussed in Volume 2, Section 4 - Human Health; Volume 3, Section 7 - Surface Water Quality; Volume 4, Section 9 – Soils; and Volume 4, Section 10 - Vegetation.

These findings, for the most part, are based on dispersion model predictions. These model predictions have varying levels of confidence, with the highest level of confidence being for the SO_2, NO_2 and $PM_{2.5}$ predictions. A lower level of confidence is placed on the PAI and nitrogen deposition predictions, as there are no direct measurements to confirm the model predictions. A lower level of confidence is also placed on the prediction of many of the other substance groups for the HHRA, as there are greater levels of uncertainty in estimating these emissions. Notwithstanding the lower level of confidence, the approach taken represents a best estimate approach for air quality assessments.

2.10 Literature Cited

Alberta Environment (AENV). 2003. Air Quality Model Guideline. Science and Standards Branch, Alberta Environment.

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2.10.1 Personal Communications

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TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

3 NOISE

3.1 Introduction

An environmental Noise Impact Assessment (NIA) for the North American Upgrader Project (the Project) near Fort Saskatchewan, Alberta, was completed, and the results are presented in this section. The purpose of the work was to measure the baseline noise levels for the existing surrounding residents (due to traffic and existing industrial facilities), and to determine the projected application case and cumulative case noise effect from the Project and other existing, approved and planned facilities within the region. Site work was conducted in March 2007.

The methods and analysis techniques used for the Project NIA are defined in Section 4.7.1 of the Final Terms of Reference (TOR) (Volume 1, Appendix A).

3.2 Study Area

The Study Area for the Project, as shown in Figure 3.2-1, is within Alberta's Industrial Heartland in Strathcona County, Alberta, approximately 13 km northeast of Fort Saskatchewan.

The Local Study Area (LSA) for noise is defined as encompassing all receptor locations within 4.5 km of the Project boundary. The Regional Study Area (RSA) for noise is defined as encompassing all of the major industrial noise sources in the area, which include: the proposed Synenco Northern Lights Upgrader to the north; the Shell Canada Scotford Complex, Petro-Canada Oil Sands Inc. Proposed Sturgeon Upgrader and the Gulf Chemical and Metallurgical Spent Catalyst Processing Facility to the west; and the Agrium Fertilizer Plants to the northwest. The eastern extent of the RSA includes Bruderheim.

The Project is situated in open farmland with the North Saskatchewan River (NSR) to the north and west of the site. Highway 15 runs east-west, approximately 800 m south of the Project, while Highway 830 runs north-south, approximately 800 m east of the Project. In addition, Range Road 560 and Township Road 211 and 212 currently intersect the Project site, along with a Canadian National Rail line along the southern area. There is also a Canadian Pacific Rail line approximately 2.5 km south, and a spur line to the north.

Nearby existing industrial facilities include the Shell Canada Scotford Complex approximately 4 km west, the Gulf Chemical and Metallurgical Spent Catalyst Processing Facility approximately 4 km west, the Agrium Fertilizer Facility approximately 4.5 km to the northwest and various other industrial facilities towards Fort Saskatchewan and on the west side of the NSR. There are also numerous oil/gas wells near the Project site.

In addition to the existing facilities, other energy facilities have been approved by the regulatory authorities and are under construction, including:

- BA Energy Heartland Oil Sands Bitumen Upgrader (located approximately 3 km northwest of the Project);
- Shell Canada Scotford Upgrader Expansion 1 Project (located approximately 4.5 km west of the Project); and
- North West Upgrading's Bitumen Upgrader (located approximately 9 km northwest of the Project).

There are also other facilities which have submitted their applications for regulatory approval, including:

- Synenco Northern Lights Upgrader (located approximately 10 km north-northwest of the Project);
- Petro-Canada Oil Sands Inc. Sturgeon Upgrader (located approximately 10 km west-northwest of the Project); and
- Shell Canada Scotford Upgrader 2 Project (located approximately 2 km west of the Project).

The Trim Blend Facility located immediately south of the North West Bitumen Upgrader was not included in the assessment. Previous work conducted in the North West Upgrading Inc. (2005) noise impact assessment indicated that the noise associated with the Trim Blend Facility would have a negligible effect on receptor locations near the North West Facility. As such, there would be a negligible effect for receptor locations further east (near the Project). The same is also true for the Kinder Morgan (Terasen Pipelines) Heartland Terminal, which, as indicated in the BA Energy Heartland Oil Sands Bitumen Upgrader EIA (2004), will result in a negligible effect on the receptor locations within this study.

There are numerous receptor locations surrounding the Project site. Specific locations at which noise monitoring and modelling were conducted are listed in Table 3.2-1 and illustrated on Figure 3.2-1. The receptors have been divided into two groups. Group 1 receptors are those within 1,500 m of the nearest Project noise source on the Project boundary. Group 2 receptors are those between 1,500 m and approximately 4,500 m of the Project boundary. Receptors outside this boundary are not considered, since, if the noise mitigation measures result in acceptable sound levels for Group 1 receptors, then receptors beyond Group 2 will be well within acceptable criteria. Also, the majority of the receptors are within Strathcona County. However, those receptors east of Highway 830 and north of Highway 15 are within Lamont County.

Topographically, the land in the Study Area is generally flat, with only small rolling hills breaking line-of-sight between some of the receptor locations and the Project. Most of the surrounding land is agricultural, with some small patches of trees and bush. As such, there will be a notable level of sound absorption in the summer months. In the winter months, when there is snow cover on the ground and no foliage on the trees, there will be less sound absorption. However, people tend to keep their windows closed more in the winter than in the summer, so the different seasonal conditions tend to balance each other.

Table 3.2-1 Receptor Locations in LSA

Receptor ID	Description	NAD 83 UTM Zone 12		PSL-Night (dBA)
		Easting	Northing	
Group 1 Receptors				
R34 (M)	House/Farmyard	368264	5961160	40
R5 (M)	House/Farmyard	366867	5960212	45
R2 (M)	House/Farmyard	369930	5962298	45
R20 (M)	House/Farmyard	369832	5964079	45
R23 (M)	House/Farmyard	368408	5964719	40
R24 (M)	House/Farmyard	367030	5963624	40
R14 (M)	House/Farmyard	366546	5962995	40
R17 (M)	House/Farmyard	365116	5963482	47
R11 (M)	House/Farmyard	364939	5961328	47
R3	House/Farmyard	370552	5963564	45
R4	House/Farmyard	370087	5963561	45

Receptor ID	Description	NAD 83 UTM Zone 12		PSL-Night (dBA)
		Easting	Northing	
Group 1 Receptors (continued)				
R6	House/Farmyard	368360	5960315	45
R7	House/Farmyard	369188	5960895	45
R8	House/Farmyard	369751	5961562	45
R9	Grain Business	368507	5962145	45
R10	House/Farmyard	365790	5960355	45
R12	House/Farmyard	364632	5960507	47
R13	House/Farmyard	365024	5962425	47
R15	House/Farmyard	365417	5962893	47
R16	House/Farmyard	365025	5962997	47
R18	House/Farmyard	369786	5961968	45
R19	House/Farmyard	369872	5963113	45
R21	House/Farmyard	368335	5964240	40
R25	House/Farmyard	368326	5965508	40
R26/27	House/Farmyard	364457	5960341	47
R28	House/Farmyard	364883	5959319	40
R29	House/Farmyard	364943	5959893	45
R30	House/Farmyard	366566	5959343	40
R31	House/Farmyard	368124	5959901	45
R32	House/Farmyard	368169	5960050	45
R88	House/Farmyard	369376	5961036	45
R94	House/Farmyard	365627	5960298	45
Group 2 Receptors				
R1	House/Farmyard	370275	5960257	45
R22	House/Farmyard	369731	5965243	45
R33	House/Farmyard	369773	5960194	45
R35	House/Farmyard	369842	5959053	40
R36	House/Farmyard	371151	5959194	40
R37	House/Farmyard	371355	5959756	40
R38	House/Farmyard	371454	5959205	40
R39/40	House/Farmyard	371728	5960095	45
R41	House/Farmyard	372906	5960067	45
R42	House/Farmyard	372967	5960587	40
R43	House/Farmyard	373037	5961334	40
R44	House/Farmyard	371572	5961490	40
R45	House/Farmyard	371440	5962468	40
R46	House/Farmyard	373055	5961967	40
R47	House/Farmyard	371660	5962466	40
R48	House/Farmyard	373113	5962465	40
R49	House/Farmyard	371967	5963123	48
R50	House/Farmyard	365585	5957062	40
R51	House/Farmyard	368179	5958462	40
R52	House/Farmyard	369689	5958576	40
R53	House/Farmyard	368039	5957693	40
R54	House/Farmyard	368020	5958047	40
R55	House/Farmyard	366630	5958239	40
R56	House/Farmyard	368057	5958605	40
R57	House/Farmyard	366314	5958425	40
R58	House/Farmyard	365291	5957189	40
R59/95/96	House/Farmyard	364825	5958616	40
R60	House/Farmyard	363072	5958305	40
R61	House/Farmyard	369554	5959301	40
R62	House/Farmyard	363936	5960424	47
R63/68	House/Farmyard	371705	5965471	40
R64	House/Farmyard	371440	5963472	45
R65	House/Farmyard	371517	5964655	40
R66	House/Farmyard	371505	5965582	40
R67	House/Farmyard	371543	5966013	40
R69	House/Farmyard	371672	5965528	40
R70	House/Farmyard	371636	5966210	40
R71	House/Farmyard	369963	5967577	45

Receptor ID	Description	NAD 83 UTM Zone 12		PSL-Night (dBA)
		Easting	Northing	
Group 2 Receptors (continued)				
R72	House/Farmyard	370078	5966896	45
R73	House/Farmyard	370041	5968315	45
R74	House/Farmyard	368243	5966039	40
R75	House/Farmyard	367868	5966756	40
R76	House/Farmyard	368291	5966578	40
R77	House/Farmyard	368345	5966376	40
R78	House/Farmyard	369919	5966711	45
R79	House/Farmyard	369764	5966800	45
R80	House/Farmyard	369884	5966768	45
R81	House/Farmyard	368311	5967597	40
R82	House/Farmyard	368289	5967882	40
R83	House/Farmyard	364602	5959099	40
R84	House/Farmyard	368197	5959112	40
R85	House/Farmyard	367310	5957015	40
R86	House/Farmyard	371094	5966951	40
R87	House/Farmyard	368882	5966738	40
R93	House/Farmyard	368884	5966764	40
R97	House/Farmyard	364794	5958821	40
R98	House/Farmyard	363977	5958680	40

Notes: PSL = Permissible Sound Level
dBA = A-weighted decibels
R = Receptor
(M) = Location where a noise monitoring was conducted
UTM Zone 12

Study Area

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date: Oct. 12/07

File:
Figure 3.2-1 Study Area.doc

Drawn by: SB	Checked: BE	Fig. No.: **3.2-1**

3.3 Issues and Assessment Criteria

3.3.1 Noise Descriptors

Environmental noise levels from various sources (including industry, road traffic and rail traffic) are commonly described in terms of equivalent sound levels, or L_{eq}. This is the level of a steady sound having the same acoustic energy, over a given time period, as fluctuating sound. In addition, this energy averaged level is A-weighted to account for the reduced sensitivity of average human hearing to low-frequency sounds. These L_{eq} in A-weighed decibels (dBA), which are the most common environmental noise measure, are often given for daytime (07:00 to 22:00) (L_{eq}Day) and nighttime (22:00 to 07:00) (L_{eq}Night), while other criteria use the entire 24-hour period (L_{eq}24).

Another method of conveying long-term noise levels uses statistical descriptors. These are calculated by taking a cumulative distribution of the sound levels over the entire measurement duration and then determining the sound level at X% of the time. In particular for this study, the L_{90} (i.e., sound level that was sustained for 90% of the time) descriptor is used, since it is a good indicator of typical "steady-state" noise levels, irrespective of the effect of events of short duration such as vehicle pass-bys. Appendix 3A presents a more detailed description of the terminology used and the various methods of sound propagation. Appendix 3B presents a list of typical noise levels associated with various noise sources.

3.3.2 Environmental Noise Criteria

The document which most directly relates to the Permissible Sound Levels (PSLs) for this Project[1] is the Alberta Energy and Utilities Board (EUB) Directive 038: Noise Control (EUB, 2007). This directive sets the PSL at the receiver location based on population density and relative distances to heavily traveled road and rail, as shown in Table 3.3-1. In most instances, there is a Basic Sound Level (BSL) of 40 dBA for the nighttime and 50 dBA for the daytime. This BSL is then adjusted, according to Table 3.3-1, for each receptor to determine their individual PSL, as presented in Table 3.2-1 (PSL-Night values shown; PSL-Day values are 10 dBA higher). The result is that, while many of the receptors have a PSL of 40 dBA, some have a PSL of 45 dBA due to their proximity to either Highway 15 or Highway 830. In addition to the PSL values determined using Table 3.3-1, the Study Area falls within Alberta's Industrial Heartland. Noise levels associated with pre-existing facilities (EUB regulated and non-regulated) have resulted in the EUB allowing higher PSLs for some of the residents. These higher sound levels apply to receptors 11, 12, 13, 15, 16, 17, 26/27 and 62 (Table 3.2-1).

---

[1] There is a noise bylaw within Strathcona County; however, it does not contain specific allowable noise levels and is generally regarded as a nuisance bylaw. There is no noise bylaw in Lamont County.

Table 3.3-1 Nighttime Basic Sound Levels (as per EUB Directive 038)

	Dwelling Density per Quarter Section of Land		
Proximity to Transportation	**1-8 Dwellings**	**9-160 Dwellings**	**>160 Dwellings**
Category 1	40	43	46
Category 2	45	48	51
Category 3	50	53	56

Category 1	Dwelling units more than 500 m from heavily travelled roads and/or rail lines and not subject to frequent aircraft flyovers
Category 2	Dwelling units more than 30 m but less than 500 m from heavily travelled roads and/or rail lines and not subject to frequent aircraft flyovers
Category 3	Dwelling units less than 30 m from heavily travelled roads and/or rail lines and not subject to frequent aircraft flyovers

3.4 Methods

3.4.1 Baseline Measurement Methods

In order to determine the baseline noise levels in the LSA, a total of nine long-term noise monitoring events were conducted at various receptor locations, as outlined in Table 3.2-1 and Figure 3.2-1. The noise-monitoring events at each location varied in duration but, at a minimum, encompassed the entire nighttime and at least 12 daytime hours. Measurement data obtained included broadband A-weighted and C-weighted sound levels and 1/3 octave-band spectra in 5-second L_{eq} sampling intervals. This allowed for a detailed analysis of the noise levels as well as the ability to determine the nighttime L_{90} sound levels and obtain a measure of the industry related noise levels irrespective of traffic and other noises. In addition, simultaneous digital audio recordings were conducted at each of the monitoring sites for post-processing data adjustment in accordance with Directive 038 (e.g., removal of non-typical events such as dogs barking nearby). Finally, a portable meteorological station was used within the LSA on all measurement nights to obtain local weather data, including wind speed, wind direction, temperature and relative humidity. Appendix 3C provides a detailed list of the measurement equipment used.

3.4.2 Baseline Monitoring Locations

3.4.2.1 Monitor #1

Receptor #34 is located approximately 50 m east of Range Road 211 and 900 m north of Highway 15. The noise monitor was located approximately 30 m SE of the house. There were a few rows of trees surrounding the house and much of the yard. Thus, there was only partial line-of-sight to Range Road 211 and Highway 15 from the noise monitor location. The amount of vegetation, however, was not sufficient to result in a notable level of noise shielding. The noise monitor was started at 11:00 on Tuesday, March 13, 2007, and ran for 24 hours until 11:00 on Wednesday, March 14, 2007.

3.4.2.2 Monitor #2

Receptor #5 is located approximately 90 m south of Highway 15 and 350 m east of Range Road 210. The noise monitor was located approximately 15 m SE of the house in an open area adjacent to the driveway. There were trees between the house and Highway 15, blocking the line-of-sight from the house westward (and blocking the line-of-sight to the Project). However, there was direct line-of-sight to Highway 15 east of the house. The noise monitor was started at 11:45 on Tuesday, March 13, 2007, and ran for just under 24 hours until 11:27 on Wednesday, March 14, 2007, when it was shut down due to dog-barking noise.

3.4.2.3 Monitor #3

Receptor #2 is located approximately 50 m east of Highway 830 and 2 km north of Highway 15. The noise monitor was located approximately 15 m SE of the house in an open area in the yard. There was direct line-of-sight from the house and noise monitor to Highway 830, as well as the Project location. The noise monitor was started at 12:30 on Tuesday, March 13, 2007, and ran for just under 24 hours until 12:00 on Wednesday, March 14, 2007, when it was shut down due to increasing wind noise.

3.4.2.4 Monitor #4

Receptor #20 is located approximately 70 m east of Highway 830 and 600 m north of Township Road 560. The noise monitor was located approximately 15 m west of the house. There were several rows of trees, as well as the house and garage blocking line-of-sight to Highway 830, but there was partial line-of-sight to the Project boundary. The noise monitor was started at 13:15 on Tuesday, March 13, 2007, and ran for just under 23 hours until 12:00 on Wednesday, March 14, 2007, when it was shut down due to increasing wind noise.

3.4.2.5 Monitor #5

Receptor #23 is located approximately 100 m east of Range Road 211 (400 m north of the Project boundary) and 1,200 m north of TWP RD 560. The resident could not be contacted to give permission to put the noise monitor on the property, so the noise monitor was located approximately 200 m SW of the house, adjacent to Range Road 211. At this location, there was direct line-of-sight to Range Road 211 and the nearby rail line, as well as the stack construction at the BA Energy Heartland Oil Sands Bitumen Upgrader to the west. There was no direct line-of-sight to the Project boundary due to thin rows of trees in between. The noise monitor was started at 15:00 on Thursday, March 22, 2007, and ran for 21.5 hours until 12:30 on Friday, March 23, 2007.

3.4.2.6 Monitor #6

Receptor #24 (21162 TWP RD 560) is located approximately 100 m north TWP RD 560 and approximately 400 m east of RG RD 212 (400 m west of the Project boundary). The noise monitor was located approximately 20 m NW of the house in an open area within the yard. At this location there was partial line-of-sight to TWP RD 560, as well as direct line-of-sight to the Project location. The noise monitor was started at 15:00 on Thursday, March 22, 2007, and ran for 21.5 hours until 12:30 on Friday, March 23, 2007.

3.4.2.7 Monitor #7

Receptor #14 is located approximately 60 m west of Range Road 212 and approximately 600 m south of Township Road 560. The noise monitor was located approximately 80 m west of the house near the back of the yard. The monitor was located here to ensure that it was not surrounded by the numerous buildings and other equipment in the yard. At this location there was no direct line-of-sight to any of the nearby roads, noise-producing facilities or the Project location. However, the noise monitor was located as close to the existing noise-producing facilities as possible while still being within the yard. The noise monitor was started at 15:00 on Thursday, March 22, 2007, and ran for 22 hours until 13:00 on Friday, March 23, 2007.

3.4.2.8 Monitor #8

Receptor #17 is located approximately 100 m east of Range Road 213 and 100 m south of Township Road 560. The noise monitor was located approximately 40 m west of the house in an open area of the yard. At this location there was partial line-of-sight to Range Road 213 but none to the nearby existing facilities or the Project location. The noise monitor was started at 15:00 on Thursday, March 22, 2007, and ran for 22 hours until 13:00 on Friday, March 23, 2007.

3.4.2.9 Monitor #9

Receptor #11 is located approximately 50 m east of Range Road 213 and 1 km north of Highway 15. The resident could not be contacted to give permission to put the noise monitor on the property, so the noise monitor was located approximately 400 m north of the house, approximately 7 m west of the centre line of Range Road 213. At this location there was direct line-of-sight to Range Road 213, and also to the house, the existing industrial facilities to the west and northwest, and east to the Project location. The noise monitor was started at 16:00 on Thursday, March 22, 2007, and ran for 22 hours until 14:00 on Friday, March 23, 2007.

3.4.2.10 Weather Monitor

The same weather monitor location was used for both monitoring nights. The monitor was located just east of Range Road 211, approximately 400 m north of Highway 15. At this location the weather monitor was completely unobstructed by trees or structures. The weather monitor for the first monitoring night was started at 11:20 on Tuesday, March 13, 2007, and ran for almost 26 hours until 13:10 on Wednesday, March 14, 2007. The weather monitor for the second monitoring night was started at 14:00 on Thursday, March 22, 2007, and ran for 24 hours until 14:00 on Friday, March 23, 2007.

3.4.3 Modelling Methods

The computer noise modelling was conducted using the CADNA/A (version 3.6.119) software package. CADNA/A allows for the modelling of various noise sources such as road, rail and various stationary sources. In addition, topographical features such as land contours, vegetation and bodies of water can be included. Finally, meteorological conditions such as temperature, relative humidity, wind speed and wind direction can be included in the calculations.

The modelling was conducted using representative conditions and not using worst-case scenarios, as per Directive 038. As such, the calculation method used for noise propagation follows the International Standards Organization (ISO) Standard 9613 (ISO 1993 and 1996). All receiver locations were assumed to be downwind from the source(s). In particular, as stated in Section 5 of the ISO standard:

> “Downwind propagation conditions for the method specified in this part of IS0 9613 are as specified in 5.4.3.3 of IS0 1996-2:1987, namely
>
> - wind direction within an angle of ± 45^o of the direction connecting the centre of the dominant sound source and the centre of the specified receiver region, with the wind blowing from source to receiver, and
> - wind speed between approximately 1 m/s and 5 m/s, measured at a height of 3 m to 11 m above the ground.
>
> The equations for calculating
>
> the average downwind sound pressure level LAT(DW) in this part of IS0 9613, including the equations for attenuation given in clause 7, are the average for

> meteorological conditions within these limits. The term average here means the average over a short time interval, as defined in 3.1.
>
> These equations also hold, equivalently, for average propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs on clear, calm nights."

The modelled temperature and relative humidity were 10°C and 70%, respectively. In addition, the ground absorption was assumed to be 0.8 (i.e., typical of summer vegetation conditions). As a result, all sound level propagation calculations for surrounding receptors match closely with those which would be present during typical summer conditions.

The computer noise modelling results were calculated in two ways. First, sound levels were calculated at specific receptor locations. Next, the sound levels were calculated using a 20 m × 20 m grid over the entire LSA. This provided colour noise contours for easier visualization of the results.

3.4.3.1 Baseline Case

The baseline case models conditions present during the baseline noise measurements (in the absence of local traffic noise). This was done to provide a means of model calibration with the measured sound levels, as well as to provide a baseline case to which the future Project sound levels (and those of other approved and planned facilities) could be compared. Although the monitoring events were conducted during winter conditions (i.e., snow-covered ground and cold temperatures), the results are still valid as a means of model calibration. Typically, the noise levels will be slightly higher in winter due to more favorable sound propagation conditions. This will result in higher modelled sound levels for existing noise sources than may be present in summer modelling conditions. This provides slightly more conservative results than if the monitoring events were conducted in the summer. Sound sources incorporated into the model include:

- Agrium Products Fertilizer Plants;
- Provident (Williams) Redwater Fractionation and Storage Facility;
- Degussa Canada Gibbons Hydrogen Peroxide Manufacturing Plant;
- Shell Canada Scotford Complex and existing Upgrader 1;
- Gulf Chemical and Metallurgical Spent Catalyst Processing Facility; and
- Ambient adjustment based on noise monitoring results.

Appendix 3E presents a detailed list of the baseline case sound levels included in the model.

3.4.3.2 Construction Case

The construction case includes the baseline conditions (i.e., existing industrial noise sources) with the construction activities of the Project, using generally accepted information provided in a published paper by Teplitzky and Wood (1978). Typical activities included in the model are:

- Earth-moving equipment;
- Cranes;

- Concrete-pouring equipment;
- Pile drivers; and
- Air compressors.

Appendix 3E provides a detailed list of the construction noise levels included in the model. The noise sources were lumped together as a single point source and located at the center of the main plant site. In addition to the site equipment, there will be an increase in traffic on nearby highways bringing supplies and personnel to the site.

3.4.3.3 Application Case

The application case includes the baseline conditions (i.e., existing industrial noise sources) with the operation of the Project.

After completion of construction, the next case modelled was typical operation of the Project without any other proposed noise sources. Information for site layout, building dimensions and equipment sound levels was used for all large noise-producing equipment associated with the Project. Engineering sound level mitigation controls are to be implemented for some of the equipment. Appendix 3E provides a detailed list of the site equipment, associated sound levels and proposed noise mitigation measures.

3.4.3.4 Cumulative Effects Cases

The cumulative effects cases include the following:

- **Approved and Proposed Facilities Case**, which models conditions present during the baseline case, as well as including noise sources from facilities already approved (and not yet operational), and also those which have submitted their applications to the regulatory authorities. Sound sources incorporated into the model include:
    - Baseline Case sound sources;
    - BA Energy Heartland Oil Sands Bitumen Upgrader;
    - Proposed Synenco Northern Lights Upgrader;
    - Proposed North West Upgrading Facility;
    - Proposed Petro-Canada Oil Sands Inc. Sturgeon Upgrader Facility; and
    - Proposed Shell Canada Scotford Upgrader Expansion 1 and Upgrader 2.

Appendix 3E provides a detailed list of the future baseline case sound levels included in the model. At the time of modelling, information was not available for the announcement of Total E&P Canada's Bitumen Upgrader.

- **Approved, Proposed and Application Case**, which models conditions present during the baseline case, the approved and proposed facilities and the Project. It is the noise levels determined from this case which will be compared to the EUB Directive 038, since noise from the Project is not to exceed the guidelines, with all other approved and proposed noise sources taken into account. As of the time of completing these model runs, there are no known proposed facilities in addition to those modelled in the approved, proposed and application case.

3.4.3.5 Modelling Confidence

As mentioned previously, the algorithms used for the noise modelling follow the ISO 9613 standard. The published accuracy for this standard is ±3 dBA between 100 m and 1,000 m. Accuracy levels beyond 1,000 m are not published. Experience on similar noise models over large distances shows that, as expected, as the distance increases, the associated accuracy in prediction decreases. Environmental factors such as wind, temperature inversions, topography and ground cover all have increasing effects over distances larger than approximately 1,500 m. As such, for all receptors within approximately 1,500 m of the Project boundary, the prediction confidence is considered high, while for all receptors beyond 1,500 m, the prediction confidence is considered moderate. The noise mitigation measures proposed for the Project are designed to reduce the noise levels for the closest affected receptors to levels below the EUB Directive 038 guidelines. Thus, for receptors further away, the noise levels will be even lower. Therefore, the decreasing accuracy associated with the model will not be as important.

3.5 Existing Conditions

3.5.1 Baseline Measurement Results (Overall)

A summary of the monitoring results at all locations is provided in Table 3.5-1. The data presented show the adjusted L_{eq}Day and L_{eq}Night sound levels. The data have been adjusted in accordance with Directive 038 to remove non-typical noise events such as dogs barking near the monitor, abnormally loud vehicles very nearby, train passages, etc. Some of the L_{eq}Day results are “partial,” in that a full 15 daytime hours were not obtained. In addition, the typical nighttime industry-related sound levels are shown, providing an indication of the typical steady-state noise levels, irrespective of events of short duration such as vehicle passages, airplane flyovers, etc. These are the sound levels that will be used as the baseline conditions calibration for the noise modelling.

Table 3.5-1 Baseline Noise Monitoring Receptor Sound Levels

Receptor	L_{eq}24* (dBA)	L_{eq}Day* (dBA)	L_{eq}Night (dBA)	Nighttime Industry Noise Level (dBA)
#34	43.3	44.6	39.3	30.0
#5	59.3	60.3	56.6	30.0
#2	52.9	53.8	50.6	28.0
#20	50.8	51.1	50.3	30.0
#23	37.8	38.8	35.4	29.0
#24	40.8	41.7	38.9	32.0
#14	37.9	38.8	35.9	33.0
#17	44.2	45.2	39.2	37.0
#11	57.2	58.2	41.1	37.0

* Partial Values. Daytime not a full 15 hours

In general, the results are as expected, with the locations closer to the nearby highways resulting in higher sound levels. L_{eq}Night sound levels in the mid 30 dBA range are considered typical for rural locations further than 500 m from a highway. The typical industry noise levels were in the mid 30 dBA range. These were obtained upon review of the audio files and removed the strong influence of the morning commuter traffic increase.

The nighttime A-weighted 1/3 octave band sound levels show a typical traffic-dominated noise climate. There is a notable amount of energy in the mid bands near 1,000 Hz, resulting from tire noise. There is, however, a distinct tone at 63 Hz which emanates completely from industrial sources. This tone was observed at all other measurement locations which were not directly adjacent to a major highway. As expected, the tone was present throughout the entire monitoring period and was more pronounced during the quieter nighttime and early-morning hours when the other noise sources subsided.

3.5.2 Baseline Measurement Results (Specific Locations)

3.5.2.1 Monitor #1

The broadband A-weighted monitoring results at Noise Monitor #1 (Receptor #34) are shown in Appendix 3D, Figure 3D-1, while the nighttime A-weighted 1/3 octave band sound levels are shown in Appendix 3D, Figure 3D-2. The results show a typical trend of slightly decreasing sound levels during the evening and overnight, with an increase in the morning as local traffic volumes increase. A section of data from 02:00–06:00 on March 14 was removed due to high wind-generated noise. Upon review of the simultaneous digital audio recording, the subjectively dominant noise source for much of the monitoring was traffic on Highway 15, followed by the many vehicle passages on Range Road 211. The wind started out of the west, then shifted to the east in the early morning. As such, Highway 15 was perpendicular to the wind at all times, resulting in a negligible effect on road noise from the wind. Due to the wind direction, noise from existing facilities was observed at the start of the monitoring but not at the end of it. There were also several train passages on the CN rail line to the north. The nighttime noise levels prior to the morning commuter traffic increase were approximately 30 dBA. This is more indicative of the actual baseline (i.e., industry-related) sound levels and, as such, will be used for comparison purposes for the remainder of the evaluation.

3.5.2.2 Monitor #2

The broadband A-weighted monitoring results at Noise Monitor #2 (Receptor #5) are shown in Appendix 3D, Figure 3D-3, while the nighttime A-weighted 1/3 octave band sound levels are shown in Appendix 3D, Figure 3D-4. The results show a noise climate which is completely dominated by local traffic on Highway 15. The lower noise levels decrease during the evening and overnight, but the maximum sound levels remain consistently near 70 dBA. As with Monitor #1, a section of data from 02:00–06:00 on March 14 was removed due to high wind-generated noise. Also, as with Monitor #1, Highway 15 was perpendicular to the wind at all times. This, coupled with the relatively short distance to the road, resulted in a negligible effect on road noise from the wind. Noise from existing facilities was inaudible at all times due to the traffic noise. The nighttime noise levels during times of low traffic (not occurring very often) and prior to the morning commuter traffic increase were approximately 30 dBA. This is indicative of the actual baseline (i.e., industry-related) sound levels and, as such, will be used for comparison purposes for the remainder of the evaluation.

3.5.2.3 Monitor #3

The broadband A-weighted monitoring results at Noise Monitor #3 (Receptor #2) are shown in Appendix 3D, Figure 3D-5, while the nighttime A-weighted 1/3 octave band sound levels are shown in Appendix 3D, Figure 3D-6. The results show a noise climate which is completely dominated by local traffic on Highway 830. The lower noise levels decrease during the evening and overnight, but the maximum sound levels remain consistently near 65 dBA. As with monitoring events #1 and #2, a section of data from 02:00–06:00 on March 14 was removed due to high wind-generated noise. Although the wind was initially from the west and then shifted out of the east (i.e., monitor was downwind and then upwind), the relatively close distance to the road resulted in a negligible effect on road noise from the wind. Noise from existing facilities was audible in the early morning during rare times with low traffic. The nighttime noise levels during these times and prior to the morning commuter traffic increase were approximately 28 dBA.

This is indicative of the actual baseline (i.e., industry-related) sound levels and, as such, will be used for comparison purposes for the remainder of the evaluation.

3.5.2.4 Monitor #4

The broadband A-weighted monitoring results at Noise Monitor #4 (Receptor #20) are shown in Appendix 3D, Figure 3D-7, while the nighttime A-weighted 1/3 octave band sound levels are shown in Appendix 3D, Figure 3D-8. Again, the results show a noise climate which is completely dominated by local traffic on Highway 830. The lower noise levels decrease slightly during the evening and overnight, but the maximum sound levels remain consistently near 65 dBA. Unlike the previous monitoring events on the same night, no data were removed due to the high wind. The location of the monitor provided shielding from wind-generated noise. However, it can be seen that there was an initial increase in the maximum sound levels when the wind was out of the west (i.e., monitor upwind from the road) to the end, when the wind was out of the east (i.e., monitor downwind of the road). Noise from existing facilities was audible in the early morning during rare times with low traffic. The nighttime noise levels during these times and prior to the morning commuter traffic increase were approximately 30 dBA. This is indicative of the actual baseline (i.e., industry-related) sound levels and, as such, will be used for comparison purposes for the remainder of the evaluation.

3.5.2.5 Monitor #5

The broadband A-weighted monitoring results at Noise Monitor #5 (Receptor #23) are shown in Appendix 3D, Figure 3D-9, while the nighttime A-weighted 1/3 octave band sound levels are shown in Appendix 3D, Figure 3D-10. The results show a slight reduction in noise levels during the nighttime as distant traffic noise was reduced. Review of the audio revealed that traffic noise and low-frequency industrial noise were dominant during the daytime. During the nighttime there was very little audible, with just a slight impact from industry to the west. All of the peaks shown in Appendix 3D, Figure 3D-9 are the result of louder vehicles on Highway 830. The wind (starting from the west, then shifting to the southeast and south during the nighttime) did not appear to have an appreciable impact on the noise levels. Finally, the 63 Hz tone can be readily seen in Appendix 3D, Figure 3D-10. The nighttime noise levels during times of low distant traffic and prior to the morning commuter traffic increase were approximately 29 dBA. This is indicative of the actual baseline (i.e., industry-related) sound levels and, as such, will be used for comparison purposes for the remainder of the evaluation.

3.5.2.6 Monitor #6

The broadband A-weighted monitoring results at Noise Monitor #6 (Receptor #24) are shown in Appendix 3D, Figure 3D-11, while the nighttime A-weighted 1/3 octave band sound levels are shown in Appendix 3D, Figure 3D-12. Site observations and review of the audio revealed that facility construction and operational noise was dominant during the daytime, while low-frequency operational noise was dominant during the nighttime. All of the short-duration peaks shown in Appendix 3D, Figure 3D-11 were caused by traffic on Township Road 560. In addition, there were several train horns and train passages noted. Again, the wind did not appear to have an appreciable impact on the noise levels. Finally, the 63 Hz tone can be readily seen in Appendix 3D, Figure 3D-12. The nighttime noise levels during times of low traffic and prior to the morning commuter traffic increase were approximately 32 dBA. This is indicative of the actual baseline (i.e., industry-related) sound levels and, as such, will be used for comparison purposes for the remainder of the evaluation.

3.5.2.7 Monitor #7

The broadband A-weighted monitoring results at Noise Monitor #7 (Receptor #14) are shown in Appendix 3D, Figure 3D-13, while the nighttime A-weighted 1/3 octave band sound levels are shown in Appendix 3D, Figure 3D-14. Site observations and review of the audio revealed that facility construction and operational noise was dominant during the daytime, while low-frequency operational noise was dominant during the nighttime. All of the short-duration peaks shown in Appendix 3D, Figure 3D-13 were caused by traffic on Range Road 212. In addition, there were several train horns and train passages noted. The ATCO plant to the south was inaudible at all times. Again, the wind did not appear to have an appreciable impact on the noise levels. Finally, the 63 Hz tone can be readily seen in Appendix 3D, Figure 3D-14. The nighttime noise levels during times of low traffic and prior to the morning commuter traffic increase were approximately 33 dBA. This is indicative of the actual baseline (i.e., industry-related) sound levels and, as such, will be used for comparison purposes for the remainder of the evaluation.

3.5.2.8 Monitor #8

The broadband A-weighted monitoring results at Noise Monitor #8 (Receptor #17) are shown in Appendix 3D, Figure 3D-15, while the nighttime A-weighted 1/3 octave band sound levels are shown in Appendix 3D, Figure 3D-16. Site observations and review of the audio revealed that facility construction and operational noise was dominant during the daytime, while low-frequency operation noise was dominant during the nighttime. All of the short-duration peaks shown in Appendix 3D, Figure 3D-15 were caused by traffic on either Range Road 213 or Township Road 560. Again, the wind did not appear to have an appreciable impact on the noise levels. Finally, the 63 Hz tone can be readily seen in Appendix 3D, Figure 3D-16. The nighttime noise levels during times of low traffic and prior to the morning commuter traffic increase were approximately 37 dBA. This matched the L_{eq}Night value and is very indicative of the actual baseline (i.e., industry-related) sound levels and, as such, will be used for comparison purposes for the remainder of the evaluation, as well as a good noise model calibration for noise from the Shell Canada Scotford Complex.

3.5.2.9 Monitor #9

The broadband A-weighted monitoring results at Noise Monitor #8 (Receptor #11) are shown in Appendix 3D, Figure 3D-17, while the nighttime A-weighted 1/3 octave band sound levels are shown in Appendix 3D, Figure 3D-18. Site observations and review of the audio revealed that facility construction and operational noise was dominant during the daytime, while low-frequency operation noise was dominant during the nighttime. All of the short-duration peaks shown in Appendix 3D, Figure 3D-17 were caused by traffic on either Range Road 213 or (to a much lesser extent) Highway 15. Again, the wind did not appear to have an appreciable impact on the noise levels. Finally, the 63 Hz tone can be seen in Appendix 3D, Figure 3D-18. The nighttime noise levels during times of low traffic and prior to the morning commuter traffic increase were approximately 37 dBA. This matched the L_{eq}Night value and is very indicative of the actual baseline (i.e., industry-related) sound levels and, as such, will be used for comparison purposes for the remainder of the evaluation, as well as a good noise model calibration for noise from the Shell Canada Scotford Complex and Gulf Chemical and Metallurgical Spent Catalyst Processing Facility.

3.5.2.10 Weather Monitoring

During noise-monitoring events #1–#4, the weather was initially clear, with a light west wind and a temperature of approximately -2°C. Overnight, the wind became reduced and shifted out of the east until about 01:00. After this point, the wind increased sharply and then reduced again at about 06:00. Upon takedown of equipment, the sky was clear, with a stiff east breeze and a temperature of approximately -10°C. Other than the 4-hour period between 02:00 and 06:00, when much of the noise-monitoring data were removed, at no other point during the nighttime was the weather considered to be in violation of the requirements specified in Directive 038 for the results obtained.

During noise-monitoring events #5–#9, the weather was initially clear, with a light west wind and a temperature of approximately 5°C. Overnight, the wind reduced slightly and became steady out of the southeast, while the temperature dropped to approximately -5°C. In the morning, the wind remained steady and shifted out of the south. At no point during the nighttime was the weather considered to be in violation of the requirements specified in Directive 038 for the results obtained.

Appendix 3F provides complete weather-monitoring data obtained on-site during the noise-monitoring events.

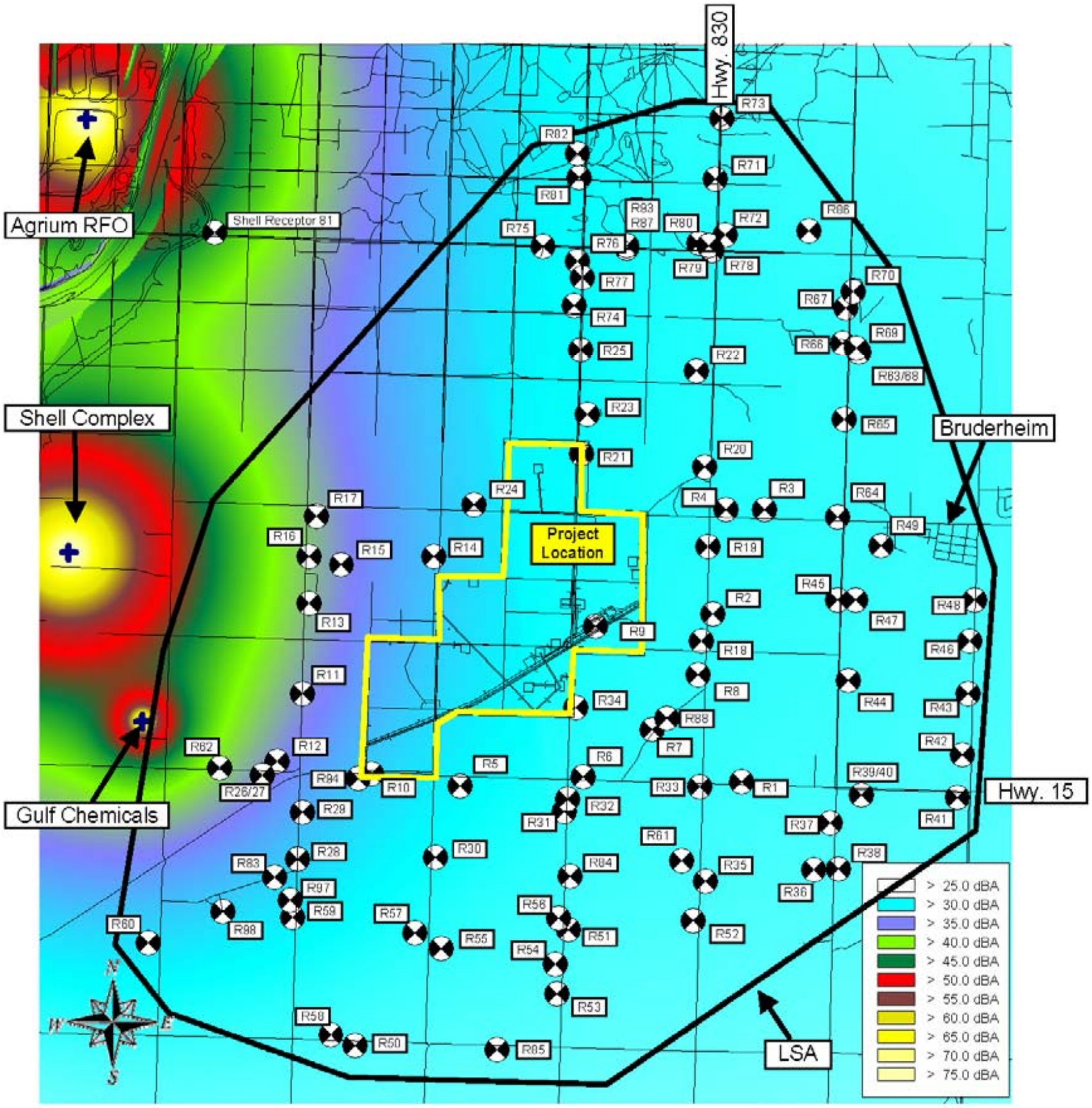
3.5.3 Baseline Case Noise Modelling Results

The results of the baseline case noise modelling are provided in Table 3.5-2 and Figure 3.5-1. The results match very well with those obtained during the baseline monitoring, and indicate that the current dominant industrial sources within the study area are associated with the Shell Canada Scotford Complex, the Gulf Chemical and Metallurgical Spent Catalyst Processing Facility and the Agrium Redwater Fertilizer Plant. All the baseline noise levels are well below the PSLs throughout the study area.

Table 3.5-2 Baseline Case Noise Modelling Results

Receptor ID	PSL-Night (dBA)	Baseline Nighttime Sound Level (dBA)	Baseline Night Minus PSL-Night (dBA)	Compliant
Group 1 Receptors				
R34	40	29.4	-10.6	YES
R5	45	30.2	-14.8	YES
R2	45	29.2	-15.8	YES
R20	45	29.3	-15.7	YES
R23	40	29.8	-10.2	YES
R24	40	31.4	-8.6	YES
R14	40	32.2	-7.8	YES
R17	47	37.0	-10.0	YES
R11	47	36.1	-10.9	YES
R3	45	29.2	-15.8	YES
R4	45	29.3	-15.7	YES
R6	45	29.2	-15.8	YES
R7	45	29.1	-15.9	YES
R8	45	29.1	-15.9	YES
R9	45	29.5	-15.5	YES
R10	45	31.9	-13.1	YES
R12	47	35.5	-11.5	YES
R13	47	37.3	-9.7	YES
R15	47	35.7	-11.3	YES
R16	47	37.5	-9.5	YES
R18	45	29.2	-15.8	YES
R19	45	29.3	-15.7	YES
R21	40	29.8	-10.2	YES
R25	40	29.9	-10.1	YES
R26/27	47	35.7	-11.3	YES
R28	40	31.8	-8.2	YES
R29	45	33.0	-12.0	YES
R30	40	29.8	-10.2	YES
R31	45	29.1	-15.9	YES
R32	45	29.2	-15.8	YES

Receptor ID	PSL-Night (dBA)	Baseline Nighttime Sound Level (dBA)	Baseline Night Minus PSL-Night (dBA)	Compliant
Group 1 Receptors (continued)				
R88	45	29.1	-15.9	YES
R94	45	32.1	-12.9	YES
Group 2 Receptors				
R1	45	28.9	-16.1	YES
R22	45	29.4	-15.6	YES
R33	45	28.9	-16.1	YES
R35	40	28.7	-11.3	YES
R36	40	28.5	-11.5	YES
R37	40	28.6	-11.4	YES
R38	40	28.5	-11.5	YES
R39/40	45	28.7	-16.3	YES
R41	45	28.5	-16.5	YES
R42	40	28.6	-11.4	YES
R43	40	28.7	-11.3	YES
R44	40	28.9	-11.1	YES
R45	40	29.0	-11.0	YES
R46	40	28.7	-11.3	YES
R47	40	28.9	-11.1	YES
R48	40	28.7	-11.3	YES
R49	48	29.0	-19.0	YES
R50	40	28.5	-11.5	YES
R51	40	28.8	-11.2	YES
R52	40	28.5	-11.5	YES
R53	40	28.5	-11.5	YES
R54	40	28.6	-11.4	YES
R55	40	29.1	-10.9	YES
R56	40	28.9	-11.1	YES
R57	40	29.3	-10.7	YES
R58	40	28.7	-11.3	YES
R59/95/96	40	30.5	-9.5	YES
R60	40	31.1	-8.9	YES
R61	40	28.7	-11.3	YES
R62	47	38.6	-8.4	YES
R63/68	40	29.0	-11.0	YES
R64	45	29.0	-16.0	YES
R65	40	29.0	-11.0	YES
R66	40	29.0	-11.0	YES
R67	40	29.0	-11.0	YES
R69	40	29.0	-11.0	YES
R70	40	29.0	-11.0	YES
R71	45	29.2	-15.8	YES
R72	45	29.2	-15.8	YES
R73	45	29.0	-16.0	YES
R74	40	30.0	-10.0	YES
R75	40	30.3	-9.7	YES
R76	40	29.9	-10.1	YES
R77	40	29.9	-10.1	YES
R78	45	29.3	-15.7	YES
R79	45	29.3	-15.7	YES
R80	45	29.3	-15.7	YES
R81	40	29.9	-10.1	YES
R82	40	29.9	-10.1	YES
R83	40	31.8	-8.2	YES
R84	40	28.9	-11.1	YES
R85	40	28.3	-11.7	YES
R86	40	29.0	-11.0	YES
R87	40	29.6	-10.4	YES
R93	40	29.6	-10.4	YES
R97	40	30.9	-9.1	YES
R98	40	31.5	-8.5	YES



Baseline Case Night-Time Noise Modelling Results

NORTH AMERICAN OIL SANDS CORPORATION

Approved:		Revision Date: October 22, 2007
File: Figure 3.5-1 Baseline Case.doc		
Drawn by: SB	Checked: BE	Fig. No.: **3.5-1**

3.6 Impact Assessment

3.6.1 Construction Case Modelling Results

The modelling results for the Construction Case are presented in Table 3.6-1 and Figure 3.6-1. Although not specifically applicable, the results have been compared to the PSL for each receptor. The noise levels at all receptors, except for R14 and R24 (residences), are below their PSLs. However, the nighttime noise levels at the two locations will only be slightly above 40 dBA, so the impact will be negligible.

The construction sound levels included in the model are based on published sound levels for equipment likely to be used in the construction of the Project. Actual equipment used on-site may differ from those modelled. In addition, the construction noise was modelled as a single continuous point source at the center of the plant site. Under actual conditions construction activity will vary in duration, amplitude of noise levels and location. This level of detail is impossible to model, since actual construction conditions are unknown. The results provided in Table 3.6-1 give a general overall impression of the anticipated noise levels. There will be times when the sound levels are well under the modelled values, and also times when the sound levels will be higher than those modelled. Section 3.7.3 provides construction noise mitigation recommendations.

Table 3.6-1 Construction Case Noise Modelling Results

Receptor ID	PSL-Night (dBA)	Construction Nighttime Sound Level (dBA)	Construction Minus Baseline Nighttime Sound Level (dBA)	Construction Night Minus PSL-Night (dBA)
Group 1 Receptors				
R34	40	39.0	9.6	-1.0
R5	45	33.7	3.5	-11.3
R2	45	33.7	4.5	-11.3
R20	45	32.3	3.0	-12.7
R23	40	33.6	3.8	-6.4
R24	40	40.6	9.2	0.6
R14	40	41.5	9.3	1.5
R17	47	37.7	0.7	-9.3
R11	47	36.7	0.6	-10.3
R3	45	31.2	2.0	-13.8
R4	45	32.4	3.1	-12.6
R6	45	33.8	4.6	-11.2
R7	45	34.1	5.0	-10.9
R8	45	33.7	4.6	-11.3
R9	45	44.6	15.1	-0.4
R10	45	33.6	1.7	-11.4
R12	47	35.8	0.3	-11.2
R13	47	38.0	0.7	-9.0
R15	47	37.3	1.6	-9.7
R16	47	38.2	0.7	-8.8
R18	45	34.1	4.9	-10.9
R19	45	33.6	4.3	-11.4
R21	40	35.9	6.1	-4.1
R25	40	31.7	1.8	-8.3
R26/27	47	36.0	0.3	-11.0
R28	40	32.2	0.4	-7.8
R29	45	33.5	0.5	-11.5
R30	40	31.3	1.5	-8.7
R31	45	32.5	3.4	-12.5
R32	45	32.9	3.7	-12.1
R88	45	33.9	4.8	-11.1
R94	45	33.5	1.4	-11.5

Receptor ID	PSL-Night (dBA)	Construction Nighttime Sound Level (dBA)	Construction Minus Baseline Nighttime Sound Level (dBA)	Construction Night Minus PSL-Night (dBA)
Group 2 Receptors				
R1	45	30.4	1.5	-14.6
R22	45	30.8	1.4	-14.2
R33	45	31.0	2.1	-14.0
R35	40	29.6	0.9	-10.4
R36	40	29.1	0.6	-10.9
R37	40	29.2	0.6	-10.8
R38	40	28.9	0.4	-11.1
R39/40	45	29.2	0.5	-15.8
R41	45	28.8	0.3	-16.2
R42	40	28.8	0.2	-11.2
R43	40	28.9	0.2	-11.1
R44	40	29.8	0.9	-10.2
R45	40	30.1	1.1	-9.9
R46	40	29.0	0.3	-11.0
R47	40	29.9	1.0	-10.1
R48	40	29.0	0.3	-11.0
R49	48	29.7	0.7	-18.3
R50	40	28.8	0.3	-11.2
R51	40	29.7	0.9	-10.3
R52	40	29.3	0.8	-10.7
R53	40	29.0	0.5	-11.0
R54	40	29.3	0.7	-10.7
R55	40	29.7	0.6	-10.3
R56	40	29.9	1.0	-10.1
R57	40	30.0	0.7	-10.0
R58	40	28.9	0.2	-11.1
R59/95/96	40	30.9	0.4	-9.1
R60	40	31.2	0.1	-8.8
R61	40	30.0	1.3	-10.0
R62	47	38.7	0.1	-8.3
R63/68	40	29.4	0.4	-10.6
R64	45	30.0	1.0	-15.0
R65	40	29.7	0.7	-10.3
R66	40	29.5	0.5	-10.5
R67	40	29.3	0.3	-10.7
R69	40	29.4	0.4	-10.6
R70	40	29.3	0.3	-10.7
R71	45	29.4	0.2	-15.6
R72	45	29.6	0.4	-15.4
R73	45	29.2	0.2	-15.8
R74	40	31.0	1.0	-9.0
R75	40	30.8	0.5	-9.2
R76	40	30.6	0.7	-9.4
R77	40	30.7	0.8	-9.3
R78	45	29.7	0.4	-15.3
R79	45	29.7	0.4	-15.3
R80	45	29.7	0.4	-15.3
R81	40	30.2	0.3	-9.8
R82	40	30.1	0.2	-9.9
R83	40	32.1	0.3	-7.9
R84	40	30.5	1.6	-9.5
R85	40	28.6	0.3	-11.4
R86	40	29.2	0.2	-10.8
R87	40	30.1	0.5	-9.9
R93	40	30.1	0.5	-9.9
R97	40	31.3	0.4	-8.7
R98	40	31.7	0.2	-8.3

3.6.2 Application Case Modelling Results

The results of the Application Case noise modelling are provided in Table 3.6-2 and Figure 3.6-2. It can be seen that the noise levels at all receptor locations, with the baseline conditions and operation of the Project, are in compliance with their respective PSLs. This is due largely to the limitation imposed by North American on the equipment supply vendors that the noise levels not exceed a maximum of 85 dBA at a distance of 0.9 m. As indicated in Appendix 3E, this limitation will substantially lower the sound levels of most noise sources compared to the un-attenuated sound levels.

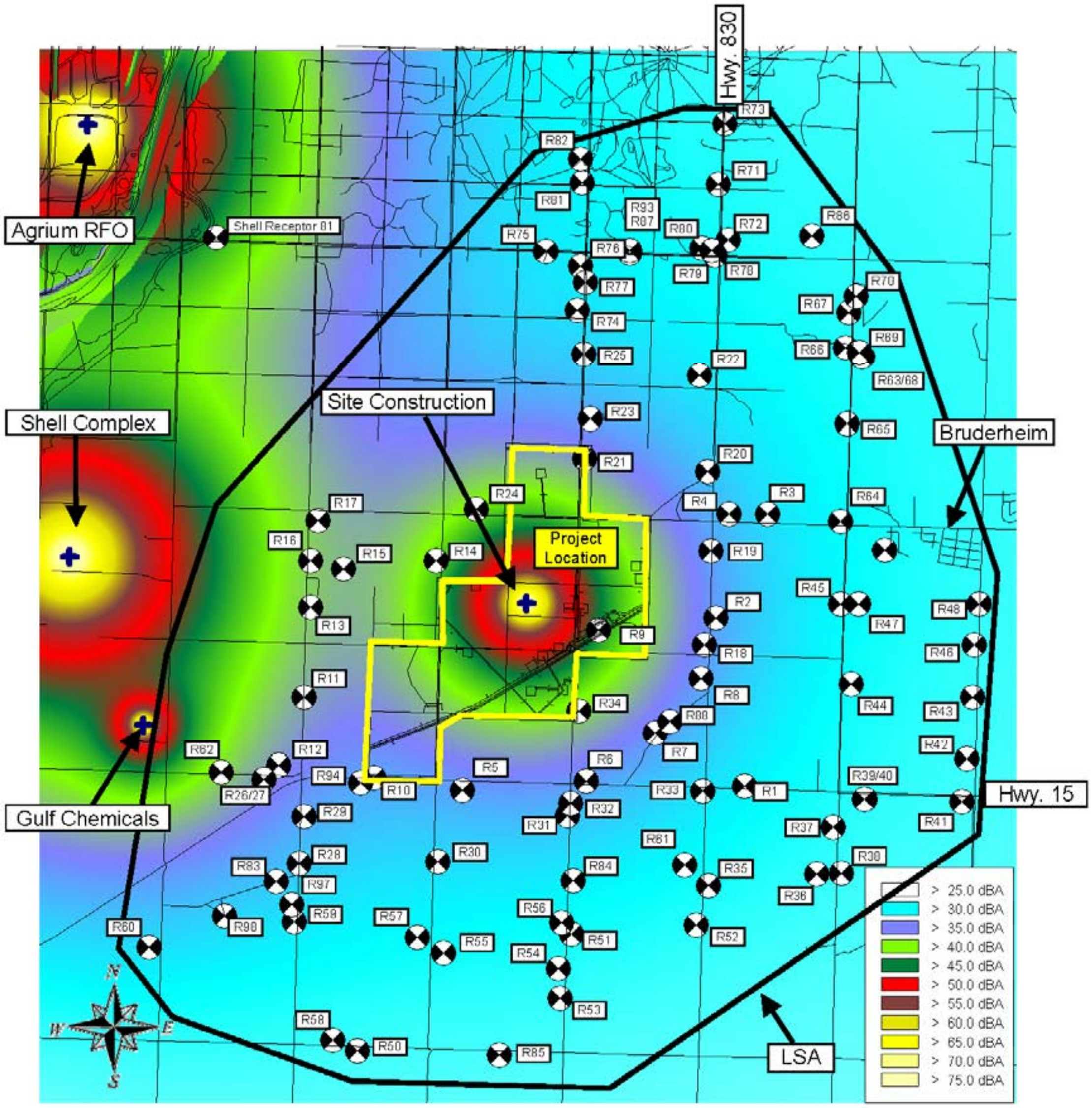
As expected, the largest increases in noise levels are at the receptors which are closest to the Project. Receptor R9 will experience the largest increase (12.6 dBA); however, this location is not a residence. Receptor R34, a vacant residential building, will experience an increase of approximately 7.0 dBA. This increase will be subjectively quite noticeable, although still well below the PSL.

Finally, the spectral analysis of the projected noise levels indicates that there will not be a strong low-frequency tonal component. Most of the noise sources are quite broadband in nature. The only sources with a strong low-frequency component are the heaters; however, these heaters are generally small and result in much lower sound levels than the other equipment.

Table 3.6-2 Application Case Noise Modelling Results

Receptor ID	PSL-Night (dBA)	Application Case Nighttime Sound Level (dBA)	Application Case Minus Baseline Nighttime Sound Level (dBA)	Application Case Night Minus PSL-Night (dBA)	Compliant
Group 1 Receptors					
R34	40	36.4	7.0	-3.6	YES
R5	45	33.2	3.0	-11.8	YES
R2	45	32.4	3.2	-12.6	YES
R20	45	31.4	2.1	-13.6	YES
R23	40	32.5	2.7	-7.5	YES
R24	40	37.2	5.8	-2.8	YES
R14	40	38.1	5.9	-1.9	YES
R17	47	37.4	0.4	-9.6	YES
R11	47	36.5	0.4	-10.5	YES
R3	45	30.7	1.5	-14.3	YES
R4	45	31.5	2.2	-13.5	YES
R6	45	32.3	3.1	-12.7	YES
R7	45	32.5	3.4	-12.5	YES
R8	45	32.3	3.2	-12.7	YES
R9	45	42.1	12.6	-2.9	YES
R10	45	33.3	1.4	-11.7	YES
R12	47	35.7	0.2	-11.3	YES
R13	47	37.7	0.4	-9.3	YES
R15	47	36.6	0.9	-10.4	YES
R16	47	37.9	0.4	-9.1	YES
R18	45	32.7	3.5	-12.3	YES
R19	45	32.4	3.1	-12.6	YES
R21	40	34.3	4.5	-5.7	YES
R25	40	31.1	1.2	-8.9	YES
R26/27	47	35.9	0.2	-11.1	YES
R28	40	32.2	0.4	-7.8	YES
R29	45	33.4	0.4	-11.6	YES
R30	40	31.0	1.2	-9.0	YES
R31	45	31.6	2.5	-13.4	YES
R32	45	31.8	2.6	-13.2	YES
R88	45	32.4	3.3	-12.6	YES
R94	45	33.2	1.1	-11.8	YES

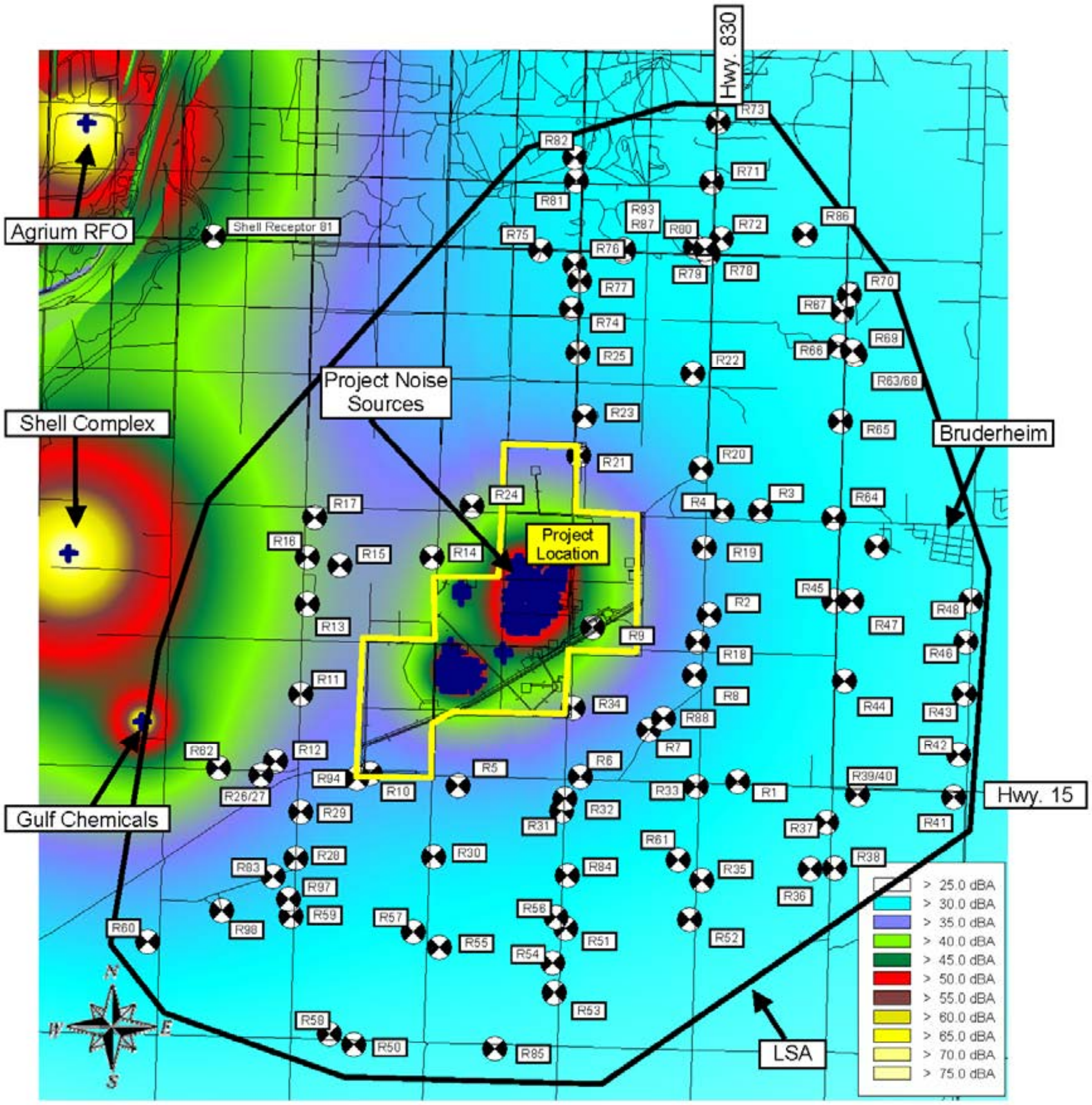
Receptor ID	PSL-Night (dBA)	Application Case Nighttime Sound Level (dBA)	Application Case Minus Baseline Nighttime Sound Level (dBA)	Application Case Night Minus PSL-Night (dBA)	Compliant
Group 2 Receptors					
R1	45	30.0	1.1	-15.0	YES
R22	45	30.4	1.0	-14.6	YES
R33	45	30.4	1.5	-14.6	YES
R35	40	29.4	0.7	-10.6	YES
R36	40	29.0	0.5	-11.0	YES
R37	40	29.1	0.5	-10.9	YES
R38	40	28.9	0.4	-11.1	YES
R39/40	45	29.1	0.4	-15.9	YES
R41	45	28.8	0.3	-16.2	YES
R42	40	28.8	0.2	-11.2	YES
R43	40	28.9	0.2	-11.1	YES
R44	40	29.6	0.7	-10.4	YES
R45	40	29.8	0.8	-10.2	YES
R46	40	29.0	0.3	-11.0	YES
R47	40	29.7	0.8	-10.3	YES
R48	40	29.0	0.3	-11.0	YES
R49	48	29.5	0.5	-18.5	YES
R50	40	28.8	0.3	-11.2	YES
R51	40	29.5	0.7	-10.5	YES
R52	40	29.1	0.6	-10.9	YES
R53	40	28.9	0.4	-11.1	YES
R54	40	29.2	0.6	-10.8	YES
R55	40	29.6	0.5	-10.4	YES
R56	40	29.7	0.8	-10.3	YES
R57	40	29.9	0.6	-10.1	YES
R58	40	28.9	0.2	-11.1	YES
R59/95/96	40	30.8	0.3	-9.2	YES
R60	40	31.2	0.1	-8.8	YES
R61	40	29.7	1.0	-10.3	YES
R62	47	38.7	0.1	-8.3	YES
R63/68	40	29.4	0.4	-10.6	YES
R64	45	29.8	0.8	-15.2	YES
R65	40	29.6	0.6	-10.4	YES
R66	40	29.4	0.4	-10.6	YES
R67	40	29.3	0.3	-10.7	YES
R69	40	29.4	0.4	-10.6	YES
R70	40	29.2	0.2	-10.8	YES
R71	45	29.4	0.2	-15.6	YES
R72	45	29.6	0.4	-15.4	YES
R73	45	29.2	0.2	-15.8	YES
R74	40	30.7	0.7	-9.3	YES
R75	40	30.7	0.4	-9.3	YES
R76	40	30.5	0.6	-9.5	YES
R77	40	30.5	0.6	-9.5	YES
R78	45	29.7	0.4	-15.3	YES
R79	45	29.7	0.4	-15.3	YES
R80	45	29.6	0.3	-15.4	YES
R81	40	30.2	0.3	-9.8	YES
R82	40	30.1	0.2	-9.9	YES
R83	40	32.0	0.2	-8.0	YES
R84	40	30.1	1.2	-9.9	YES
R85	40	28.6	0.3	-11.4	YES
R86	40	29.2	0.2	-10.8	YES
R87	40	30.0	0.4	-10.0	YES
R93	40	30.0	0.4	-10.0	YES
R97	40	31.2	0.3	-8.8	YES
R98	40	31.7	0.2	-8.3	YES



Construction Case Nighttime Noise Modelling Results

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:		Revision Date: October 22, 2007
File: Figure 3.6-1 Construction Case.doc		
Drawn by: SB	Checked: BE	Fig. No.: **3.6-1**



Application Case Nighttime Noise Modelling Results

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date: October 22, 2007

File:
Figure 3.6-2 Application Case.doc

Drawn by: SB	Checked: BE	Fig. No.: **3.6-2**

3.7 Cumulative Effects Assessment and Mitigative Measures

3.7.1 Approved and Proposed Case Modelling Results

The results of the Approved and Proposed Case noise modelling are provided in Table 3.7-1 and Figure 3.7-1. The noise levels at all receptor locations are in compliance with their respective PSLs. There are, however, some locations which are at or very close to the limit. These include locations near the proposed Shell Canada Upgraders immediately west and northwest of the Project. As a result, there is very little room left to "add" to the noise climate for these receptors.

Table 3.7-1 Approved and Proposed Case Noise Modelling Results

Receptor ID	PSL-Night (dBA)	Approved + Proposed Case Nighttime Sound Level (dBA)	Approved + Proposed Minus Baseline Nighttime Sound Level (dBA)	Approved + Proposed Case Night Minus PSL-Night (dBA)	Compliant
Group 1 Receptors					
R34	40	30.9	1.5	-9.1	YES
R5	45	32.6	2.4	-12.4	YES
R2	45	30.1	0.9	-14.9	YES
R20	45	30.5	1.2	-14.5	YES
R23	40	32.5	2.7	-7.5	YES
R24	40	36.4	5.0	-3.6	YES
R14	40	37.4	5.2	-2.6	YES
R17	47	45.0	8.0	-2.0	YES
R11	47	43.1	7.0	-3.9	YES
R3	45	30.1	0.9	-14.9	YES
R4	45	30.2	0.9	-14.8	YES
R6	45	30.3	1.1	-14.7	YES
R7	45	30.1	1.0	-14.9	YES
R8	45	30.0	0.9	-15.0	YES
R9	45	31.2	1.7	-13.8	YES
R10	45	35.4	3.5	-9.6	YES
R12	47	39.7	4.2	-7.3	YES
R13	47	47.0	9.7	0.0	YES
R15	47	43.4	7.7	-3.6	YES
R16	47	46.7	9.2	-0.3	YES
R18	45	30.1	0.9	-14.9	YES
R19	45	30.3	1.0	-14.7	YES
R21	40	32.5	2.7	-7.5	YES
R25	40	32.8	2.9	-7.2	YES
R26/27	47	39.4	3.7	-7.6	YES
R28	40	34.3	2.5	-5.7	YES
R29	45	36.1	3.1	-8.9	YES
R30	40	31.8	2.0	-8.2	YES
R31	45	30.4	1.3	-14.6	YES
R32	45	30.3	1.1	-14.7	YES
R88	45	30.0	0.9	-15.0	YES
R94	45	35.7	3.6	-9.3	YES
Group 2 Receptors					
R1	45	29.4	0.5	-15.6	YES
R22	45	30.7	1.3	-14.3	YES
R33	45	29.5	0.6	-15.5	YES
R35	40	29.1	0.4	-10.9	YES
R36	40	28.9	0.4	-11.1	YES
R37	40	29.0	0.4	-11.0	YES
R38	40	28.9	0.4	-11.1	YES
R39/40	45	29.0	0.3	-16.0	YES

Receptor ID	PSL-Night (dBA)	Approved + Proposed Case Nighttime Sound Level (dBA)	Approved + Proposed Minus Baseline Nighttime Sound Level (dBA)	Approved + Proposed Case Night Minus PSL-Night (dBA)	Compliant
Group 2 Receptors (continued)					
R41	45	28.8	0.3	-16.2	YES
R42	40	28.9	0.3	-11.1	YES
R43	40	29.0	0.3	-11.0	YES
R44	40	29.3	0.4	-10.7	YES
R45	40	29.5	0.5	-10.5	YES
R46	40	29.0	0.3	-11.0	YES
R47	40	29.5	0.6	-10.5	YES
R48	40	29.1	0.4	-10.9	YES
R49	48	29.5	0.5	-18.5	YES
R50	40	29.5	1.0	-10.5	YES
R51	40	29.5	0.7	-10.5	YES
R52	40	29.0	0.5	-11.0	YES
R53	40	29.3	0.8	-10.7	YES
R54	40	29.5	0.9	-10.5	YES
R55	40	30.3	1.2	-9.7	YES
R56	40	29.8	0.9	-10.2	YES
R57	40	30.8	1.5	-9.2	YES
R58	40	29.8	1.1	-10.2	YES
R59/95/96	40	32.4	1.9	-7.6	YES
R60	40	32.6	1.5	-7.4	YES
R61	40	29.3	0.6	-10.7	YES
R62	47	41.4	2.8	-5.6	YES
R63/68	40	29.6	0.6	-10.4	YES
R64	45	29.7	0.7	-15.3	YES
R65	40	29.7	0.7	-10.3	YES
R66	40	29.7	0.7	-10.3	YES
R67	40	29.6	0.6	-10.4	YES
R69	40	29.6	0.6	-10.4	YES
R70	40	29.6	0.6	-10.4	YES
R71	45	30.1	0.9	-14.9	YES
R72	45	30.2	1.0	-14.8	YES
R73	45	29.9	0.9	-15.1	YES
R74	40	32.9	2.9	-7.1	YES
R75	40	33.5	3.2	-6.5	YES
R76	40	32.6	2.7	-7.4	YES
R77	40	32.6	2.7	-7.4	YES
R78	45	30.4	1.1	-14.6	YES
R79	45	30.5	1.2	-14.5	YES
R80	45	30.4	1.1	-14.6	YES
R81	40	31.9	2.0	-8.1	YES
R82	40	31.7	1.8	-8.3	YES
R83	40	34.0	2.2	-6.0	YES
R84	40	29.8	0.9	-10.2	YES
R85	40	29.0	0.7	-11.0	YES
R86	40	29.7	0.7	-10.3	YES
R87	40	31.4	1.8	-8.6	YES
R93	40	31.4	1.8	-8.6	YES
R97	40	33.0	2.1	-7.0	YES
R98	40	33.3	1.8	-6.7	YES

3.7.2 Approved, Proposed and Application Case Modelling Results

The results of the Approved, Proposed and Application Case noise modelling are provided in Table 3.7-2 and Figure 3.7-2. The noise levels at all receptor locations are in compliance with their respective PSLs. Most of the receptors will see only minimal increases relative to the Approved and Proposed Case (approximately ½ of the Group 1 receptors and all of the Group 2 receptors). The largest increases will be for those receptors relatively near the Project but still far east enough that there is a lesser impact from the proposed Shell Canada Upgraders (Scotford Upgrader Expansion 1 and Scotford Upgrader 2).

The modelling indicates sound levels which are at or very near the PSLs for several of the receptors. The modelling was conducted under “representative” summertime environmental conditions (i.e., mild downwind from all sources to all receptors, as well as highly absorptive ground cover). There will be times at which atmospheric conditions and/or more reflective ground conditions will result in sound levels in excess of the PSLs for some receptors. These occasional occurrences do not mean noncompliance according to Directive 038.

Table 3.7-2 Approved, Proposed and Application Case Noise Modelling Results

Receptor ID	PSL-Night (dBA)	Approved + Proposed + Application Case Nighttime Sound Level (dBA)	Approved + Proposed + Application Minus Approved + Proposed Nighttime Sound Level (dBA)	Approved + Proposed + Application Case Night Minus PSL-Night (dBA)	Compliant
Group 1 Receptors					
R34	40	36.8	5.9	-3.2	YES
R5	45	34.6	2.0	-10.4	YES
R2	45	32.8	2.7	-12.2	YES
R20	45	32.2	1.7	-12.8	YES
R23	40	34.2	1.7	-5.8	YES
R24	40	39.2	2.8	-0.8	YES
R14	40	39.9	2.5	-0.1	YES
R17	47	45.1	0.1	-1.9	YES
R11	47	43.2	0.1	-3.8	YES
R3	45	31.3	1.2	-13.7	YES
R4	45	32.1	1.9	-12.9	YES
R6	45	32.9	2.6	-12.1	YES
R7	45	33.0	2.9	-12.0	YES
R8	45	32.7	2.7	-12.3	YES
R9	45	42.2	11.0	-2.8	YES
R10	45	36.1	0.7	-8.9	YES
R12	47	39.8	0.1	-7.2	YES
R13	47	47.0	0.0	0.0	YES
R15	47	43.6	0.2	-3.4	YES
R16	47	46.8	0.1	-0.2	YES
R18	45	33.1	3.0	-11.9	YES
R19	45	32.9	2.6	-12.1	YES
R21	40	35.4	2.9	-4.6	YES
R25	40	33.5	0.7	-6.5	YES
R26/27	47	39.5	0.1	-7.5	YES
R28	40	34.5	0.2	-5.5	YES
R29	45	36.3	0.2	-8.7	YES
R30	40	32.5	0.7	-7.5	YES
R31	45	32.3	1.9	-12.7	YES
R32	45	32.4	2.1	-12.6	YES
R88	45	32.8	2.8	-12.2	YES
R94	45	36.2	0.5	-8.8	YES
Group 2 Receptors					
R1	45	30.4	1.0	-14.6	YES
R22	45	31.5	0.8	-13.5	YES
R33	45	30.9	1.4	-14.1	YES
R35	40	29.8	0.7	-10.2	YES
R36	40	29.3	0.4	-10.7	YES
R37	40	29.5	0.5	-10.5	YES
R38	40	29.2	0.3	-10.8	YES
R39/40	45	29.5	0.5	-15.5	YES
R41	45	29.0	0.2	-16.0	YES

Receptor ID	PSL-Night (dBA)	Approved + Proposed + Application Case Nighttime Sound Level (dBA)	Approved + Proposed + Application Minus Approved + Proposed Nighttime Sound Level (dBA)	Approved + Proposed + Application Case Night Minus PSL-Night (dBA)	Compliant
Group 2 Receptors (continued)					
R42	40	29.1	0.2	-10.9	YES
R43	40	29.2	0.2	-10.8	YES
R44	40	30.0	0.7	-10.0	YES
R45	40	30.3	0.8	-9.7	YES
R46	40	29.3	0.3	-10.7	YES
R47	40	30.1	0.6	-9.9	YES
R48	40	29.3	0.2	-10.7	YES
R49	48	30.0	0.5	-18.0	YES
R50	40	29.7	0.2	-10.3	YES
R51	40	30.2	0.7	-9.8	YES
R52	40	29.5	0.5	-10.5	YES
R53	40	29.6	0.3	-10.4	YES
R54	40	30.0	0.5	-10.0	YES
R55	40	30.7	0.4	-9.3	YES
R56	40	30.5	0.7	-9.5	YES
R57	40	31.2	0.4	-8.8	YES
R58	40	29.9	0.1	-10.1	YES
R59/95/96	40	32.6	0.2	-7.4	YES
R60	40	32.6	0.0	-7.4	YES
R61	40	30.1	0.8	-9.9	YES
R62	47	41.5	0.1	-5.5	YES
R63/68	40	29.9	0.3	-10.1	YES
R64	45	30.3	0.6	-14.7	YES
R65	40	30.1	0.4	-9.9	YES
R66	40	30.0	0.3	-10.0	YES
R67	40	29.9	0.3	-10.1	YES
R69	40	29.9	0.3	-10.1	YES
R70	40	29.8	0.2	-10.2	YES
R71	45	30.3	0.2	-14.7	YES
R72	45	30.5	0.3	-14.5	YES
R73	45	30.0	0.1	-15.0	YES
R74	40	33.3	0.4	-6.7	YES
R75	40	33.7	0.2	-6.3	YES
R76	40	32.9	0.3	-7.1	YES
R77	40	32.9	0.3	-7.1	YES
R78	45	30.7	0.3	-14.3	YES
R79	45	30.8	0.3	-14.2	YES
R80	45	30.7	0.3	-14.3	YES
R81	40	32.0	0.1	-8.0	YES
R82	40	31.9	0.2	-8.1	YES
R83	40	34.1	0.1	-5.9	YES
R84	40	30.8	1.0	-9.2	YES
R85	40	29.3	0.3	-10.7	YES
R86	40	29.9	0.2	-10.1	YES
R87	40	31.7	0.3	-8.3	YES
R93	40	31.7	0.3	-8.3	YES
R97	40	33.1	0.1	-6.9	YES
R98	40	33.4	0.1	-6.6	YES

3.7.3 Mitigation

3.7.3.1 Construction Noise

Although there are no specific construction noise level limits detailed by Directive 038, there are general recommendations for construction noise mitigation. The document states:

> "While Directive 038 is not applicable to construction noise, licensees should attempt to take the following reasonable mitigating measures to reduce the impact on nearby dwellings of construction noise from new facilities or modifications to existing facilities. Licensees should:
>
> - Limit construction activity to the hours of between 07:00 and 22:00 to reduce the potential impact of construction noise.
> - Advise nearby residents of significant noise-causing activities and schedule these to create the least disruption to neighbours.
> - Ensure all internal combustion engines are fitted with appropriate muffler systems.
> - Take advantage of acoustical screening from existing on-site buildings to shield residential locations from construction equipment noise.
> - Where possible, schedule steam blow downs and venting to the daytime period of between 07:00 and 22:00 hours.
>
> Should a complaint be made during construction, the licensee will be expected to respond expeditiously and take appropriate action to ensure that the issue has been managed responsibly."

Further to the information listed above, if construction activities are scheduled between the hours of 22:00–07:00, they should be limited as much as possible to "quiet" operations.

North American is committed to the implementation of the above recommendation set out in Directive 038.

3.7.3.2 Transportation Noise

During construction and regular operation activities at the Project, most material deliveries will be made during the hours of 07:00–22:00. While the movement of heavy loads during nighttime will increase the nighttime sound levels, the duration will be short and frequency relatively low. Large dimensional heavy loads requiring specific traffic control measures will be limited to nighttime (01:00–5:00), and will be announced to the community. As such, the noise associated with them is not typically the source of noise complaints.

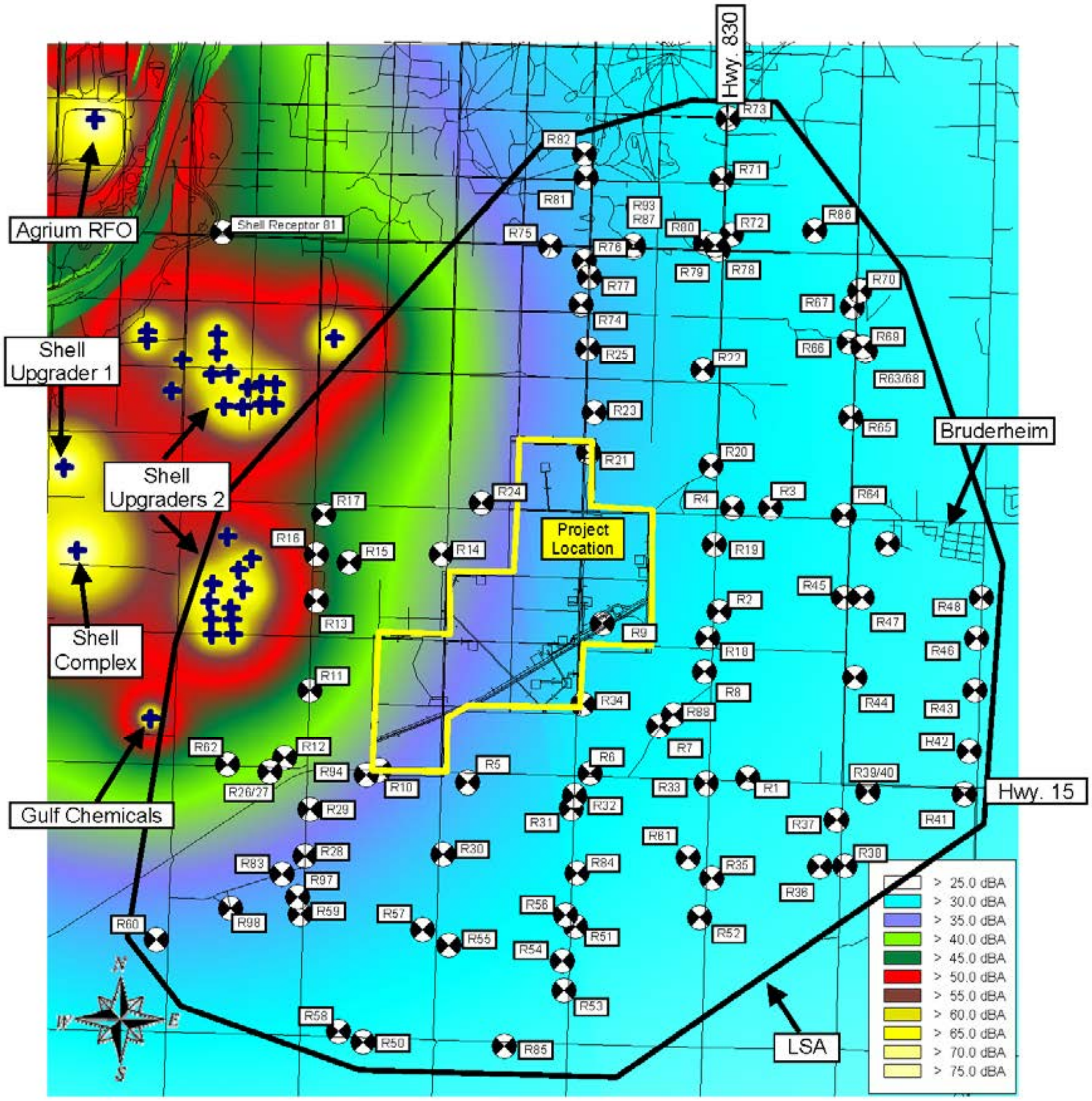
3.7.3.3 Flaring Noise

For non-emergency situations, flaring activity will be scheduled between the hours of 07:00–20:00. Group 1 residents will also be notified prior to any scheduled major flaring activity.

3.7.3.4 Additional Recommendations

The site-specific noise level information in Appendix 3E provides the approximate level of noise mitigation required by the equipment suppliers to meet the North American requirement of 85 dBA at 0.9 m. Given the already high noise levels in the area from industrial sources and the increases as a result of approved and proposed facilities, and the relatively minimal increases associated with the Project (except at receptors located immediately adjacent to the Project), there is no notable improvement which would be realized with additional mitigation on the Project stationary noise sources.

Notwithstanding the aforementioned statement, North American will reduce noise during planned events, such as start-up and shutdown, by use of silencers on steam-venting systems and attempt to schedule noise events during daytime. In addition, North American's commissioning and start-up plans will be tailored to the sensitivity of the residents.



Approved and Proposed Case Nighttime Noise Modelling Results

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:

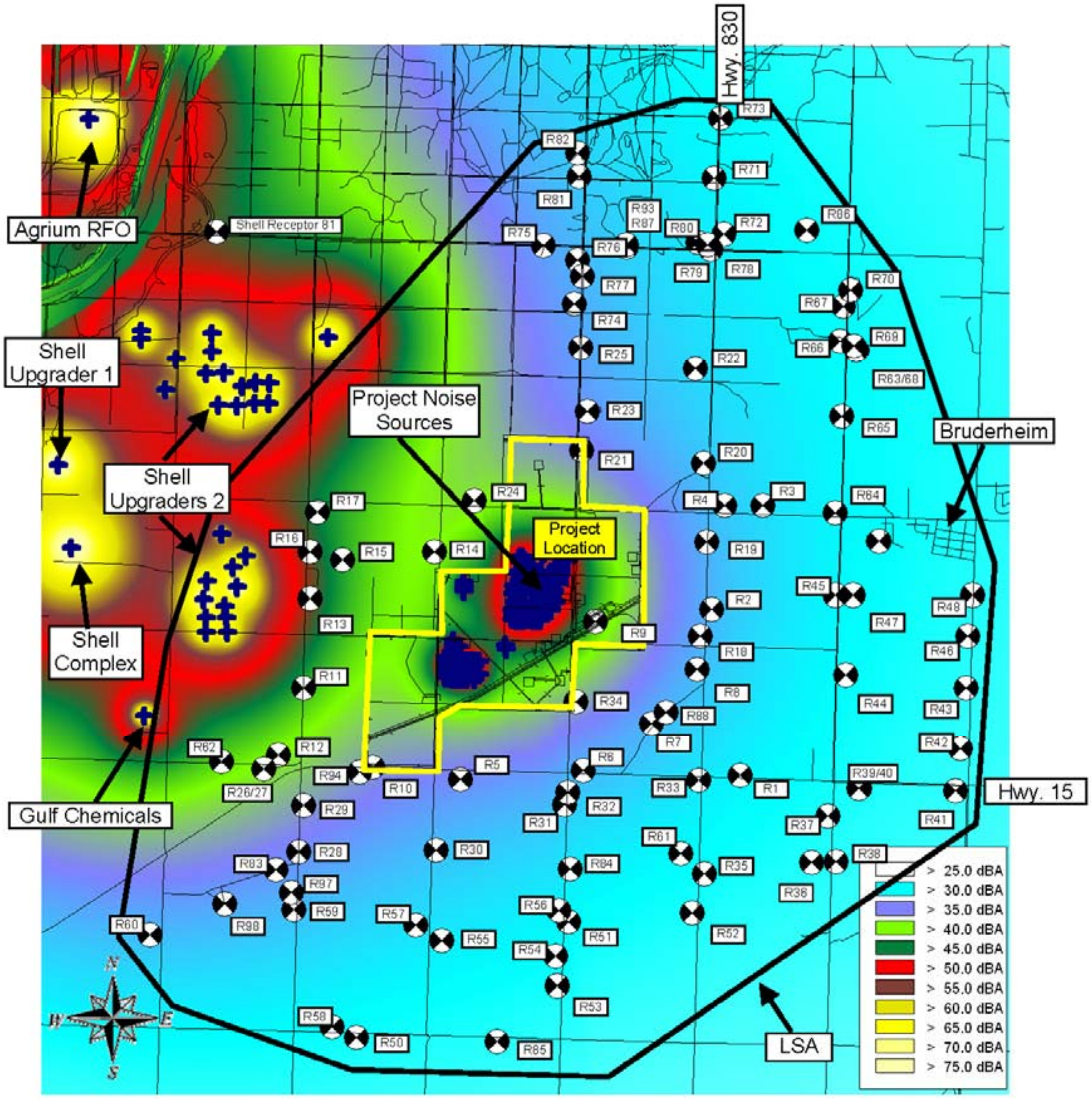
Revision Date:
October 22, 2007

File:
Figure 3.7-1 Approved Proposed Case.doc

Drawn by:
SB

Checked:
BE

Fig. No.:
3.7-1



Approved, Proposed, and Application Case Nighttime Noise Modelling Results

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date: October 22, 2007

File: Figure 3.7-2 Approved Proposed Application.doc

Drawn by: SB	Checked: BE	Fig. No.: **3.7-2**

3.8 Follow-up and Monitoring

As per EUB Directive 038, there are no follow-up noise measurements required by North American unless a complaint is lodged with either the EUB or North American. However, North American will actively participate in the Northeast Capital Industrial Association (NCIA) Noise Management Plan. As a participant, North American will conduct ongoing assessments of its noise mitigation program and maintain best practices and continuous improvement programs in facility noise control.

3.9 Summary

The baseline noise monitoring indicated that there are currently relatively high noise levels for those residents near the existing industrial noise sources. The dominant noise sources in the area are associated with the industrial facilities as well as the local highways. The noise modelling of the baseline conditions indicated results similar to those obtained from the baseline noise monitorings.

Project construction noise is likely to be within acceptable limits due to the existing noise levels and mitigation measures to be utilized by North American. There will be times, however, when construction-related activities result in subjectively noticeable noise levels for the adjacent residents. Efforts will be undertaken to minimize these impacts.

Application case noise levels resulted in low increases for most surrounding residents. Only those directly near the Project will experience medium noise level increases. All projected sound levels are within the EUB Directive 038 PSLs. Cumulative noise levels with all existing and proposed nearby facilities, as well as the Project, will be at or under the PSLs at all receptors.

The summary of project effects is presented in Table 3.9-1.

Table 3.9-1 Summary of Project Effects

Receptors	Type of Impact or Effect	Nature of Potential Impact or Effect	Mitigation / Protection Plan	Geographical Extent [1]	Magnitude [2]	Duration [3]	Frequency [4]	Reversibility [5]	Confidence Rating [6]	Final Impact Rating
Within 1,500 m	Construction	Noise Disturbance	Activity Times Restricted	Local	Medium	Short-term	Occasional	Reversible in Short-term	High	Low
Within 1,500 m	Operation Project	Noise Disturbance	Noise Source Mitigation	Local	Medium	Long-term	Continuous	Reversible in Short-term	High	Medium
Greater than 1,500 m	Construction	Noise Disturbance	Activity Times Restricted	Local	Low	Short-term	Occasional	Reversible in Short-term	High	Low
Greater than 1,500 m	Operation Project	Noise Disturbance	Noise Source Mitigation	Local	Low	Long-term	Continuous	Reversible in Short-term	High	Low

1. Local, Regional, Extra-regional

2. Nil (less than 1 dBA increase), Low (1-5 dBA increase) , Medium (6-10 dBA increase), High (greater than 10 dBA increase)

3. Short, Long, Extended, Residual

4. Continuous, Isolated, Periodic, Occasional, Accidental, Seasonal

5. Reversible in Short-Term, Reversible in Long-Term, Irreversible - rare

6. Low, Moderate, High

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TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

4 HUMAN HEALTH

4.1 Introduction

The Human Health Risk Assessment (HHRA) and odour assessment is based on the air quality assessment of emissions from the Project.

4.2 Study Area

The Project site is located on industrial lands within Township 55, Range 21 and Township 56 Range 21, approximately 3 km west of the town of Bruderheim, Alberta. The Project site footprint is about 562 ha. Two study areas are defined within the air quality assessment (Volume 2, Section 2):

- **Local Study Area (LSA)**: Area within 4.0 km centred on the Project boundaries.
- **Regional Study Area (RSA)**: Comprised of a 50 km x 50 km area centred on the Project boundaries. The RSA includes industrial sites within the Alberta Industrial Heartland area and the communities of Fort Saskatchewan, Bruderheim, Lamont, Redwater, Bon Accord and Gibbons. It also includes public use areas such as the Astotin Natural Area and Elk Island National Park.

4.3 Issues and Assessment Criteria

The primary objective of the HHRA is to describe the nature and significance of any potential health risks to humans from the Project's release of chemicals into the environment. The primary objective of the odour assessment is to describe the potential nuisance odours that might occur from the Project's emissions.

The HHRA examined the potential short-term (acute) and long-term (chronic) effects associated with the Project's emissions. Project emissions were evaluated in combination with existing or approved developments in the region, as well as in combination with proposed or planned future developments. Predicted ground-level air concentrations were compared to reputable exposure limits protective of human health to characterize potential risks. In order to characterize potential odours, predicted short-term ground-level air concentrations were compared to established odour thresholds.

4.3.1 Terms of Reference

The overall scope of the HHRA was primarily based on provincial regulatory requirements. Specific health-related issues and concerns addressed in this HHRA correspond to the following Terms of Reference (TOR) (Volume 1, Appendix A), issued by Alberta Environment (AENV):

- identify and discuss the data and methods used by North American to assess the impacts of the Project on human health and safety;
- assess the potential health implications of the compounds that will be released to the environment from the proposed Project in relation to exposure limits established to prevent acute and chronic adverse effects on human health;
- identify the human health impact of the potential contamination of country foods and natural food sources taking into consideration all Project activities;

- provide information on samples of selected species of vegetation known to be consumed by humans;
- discuss the potential to increase human exposure to contaminants from changes to water quality, air quality and soil quality taking into consideration all Project activities;
- assess cumulative health effects to receptors, including First Nations and Aboriginal receptors, that are likely to result from the Project in combination with other existing, approved and planned projects;
- as appropriate, identify anticipated follow-up work, including regional cooperative studies. Identify how such work will be implemented and coordinated with ongoing air, soil and water quality initiatives;

In addition, the odour assessment addressed the following TOR:

- identify the potential for reduced air quality (including odours) resulting from the Project and discuss any implications of the expected air quality for environmental protection and public health.

4.4 Methods – Human Health

Potential human health risks associated with the Project's estimated emissions were examined using a conventional risk assessment paradigm that applied several conservative assumptions. The risk assessment paradigm is consistent with those developed by Health Canada (2004), the Canadian Council of Ministers of the Environment (CCME, 1996), the U.S. National Research Council (U.S. NRC, 1983; 1996) and the U.S. Environmental Protection Agency (U.S. EPA, 1991, 2004). This methodology has been endorsed by a number of provincial regulatory authorities, including AENV, Alberta Health and Wellness (AHW) and the Alberta Energy and Utilities Board (EUB).

Human health risk assessments involve four steps:

- **Problem Formulation,** which involves the characterization of the Project and the site and the identification and characterization of people potentially at risk. It also involves the determination of the relevant exposure pathways, and the identification of the chemicals of potential concern (COPCs) associated with the Project's emissions.
- **Exposure Assessment,** which involves the identification of relevant exposure pathways, and the quantification of the amount or dose of each COPC to which human receptors will be exposed.
- **Toxicity Assessment,** which involves the identification of potential adverse health effects associated with each of the COPCs, the conditions under which these effects are observed and determination of the maximum safe dose for the most sensitive subjects following exposure for a prescribed time period (i.e., identification of acute and chronic exposure limits for COPCs). Details regarding the exposure limits and critical toxicological effects of the COPCs are provided in Appendix 4A.
- **Risk Characterization,** which involves the comparison of exposure limits (established in the toxicity assessment) with estimated exposures (determined in the exposure assessment) to identify potential health risks for the different assessment cases, as well as discussion of sources of uncertainty and how these were addressed in the HHRA.

Figure 4.4-1 provides an illustration of how these four steps relate to each other and the overall assessment. Additional details regarding each step of the risk assessment are provided in the following sections.

Consistent with the air quality assessment (Volume 2, Section 2), the potential health risks were assessed based on the following five assessment cases:

- **Existing Case:** includes existing ambient air sources within the area.
- **Baseline Case:** includes existing ambient air sources (i.e., community and traffic sources), as well as approved and existing commercial and industrial projects or activities in the air quality study area. The approved projects include facilities that have received regulatory approval, but are not yet operating.
- **Project Case:** includes the emission sources from the Project alone.
- **Application Case:** includes existing ambient air sources, existing and approved regional sources, as well as the proposed Project (i.e., Baseline case plus the Project).
- **Cumulative Case:** includes existing ambient air quality, existing and approved regional sources, the proposed Project (i.e., Application Case), as well as all other planned or proposed industrial activities or projects in the air quality study area.

Project-specific potential health risks were evaluated by comparing the Application Case to the Baseline Case. Cumulative potential health risks were assessed by comparing the Cumulative Case to the Baseline Case.

In addition, the risks associated with existing background conditions (attributable to a combination of natural and anthropogenic sources) were evaluated in the HHRA. Further details regarding the assessment of background conditions are provided in Appendix 4D.

4.4.1 Problem Formulation

The purpose of the problem formulation is to focus the HHRA on key areas of interest by further defining the following issues:

- **Receptor characterization:** the identification of people who may be exposed to emissions from the Project, with special consideration given to sensitive and more susceptible individuals (e.g., infants and young children, the elderly, individuals with compromised health);
- **Identification of COPCs:** the identification of the Project's COPCs that may present a risk to human health;
- **Identification of exposure pathways:** all applicable exposure pathways are identified, with consideration given to the physico-chemical properties of the COPCs, their fate and transport and their persistence in the environment.

4.4.1.1 Receptor Characterization

Within HHRAs, persons that have the highest likelihood of being adversely affected by the COPCs are included in the assessment to represent estimates of reasonable maximum exposure. The rationale behind this approach is that, if unacceptable health risks are not identified for a hypothetical case of highly exposed and susceptible individuals, unacceptable risks are unlikely to occur in individuals who received a lower degree of exposure, or who may be less susceptible to the effects of the COPCs.

The HHRA evaluated the potential for adverse health effects to occur in individuals who continuously reside in the area (i.e., 24-hours/day, 7-days/week, 52-weeks/year), as well as those who may work at industrial/commercial locations, or may use public recreational areas within the study area.

Six receptor groups were included in the HHRA:

- **Agricultural Receptor (AGR):** includes individuals in the area who live in agricultural areas, and are assumed to obtain 100% of their food from local sources. It is assumed these individuals live in the area for the duration of their lifetimes. All receptor locations within agricultural and rural areas were included in the agricultural group. In the event that it was not evident whether an active agricultural operation was present at the site, or whether individuals live at the site, it was conservatively assumed that these locations all fell under the agricultural group.

- **Residential Receptor (RES):** includes individuals who live in the neighbouring communities. These individuals are expected to consume some local game meats and garden produce, but the majority of their diet is from non-local sources (i.e., supermarket foods). Again, the HHRA assumed that these individuals live in the area for the duration of their lifetimes. This group includes residents of nearby communities with developed residential areas (e.g., Fort Saskatchewan, Bon Accord, Gibbons, Josephburg, Lamont and Redwater).

- **Industrial/Commercial (IND):** includes individuals who work at industrial/commercial sites within the area.

- **Public Use Area (PUA):** includes individuals who visit the area occasionally for recreational purposes. Locations assessed as part of this group include areas such as parks and campgrounds (e.g., Bruderheim Natural Area, Astotin Natural Area, Fort Saskatchewan Natural Area, Elk Islands National Park).

- **Monitoring Stations (MON):** includes air quality monitoring stations that are within the study area. These were included in the HHRA in order to evaluate the potential for health effects associated with predicted concentrations at the monitoring locations in the future.

- **Fenceline:** Air concentrations at the edge of the North American Project boundary were evaluated to represent a reasonable estimate of maximum concentrations to which transient persons may be exposed to on a short-term basis. There are no residences at these locations; therefore, the health risks predicted at the Project fenceline are largely hypothetical.

The distinction between the receptor groups is necessary, as food consumption patterns and behaviours (e.g., time spent at the site) vary between the groups of people evaluated. Additional detail regarding food consumption rates and proportions of local food consumed is provided in Appendix 4B. The agricultural and residential groups represent individuals who reside in the area over a lifetime, with the only distinctions between the two being location (urban vs. farm) and consumption patterns.

A construction worker scenario was not specifically evaluated, given that the HHRA focused on a reasonable maximum exposure scenario that assumed the Project was fully operational. The Project is not operational during construction, thus the workers are not exposed to Project emissions. The assessment of the other receptor types (AGR, RES, IND) involve more conservative exposure estimates, and “covers” those individuals who may live or work within the area (including but not limited to construction workers).

When considering multiple pathways of exposure on a long-term basis, it is important to consider different life stages. Within the current assessment, receptors of all life stages were assessed. The five human life stages that were included are consistent with Health Canada guidance (Health Canada, 2004a):

- Infant (0 to 6 months);
- Toddler (7 months to 4 years);
- Child (5 to 11 years);
- Adolescent (12 to 19 years); and
- Adult (20 to 75 years).

For the multi-pathway assessment of carcinogens, a composite receptor that represents all human life stages (i.e., from infant to adult) was used to represent cumulative exposure over a 75-year lifetime.

4.4.1.2 Identification of Chemicals of Potential Concern

The identification of COPCs began with the development of an inventory of chemicals that could be released into the atmosphere and to which nearby residents might be exposed.

The COPCs selected for evaluation in the HHRA included both Criteria Air Contaminants (CACs) and non-criteria air contaminants. Criteria air contaminants include: sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and fine Particulate Matter 2.5 um in diameter or smaller ($PM_{2.5}$). Typically, particles arising from combustion processes are less than 2.5 um in diameter, while particles greater than 2.5 um are associated with mechanical disturbances, such as agriculture, mining and road traffic (Schwartz et al., 1996). The Project-related sources of fine particulate emissions are the direct emission of $PM_{2.5}$ and the formation of secondary particulates. Given that the emissions from the Project will be combustion related, and that the primary and secondary particulates fall within the $PM_{2.5}$ size fraction, the health assessment of particulate matter is focused on the $PM_{2.5}$ fraction only. Evidence suggests that $PM_{2.5}$ is a better predictor of potential health effects than PM_{10} (WHO, 2000). The HHRA has conservatively assumed that all fine particulate matter (PM less than 10 um) generated by the Project is equivalent to $PM_{2.5}$ (e.g., all fine particulate matter = $PM_{2.5}$). Thus, PM_{10} was not assessed separately within the HHRA. A separate assessment of PM using the Health Canada SUM15 method is provided in Appendix 4A.

The non-criteria air contaminants included Volatile Organic Compounds (VOCs), Polycyclic Aromatic Hydrocarbons (PAHs), Reduced Sulphur Compounds (RSCs) and other compounds. Little to no toxicological information was available for some of the COPCs. These compounds were grouped according to molecular structure and were assessed using a surrogate chemical that adequately represented the compounds within the entire group. When possible, the COPC in the group that possessed either the highest degree or best characterized toxicity was selected as the surrogate. All substances within a group were assumed to have toxicological properties equivalent to the selected surrogate. The chemical composition of each group is provided in Appendix 4A.

Table 4.4-1 lists all the individual compounds and chemical groups that were evaluated in the HHRA.

Table 4.4-1 Chemicals of Potential Concern

Criteria Cir Contaminants	Volatile Organic Compounds	Polycyclic Aromatic Hydrocarbons	Reduced Sulphur Compounds	Other
Sulphur dioxide	1,3-butadiene	2-methylnaphthalene	Carbon disulphide	Ammonia
Nitrogen dioxide	Acetaldehyde	2-chloronaphthalene	Carbonyl sulphide	Diethanolamine
Carbon monoxide	Acrolein	Acenaphthylene	Hydrogen sulphide	
$PM_{2.5}$	Aliphatic C_5-C_8 group	Acenaphthene	Mercaptans$^{(1)}$	
	Aliphatic C_9-C_{16} group	Anthracene	Thiophene$^{(1)}$	
	Aliphatic C_{17}-C_{34} group	Benzo(a)anthracene		
	Aliphatic alcohols group	Benzo(a)pyrene		
	Aliphatic aldehydes group	Benzo(b)fluoranthene		
	Aliphatic ketones group	Benzo(e)pyrene		
	Aromatic C_9-C_{16} group	Benzo(g,h,i)perylene		
	Aromatic C_{17}-C_{34} group	Benzo(k)fluoranthene		
	Benzaldehyde	Chrysene		
	Benzene	Dibenz(a,h)anthracene		
	Biphenyl	Fluoranthene		
	Dichlorobenzene	Fluorene		
	Ethylbenzene	Indeno(1,2,3-cd)pyrene		
	Formaldehyde	Naphthalene		
	Hexane	Phenanthrene		
	Isopropylbenzene	Pyrene		
	Methylene chloride			
	Propylene oxide			
	Styrene			
	Toluene			
	Xylenes			

Note:

1 Only included in the odour assessment due to a lack of suitable toxicity information.

4.4.1.3 Identification of Exposure Pathways

For human exposure to take place (and potential health risks to occur), exposure pathways must exist from the point of chemical release to the point of contact with humans. For this reason, the applicable exposure pathways can only be determined after considering the environmental media that might be affected (either directly or indirectly) by the Project's chemical releases. Environmental media considered for the HHRA included:

- Air;
- Surface water;
- Groundwater;
- Soil, and
- Food.

The environmental media and associated exposure pathways are discussed in the following sections. Figures 4.4-2 through 4.4-5 present visual summaries of the relationship between the exposure pathways and human receptor groups.

Air

The Project will emit chemicals into the air from various sources. As described in the air quality assessment (Volume 2, Section 2), ambient air concentrations are expected to increase for certain COPCs emitted from the Project, resulting in changes to local and regional air quality. As people live and work near these emission sources, direct exposure caused by inhalation was included in the HHRA.

Surface Water

As described in Volume 3, Section 7 - Surface Water Quality, sediment release, dewatering activities and surface runoff from the Project are not expected to measurably change surface water quality in the local study area.

Potential changes to the water quality of the North Saskatchewan River (NSR) as a result of the Project's treated effluent discharge were assessed using the Cornell Mixing Zone Expert System (CORMIX) model (Volume 3, Section 7). The findings of the CORMIX modelling exercise indicate that the predicted phenol and metal concentrations downstream from the Project's outfall were either less than or equal to measured concentrations in the NSR or met relevant health-related guidelines. Appendix 4D contains a more detailed assessment of the surface water quality.

PAHs are not expected to be present in the Project's treated effluent. As well, environmental investigations in the area have consistently been unable to detect PAHs in surface water and fish (PCOSI, 2006; Synenco, 2006; North West Upgrading, 2005).

For these reasons, any exposure pathways related to surface water, whether direct (e.g., drinking water) or indirect (e.g., fish consumption), were excluded from the HHRA.

Groundwater

The Project's potential impacts on groundwater quality are discussed in detail in the Hydrogeology section (Volume 3, Sections 5.6 and 5.7). In light of the mitigative measures described in the groundwater assessment (Volume 3, Section 5.6), the depth below ground surface and the low hydraulic conductivity of the overlying till, accidental releases from ground surface are not expected to adversely affect the water quality of existing groundwater users.

Although groundwater is a source of drinking water for many of the residents in the area, groundwater ingestion was excluded from the HHRA due to the apparent absence of COPCs in groundwater (Volume 3, Section 5 and Shell, 2007) and the premise that the Project will not alter groundwater quality.

Soil

Some deposition of chemical emissions will occur in the vicinity of the Project, a portion of which will be taken up by soil. As a result, direct exposure through inhalation of dust, inadvertent ingestion of soil and skin (dermal) contact with soil were included in the HHRA.

Food

Some COPCs may enter the food chain via deposition onto soils. There is some potential that COPCs emitted from the Project may ultimately transfer to and accumulate in plant and animal tissue. Individuals living within the study area may rely on local foods as primary food sources, such as game animals and birds, beef, dairy and plant foods. Plants may take up substances present in soils via root and stomata uptake and from airborne deposition onto leaves. Birds and animals that ingest plants or soil organisms as a food source also may accumulate COPCs.

Thus, several food pathways were quantitatively evaluated within the HHRA. Additional information regarding these pathways and consumption rates is presented in Appendix 4B.

Summary of Applicable Exposure Pathways

Table 4.4-2 summarizes the "open" (i.e., relevant) and "closed" exposure pathways for the six receptor groups.

Table 4.4-2 Summary of Relevant Exposure Pathways for the Receptor Groups

Pathway	AGR	RES	IND	PUA	MON	Fenceline
Outdoor vapour inhalation	✓	✓	✓	✓	✓	✓
Indoor vapour inhalation	✓	✓	✓	x	x	x
Outdoor dust inhalation	✓	✓	✓	x	x	x
Indoor dust inhalation	✓	✓	✓	x	x	x
Outdoor soil ingestion	✓	✓	✓	x	x	x
Indoor dust ingestion	✓	✓	✓	x	x	x
Surface water consumption	x	x	x	x	x	x
Groundwater (drinking water) consumption	x	x	x	x	x	x
Fish consumption	x	x	x	x	x	x
Game meat consumption	✓	✓	x	x	x	x
Local agricultural products (beef, poultry, eggs, dairy)	✓	✓	x	x	x	x
Fruit and vegetable consumption	✓	✓	x	x	x	x
Outdoor dermal exposure	✓	✓	✓	x	x	x
Indoor dermal exposure	✓	✓	✓	x	x	x

✓ = exposure route open x = exposure route closed (i.e., not applicable)

Industrial/commercial receptors may be exposed at sites associated with specific industrial/commercial activities, and are unlikely to consume local food or water over a long duration of time as it is assumed that people do not live at industrial/commercial receptor locations. However, given that they may come into contact with dusts, and be working within indoor environments, the dermal contact and ingestion pathways for soil and dusts were considered to be open. In the event that industrial/commercial workers reside in the area, the agricultural and residential multi-pathway assessments cover all other relevant pathways.

The recreational public use area receptors were assumed to spend short, sporadic periods of time in the area and to have minimal exposures to local food.

In contrast to the other receptor groups, the monitoring locations represent existing air monitoring stations. These locations are intended for the ongoing monitoring of air quality in the area. These locations do not represent areas where people are known to spend appreciable amounts of time. As a result, only the inhalation route was evaluated at these locations.

Fenceline concentrations were assessed in an attempt to present the worst-case short-term air concentrations along the boundary of the North American site. Although residences are not located at the fenceline, it is possible that a transient person may be exposed on a short-term basis when near the property boundary. An acute assessment of outdoor air was completed for the fenceline receptor group, as it is unlikely that individuals would be exposed to fenceline concentrations over extended periods of time.

No health concerns among Aboriginal stakeholders have been identified, nor is it expected that the Project will impact traditional lifestyles.

4.4.2 Exposure Assessment

The exposure assessment step of the risk assessment paradigm is concerned with estimating the amount or “dose” of each of the COPCs that might be received by potentially affected persons. Distinction is typically made between conditions that provide short-term exposure (acute conditions) versus those that allow for long-term exposure (chronic conditions).

Levels of potential exposure were estimated for the six receptor groups for all four development cases (Baseline, Project, Application and Cumulative, as well as for existing background conditions. The inhalation pathway was evaluated on both an acute and chronic basis, while the dermal contact and ingestion pathways were evaluated on a chronic basis only. As described earlier, acute exposures were assumed to range from minutes to 24 hours, while long term exposures were evaluated on an annual basis.

Exposure estimates were determined using a combination of predictive modelling results and ambient measurements. The exposure estimate of each COPC involved a series of mathematical equations or algorithms that represented the assumed transfer of the COPCs from its source to the eventual receptor (i.e., exposed person). To compensate, in part, for the uncertainty surrounding the use of modelled predictions of exposure, “worst-case” assumptions are often applied to describe the movement of chemicals through the environment to ensure that the predictions are not underestimates of actual exposures.

The main purpose of the exposure assessment is to predict the potential exposure to the COPCs at each of the receptor locations. Several factors were considered in estimating potential COPC exposures, including but not limited to:

- Predicted air concentrations as a result of atmospheric emissions from the Project in combination with those from other regional sources;

- The use of predicted air concentrations based upon a fully operational Project (i.e., maximum emission profile) to provide an estimate of maximum COPC releases;

- Background exposures of the COPC that a person may receive via inhalation and consumption of local foods,

- An assumed 75-year operational lifetime of the Project, which is equivalent to an average person’s lifespan;

- Physical and chemical characteristics of the COPCs (e.g., water solubility, volatility, deposition rates) that determine the environmental fate and transport of the COPCs;
- Concentration of a COPC transferred from air to other environmental media (e.g., soil, vegetation);
- Relevant pathways of exposure; and
- Activity patterns and characteristics of the individuals within the six receptor groups.

4.4.2.1 Identification of COPCs for the Multiple Pathway Exposure Assessment

As described, in addition to the primary pathway of exposure (i.e., inhalation), people living and working in the area may be exposed to the COPCs via secondary pathways. For example:

- Some deposition of the COPCs emitted to the atmosphere will occur surrounding the Project and a portion of the deposition will be taken up by soils. Depending on the fate, transport and persistence of the COPC in the environment, this chemical deposition could affect the chemical concentrations in local soil. Exposure through inhalation of dust, inadvertent ingestion of soil and dermal contact with soil were included in the HHRA.
- Some COPC concentrations in local vegetation could be affected by both direct deposition of atmospheric emissions on to plant surfaces and uptake of COPCs from soils. Exposure through ingestion of local fruits and vegetables was included in the HHRA.
- Some COPC concentrations in livestock, poultry, dairy products and wild game could be affected by inhalation of the atmospheric emissions and ingestion of water (e.g., from dug-outs). Depending on the fate, transport and persistence of the COPC in the environment, game, livestock and poultry might be affected by the ingestion of local soil, soil invertebrates, vegetation and prey. Exposure through ingestion of game, livestock, poultry and dairy products was included in the HHRA.

These secondary pathways were also incorporated in the multiple pathway exposure assessment. As a result, it was necessary to identify those COPCs that, although only emitted into the air, would be likely to deposit onto surface soils and vegetation and persist or accumulate in the environment in sufficient quantities for residents and workers to be exposed via secondary pathways.

An evaluation of environmental fate was conducted using a multi-media model for the COPCs that have physico-chemical properties that could result in accumulation in the food chain or persistence in environmental media to which humans may be exposed. Chemicals that met certain physico-chemical criteria were assessed through multiple routes of exposure (i.e., inhalation, oral and dermal). These criteria were adopted from Environment Canada (2007) and include:

- Soil half life $\geq$ 182 days
- Octanol-water partition coefficient (Log Kow) $\geq$ 5

This assessment is based on the premise that, if one of these criteria is not exceeded, the substance is unlikely to accumulate to appreciable amounts in food items or to persist in the environment. However, in the event that one of these criteria is exceeded, the COPC was assessed in the multi-pathway model (in addition to being assessed in the inhalation model). All COPCs were included in the acute and chronic inhalation assessment.

The potential health effects caused by the federally regulated chemicals (i.e., SO_2, NO_2, CO and $PM_{2.5}$) are associated with inhalation only as they primarily act at the point of contact (i.e., respiratory system).

Table 4.4-3 summarizes the results of the fate and persistence evaluation. Reference to surrogate compounds is made for some chemical groups. For more information regarding chemical surrogates, please refer to Appendix 4A.

Table 4.4-3 Identification of COPCs for the Multi-Pathway Exposure Assessment

COPC	Soil half Life (Criterion: > 182 d or 4,368 h)	log Kow (Criterion: $\geq$ 5)	Include in Multi-Pathway Assessment?
2-methylnaphthalene	--	--	Y(1)
1,3-butadiene	168 - 672 h	1.56 - 2.22	N
2-chloronaphthalene	59 - 79 d	3.9	N
Acenaphthene	12 - 102 d	3.32 - 4.45	N
Acetaldehyde	--	0.43	N
Acrolein	--	-0.01	N
Aliphatic C_5-C_8	712 d	3.81	Y
Aliphatic C_9-C_{16}	1,750 d	6.91	Y
Aliphatic C_{17}-C_{34}	--	--	Y(2)
Aliphatic alcohols (isopropanol)	24 - 168 h	-0.81	N
Aliphatic aldehydes (priopionaldehyde)	24 - 168 h	--	N
Aliphatic ketones (Methyl ethyl ketone)	4.9 d	0.29	N
Ammonia	--	--	N
Anthracene	3.3 - 175 d	3.45 - 4.67	Y(3)
Aromatic C_9-C_{16}	1,750 d	3.91	Y
Aromatic C_{17}-C_{34}	1,400 d	6.42	Y
Benzaldehyde	--	1.48	N
Benzene	5 - 16 d	1.5 - 2.27	N
Benzo(a)anthracene	4 – 6,250 d	5.5 - 7.5	Y
Benzo(a)pyrene	229 d - 8 years	5.81 - 8.5	Y
Benzo(b)fluoranthene	211 - 294 d	5.78 - 6.57	Y
Benzo(e)pyrene	--	6.44 - 7.40	Y
Benzo(ghi)perylene	590 - 650 d	6.5 - 7.6	Y
Benzo(k)fluoranthene	2.5 - 8.7 y	6.06 - 7.2	Y
Biphenyl	328 - 1000d	5.01 - 7.1	Y
Carbon disulphide	--	1.94	N
Carbonyl sulphide	--	1.33	N
Chrysene	328 - 1000d	5.01 - 7.1	Y
CO	--	--	N
Dibenz(ah)anthracene	361 - 420 d	6.5 - 7.19	Y
Dichlorobenzene	672 - 4320 h	2.59 - 5	N
Diethanolamine	14.4 - 168 h	<1	N
Ethylbenzene	3 - 10 d	2.98 - 3.3	N
Fluoranthene	34 d - 7.8 y	4.78 - 6.5	Y

COPC	Soil half Life (Criterion: > 182 d or 4,368 h)	log Kow (Criterion: > 5)	Include in Multi-Pathway Assessment?
Fluorene	32-60 d	4.12 - 4.47	Y
Formaldehyde	--	0.35	N
Hexane	--	2.98 - 3	N
Hydrogen sulphide	--	--	N
Indeno(1,2,3cd)pyrene	139 d	6.7	Y
Isopropylbenzene	--	3.43 - 3.66	N
Mercaptans	--	0.65	N
Methylene chloride	--	1.25	N
Naphthalene	2.1d - > 80 d	0.47 - 0.67	N
NO_2	--	--	N
Phenanthrene	2.5d - 5.7 y	3.6- 5.92	Y
$PM_{2.5}$	--	--	N
Propylene oxide	--	0.03	N
Pyrene	0.1 d - 8.5 y	4.45 - 6.7	Y
Styrene	336 - 672 h	2.87 - 3.39	N
SO_2	--	--	N
Thiophene	--	1.79 - 1.81	N
Toluene	4 -22 d	1.83 - 2.79	N
Xylenes	7 - 28 d	2.1 - 3.14	N

Notes:

--: no data available; h: hours; d: days, y: years.

1 Iincluded as part of the aromatic C_9-C_{16} group.

2 Despite absence of low Kow and soil half-life, evaluated through multiple routes of exposure due to the group's known environmental tendencies (CCME, 2001).

3 Although did not meet persistence/bioaccumulation criteria, was still assessed through multiple routes of exposure as part of the carcinogenic PAH group (e.g., benzo(a)pyrene etc.)

4.4.2.2 Characterizing Existing Exposure

Exposures to chemicals are generally associated with multiple sources, natural and anthropogenic. It is therefore important to include measured background concentrations of the COPCs in environmental media. Background exposures were assessed individually, but were also included in the assessment of the four development cases (Baseline, Application, Cumulative and the Project). A general summary of the approach used is provided below. The specific approaches, background concentrations evaluated, and results of the background assessment are described in more detail in Appendix 4D.

Air

Existing sources of exposure to the COPCs in both outdoor and indoor air were evaluated in the assessment.

The predicted ground level air concentrations involved a thorough assessment of existing sources of the COPCs within the study area for the discrete receptor locations. These background or existing emissions have been included in the air quality predictions for the Baseline, Application and Cumulative cases and were also generated as a separate data set to permit the evaluation of the potential health effects of existing COPC concentrations.

Indoor air is a potential source of background exposures to the COPCs, given that many of the COPCs have sources that may be present indoors (e.g., building materials, household products etc.) Indoor air exposures are considered to be most relevant to long-term, regular exposures to the chemicals rather than short-term emissions. For this reason, indoor air values were considered on an annual basis only.

Measured indoor air concentrations from Alberta were used where possible. Alternatively, indoor air concentrations from Canadian or American homes were selected. Average indoor air concentrations were identified as being the most representative of indoor air exposure to which individuals may be exposed to over a lifetime. Indoor and outdoor background exposures were evaluated for the agricultural, residential and industrial groups as these individuals may be exposed to both indoor and outdoor sources in the area over an extended period of time. Indoor air exposures are not relevant at the fenceline, public use area and monitoring locations. Due to the different behavioral characteristics of the receptors in these groups, different assumptions regarding the duration of time spent indoors and outdoors were applied in the inhalation assessment. These assumptions are summarized in Table 4.4-4.

Table 4.4-4 Assumptions Applied for Indoor to Outdoor Air Exposures

Receptor Group	Estimated Time Indoors (h/day)	Estimated Time Outdoors (h/day)	References
AGR	19	5	U.S. EPA, 1997
RES	22.5	1.5	Health Canada, 2004a
IND	8	16	Health Canada, 2004a
MON	--	24	Assumed
PUA	--	24	Assumed
Fence-line	--	24	Assumed

Risk estimates were determined at all receptor locations (with background included where appropriate), with the highest value for the group selected for presentation within this report.

Soil

Previous investigations have indicated that background soil concentrations of PAHs are below analytical detection limits in the Fort Saskatchewan area (PCOSI, 2006; North West Upgrading, 2007). Soil sampling for North American was conducted in June 2007. All PAH and VOC levels of the COPCs tested were determined to be below the level of analytical detection (Appendix 4D) As a result, the background soil concentrations were predicted using a combination of background air concentrations and assumed depositional rates.

Vegetation

As is the case for soil quality, investigations conducted in support of previous upgrader applications in the area have found that plant concentrations of PAHs are consistently below the level of analytical detection (PCOSI, 2006; North West Upgrading, 2007; Shell, 2007; Synenco, 2006). Vegetation sampling for the North American application was conducted in September 2007, and levels of PAHs were again found to be less than analytical detection limits. Consequently, COPC concentrations in vegetation were predicted using a combination of background air quality, assumed depositional rates, and predicted soil quality and literature-based uptake equations.

4.4.3 Toxicity Assessment

Some key toxicological principles were applied in the HHRA. These principles are common to the study of the potential health effects of all chemicals, regardless of source, that have been proven through years of scientific investigation and observation. These principles are as follows:

- All chemicals, regardless of type or source, possess some degree of intrinsic toxicity (i.e., all chemicals have the capacity to cause some level of harm or injury).
- The health effects produced by any chemical are equally dependent on the toxicological properties of the substance and the exposure, or dose, that is received.
- In general, for non-carcinogenic substances (i.e., chemicals that do not cause cancer), the intrinsic toxicity of a chemical (i.e., the capacity to produce a harmful effect or physiological injury) is only expressed if the exposure exceeds a critical threshold level. Below this threshold dose, adverse health effects are unlikely to occur.
- If the threshold dose is exceeded, adverse health effects may occur. The severity of these effects will depend on the level of exposure received, with more severe effects occurring with increasing dose, and the sensitivity of an individual to the particular substance.
- The toxicity of a chemical largely depends on its molecular structure. Within limits, chemicals having similar structures will produce similar toxicological effects. This principle allows the health effects of a chemical of unknown toxicity to be predicted by comparison to the known health effects produced by a second surrogate chemical with similar molecular structure.
- The health effects produced by a chemical are dependent on the route, concentration and duration of exposure. Health effects may differ according to the route of exposure (e.g., inhalation vs. oral ingestion exposure). It is also important to distinguish between the health effects that may result from acute exposures of short duration and effects that may occur following chronic or long-term exposure.

The assessment of the potential toxicity of the COPCs requires an understanding of their respective critical toxicological endpoints of concern. In general, this information is obtained from published scientific studies in humans or animals where the relationship between exposure and toxicity has been examined.

When evaluating the toxicity of a substance in relation to health, consideration must be given to the dose of the substance to which the receptor may be exposed. It is a general principle of toxicology that the dose determines the type and severity of any potential adverse effects that may be observed in association with exposure. Specifically, it is the amount of the substance that is absorbed and reaches the toxicological site of interest in the organism (in this case, humans) that determines the probability of the effect occurring.

Substances may differ not only with respect to the dosage required to cause an adverse effect, but also in the mechanisms by which adverse effects are elicited. For example, carcinogenic and non-carcinogenic compounds act via different modes of action. For this reason, two general categories are used to evaluate substances based upon their mode of action or mechanism of toxicity: threshold and non-threshold.

Threshold substances are generally non-carcinogenic substances that require a certain threshold (or maximum dose) be exceeded before there is a significant risk of adverse effects. For these substances, it is necessary to evaluate the available information to identify effect-levels at which no effects are observed (i.e., a no observed effect level or NOEL), no adverse effects are observed (i.e., a no observed adverse effect level or NOAEL), or the lowest dose at which an adverse effect has been observed (i.e., a lowest observed adverse effect level or LOAEL). In some cases, benchmark doses (BMD) are derived, and represent a dose level associated with a specific magnitude of response (e.g., 5% or 10% incidence within the study population). In general, BMDs are analogous to NOAELs. All of these endpoints provide an indication of exposure levels that are associated with either minimal or negligible health effects, and are often used in the derivation of exposure limits (or toxicity reference values) by governmental and non-governmental organizations.

Carcinogens are generally assumed to not have a threshold of effects. There are various known modes of actions for carcinogens, such as mutagenicity, cytotoxicity, inhibition of cell death, mitogenesis (uncontrolled cell proliferation), and immune suppression (U.S. EPA, 2005). In general, tumourigenicity data from animals or human epidemiological studies is evaluated and examined using mathematical models. From these data sets, Risk Specific Concentrations (RsC), Unit Risk Estimates (URE) or slope factors (SF) are identified. If the modelling and data set is appropriate, these carcinogenic effect levels are used in the development of exposure limits.

Regulatory agencies such as Health Canada and the U.S. EPA assume that any level of long-term exposure to carcinogenic chemicals is associated with some cancer risk. As a result, Health Canada and AENV have specified an incremental (i.e., over and above background) lifetime cancer risk of 1 in 100,000, which these agencies consider acceptable, tolerable or essentially negligible (AENV, 2001; Health Canada, 2004a). The CCME acknowledges that the designation of negligible cancer risk is an issue of policy rather than science.

An assumed incremental cancer risk of 1 in 100,000 increases a person’s lifetime cancer risk from 0.40000 (based on the 40% lifetime probability of developing cancer in Canada) to 0.40001.

The terminology used to define threshold and non-threshold exposure limits differs according to the source and type of exposure. Also, it often varies between regulatory jurisdictions. Generic nomenclature has been developed, with the following terms and descriptions commonly used:

- Reference Concentration (RfC): refers to the safe level of an airborne chemical for which the primary avenue of exposure is inhalation. It is expressed as a concentration of the chemical in air (expressed in ug/m^3) and applies only to threshold chemicals.

- Reference Dose (RfD): refers to the safe level or dose of a chemical for which exposure occurs through multiple pathways (i.e., inhalation, ingestion and dermal). It is most commonly expressed in terms of the total intake of the chemical per unit of body weight (i.e., expressed as ug/kg of body weight per day, ug/kg bw/d). This term applies only to threshold chemicals.

- Risk-specific Concentration (RsC): reserved for carcinogens and refers to the level of an airborne carcinogen for which the primary route of exposure is inhalation that results in a “regulatory acceptable” incremental increase in cancer (typically 1 in 100,000). It is expressed as a concentration of the chemical in air (i.e., ug/m^3).

- Risk-specific Dose (RsD): reserved for carcinogens and refers to the dose of a carcinogen for which exposure occurs through multiple pathways that results in a “regulatory acceptable” increased incidence of cancer (typically 1 in 100,000). It is expressed in terms of the total intake of the chemical (i.e., ug/kg bw/d).

In the derivation of exposure limits, uncertainty factors are applied to an effect level to account for inter-species differences (i.e., extrapolation of animal data to humans), intra-species differences (variation within a population where some individuals are more sensitive than others), the extrapolation of sub-chronic data to a chronic exposure, or limitations in the scientific database.

Consideration must also be given to the duration of time to which a potential exposure may occur, as the effects of short-term and long-term exposures to a COPC may be different. Within this HHRA, substances are evaluated on an acute (1-hour, 8-hour or 24-hour) and chronic (annual) basis. Exposure limits appropriate to the duration of exposure were selected where possible.

The potential critical health effects of the COPCs and available exposure limits are discussed in Appendix 4A.

4.4.3.1 Exposure Limits

Exposure limits (also known as toxicological reference values or TRVs) that have been derived and published by various governmental and non-governmental organizations for the protection of human health were evaluated for each COPC on both an acute and chronic basis. Priority was given to exposure limits that had adequate supporting documentation, as this permitted the evaluation of their basis to ensure that the values were relevant and sufficient. The organizations that were surveyed for exposure limits included:

- AENV;
- Agency for Toxic Substances and Disease Registry (ATSDR);
- CCME;
- Health Canada;
- California’s Office of Environmental health Hazard Assessment (OEHHA);
- Ontario Ministry of the Environment (OMOE);
- Netherlands National Institute of Public Health and the Environment (RIVM);
- U.S. EPA; and
- WHO.

The effects of a chemical generally vary between acute (short-term) and chronic (long-term) exposure. Limits for these exposure durations as applied in this HHRA are defined as follows:

- **Acute Exposure Limit:** The amount or dose of a chemical that may be tolerated without adverse effects on a short-term basis. Acute limits are generally applied to exposures ranging from a few hours to 24-hours.
- **Chronic Exposure Limit:** The amount or dose of a chemical that may be tolerated without adverse health effects even with continuous or repeated exposures over extended periods of time, possibly extending over a lifetime.

The criteria used in the determination of exposure limits may differ in relation to the organization that derived the value. The limits may also vary with respect to the critical toxicological effect upon which the limit is based, and the level of protection incorporated into the limit through the use of uncertainty factors.

To be selected for use in the HHRA, the exposure limits must be:

- Protective of the health of the general public, based upon current scientific knowledge of the health effects associated with exposure to the COPC;
- Adequately protective of sensitive individuals (e.g., children, the immunocompromised, the elderly) through the incorporation of uncertainty factors;
- Derived or recommended by reputable scientific authorities; and
- Supported by adequate and available supporting documentation.

In general, if the criteria were fulfilled for more than one regulatory limit, the most stringent value was selected. In the event that the most stringent limit was not selected, the rationale for doing so was based upon the overall quality of the data and the documentation available. Additional detail regarding exposure limits and their selection is provided in Appendix 4A.

Tables 4.4-5 and 4.4-6 summarize the acute and chronic exposure limits used in the HHRA. Distinctions are provided for averaging time in the acute table and for limit type in the chronic table (to provide an indication of a carcinogenic vs. non-carcinogenic basis).

Table 4.4-5 Summary of Acute Exposure Limits

COPC	Averaging Period	Value (ug/m^3)	Source/Comment
1,3-butadiene	1 h	800	TCEQ, 2007
2-chloronaphthalene	NV	NV	No appropriate value identified
Acetaldehyde	1 h	2,300	ACGIH, 1996; 2006
Acrolein	1 h	0.29	OEHHA, 1999
Aliphatic C_5-C_8 Group	1 h	100,000	TPHCWG, 1997; CCME, 2000a
Aliphatic C_9-C_{16} Group	1 h	2,600	MADEP, 2003
Aliphatic C_{17}-C_{34} Group	NV	NV	No appropriate value identified
Aliphatic Alcohol Group	1 h	2,300	OEHHA, 1999; 2000
Aliphatic Aldehyde Group	NV	NV	No appropriate value identified
Aliphatic Ketone Group	1 h	13,000	OEHHA, 1999; 2000
Ammonia	1 h	3,200	OEHHA, 2000
Aromatic C_9-C_{16}	1 h	9,000	TPHCWG, 1997; CCME, 2000a; MADEP, 2003
Aromatic C_{17}-C_{34}	NV	NV	No appropriate value identified
Benzaldehyde	NV	NV	No appropriate value identified
Benzene	24 h	30	ATSDR, 1995; 2006
Benzo(a)pyrene group	NV	NV	No appropriate value identified
Biphenyl	NV	NV	No appropriate value identified
Carbon Disulphide Group	1 h	6,200	OEHHA, 2000
CO	1 h	15,000	AENV, 2005
CO	8 h	6,000	AENV, 2005
Cyclohexane	24 h	61,000	OMOE, 2005a
Dichlorobenzene	24 h	12,000	ATSDR, 2005
Ethylbenzene	24 h	4,340	ATSDR, 1999a; 2006
Formaldehyde	1 h	50	ATSDR, 1999a; 2005
n-Hexane	24 h	4,300	U.S. EPA, 2007
Hydrogen sulphide	1 h	98	ATSDR, 2006

COPC	Averaging Period	Value (ug/m^3)	Source/Comment
Isopropylbenzene	NV	NV	No appropriate value identified
Methylene chloride	24 h	2,100	ATSDR, 2000; 2006
Naphthalene	1 h	2,000	ACGIH, 1991; 2006a
NO_2	1 h	400	AENV, 2005
NO_2	24 h	200	AENV, 2005
$PM_{2.5}$	24 h	30	CCME, 2000c
Propylene oxide	1 h	3,100	OEHHA, 2000
Styrene	1 h	21,000	OEHHA, 1999, 2000
SO_2	10 min	500	WHO, 2000
SO_2	1 h	450	AENV, 2005
SO_2	24 h	150	AENV, 2005
Toluene	1 h	37,000	OEHHA, 1999, 2000
Xylenes	1 h	8,700	ATSDR, 2005, 2006

NV: No Value

Table 4.4-6 Summary of Chronic Exposure Limits

COPC	Limit Type	Value (ug/m^3)	Reference/Comment
1,3-butadiene	RsC	0.3	U.S. EPA, 2007
2-chloronaphthalene	RfC	1	RIVM, 2003
Acetaldehyde	RsC	17.2	Health Canada, 2004c
Acrolein	RfC	0.02	U.S. EPA, 2007
Aliphatic C_5-C_8 Group	RfC	18400	TPHCWG, 1997
	RfD	5,000 ug/kg-bw/d	CCME, 2000
Aliphatic C_9-C_{16} Group	RfC	200	MADEP, 2003
	RfD	100 ug/kg-bw/d	MADEP, 2003
Aliphatic C_{17}-C_{34} Group	RfC	9000	MADEP, 2003
	RfD	2,000 ug/kg-bw/d	TPHCWG, 1997; MADEP, 2003
Aliphatic Alcohol Group	RfC	4000	OEHHA, 2005
Aliphatic Aldehyde Group	RfC	1700	ACGIH, 2002; 2006
Aliphatic Ketone Group	RfC	5000	U.S. EPA, 2007
Ammonia	RfC	77	U.S. EPA, 2007
Aromatic C_9-C_{16}	RfC	200	CCME, 2000a
	RfD	40 ug/kg-bw/d	CCME, 2000
Aromatic C_{17}-C_{34}	RfC	130	CCME, 2000
	RfD	30	CCME, 2000
Benzaldehyde	RfC	360	U.S. EPA, 2007
Benzene	RsC	1.3	U.S. EPA, 2007
Benzo(a)pyrene IPM	RsC	0.32	Health Canada, 2004b
	RsD	0.0014	U.S. EPA, 2007
Benzo(a)pyrene WMM	RsC	0.00012	WHO, 2000
	RsD	0.0034 ug/kg bw/d	OMOE, 1997
Biphenyl	RfC	46	ACGIH, 2006
	RfD	50	U.S. EPA, 2007
Carbon Disulphide Group	RfC	100	Health Canada, 2004b
Cyclohexane	RfC	6000	U.S. EPA, 2007

COPC	Limit Type	Value (ug/m^3)	Reference/Comment
Dichlorobenzene	RfC	60	ATSDR, 2006
Diethanolamine	RfC	3	OEHHA, 2000
Ethylbenzene	RfC	1,000	RIVM, 2003
Formaldehyde	RsC	0.77	U.S. EPA, 2007
n-Hexane	RfC	700	U.S. EPA, 2007
Hydrogen Sulphide	RfC	2	U.S. EPA, 2007
Isopropylbenzene	RfC	400	U.S. EPA, 2007
Methylene chloride	RsC	20	U.S. EPA, 2007
Naphthalene	RfC	3	U.S. EPA, 2007
	RfD	20	U.S. EPA, 2007
NO_2	AAQO	60	AENV, 2005
$PM_{2.5}$	AAQO	12	CARB, 2002
Propylene Oxide	RsC	3	U.S. EPA, 2007
Styrene	RfC	1,000	U.S. EPA, 2007
SO_2	AAQO	30	AENV, 2005
Toluene	RfC	5,000	U.S. EPA, 2007
Xylenes	RfC	100	U.S. EPA, 2007

The carcinogenic PAH fraction was assessed using two different approaches. The benzo(a)pyrene Individual PAH Method (IPM) accounts for each individual PAH that exhibits a potential to cause cancer and for which a toxic equivalency factor has been developed. The Whole Mixture Model (WMM) represents the second approach and is based on the assumption that the potency of the carcinogenic PAH fraction of any environmental mixture is proportional to the benzo(a)pyrene content of the mixture.

Separate assessments were completed for both the acute and chronic exposure scenarios using the selected exposure limits in recognition that the effects of COPCs may vary in relation to the duration of exposure.

As per direction from AHW, potential changes to Baseline mortality and morbidity rates associated with predicted $PM_{2.5}$ concentrations were evaluated using Health Canada's SUM15 method. This assessment is provided in Appendix 4C.

4.4.3.2 Mixtures

Because chemical exposures rarely occur in isolation, the potential health effects associated with COPC mixtures were assessed in the HHRA. The interaction between chemicals can take many forms, with additive interactions being assumed for the HHRA (Health Canada, 2004a). Additive interactions apply most readily to chemicals that are structurally similar, act toxicologically through similar mechanisms or affect the same target tissue in the body (i.e., commonality in effect) (Health Canada, 2004a).

Potential additive interactions were identified for specific COPCs that may cause:

- Eye irritation;
- Nasal irritation;
- Respiratory irritation;

- Liver effects (“hepatotoxicants”);
- Kidney effects (“nephrotoxicants”);
- Nervous system effects (“neurotoxicants”);
- Reproductive system effects;
- Cancer (e.g., leukemia, nose and lung).

The endpoints of the exposure limits used in the HHRA provided the basis for an individual chemical’s inclusion in a chemical mixture. For example, the acute inhalation exposure limit for acetaldehyde is based on its ability to cause eye and respiratory irritation, thus acetaldehyde was included in both the acute inhalation “eye irritant” and “respiratory tract irritant” mixtures.

Additional information regarding the composition of these chemical mixtures is provided in Appendix 4A.

4.4.4 Risk Characterization

The potential health effects associated with background, the three development cases and the Project alone are presented as ratios of the COPCs’ exposure estimates to their exposure limits.

Potential health effects associated with the non-carcinogenic COPCs are expressed as Risk Quotients. Potential cancer risks are expressed as either Lifetime Cancer Risks (LCR) for the background scenario and the three development cases (Baseline, Application and Cumulative), or as Incremental Lifetime Cancer Risks (ILCR) for the assessment of the Project alone. These terms are described below.

Risk Quotients (RQ) were calculated by comparing the predicted levels of exposure for the non-carcinogenic COPCs to their respective exposure limits (described in Section 4.3.3.3 above and Appendix 4A). The RQs for the Baseline, Application and Cumulative cases presented in this report all have had background exposures added. To permit the examination of health risks in association with the Project alone, RQs for the Project do not include background exposures. RQs were calculated using Equation 1, below:

$$\mathbf{RQ} = \frac{\textbf{Predicted Exposure (ug/kg/d or ug/m}^{\mathbf{3}}\textbf{)}}{\textbf{Exposure Limit}} \qquad \textit{\textbf{Equation 1}}$$

Interpretation of the RQ values proceeded as follows:

RQ ≤ 1.0	Indicates that the estimated exposure is less than or equal to the exposure limit (i.e., the assumed safe level of exposure). RQs less than one are associated with negligible health risks, even in sensitive individuals given the level of conservatism incorporated in the derivation of the exposure limit and exposure estimate.
RQ > 1.0	Indicates that the exposure estimate exceeds the exposure limit. This suggests an elevated level of risk, the significance of which must be balanced against the high degree of conservatism incorporated into the risk assessment (i.e., the margin of safety is reduced but not removed entirely).

Potential risks from carcinogenic COPCs are expressed as LCRs for the Background, Baseline, Application and Cumulative cases, or as ILCRs for the Project alone. The key difference between the two is in how they should be interpreted.

Lifetime Cancer Risks (LCR) simply refer to the number of cancer cases that could potentially result in association with exposures to carcinogens per 100,000 people. There is no clear benchmark for what is an acceptable risk to compare with a calculated LCR, given that the predicted LCRs for these cases not only include background levels (both natural and anthropogenic), but also include emissions from multiple different sources that may impact various environmental media. The overall probability of a person developing cancer in Canada is about 0.4 or 40% (Health Canada, 2004a). This probability could be interpreted as a comparative cancer incidence rate in the population; however, no guidance is provided to this effect. Some individuals may be more susceptible to developing cancer than others, and background exposures alone may exceed reasonably safe exposure levels and may result in the development of cancer in such sensitive individuals (Graham, 1993). Thus, the LCR is a predicted incidence rate per 100,000 people in a population, but does not readily distinguish an acceptable vs. unacceptable increased cancer risk above background. The LCR values have been calculated according to Equation 2.

$$\textbf{LCR} = \frac{\textbf{Background or Predicted Exposure (ug/kg/d or ug/m}^3\textbf{)}}{\textbf{Carcinogenic Exposure Limit}} \qquad \textit{Equation 2}$$

Given that several cancer risk estimates include both background and future sources (Baseline, Application, and Cumulative cases); they should be interpreted as LCRs. At this time, there is no clear regulatory benchmark for LCR.

The regulatory benchmark of an acceptable cancer risk of 1 in 100,000 is policy-based, and its interpretation by various regulatory agencies differs. Although the basis for the 10^{-5} benchmark is complex and not always clear, it is apparent that these benchmark values were established to evaluate risks on a “per product” or “per site basis”. Health Canada (2004a) requires that carcinogens be assessed on an incremental basis and mandates an acceptable ILCR of 1 in 100,000. In relation to the current HHRA, it is most appropriate to compare ILCR associated with the Project to the 10^{-5} (1 in 100,000) benchmark as this level of risk is considered acceptable by AENV and Health Canada. Background exposures were not included in the ILCR calculation such that the potential incremental impact on health due the Project alone could be assessed. The ILCR values were calculated using Equation 3.

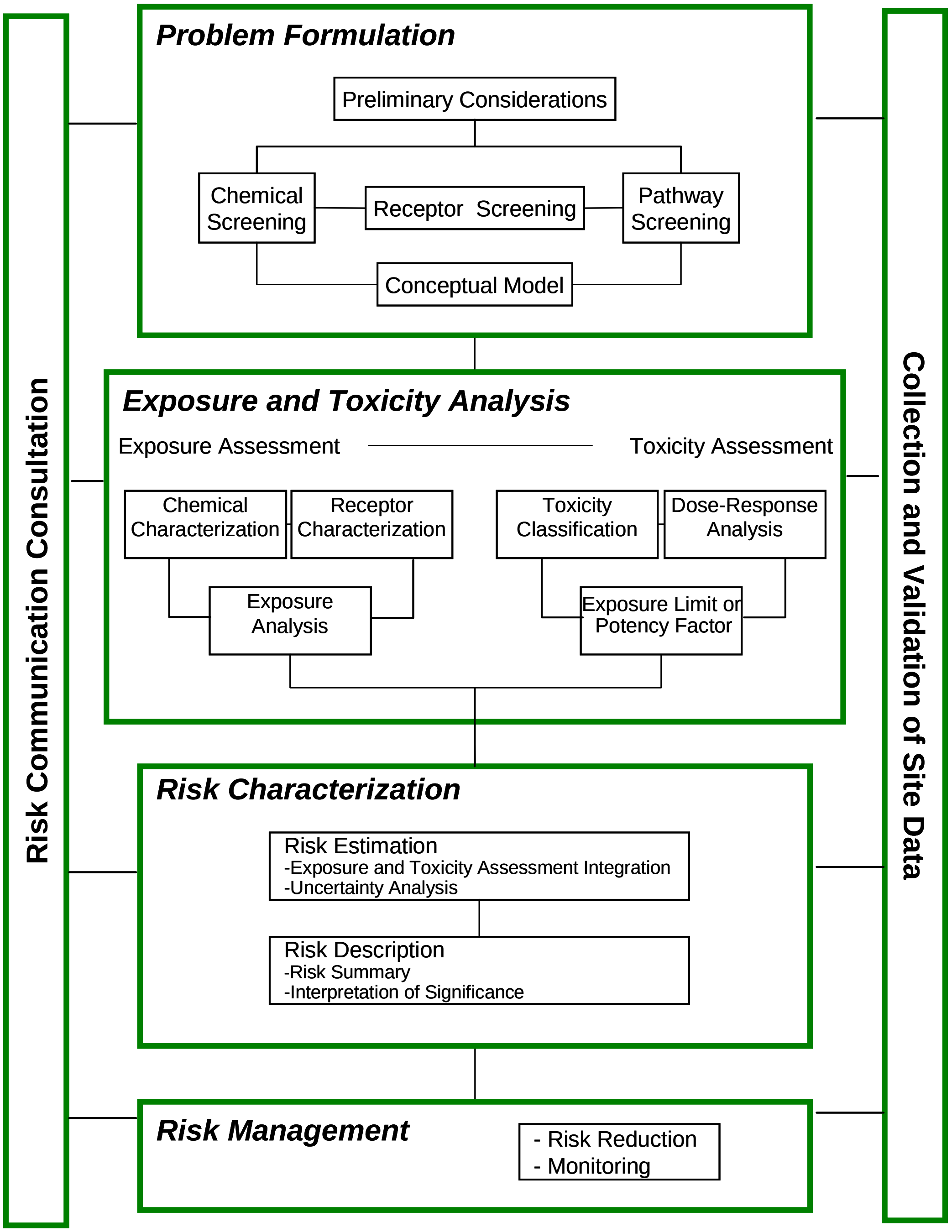
$$\textbf{ILCR} = \frac{\textbf{Project-related exposure (ug/kg/d or ug/m}^3\textbf{)}}{\textbf{Carcinogenic Exposure Limit}} \qquad \textit{Equation 3}$$

Interpretation of the ILCR values from Equation 3 should be interpreted as follows:

ILCR ≤ 1.0	Denotes an incremental lifetime cancer risk that is below the benchmark ILCR of 1 in 100,000 (i.e., within the accepted level of risk set by provincial and federal regulatory agencies).
ILCR > 1.0	Indicates an incremental lifetime cancer risk that is greater than the negligible risk level of 1 in 100,000, the interpretation of which must consider the conservatism incorporated into the assessment.

As described previously, COPCs with common toxicological endpoints were evaluated as chemical mixtures, assuming additivity in accordance with Health Canada (2004a) guidance. Mixture calculations were completed by summing the RQs for the components of each mixture to calculate an RQ or LCR for each type of mixture.

Additional information regarding the mixture components and endpoints is provided in Appendix 4A.



Risk Assessment Paradigm

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:

Revision Date:
Nov 26/07

File:
Figure 4.4-1 Risk Assessment Paradigm.doc

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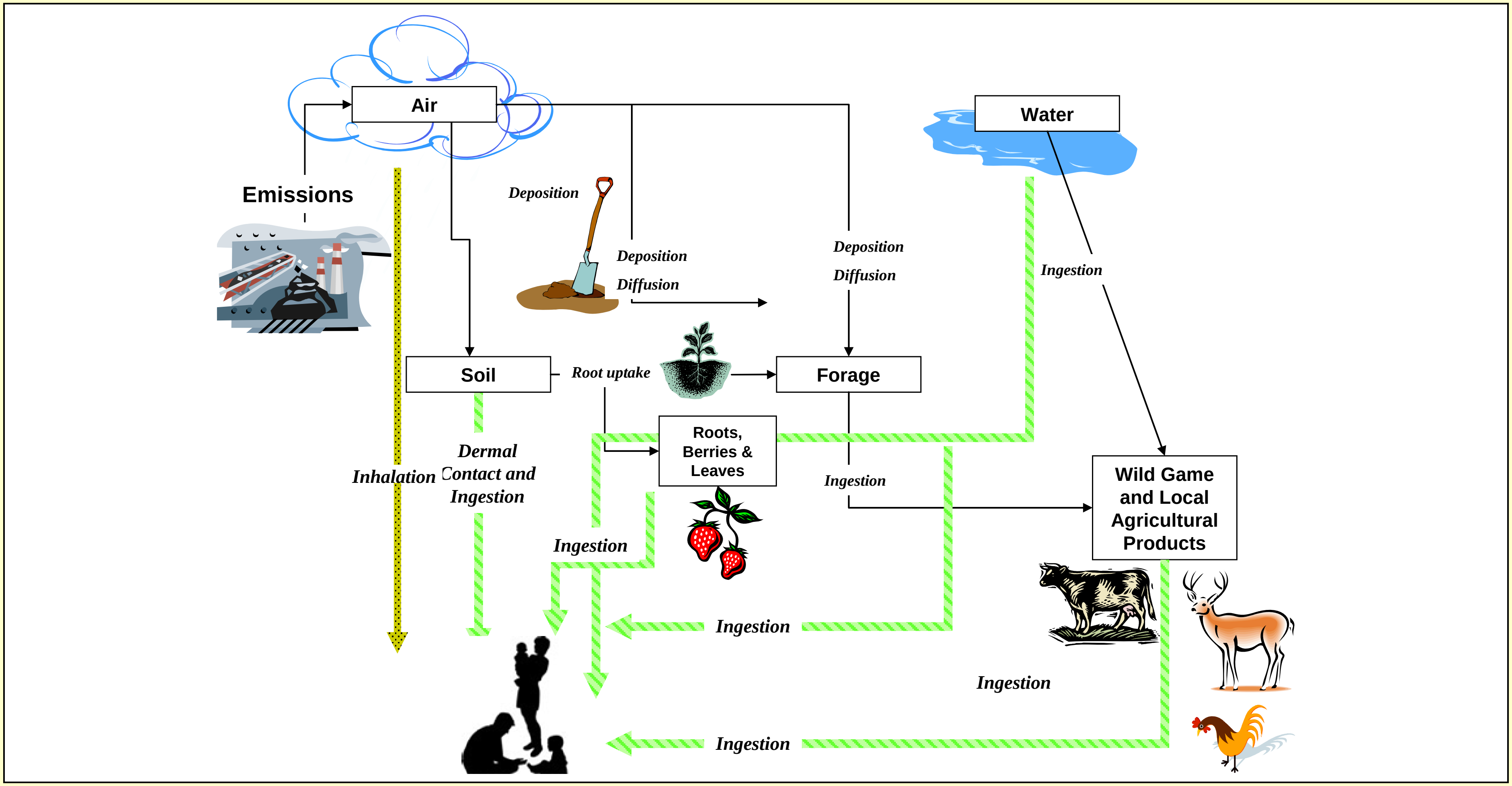
Fig. No.:
4.4-1



Conceptual Site Model for the Agricultural Receptor

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Figure 4.4-2 Conceptual Site Model Agricultural Receptor.doc

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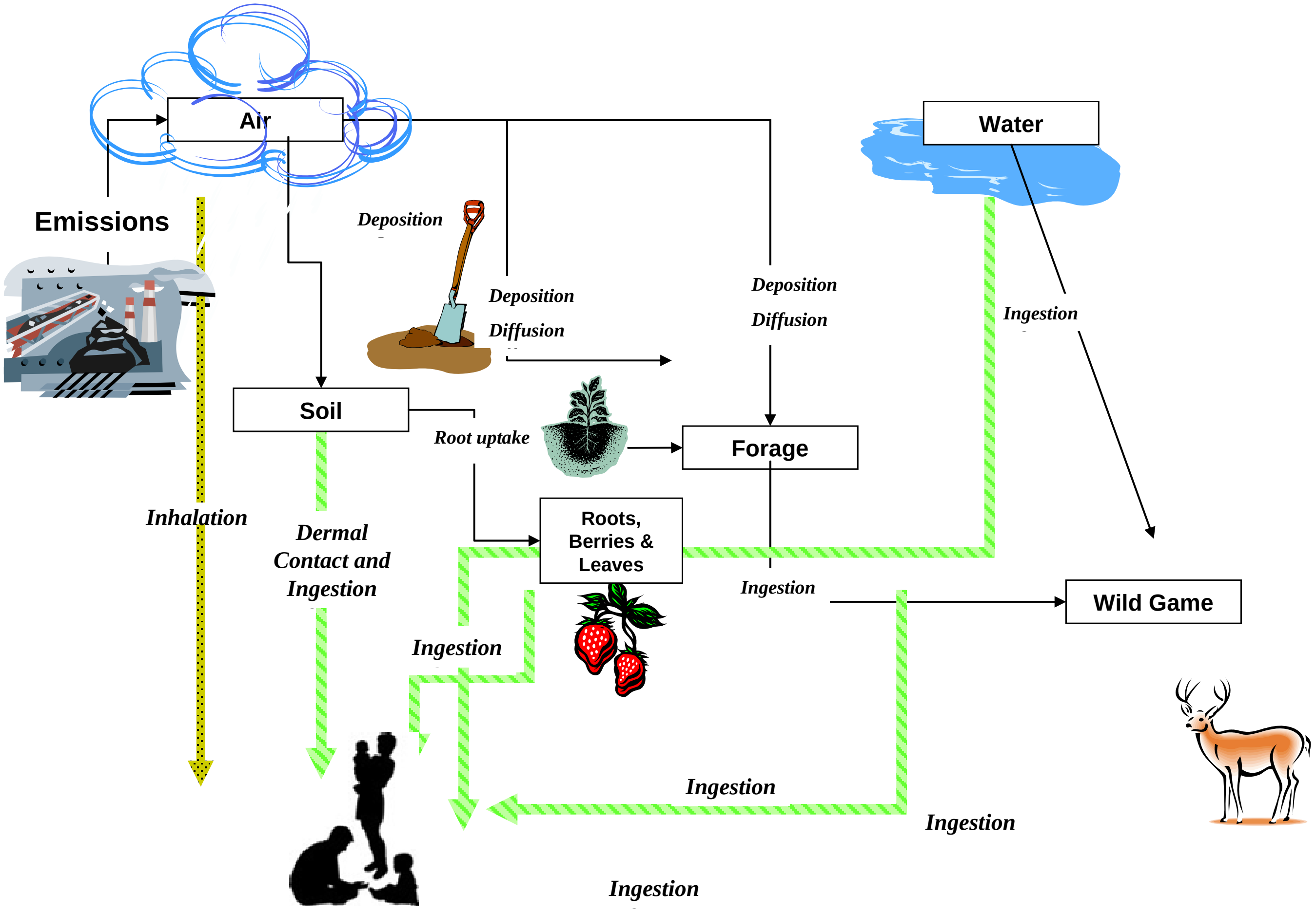

Conceptual Site Model for the Residential Receptor

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Figure 4.4-3 Conceptual Site Mode Residential Receptor.doc

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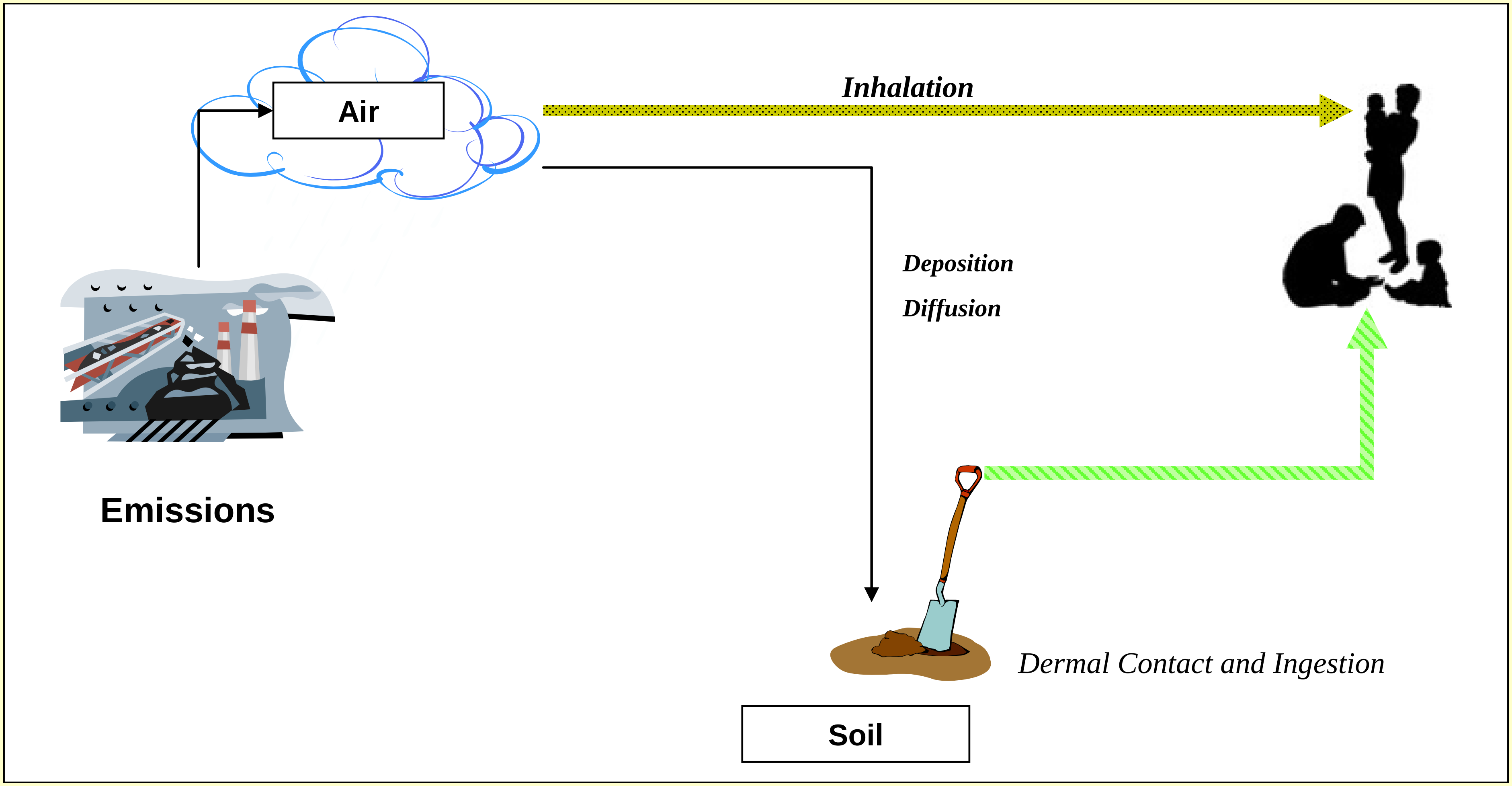

Air

Inhalation

Deposition

Diffusion

Emissions

Dermal Contact and Ingestion

Soil

Conceptual Site Model for the Industrial / Commercial Receptor

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Figure 4.4-4 Conceptual Site Model Industrial Receptro.doc

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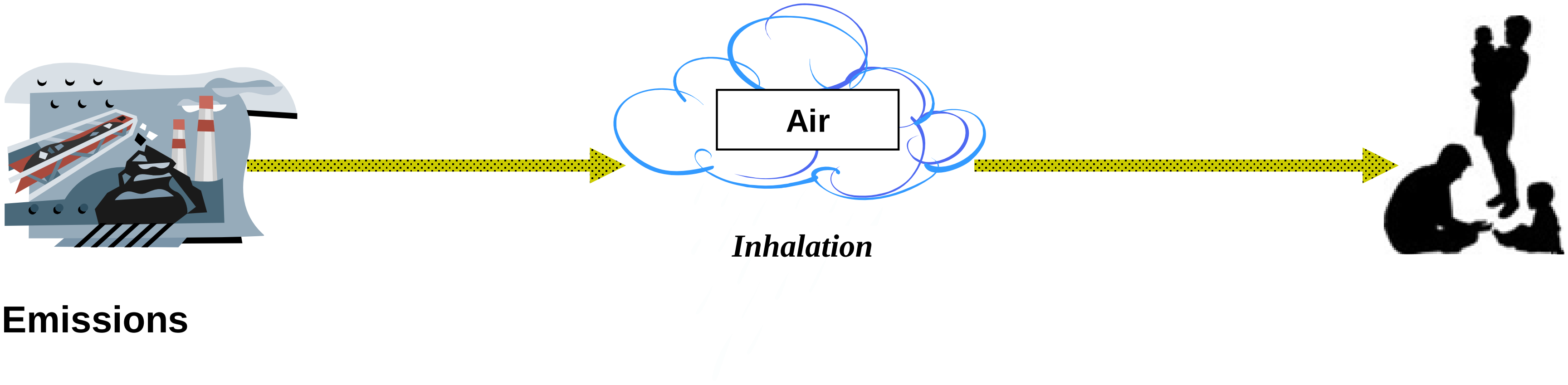

Conceptual Site Model for Public Use Area, Monitoring and Fenceline Receptors

North American Oil Sands Corporation

Approved:	Revision Date: Nov 26/07

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Figure 4.4-5 Conceptual Site Model for Public.doc

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4.5 Existing Conditions

As described in Section 4.4, exposures associated with existing levels of the COPCs from natural and anthropogenic sources were evaluated separately, in addition to being included in the predicted exposures from the Baseline, Application and Cumulative cases. The purpose of the assessment of existing, background conditions is to gain an understanding of how existing conditions may impact human health, as well as contribute to future exposures.

Appendix 4D summarizes the measured data collected in support of the Project and characterizes the health risks associated with existing conditions in the Project area.

4.5.1 Assessment of Current Health Status of Area

The Project will be located within the Capital Health Region, which includes the cities of Edmonton and Fort Saskatchewan and the counties of Strathcona and Sturgeon.

Information on the Baseline conditions of this region was collected from community health and exposure studies by AENV, Capital Health, AHW and the Fort Air Partnership (FAP).

4.5.1.1 Air Quality

A 2003 FAP study identified air quality as being of significant concern to area residents. Approximately one-third of FAP survey respondents perceive the regional air quality to be worse than other Alberta communities (FAP, 2003).

Based upon recent air quality monitoring studies, AENV has observed only minor differences between ambient air quality data in the Fort Saskatchewan area and other Alberta locations (AENV, 2003; FAP, 2003a; FAP, 2004). Substances monitored in these air quality studies include various criteria air contaminants (i.e., CO, NO_2, O_3, PM, SO_2), hydrogen sulphide, reduced sulphur, ammonia and over 150 VOCs. No exceedances of Alberta Ambient Air Quality Objectives (AAQOs) were observed.

Between August 2001 and August 2002, AENV collected 38 air samples at three different residences near industrial facilities in the Fort Saskatchewan area in response to odour complaints. These samples were analyzed for 158 VOCs (AENV, 2004). Results from this study indicated that in general, VOC concentrations were low and below Alberta AAQOs in all cases. A comparison of the measured VOC concentrations with levels measured in Calgary and Edmonton (based on 2001 data), showed 133 of the 158 compounds to be lower in the Fort Saskatchewan area (AENV, 2004).

In another study, FAP and Environment Canada measured 150 VOCs over 19 months (September 2004 to March 2006). Twenty-four hour ambient air samples were collected every six days at six different sites in the Fort Saskatchewan area. These results were compared with other national air pollutant surveillance (NAPS) Canadian sites, with all but eight substances found to be below the Canadian NAPS sites' averages (FAP, 2006a). In the 2004 annual report (FAP, 2005), FAP stated that "there has been no historical information to indicate that VOC concentrations in Fort Saskatchewan are unacceptable".

4.5.1.2 Community Health

The residents of the Capital Health Region have been reported to generally be in good health, and rank highly on many standard measures of population health (Capital Health, 2004a). For instance, mortality rates for heart disease in the Capital Health Region were lower than the provincial average from 2000 to 2003 and mortality rates for stroke and cancer were similar to the provincial average (Capital Health, 2005). Similar to other regions, the rates of chronic diseases (e.g., asthma, diabetes, high blood pressure) in the Capital region are increasing (Capital Health, 2004a).

In a study by Hessel et al. (1996), the incidence of childhood asthma in Fort Saskatchewan and Sherwood Park was reported to be more than twice the rate of the rest of Canada. Refuting the results of Hessel et al., AHW (1996) did a follow-up study that found no evidence of mortality and hospital admissions of asthma greater than other provinces. Although the asthma rate has increased from 1996 to 2003, it continues to be lower than both the provincial and national averages (Capital Health, 2004b).

AHW (2003) also examined the link between public health and environmental exposure by analyzing data collected from Fort Saskatchewan, Bruderheim and Redwater between June 12 and November 8, 2001.

The objectives of this study were to:

- estimate the extent of personal and population exposure to airborne chemicals;
- quantify the relative contribution of indoor and outdoor air on personal exposure; and
- evaluate possible associations between exposure to airborne chemicals and human health effects by analyzing the relationships between selected exposures, biomarkers and health outcomes

Although the study was unable to reach the target number of volunteers, those sampled provided measures of exposure for the test areas.

Results of the assessment indicated that NO_2 and SO_2 concentrations were lower than existing guideline values and $PM_{2.5}$ concentrations were low compared with existing guideline values and similar to other communities. Furthermore, the researchers found that indoor VOC concentrations predominantly influenced personal VOC exposure. Finally, personal exposure to PAHs was found to be entirely caused by outdoor sources, with the exception of those who smoked. Residents in Fort Saskatchewan appear to be exposed to higher levels of PAHs than surrounding areas, but lower levels compared with large urban centres.

The primary findings of the health outcome of the assessment were:

- The individual rates of asthma, bronchitis, Chronic Obstructive Pulmonary Disease (COPD) and non-accidental deaths (e.g., respiratory) in Fort Saskatchewan were not notably higher when compared with the reference population of Lethbridge.
- The combined rate for all respiratory disorders (when measured in terms of prevalence and frequency of physician visits) is higher in Fort Saskatchewan than in Lethbridge. AHW determined that this difference was likely due to increased common cold and upper respiratory infections in the Fort Saskatchewan area for the period of the study.

According to AHW (1999), Albertans are generally healthy compared with other provinces and many countries around the world. Albertans can expect to live longer, and in most cases, healthier lives. Although the prevalence of cardiovascular disease appears to be rising in Alberta, mortality rates show a notable decline and are currently lower than the Canadian average (AHW, 2002; 2006). Currently, cardiovascular disease affects 15% of males and 12% of females (AHW, 2006).

The leading cause of death among cancers in Alberta is lung cancer (Capital Health, 2005). However, the mortality rate for lung cancer is similar to the national average and the mortality and incidence rates in men are lower than the national rates (AHW, 2002). Stroke is the second highest leading cause of death in Alberta. This rate has been ranked as being the second highest in Canada. In 1997, the mortality rate for stroke in Alberta was higher than the national rate (50.4 per 100,000 versus 47.8 per 100,000) (AHW, 2000). However, in 2003, treated prevalence of cerebrovascular disease (i.e., stroke or brain attack) was notably lower than the provincial average for the Capital Health Region and mortality rates show a decreasing trend in all of Alberta (AHW, 2006a).

The mortality rate from COPD and allied conditions (excluding asthma) in Alberta was fourth highest among Canadian provinces in 1997 and third highest for asthma (AHW, 2000). The COPD mortality rate was slightly lower than the Canadian average and has been declining for the past decade for men but increasing for women (AHW, 2000). Whereas, treated prevalence rates for COPD have shown a general decrease in both sexes over time and the Capital Health region had measurably lower prevalence rates than the provincial average in 2003 (AHW, 2006a). It is believed that reduced cigarette smoking accounts for some of this trend.

In Alberta, the prevalence of asthma is similar for males and females, but both are above the Canadian average (AHW, 2006). The prevalence of asthma was highest in the Capital and Calgary Health regions in Alberta during 2003; however, the Capital Health Region did not differ from the provincial average (AHW, 2006).

4.6 Methods – Odour

The odour assessment determines the potential contribution of Project emissions to noticeable odours in the area. The odour assessment is based on the premise that people will detect odours at a certain threshold. However, various factors may affect how an individual reacts to odours. Further discussion of these factors and odour thresholds is provided below.

4.6.1 Factors Affecting the Sense of Smell

There are a variety of individual, environmental and substance-based factors that influence the sense of smell. For instance, the ability of a person to detect a particular odour is strongly influenced by their innate olfactory power (i.e., “acuteness” of smell), their prior experience with that odour, and by the degree of attention they grant to the matter. The detection of odours may also be influenced by environmental factors, such as wind speed and temperature. Also, the inherent ability of a substance to excite the olfactory receptors may be determined by such factors as its molecular structure or reactivity. All these influences combined contribute to the complexity surrounding the sense of smell. This complexity must be respected as part of any odour assessment. The various influences affecting the sense of smell are presented in Table 4.6-1.

Table 4.6-1 Factors Affecting the Sense of Smell

Category	Influences
Individual	Innate power of smell Age Sex Prior experience with the odour State of health Degree of attentiveness
Environment	Temperature Humidity Wind speed and direction
Substance-based	Molecular structure Stability/reactivity Physical properties (e.g., vapour pressure, water solubility)

Sources: Based on Ruth (1986) and Amoore and Hautala (1983).

Adding to the complexity of the sense of smell is the number and interaction of components within a mixture, which may influence the ability of humans to detect, identify and discriminate between the components of a mixture. In studies involving mixtures, odourants in the mixture were processed and perceived in series. The odourants were temporally processed with up to several hundred milliseconds separating individual constituents. The odourants determined to be “fast” have been found to suppress the “slow” odourants. This is possibly a result of their relative chemical polarities, which affect access to and competition for membrane receptor sites in the olfactory epithelium (Laing et al., 1994a; Bell et al., 1987).

A study examining the interactions of different odourants emitted by sewage treatment plants (including hydrogen sulphide) measured the perceived intensity (odour strength) of individual odourants alone and in mixtures, as well as the odour characteristics and unpleasantness of mixtures (Laing et al., 1994b). It was observed that:

- The perceived odour intensity of mixtures was equal to or greater than that of any of the individual constituents, but less than the sum of their intensities. As the number of constituents in the mixtures increased, the intensity of the mixture was typically attributable to the intensity of the most dominant odourant.

- The intensity of an odourant was never enhanced by another (i.e., no synergistic interactions were observed).

- The greater the number of odourants in the mixture, the more difficult it was to identify the individual constituents.

- The greater the number of components in the mixture, the greater the degree of suppression of the individual constituents.

- Hydrogen sulphide was the least frequently suppressed odourant.

- The unpleasantness of the odourant mixture was typically greater than that of the individual constituents, indicating that models for predicting complaint levels in communities affected by odourous mixtures, but which are based on single odourants, will usually underestimate the number of complaints.

The greater the number of odourants in the mixture , the more difficult it is to identify the individual constituents and the greater the degree of possible suppression of the individual odourants (Bell et al., 1987; Laing et al., 1994a; Jinks and Laing, 2001). As the current assessment includes many different chemicals through the use of chemical fractions and surrogate groupings, many of the odourants assessed may never be detected. However, as some odourants such as hydrogen sulphide are not typically suppressed, it is difficult to accurately predict the perceived intensity of the odour mixture.

4.6.2 Determining the Threshold of Odour

Critical to determining the Project's likelihood of contributing to noticeable odours in the area is the need to understand the intrinsic odour properties of the chemicals emitted as reflected by the available odour thresholds for the various COPCs. The odour threshold refers to the lowest concentration of a chemical that can be detected by smell following presentation of the chemical in a clean, controlled environment, without influence of any outside odours (Ruth, 1986).

Odour thresholds are often determined in clinical setting-type studies where a panel of subjects is exposed to a particular chemical in air or water and asked to record the concentration at which odour is first detected. However, the procedures followed in these studies often differ in sample presentation methods, panel selection, purity of chemicals used and data interpretation. Moreover, the definition of the term "threshold" varies. Some studies report thresholds at which odour was first detected and other studies report thresholds at which recognition of the odour (e.g., association of the odour with a specific chemical) was reported. Due to these differences, a wide variety of odour thresholds are reported for most chemicals, including the COPCs in scientific literature.

For some substances, odour may serve as a warning against adverse health effects. This may occur in situations where the odour threshold of the chemical is lower than the concentration required to produce toxicity. In cases where the odour threshold is higher than the concentration associated with adverse health effects, odour does not serve as an adequate warning. Therefore, the presence of odour may or may not necessarily be related to the risk of health effects. As such, the significance of odour in terms of potential health hazards must be reviewed on a chemical-by-chemical basis.

4.6.3 Evaluation of Potential Odour Impacts

The potential for the Project's emissions to contribute to nuisance odours was assessed by comparing either 3-minute or 1-hour COPC concentrations against established odour thresholds. Three-minute peak concentrations were derived from the predicted 1-hour ground-level air concentrations as follows:

$$\textbf{Predicted 3-minute peak concentration} = \textbf{1-hour concentration} \times [(60\ \text{minutes}/3\ \text{minutes})]^{0.2}$$

Where:

1 hour concentration = predicted one-hour concentration

0.2 = exponent for the 3-minute multiplier

The exponent (i.e., 0.2) for the three-minute multiplier used for this assessment is based on neutral atmospheric conditions (OMOE, 1996; Duffee et al., 1991).

Given that odours can appear instantaneously and are commonly observed over very short periods, 3-minute peak concentrations were estimated for most of the COPCs. The potential for COPCs to contribute to nuisance odours was assessed as follows:

- The maximum peak air concentrations were predicted for each receptor group (i.e., monitoring, industrial, residence, agricultural and public use areas) in the study area.
- The 3-minute or 1-hour air concentrations were compared to the corresponding odour threshold for each assessment case (i.e., Baseline, Project, Application and Cumulative).

As the 3-minute peak concentrations were predicted using 1-hour ground-level air concentrations, the COPC levels that might be encountered under most circumstances may be exaggerated, resulting in conservative odour estimates.

Odour thresholds for the COPCs were obtained from several review articles (Amoore and Hautala, 1983; van Gemert, 1999; Ruth, 1986; Verschueren, 1983) and are summarized in Table 4.6-2. For most COPCs, the average odour thresholds are listed, together with the range of values reported in the literature. The lower the odour threshold, the more odorous the chemical is considered. The lower end of the range represents the “minimum” odour threshold. COPCs were evaluated as groups when applicable.

Table 4.6-2 Odour Characteristics and Odour Thresholds

Chemical[1,2]	Odour Character[3]	Odour Threshold (ug/m^3)		Reference
		Mean	Range	
1,3-Butadiene	Gasoline	3,500	220 to 169,000	Amoore and Hautala, 1983; van Gemert, 1999
2-Chloronaphthalene	--	--	--	--
2-Methylnaphthalene	--	--	58 to 290	Ruth, 1986
Acetaldehyde	Pungent and fruity	90	2.7 to 1,800,000	Amoore and Hautala, 1983; van Gemert, 1999
Acrolein	Pungent	370	50 to 4,100	Amoore and Hautala, 1983; van Gemert, 1999
Aliphatic C_5-C_8 group	Sweet	458,000	107,000 to 875,000	Amoore and Hautala, 1983
Aliphatic C_9-C_{16} group	Gasoline	60,000	--	AENV, 2005
Aliphatic C_{17}-C_{34} group	--	--	--	--
Aliphatic alcohol group	Pungent	131,000	4,000 to 260,000,000	Amoore and Hautala, 1983; van Gemert, 1999
Aliphatic aldehyde group	Pungent and fruity	--	3.6 to 240,000	van Gemert, 1999
Aliphatic ketone group	Acetone-like, sweet	15,900	750 to 1,000,000	Amoore and Hautala, 1983; van Gemert, 1999
Ammonia[4]	Pungent and irritating	1,400	30 to 42,000	AENV, 2005; van Gemert, 1999
Aromatic C_9-C_{16} group	--	440	7 to 5,340	Amoore and Hautala, 1983; van Gemert, 1999
Aromatic C_{17}-C_{34} group	--	--	--	--
Benzaldehyde	--	--	<10 to 3,400,000	van Gemert, 1999
Benzene	Aromatic, sweet, solvent	38,300	1,500 to 1,000,000	Amoore and Hautala, 1983; van Gemert, 1999
Benzo(a)pyrene group	Weak aromatic	--	--	--
Biphenyl	Pleasant/ butter-like	5.2	--	Amoore and Hautala, 1983;
Carbon disulphide group	Sweet, aromatic	30	23 to 98,900	AENV, 2005; van Gemert, 1999
Carbon monoxide	Odourless	115,000,000	--	Amoore and Hautala, 1983

Chemical[1,2]	Odour Character[3]	Odour Threshold (ug/m^3)		Reference
		Mean	Range	
Cyclohexane	Sweet, petroleum-like	86,000	1,800 to 2,700,000	Amoore and Hautala, 1983; van Gemert, 1999
Dichlorobenzenes	Camphor, mothballs	1,080	730 to <90,000	Amoore and Hautala, 1983; van Gemert, 1999
Diethanolamine		1160		Amoore and Hautala, 1983
Ethylbenzene	Oily, solvent	9,990	10 to 78,300	Amoore and Hautala, 1983; van Gemert, 1999
Formaldehyde	Pungent	1,020	33 to 12,000,000	Amoore and Hautala, 1983; van Gemert, 1999
n-Hexane	Gasoline-like	458,000	107,000 to 875,000	Amoore and Hautala, 1983; van Gemert, 1999
Hydrogen sulphide[5]	Rotten eggs	14	0.06 to 5,000	AENV, 2005; van Gemert, 1999
Isopropylbenzene	Sharp, gasoline-like	430	17 to 6,400	Amoore and Hautala, 1983; van Gemert, 1999
Mercaptans	Sulphur, rotten cabbage	20	0.000000001 to 1,100	OMOE, 2005; van Gemert, 1999
Methylene chloride	Chloroform-like	869,000	730,000 to 1,530,000	Amoore and Hautala, 1983; van Gemert, 1999
Naphthalene	Tar, creosote, mothballs	440	7 to 5,340	Amoore and Hautala, 1983; van Gemert, 1999
Nitrogen dioxide	Bleach	400	110 to <9,400	AENV, 2005; van Gemert, 1999
Propylene oxide group	Benzene-like	104,500	24,000 to 473,000	Amoore and Hautala, 1983; van Gemert, 1999
Styrene	Sweet, sharp	1,360	12 to 258,000	Amoore and Hautala, 1983; van Gemert, 1999
Sulphur dioxide	Metallic taste, sharp irritating	2,880	870 to 21,000	Amoore and Hautala, 1983; van Gemert, 1999
Thiophene group	--	--	6 to 21,000	Van Gemert 1999
Toluene	Sour, burnt	10,900	80 to 1,000,000	Amoore and Hautala, 1983; van Gemert, 1999
Xylenes	Sweet	4,780	350 to 86,000	Amoore and Hautala, 1983; van Gemert, 1999

Notes:

1 The aliphatic C_5-C_8 group is based on n-hexane, aliphatic C_9-C_{16} group based on n-decane, aliphatic C_{17}-C_{34} group based on n-decane, aliphatic alcohol group based on methanol, aliphatic aldehyde group based on propionaldehyde, aliphatic ketone group based on methyl ethyl ketone, aromatic C_9-C_{16} group based on naphthalene, and the aromatic C_{17}-C_{34} group based on 3-methylcholanthrene.

2 The odour thresholds for the aliphatic C_9-C_{16} group, ammonia, carbon disulphide group, hydrogen sulphide, methyl mercaptan group and nitrogen dioxide are odour-based regulatory air quality guidelines for a 1-hour averaging period.

3 Sourced from AIHA (1989).

4 The AENV (2005) provides odour complaint levels for ammonia that range between 12,000 ug/m^3 and 14,000 ug/m^3.

5 The mean odour threshold for hydrogen sulphide appears to be based on a vegetation effects level, with an uncertainty factor of 10 applied (AENV 2004b).

-- no information available.

Concentration Ratios (CRs) are calculated according to the equation below to determine the ratio of the highest peak air concentration to the average odour threshold for a substance.

$$\mathbf{CR} = \frac{\textbf{Peak Air Concentration (3-min or 1 h)}}{\textbf{Mean Odour Threshold (3-min or 1 h)}}$$

CR ≤1	Signifies that the maximum predicted air concentration is less than or equal to the mean odour threshold and nuisance odours associated with that COPC are unlikely.
CR >1	Signifies the potential for individuals to detect odours associated with that COPC. The significance of these results must be further evaluated and balanced against the conservatism incorporated in the odour assessment.

The results are based on maximum predicted one-hour air concentrations or on three-minute “peak” concentrations. Odour assessments are typically based on peak concentrations, but the AENV and OMOE odour-based air quality guidelines and criteria are based on hourly averaging times; thus, the odour thresholds for these COPCs were compared with their predicted maximum one-hour air concentrations.

4.7 Human Health Impact Assessment and Mitigative Measures

This section describes the potential risks of the Project to human health. The findings of the acute and chronic assessments of the Baseline, Application and Cumulative cases are presented for each receptor group. The values in the tables represent the maximum for each chemical, for each group, of the combined RQ of background and development case (with the exception of the Project). Maximum background RQs for each group are presented in a separate column for comparison purposes. However, it should be noted that the maximum background level of a chemical may occur at a different location than the maximum combination of development case (Baseline, Application or Cumulative) plus background.

Each of the tables within this section has a separate column for the Project results, as background exposures have not been included in the Project risk estimates. The Baseline, Application and Cumulative risk estimates do include Background.

In the case of non-carcinogenic health risks, results are discussed in detail only for those COPCs presenting RQ estimates that exceed the benchmark of one. For carcinogenic health risks, results are discussed in detail only for those COPCs presenting ILCR estimates that exceed the regulatory benchmark of 1 in 100,000. Because no regulatory benchmark exists for acceptable background lifetime cancer risks, LCR estimates are not discussed in detail in the following sections. Instead, Appendix 4D provides additional detail on background carcinogenic health risks.

No health concerns among aboriginal stakeholders have been identified, nor is it expected that the project will impact traditional lifestyles. There are no First Nations within the 50 km x 50 km RSA.

4.7.1 Agricultural Receptor Group

4.7.1.1 Acute Inhalation Results for the Agricultural Group

Table 4.7-1 presents the RQ values for the acute effects assessment of the agricultural receptor group. Baseline, Application and Cumulative cases are presented with background RQs included in the value. RQ values in the Project column do not include background, and represent an assessment of the potential health effects of the Project emissions alone.

Table 4.7-1 Acute Inhalation RQ Values for the Agricultural Receptor

COPCs	Period	Background Maximum	Baseline	Application	Cumulative	Project
1,3-butadiene	1 h	9.9E-04	9.9E-04	3.8E-03	3.9E-03	3.7E-03
Acetaldehyde	1 h	7.0E-03	7.0E-03	7.0E-03	7.0E-03	2.0E-03
Acrolein	1 h	**2.0E+00**	**2.0E+00**	**2.0E+00**	**2.0E+00**	**1.3E+00**
Aliphatic alcohols group	1 h	2.4E-02	2.4E-02	2.4E-02	2.4E-02	2.0E-05
Aliphatic C_5-C_8 group	1 h	9.3E-04	1.3E-03	3.1E-03	4.9E-03	3.0E-03
Aliphatic C_9-C_{16} group	1 h	3.0E-03	3.0E-03	3.6E-03	5.2E-03	3.1E-03
Aliphatic ketones group	1 h	1.5E-04	1.5E-04	1.5E-04	1.5E-04	7.3E-05
Ammonia	1 h	1.3E-02	1.3E-02	1.3E-02	1.3E-02	0.0E+00
Aromatic C_9-C_{16} group	1 h	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.4E-03
Benzene	24 h	1.2E-01	1.2E-01	1.4E-01	1.9E-01	1.1E-01
Carbon disulphide group	1 h	8.5E-05	8.5E-05	1.7E-03	1.7E-03	1.7E-03
CO	1 h	1.5E-01	1.5E-01	1.5E-01	1.5E-01	5.5E-03
Cyclohexane	24 h	9.5E-06	1.4E-05	1.4E-05	5.9E-05	7.0E-06
Dichlorobenzenes	24 h	1.4E-05	1.4E-05	2.7E-05	2.7E-05	1.3E-05
Ethylbenzene	24 h	4.0E-04	4.0E-04	4.0E-04	4.9E-04	3.0E-04
Formaldehyde	1 h	5.8E-01	5.8E-01	5.8E-01	**1.4E+00**	5.1E-02
H_2S	1 h	3.9E-02	5.3E-02	3.3E-01	3.3E-01	3.1E-01
Hexane	24 h	1.4E-03	1.6E-03	5.0E-03	5.1E-03	4.8E-03
Methylene chloride	24 h	5.0E-04	5.0E-04	5.0E-04	5.0E-04	3.3E-13
Naphthalene	1 h	1.9E-04	1.9E-04	2.3E-04	2.3E-04	1.8E-04
NO_2	1 h	2.5E-01	2.5E-01	2.7E-01	2.8E-01	2.6E-01
NO_2	24 h	2.9E-01	2.9E-01	3.6E-01	3.8E-01	2.6E-01
PM	24 h	5.1E-01	5.2E-01	5.6E-01	7.9E-01	1.2E-01
Propylene oxide	1 h	3.8E-07	3.8E-07	9.1E-05	9.1E-05	9.1E-05
SO_2	10 min	3.4E-01	5.2E-01	7.5E-01	9.3E-01	6.6E-01
SO_2	1 h	2.7E-01	4.0E-01	5.8E-01	7.2E-01	5.1E-01
SO_2	24 h	3.3E-01	4.2E-01	6.2E-01	9.5E-01	4.6E-01
Styrene	1 h	3.9E-04	3.9E-04	3.9E-04	3.9E-04	1.7E-07
Toluene	1 h	4.0E-04	4.0E-04	4.0E-04	5.7E-04	3.2E-04
Xylenes	1 h	9.7E-04	9.7E-04	9.7E-04	1.8E-03	7.7E-04

Bold values represent exceedances of the exposure limit.

Acrolein and formaldehyde are the only COPCs that present an acute RQ value greater than one. All other RQ values are less than one, suggesting that the potential for acute health effects occurring at the agricultural locations is generally negligible.

Acrolein

The RQ values for acrolein are 2.0 in the Baseline, Application and Cumulative cases, and 1.3 in the Project case. The predicted Baseline and Application RQ values are being “driven” by existing levels of acrolein in the area (i.e., from ambient sources), given that these RQ values are identical to the RQ value of 2.0 for the maximum background RQ for this receptor group.

Table 4.7-2 summarizes the potential short-term effects of acrolein associated with various exposure levels.

Table 4.7-2 Potential Acute Effects of Acrolein Exposure

Exposure Concentration [(1)] (ug/m^3)	**Acute Health Effects**	**References**
138 (2) to 210	mild eye irritation (This study formed the basis of the acute inhalation exposure limit for acrolein of 0.29 ug/m^3)	Darley et al., 1960; Weberr-Tschopp et al., 1977
230 (3)	Lacrimation and irritation of the eyes, nose and throat	Fassett, 1962
350	Nasal irritation	Weber-Tschopp et al., 1977
700	decreased respiratory rate and throat irritation	Weber-Tschopp et al., 1977
350,000 (b)	lethality	Prentiss, 1937

Notes:

1 On an acute basis, the toxicity of acrolein is determined to a greater extent by the exposure concentration than by duration. As such, the air concentrations were not duration-adjusted. Unless stated otherwise, the air concentrations are based on a 1-hour exposure duration.

2 Air concentration is based on a 5-minute exposure duration.

3 Air Concentration is based on a 10-minute expsorue duration.

The California OEHHA (2000) identified a LOAEL for acrolein of 138 ug/m^3, based on the incidence of eye irritation in humans. The predicted RQ value of 2.0 corresponds to an approximate air concentration 0.6 ug/m^3, which is more than 200 times lower than the LOAEL.

Given the degree of conservatism incorporated into the exposure limit, and that the predicted exposures are much lower than the threshold at which adverse effects might be observed, adverse effects in association with acute acrolein exposures to individuals at the agricultural receptor locations are unlikely to occur.

Formaldehyde

The Cumulative Case acute RQ for formaldehyde is predicted to be 1.4 while the RQ value for the Project alone is much lower (0.051). There is no difference between the Background, Baseline and Application cases, suggesting that the Project will have a negligible impact on formaldehyde concentrations at the agricultural locations.

As discussed in Appendix 4A, the acute exposure limit for formaldehyde of 50 ug/m^3 is based on an effects level of 500 ug/m^3 observed in sensitized individuals. The exposure limit has a 10-fold uncertainty factor built into it. The limit is based on a two-hour exposure duration, suggesting that the level at which effects would be realized under a shorter duration may actually be higher. As a result, the acute risks predicted for the Cumulative Case could be overestimates of actual risks.

4.7.1.2 Chronic Inhalation Results for the Agricultural Group

Tables 4.7-3 and 4.7-4 present non-carcinogenic and carcinogenic risk estimates for the agricultural receptor group. In Table 4.7-3, Baseline, Application and Cumulative cases are presented with background RQs included in the value. RQ values in the Project column do not include Background, and represent an assessment of the potential health effects of the Project emissions alone. Table 4.7-4 presents LCR estimates for Background, Baseline with Background, Application with Background and Cumulative with Background. The ILCR estimates for the Project alone do not include Background.

Table 4.7-3 Chronic Inhalation RQ Values for the Agricultural Group

COPC	Period	Background	Baseline	Application	Cumulative	Project
2-chloronaphthalene	annual	5.1E-11	5.1E-11	5.1E-11	2.5E-09	0.0E+00
Acrolein	annual	**5.2E+01**	**5.2E+01**	**5.2E+01**	**5.2E+01**	4.0E-01
Aliphatic alcohols group	annual	5.2E-04	5.2E-04	5.2E-04	5.2E-04	5.4E-07
Aliphatic aldehydes group	annual	2.8E-05	2.8E-05	9.2E-05	9.5E-05	7.1E-05
Aliphatic C_{17}-C_{34} group	annual	1.3E-07	1.3E-07	4.1E-06	4.1E-06	4.0E-06
Aliphatic C_5-C_8 Group	annual	4.1E-04	4.7E-04	9.8E-04	1.7E-03	5.5E-04
Aliphatic C_9-C_{16} group	annual	9.9E-02	1.0E-01	1.0E-01	1.0E-01	1.2E-03
Aliphatic ketones group	annual	4.0E-04	4.0E-04	4.1E-04	4.1E-04	4.2E-06
Ammonia	annual	4.6E-03	4.6E-03	4.6E-03	5.5E-03	0.0E+00
Aromatic C_{17}-C_{34} group	annual	1.6E-06	1.6E-06	5.3E-06	5.3E-06	4.1E-06
Aromatic C_9-C_{16} Group	annual	6.5E-03	6.5E-03	8.5E-03	8.9E-03	2.1E-03
Benzaldehyde	annual	1.4E-05	1.5E-05	3.7E-05	4.3E-05	2.5E-05
Biphenyl	annual	0.0E+00	0.0E+00	7.1E-09	7.1E-09	7.1E-09
Carbon disulphide Group	annual	5.0E-03	5.0E-03	6.5E-03	6.6E-03	1.5E-03
Cyclohexane	annual	8.7E-04	8.8E-04	8.8E-04	9.2E-04	4.2E-06
Dichlorobenzenes	annual	4.8E-01	4.8E-01	4.8E-01	4.8E-01	2.6E-04
Diethanolamine	annual	0.0E+00	0.0E+00	1.7E-04	1.7E-04	1.7E-04
Ethylbenzene	annual	5.2E-03	5.2E-03	5.3E-03	5.3E-03	8.3E-05
H_2S	annual	8.6E-02	1.3E-01	5.3E-01	5.8E-01	4.1E-01
Hexane	annual	2.6E-03	2.7E-03	4.8E-03	5.1E-03	2.2E-03
Isopropylbenzene	annual	4.9E-06	4.9E-06	2.3E-05	2.5E-05	1.8E-05
Naphthalene	annual	1.4E-03	1.4E-03	4.8E-03	4.9E-03	3.6E-03
NO_2	annual	5.3E-02	6.3E-02	8.1E-02	1.8E-01	6.5E-03
PM	annual	5.9E-02	7.1E-02	9.5E-02	1.8E-01	3.3E-02
SO_2	annual	3.8E-02	9.8E-02	1.5E-01	3.3E-01	6.1E-02
Styrene	annual	6.0E-04	6.0E-04	6.0E-04	6.0E-04	1.2E-07
Toluene	annual	2.9E-03	2.9E-03	3.0E-03	3.0E-03	7.9E-05
Xylenes	annual	3.3E-02	3.3E-02	3.5E-02	3.8E-02	2.2E-03

Bold values represent exceedances of the exposure limit.

Table 4.7-4 Chronic Inhalation LCR and ILCR Estimates for the Agricultural Group

COPC	Background (LCR)	Baseline (LCR)	Application (LCR)	Cumulative (LCR)	Project (ILCR)
1,3-butadiene	7.5E-01	7.6E-01	9.6E-01	9.7E-01	2.7E-01
Acetaldehyde	1.3E+00	1.3E+00	1.3E+00	1.3E+00	5.6E-03
Benzene	3.9E+00	4.0E+00	4.1E+00	4.3E+00	1.4E-01
Benzo(a)pyrene WMM	6.1E-02	6.1E-02	1.9E-01	1.9E-01	1.2E-01
Benzo(a)pyrene IPM-TEQ	4.3E-03	4.3E-03	4.4E-03	4.4E-03	1.3E-04
Formaldehyde	3.9E+01	3.9E+01	3.9E+01	4.2E+01	1.0E-01
Methylene chloride	7.9E-01	7.9E-01	7.9E-01	7.9E-01	1.5E-12
Propylene oxide	2.1E-06	2.1E-06	3.0E-03	3.0E-03	2.9E-03
Regulatory Benchmark	*n/a*	*n/a*	*n/a*	*n/a*	*1 in 100,000*

Bold values represent exceedances of the exposure limit; n/a: not applicable.

The maximum predicted long-term RQ value for acrolein is 52 for the Baseline, Application and Cumulative cases. All other chronic RQ values are less than one, suggesting that the potential risk of long-term adverse health effects associated with inhalation of these COPCs is likely negligible.

None of the RQs are predicted to exceed one for the Project alone, suggesting that adverse non-carcinogenic health effects associated with the Project alone are anticipated to be negligible.

LCR estimates greater than one are predicted for acetaldehyde, benzene and formaldehyde as a result of chronic inhalation for the agricultural group, however, there is no regulatory benchmark for the interpretation of LCRs (Appendix 4D). All ILCR values are less than one, indicating that the risk of carcinogenicity due to inhalation of the Project emissions is essentially negligible.

The predicted risks to the agricultural group are discussed further below.

Acrolein

Given that the RQ for background concentrations of acrolein is the same as the RQ values for Baseline, Application and Cumulative (RQ = 52), existing ambient sources of acrolein (indoor and outdoor) appear to be driving the chronic risks for the agricultural locations. Most of the risk appears to be attributable to the background indoor air value used in the assessment, as the indoor air RQ is about 51 relative to the outdoor background RQ of 0.2. Due to the conservative estimates of indoor and outdoor air exposures to acrolein (Appendix 4D), the background concentrations included in the assessment are likely over-estimates of actual exposure levels.

The chronic exposure limit for acrolein is based on the incidence of non-cancerous nasal lesions in rats from a subchronic study. No long-term studies of the long-term effects of acrolein are available (U.S. EPA, 2003; WHO, 2002; Government of Canada, 2000; WHO IPCS, 1991), thus the true threshold of effects in humans on a long-term basis is unknown. As a result, studies have been based on acute human or acute and sub-chronic animal exposures. Through the application of uncertainty factors in the derivation of the exposure limit, the effect-threshold for nasal lesions in rats has been adjusted such that the estimated human threshold is about 1,000-times lower than in rats. As such, the true risk of experiencing adverse nasal irritation as a result of current background exposures is likely much less than predicted. Appendix 4A provides additional information regarding the chronic acrolein exposure limit.

The background risk for acrolein for the agricultural, residential and industrial groups is primarily due to the use of an indoor air concentration of 1.3 ug/m^3 in the exposure assessment (obtained from Gilbert et al., 2005). This value is based on 59 indoor air samples collected from Canadian cities.

The background outdoor air concentration used for all of the receptor groups represented the highest concentrations for those groups in association with existing sources of acrolein in the area.

Table 4.7-5 presents a summary of acrolein indoor air concentrations measured at locations across North America and Japan, along with their associated RQ values (assuming the same exposure limit of 0.02 ug/m^3 used in the HHRA).

Table 4.7-5 Mean Acrolein Concentrations Measured in Indoor Air and Associated Risk Quotients

Location	Air Concentration (ug/m^3)	Number of Residences Evaluated	Risk Quotient
Hamilton, Ontario	1.1	11	55
Windsor, Ontario	3.0	29	150
Los Angeles, California	1.2	134	60
Elizabeth, New Jersey	0.96	139	48
Houston, Texas	3.1	125	155
Japan	8.3	1,417	415

The chronic risks predicted for the agricultural residents in the area surrounding the Project appear to be less than those estimated in other parts of Canada and the world.

Acetaldehyde

No change was evident between the LCR values for Baseline, Application and Cumulative cases. The exposure level in this assessment for background acetaldehyde represents both background indoor and outdoor exposures, and is dominated by indoor air exposure. As there is negligible change between the development cases, future sources in the area are not anticipated to increased health risks associated with acetaldehyde. Appendix 4D provides additional information.

Benzene

Benzene presented LCR values of 4.0, 4.1 and 4.3 for the Baseline, Application and Cumulative cases, respectively. Estimated background exposures to benzene appear to contribute the most risk. Potential future sources included in the Baseline and Application cases contribute a small change above background levels. Appendix 4D provides further interpretation of background risks.

Formaldehyde

Baseline and Application LCR values were both predicted to be 39, with a slight increase to 42 in the Cumulative Case. Background formaldehyde exposures for the agricultural group were associated with an LCR of 39, suggesting the existing sources contribute the most risk with only slight increases being associated with developments included in the Baseline and Application cases. These estimated background exposures were dominated by indoor air exposure, given that the LCR for indoor air is 37 compared to 2.4 for outdoor air. Appendix 4D provides further interpretation of background risks.

As discussed in Appendix 4D, although formaldehyde is recognized as a human carcinogen (IARC, 2006), the majority of the evidence appears to be from animal studies with high exposure levels and from epidemiologic (occupational) case control studies. There is some controversy over whether carcinogenicity is the critical effect of formaldehyde exposures.

4.7.1.3 Chronic Multi-Pathway Results for the Agricultural Group

Tables 4.7-6 and 4.7-7 summarize the potential non-carcinogenic RQ values, and LCR and ILCR values for the agricultural receptor as a result of multiple routes of exposure. Background risks are provided for comparison purposes. The Baseline and Application values include background exposures, while the Project does not.

Table 4.7-6 Chronic Multi-Pathway Assessment RQ Values for the Agricultural Receptor Group (Dermal contact and ingestion only)*

COPCs	Background	Baseline	Application	Cumulative	Project
Aliphatic C_{17}-C_{34}	2.7E-05	2.7E-05	1.9E-04	1.9E-04	1.7E-04
Aliphatic C_5-C_8	2.4E-09	3.3E-09	1.1E-08	2.1E-08	7.9E-09
Aliphatic C_9-C_{16}	3.7E-05	5.1E-05	7.8E-05	1.4E-04	3.2E-05
Aromatic C_{17}-C_{34}	8.9E-04	9.1E-04	1.1E-03	1.4E-03	5.5E-05
Aromatic C_9-C_{16}	2.5E-05	2.5E-05	4.7E-05	5.2E-05	2.2E-05
Biphenyl	4.7E-07	4.7E-07	5.6E-07	5.7E-07	4.8E-08

*Dust inhalation was considered to be an oral exposure.

All RQ values for the agricultural receptor are less than one, suggesting that the health risks associated with long-term multi-media exposure to the non-carcinogenic substances are negligible.

Table 4.7-7 Chronic Multi-Pathway Assessment LCR and ILCR Values for the Agricultural Receptor Group

COPCs	Background	Baseline (LCR)	Application (LCR)	Cumulative (LCR)	Project (ILCR)
Benzo(a)pyrene (WMM)	2.6E-02	2.6E-02	3.6E-02	3.7E-02	1.1E-02
Benzo(a)pyrene IPM-TEQ	1.1E-01	1.1E-01	5.2E-01	5.3E-01	1.2E-03
Regulatory Benchmark	*n/a*	*n/a*	*n/a*	*n/a*	*1 in 100,000*

The multi-media LCR values for the Baseline and Application cases for both benzo(a)pyrene WMM and benzo(a)pyrene IPM-TEQ are less than 1 in 100,000. The ILCR associated with the emissions of the Project is associated with an essentially negligible level of cancer risk from the carcinogenic PAH mixture.

4.7.2 Residential Receptor Group

4.7.2.1 Acute Inhalation Results for the Residential Group

Table 4.7-8 presents the RQ values for the acute effects assessment of the residential receptor group. Baseline, Application and Cumulative cases are presented with background RQs included in the value. RQ values in the Project column do not include background, and represent an assessment of the potential health effects of the Project emissions alone.

Table 4.7-8 Acute Inhalation RQ Values for the Residential Receptor

COPCs	Period	Background	Baseline	Application	Cumulative	Project
1,3-butadiene	1 h	9.9E-04	1.0E-03	1.0E-03	1.0E-03	6.8E-04
Acetaldehyde	1 h	7.1E-03	7.1E-03	7.1E-03	7.1E-03	2.4E-04
Acrolein	1 h	**2.1E+00**	**2.1E+00**	**2.1E+00**	**2.1E+00**	1.5E-01
Aliphatic alcohols group	1 h	2.4E-02	2.4E-02	2.4E-02	2.4E-02	2.1E-06
Aliphatic C_5-C_8 group	1 h	4.2E-04	4.2E-04	4.9E-04	7.9E-04	3.8E-04
Aliphatic C_9-C_{16} group	1 h	3.2E-03	3.2E-03	3.2E-03	5.5E-03	2.8E-04
Aliphatic ketones group	1 h	1.6E-04	1.6E-04	1.6E-04	1.6E-04	9.5E-06
Ammonia	1 h	7.9E-03	7.9E-03	7.9E-03	7.9E-03	0.0E+00
Aromatic C_9-C_{16} group	1 h	1.7E-03	1.7E-03	1.7E-03	1.7E-03	2.3E-04
Benzene	24 h	8.7E-02	8.7E-02	8.7E-02	8.7E-02	9.8E-03
Carbon disulphide group	1 h	4.7E-05	4.7E-05	4.7E-04	4.8E-04	4.7E-04
CO	1 h	1.6E-01	1.6E-01	1.6E-01	1.6E-01	1.0E-03
CO	8 h	3.7E-01	3.7E-01	3.7E-01	3.7E-01	1.8E-03
Cyclohexane	24 h	6.0E-06	6.6E-06	6.7E-06	1.0E-05	3.5E-07
Dichlorobenzenes	24 h	1.4E-05	1.4E-05	1.7E-05	1.7E-05	2.7E-06
Ethylbenzene	24 h	2.1E-04	2.1E-04	2.1E-04	2.1E-04	2.1E-05
Formaldehyde	1 h	5.8E-01	5.8E-01	5.8E-01	6.0E-01	7.3E-03
H_2S	1 h	3.5E-02	3.6E-02	6.9E-02	7.1E-02	4.6E-02
Hexane	24 h	9.2E-04	9.2E-04	1.1E-03	1.2E-03	5.0E-04
methylene chloride	24 h	5.0E-04	5.0E-04	5.0E-04	5.0E-04	2.4E-14
Naphthalene	1 h	2.0E-04	2.0E-04	2.0E-04	2.0E-04	3.7E-05
NO_2	1 h	2.9E-01	2.9E-01	2.9E-01	2.9E-01	7.2E-02
NO_2	24 h	4.0E-01	4.0E-01	4.0E-01	4.1E-01	5.3E-02
PM	24 h	6.8E-01	7.0E-01	7.0E-01	7.5E-01	4.4E-02
propylene oxide	1 h	1.9E-07	1.9E-07	8.5E-06	8.7E-06	8.5E-06
SO_2	10 min	1.9E-01	2.3E-01	4.3E-01	6.4E-01	2.5E-01
SO_2	1 h	1.5E-01	1.8E-01	3.3E-01	5.0E-01	1.9E-01
SO_2	24 h	1.5E-01	2.2E-01	3.3E-01	7.1E-01	2.0E-01
Styrene	1 h	4.6E-05	4.6E-05	4.6E-05	4.6E-05	1.6E-08
Toluene	1 h	4.2E-04	4.2E-04	4.2E-04	4.2E-04	3.7E-05
Xylenes	1 h	1.0E-03	1.0E-03	1.0E-03	1.0E-03	7.5E-05

Bold values represent exceedances of the exposure limit.

Acrolein is the only COPC with an RQ value greater than one. All other RQ values are less than one, suggesting that the risk of acute health risks to individuals in residential communities is negligible for those COPCs.

Acrolein

Hourly acrolein air concentrations are associated with a maximum RQ of 2.1 at the residential receptor locations for the Baseline, Application and Cumulative cases. Short-term health risks appear to be due to the assumed background levels of acrolein assumed for the residential locations. For the reasons outlined in Section 4.6.1.1, the background acrolein concentrations are considered to be conservative estimates of actual acrolein concentrations in the area.

Given the degree of conservatism incorporated into the exposure limit, and that the predicted exposures are much lower than the threshold at which adverse effects might be observed, adverse effects in association with acute acrolein exposures to individuals at the residential locations are unlikely to occur.

4.7.2.2 Chronic Inhalation Results for the Residential Group

Tables 4.7-9 and 4.7-10 present the risk estimates for the non-carcinogenic and carcinogenic COPCs, respectively.

Baseline, Application and Cumulative values include background, while Project values represent the Project emissions alone. In Table 4.7-10, cancer risks are expressed as LCR for the background case as well as the Baseline, Application and Cumulative cases, while the Project risks are expressed as ILCR estimates.

Table 4.7-9 Chronic Inhalation RQ Values for the Residential Receptor

COPCs	Period	Background	Baseline	Application	Cumulative	Project
2-chloronaphthalene	annual	1.2E-11	1.2E-11	1.2E-11	1.8E-09	0.0E+00
Acrolein	annual	**6.1E+01**	**6.1E+01**	**6.1E+01**	**6.1E+01**	7.0E-02
Aliphatic alcohols group	annual	1.6E-04	1.6E-04	1.6E-04	1.6E-04	5.2E-08
Aliphatic aldehydes group	annual	9.3E-06	9.3E-06	1.8E-05	2.1E-05	1.1E-05
Aliphatic C_{17}-C_{34} group	annual	4.5E-08	4.5E-08	4.4E-07	4.4E-07	4.0E-07
Aliphatic C_5-C_8 Group	annual	4.5E-04	4.6E-04	5.3E-04	6.2E-04	6.6E-05
Aliphatic C_9-C_{16} group	annual	1.2E-01	1.2E-01	1.2E-01	1.2E-01	1.1E-04
Aliphatic ketones group	annual	4.8E-04	4.8E-04	4.8E-04	4.8E-04	6.8E-07
Ammonia	annual	9.2E-04	9.2E-04	9.2E-04	1.2E-03	0.0E+00
Aromatic C_{17}-C_{34} group	annual	5.4E-07	5.4E-07	1.1E-06	1.1E-06	6.7E-07
Aromatic C_9-C_{16} group	annual	7.2E-03	7.2E-03	7.5E-03	7.8E-03	3.2E-04
Benzaldehyde	annual	4.6E-06	4.7E-06	8.5E-06	1.3E-05	4.4E-06
Biphenyl	annual	0.0E+00	0.0E+00	8.7E-10	8.7E-10	8.7E-10
Carbon disulphide group	annual	5.9E-03	5.9E-03	6.6E-03	6.6E-03	6.6E-04
Cyclohexane	annual	1.0E-03	1.0E-03	1.0E-03	1.0E-03	3.0E-07
Dichlorobenzenes	annual	5.6E-01	5.6E-01	5.6E-01	5.6E-01	3.6E-05
Diethanolamine	annual	0.0E+00	0.0E+00	2.4E-05	2.4E-05	2.4E-05
Ethylbenzene	annual	6.1E-03	6.1E-03	6.1E-03	6.1E-03	7.1E-06
H_2S	annual	2.5E-02	4.3E-02	1.2E-01	1.5E-01	8.0E-02
Hexane	annual	2.9E-03	2.9E-03	3.2E-03	3.4E-03	2.8E-04
Isopropylbenzene	annual	1.5E-06	1.5E-06	3.0E-06	4.2E-06	1.5E-06
Naphthalene	annual	8.5E-04	8.6E-04	1.8E-03	1.8E-03	9.8E-04
NO_2	annual	1.6E-02	2.1E-02	3.9E-02	9.2E-02	1.2E-02
PM	annual	1.8E-02	2.5E-02	4.7E-02	1.2E-01	1.5E-02
SO_2	annual	6.0E-03	5.1E-02	7.8E-02	2.1E-01	2.7E-02
Styrene	annual	6.6E-04	6.6E-04	6.6E-04	6.6E-04	1.0E-08
Toluene	annual	3.4E-03	3.4E-03	3.4E-03	3.41E-03	9.7E-06
Xylenes	annual	3.9E-02	3.9E-02	3.9E-02	3.93E-02	2.1E-04

Bold values represent exceedances of the exposure limit.

Table 4.7-10 Chronic Inhalation LCR and ILCR Values for the Residential Receptor

COPCs	Period	Background	Baseline (LCR)	Application (LCR)	Cumulative (LCR)	Project (ILCR)
1,3-butadiene	annual	8.5E-01	9.2E-01	9.3E-01	9.4E-01	5.5E-02
acetaldehyde	annual	1.5E+00	1.5E+00	1.5E+00	1.5E+00	8.8E-04
Benzene	annual	4.6E+00	4.6E+00	4.6E+00	4.7E+00	1.8E-02
benzo(a)pyrene	annual	1.8E-02	1.8E-02	5.4E-02	5.8E-02	3.6E-02
Benzo(a)pyrene IPM-TEQ	annual	5.1E-03	5.1E-03	5.1E-03	5.1E-03	3.6E-05
formaldehyde	annual	4.5E+01	4.5E+01	4.5E+01	4.5E+01	2.5E-02
methylene chloride	annual	9.3E-01	9.3E-01	9.3E-01	9.3E-01	2.7E-13
propylene oxide	annual	4.9E-07	4.9E-07	2.6E-04	3.4E-04	2.6E-04
Regulatory Benchmark		*n/a*	*n/a*	*n/a*	*n/a*	*1 in 100,000*

Bold values represent exceedances of the exposure limit, n/a: not applicable.

Acrolein is the only COPC with a chronic RQ value above one. All other COPCs are associated with RQ values less than one, suggesting that the potential health risks to residential receptors from chronic inhalation of these substances are minimal.

All RQ values associated with the Project alone are less than one, indicating that the Project is expected to have a negligible impact on health.

The LCR estimates exceed one for acetaldehyde, benzene and formaldehyde, while none of the ICLR estimates exceed one, indicating that the Project-attributable cancer risk is essentially negligible. There is no clear regulatory benchmark for the interpretation of LCRs values, background cancer risks are described in more detail in Appendix 4D.

Acrolein

Predicted annual acrolein air concentrations are associated with a maximum RQ of 61 at the residential receptor locations for the Background, Baseline, Application and Cumulative cases. Long-term health risks appear to be due to the assumed indoor air concentrations of acrolein at the residential locations, as the background RQ for this receptor was about 61 compared to 0.07 for outdoor air. The Project's acrolein emissions are not expected to have an appreciable impact on background health risks.

As described in Section 4.6.1.2, given the degree of conservatism incorporated into the exposure limit and that the chronic risks to the residential receptors are similar to those estimated in other parts of Canada, adverse effects due to chronic inhalation of acrolein are not expected.

Acetaldehyde

There was no apparent change between the Background, Baseline, Application, and Cumulative cases for the residential receptor. Background exposures contribute the risk to the development cases, and the exposure level in this assessment for background acetaldehyde represents both background indoor and outdoor exposures, and is dominated by indoor air exposure (LCR for indoor air is about 1.2 compared to 0.1 for outdoor air). Appendix 4D provides additional information.

Benzene

The LCR values for Baseline and Application were both 4.6, and a slight increase to 4.7 was observed in the Cumulative Case. Estimated background exposures to benzene appear to contribute the most risk, as the background LCR for the residential group is also 4.6. Similar to the agricultural receptor, indoor air appears to contribute the most risk. Potential future sources included in the Cumulative Case appear to contribute some additional risk. Appendix 4D provides additional information.

Formaldehyde

No change was apparent in the Baseline, Application and Cumulative values. Existing sources contribute the most risk with negligible increases being associated with future developments. Appendix 4D provides additional information.

4.7.2.3 Chronic Multi-Pathway Results for the Residential Group

Tables 4.7-11 and 4.7-12 summarize the potential non-carcinogenic and carcinogenic risks associated with multiple routes of exposure.

Table 4.7-11 Chronic Multi-Pathway RQ Values for the Residential Receptor Group

COPC	Background	Baseline	Application	Cumulative	Project
Aliphatic C_{17}-C_{34}	8.6E-07	8.6E-07	1.7E-06	1.7E-06	8.7E-07
Aliphatic C_5-C_8	2.9E-11	4.4E-11	5.8E-11	1.0E-10	2.4E-11
Aliphatic C_9-C_{16}	8.2E-07	9.5E-07	9.9E-07	4.2E-06	1.3E-07
Aromatic C_{17}-C_{34}	3.9E-04	4.0E-04	4.7E-04	6.2E-04	2.8E-07
Aromatic C_9-C_{16}	4.4E-07	4.4E-07	5.2E-07	5.7E-07	7.8E-08
Biphenyl	2.4E-07	2.4E-07	2.6E-07	2.6E-07	7.8E-11

All RQ values are less than one for the residential receptor group, indicating that the health risks associated with long-term multi-media exposure to the non-carcinogenic COPCs are negligible.

Table 4.7-12 Chronic Multi-Pathway LCR and ILCR Values for the Residential Receptor Group

COPC	Background (LCR)	Baseline (LCR)	Application (LCR)	Cumulative (LCR)	Project (ILCR)
Benzo(a)pyrene (WMM)	1.7E-03	1.7E-03	2.0E-03	2.0E-03	2.2E-04
Benzo(a)pyrene IPM-TEQ	7.0E-03	7.0E-03	1.2E-02	1.2E-02	4.7E-03
Regulatory Benchmark	*n/a*	*n/a*	*n/a*	*n/a*	*1 in 100,000*

n/a: not applicable.

The multi-media LCR values for the Baseline, Application and Cumulative cases are all less than one. Further, the ILCR for the Project alone is associated with an essentially negligible level of cancer risk for the carcinogenic COPCs (i.e., less than 1 in 100,000).

4.7.3 Industrial Receptor Group

4.7.3.1 Acute Inhalation Results for the Industrial Group

Table 4.7-13 summarizes the acute RQ values for the COPCs for the Baseline, Application, Cumulative and Project cases. Maximum background RQ values are provided for comparison purposes. The values for Baseline, Application and Cumulative cases include Background, while the Project RQ values only represent Project emissions.

Table 4.7-13 Acute Inhalation RQ Values for the Industrial Receptors

COPC	Period	Background	Baseline	Application	Cumulative	Project
1,3-butadiene	1 h	8.7E-04	8.7E-04	6.0E-03	6.0E-03	6.0E-03
Acetaldehyde	1 h	6.6E-03	6.6E-03	6.6E-03	6.6E-03	1.7E-03
Acrolein	1 h	**1.8E+00**	**1.8E+00**	**1.8E+00**	**1.8E+00**	**1.1E+00**
Aliphatic alcohols group	1 h	2.4E-02	2.4E-02	2.4E-02	2.5E-02	1.2E-05
Aliphatic C_5-C_8 group	1 h	6.0E-03	6.7E-03	6.8E-03	7.7E-03	2.6E-03
Aliphatic C_9-C_{16} group	1 h	5.9E-03	8.2E-03	8.3E-03	5.2E-02	3.7E-03
Aliphatic ketones group	1 h	1.4E-04	1.4E-04	1.4E-04	7.4E-04	7.8E-05
Ammonia	1 h	6.1E-02	6.1E-02	6.1E-02	6.1E-02	0.0E+00
Aromatic C_9-C_{16} group	1 h	1.5E-03	1.5E-03	1.5E-03	4.5E-03	8.0E-04
Benzene	24 h	1.6E-01	1.7E-01	1.7E-01	2.4E-01	7.4E-02
Carbon disulphide group	1 h	9.0E-05	9.3E-05	2.3E-03	2.3E-03	2.3E-03
CO	1 h	1.4E-01	1.4E-01	1.4E-01	1.4E-01	5.9E-03
CO	8 h	2.5E-01	2.5E-01	2.5E-01	2.5E-01	2.6E-03
cyclohexane	24 h	5.5E-05	7.7E-05	7.7E-05	8.6E-05	1.8E-06
Dichlorobenzenes	24 h	1.4E-05	1.4E-05	3.1E-05	3.1E-05	1.7E-05
Ethylbenzene	24 h	4.2E-04	5.8E-04	5.9E-04	1.9E-03	8.8E-05
Formaldehyde	1 h	5.6E-01	5.7E-01	5.7E-01	**1.2E+00**	4.9E-02
H_2S	1 h	1.4E-01	1.4E-01	4.1E-01	4.1E-01	
Hexane	24 h	6.4E-03	8.4E-03	8.5E-03	8.6E-03	2.7E-03
Methylene chloride	24 h	5.0E-04	5.0E-04	5.0E-04	5.0E-04	4.8E-13
Naphthalene	1 h	4.6E-04	4.6E-04	4.6E-04	4.6E-04	2.9E-04
NO_2	1 h	3.0E-01	3.0E-01	3.0E-01	3.3E-01	2.3E-01
NO_2	24 h	4.2E-01	4.2E-01	4.2E-01	4.3E-01	2.0E-01
PM	24 h	5.5E-01	6.1E-01	6.3E-01	8.0E-01	1.3E-01
Propylene oxide	1 h	5.4E-07	5.4E-07	5.2E-05	5.2E-05	5.2E-05
SO_2	10-min	**2.4E+00**	**2.4E+00**	**2.4E+00**	**2.5E+00**	9.1E-01
SO_2	1 h	**1.9E+00**	**1.9E+00**	**1.9E+00**	**1.9E+00**	7.0E-01
SO_2	24 h	**1.3E+00**	**1.6E+00**	**1.6E+00**	**1.6E+00**	6.2E-01
Styrene	1 h	6.7E-04	6.7E-04	6.7E-04	6.7E-04	1.0E-07
Toluene	1 h	5.6E-04	5.7E-04	5.7E-04	1.5E-03	2.8E-04
Xylenes	1 h	2.9E-03	2.9E-03	2.9E-03	3.1E-03	4.8E-04

Bold values represent exceedances of the exposure limit.

Acrolein, formaldehyde and sulphur dioxide are the only COPCs with predicted RQ values greater than one for the industrial group. The RQ values for all other COPCs are less than one, suggesting that the potential for acute health effects at the industrial locations is generally negligible.

Acrolein

Predicted acrolein exposures are associated with an RQ value of 1.8 for both the Baseline and Application cases for the industrial group. Given that the background RQ for acrolein is also 1.8, existing sources of acrolein appear to be contributing the most risk, with negligible amounts being contributed by future sources included in the Baseline and Application cases.

For the reasons outlined in Section 4.6.1.1, the background acrolein concentrations are considered to be conservative estimates of actual acrolein concentrations in the area. Given the degree of conservatism incorporated into the exposure limit, and that the predicted exposures are much lower than the threshold at which adverse effects might be observed, adverse effects in association with acute acrolein exposures to individuals at the industrial locations are unlikely to occur.

Formaldehyde

The Cumulative Case acute RQ for formaldehyde is predicted to be 1.2 while the RQ value for the Project alone is much lower (0.049). There is no difference between the Background, Baseline and Application cases (RQ 0.57), suggesting that the Project will have a negligible impact on formaldehyde concentrations at the industrial locations.

For reasons presented in Section 4.6.1.1, the acute risks predicted for the Cumulative Case are expected to be overestimates of actual risks to formaldehyde.

Sulphur Dioxide

Sulphur dioxide is associated with RQ values of 2.4, 1.9 and 1.6 on a 10-minute, 1-hour and 24-hour basis, respectively for the Baseline, Application and Cumulative cases. These RQ values are associated with air concentrations of 1,218 ug/m^3 (10-minute), 851 ug/m^3 (1-hour) and 240 ug/m^3 (24-hour). As shown in Table 4.7-11, the differences in the acute risks between the Background, Baseline and Application cases are generally negligible, suggesting that the Project's sulphur dioxide emissions will not add appreciably to acute health risks to the industrial receptor group.

In clinical studies (ATSDR, 1998; Environment Canada, 1987; Linn et al., 1983; UK Department of Health, 1995), clear respiratory responses have not been observed in healthy individuals exposed to brief periods of concentrations of SO_2 less than 2,000 ug/m^3 to 2,600 ug/m^3. At a concentration of 1,300 ug/m^3, non-exercising asthmatics displayed a similar lack of respiratory response (Linn et al., 1983; Sheppard et al., 1981). The maximum predicted SO_2 concentrations for the industrial receptor group fall inside the range of air concentrations wherein mild effects may be realized in the most sensitive individuals (Table 4.7-14). All three of these predicted concentrations are below the range of 2,000 ug/m^3 to 2,600 ug/m^3 discussed above.

Table 4.7-14 Summary of the Potential Short-term Health Effects of Sulphur Dioxide

Air Concentration (ug/m^3)	Description of Potential Health Effects
530 to 1,300	Increased airway resistance and potential bronchoconstriction in asthmatic or sensitive individuals engaged in moderate exercise, but typically no effect on lung function in normal individuals.
1,300 to 2,600	Increased resistance in airways and difficulties breathing may be experienced by normal individuals (in addition to asthmatics and sensitive individuals). Sore throat and the ability to taste and smell SO_2 may also be apparent. Effects in asthmatics and other sensitive individuals may also include wheezing, dyspnea, and bronchoconstriction.
2,600 to 13,000	Odour is detectable. Increased resistance in airways, decreased lung volume, reduced bronchial clearance and evidence of lung irritation (increased macrophages in lung fluid) have been observed at this exposure level. Headache, coughing, throat irritation, nasal congestion, increased salivation may be evident, and some symptoms may persist for several days after exposure. Mucociliary transport in the nasal passages may also be impaired, potentially leading to nasal congestion. Respiratory effects may be more severe in asthmatics and sensitive individuals.
13,000 to 26,000	Increased resistance in airways, decreased respiratory volume, difficulties breathing and lung irritation have been reported at this exposure level. Nasal, throat and eye irritation, nosebleeds, coughing, potentially accompanied by erythema of trachea and bronchi may occur. Respiratory effects may be more severe in asthmatics and sensitive individuals.
26,000 to 130,000	Symptoms of more severe respiratory irritation may appear, such as burning of nose and throat, sneezing, severe airway obstruction, choking, and dyspnea. Exposure may result in damage to airway epithelium that may progress to epithelial hyperplasia, an increased number of secretory goblet cells, and hypertrophy of the sub-mucousal glands. A condition known as Reactive Airway Dysfunction Syndrome may arise in the concentration ranges (as well as above) as a result of bronchial epithelial damage. Chronic respiratory effects may develop. Eye irritation, watery eyes, and skin eruptions (rashes) may be evident. Respiratory effects may be more severe in asthmatics and sensitive individuals.
130,000 to 260,000	Symptoms of severe respiratory irritation may occur, such as bronchitis, intolerable irritation of mucous membranes in addition to other effects described above, such as decreased lung capacity and breathing difficulties, runny nose, eye and skin irritation.
>260,000	Immediately dangerous to life and health. Chemical bronchopneumonia and asphyxia have been reported at high levels of exposure. Death may result from severe respiratory depression at concentrations of approximately 2,600,000 ug/m^3.

Sources: NIOSH (1974); WHO (1979); ATSDR (1998); HSDB (2007); California EPA (1999); WHO (2000)

AHW recently evaluated the potential health effects associated with short-term SO_2 exposures. Based upon a review of human clinical evidence, AHW (2006) concluded that healthy individuals may be exposed to concentrations up to 26,000 ug/m^3 (10 ppm) with transitory effects on pulmonary function, even under extreme conditions involving hyperventilation, mouth-only exposure and heavy exercise.

AHW (2006) also states that:

> *The weight of evidence suggests that for single exposures up to four hours and repeated exposures between three days and three weeks, transitory pulmonary effects might occur for asthmatics at exposure concentrations between 0.5 ppm [1,300 $ug/m^{3]}$ and 1 ppm [2,600 ug/m^3] with exercise and for healthy humans between 0.75 ppm [1,950 ug/m^3] and 25 ppm [65,000 ug/m^3] with exercise, with some evidence for a concentration-dependent response in healthy subjects.*

The maximum predicted SO_2 concentrations are on the low end of the range where health effects have been noted in exercising asthmatics. However, the predicted RQ values should be considered conservative estimates of actual risks, bearing in mind that these locations are industrial settings. The American Conference of Governmental Industrial Hygienists (ACGIH) lists occupational limits for SO_2 as 5,200 ug/m^3 for a time weighted average (TWA) and 13,000 ug/m^3 for a Short-Term Exposure Limit (STEL). ACGIH (2004) describes a TWA as a “concentration for a conventional 8-hour workday and 40-hour workweek to which it is believed that nearly all workers may be repeatedly exposed, day after day, for a working lifetime without adverse effect”. ACGIH further describes a STEL as a “15-minute TWA exposure … to which it is believed that workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage …” Both the TWA and STEL limits are considerably greater than the predicted SO_2 air concentrations.

When compared against occupational limits and in light of the information presented in AHW’s recent review, the predicted short-term SO_2 concentrations are not expected to result in adverse health effects to the industrial receptor group.

4.7.3.2 Chronic Inhalation Results for the Industrial Receptors

Tables 4.7-15 and 4.7-16 below present the RQ, LCR and ILCR values for the four development cases. Only the Baseline, Application and Cumulative values include background while the Project values represent the risks associated with the Project emissions alone.

Table 4.7-15 Chronic Inhalation RQ Values for the Industrial Receptor Group

COPC	Period	Background	Baseline	Application	Cumulative	Project
2-chloronaphthalene	annual	7.7E-11	7.7E-11	7.7E-11	4.3E-09	0.0E+00
Acrolein	annual	**4.4E+01**	**4.4E+01**	**4.4E+01**	**4.4E+01**	5.1E-01
Aliphatic alcohols group	annual	8.3E-04	8.3E-04	8.3E-04	9.6E-04	3.2E-07
Aliphatic aldehydes group	annual	3.6E-05	3.6E-05	1.3E-04	3.2E-04	9.8E-05
Aliphatic C_{17}-C_{34} group	annual	1.7E-07	1.7E-07	2.5E-06	2.5E-06	2.3E-06
Aliphatic C_5-C_8 Group	annual	6.1E-04	6.8E-04	8.4E-04	2.3E-03	4.7E-04
Aliphatic C_9-C_{16} group	annual	8.4E-02	8.8E-02	8.8E-02	1.4E-01	1.5E-03
Aliphatic ketones group	annual	3.4E-04	3.4E-04	3.5E-04	5.0E-04	6.4E-06
Ammonia	annual	2.4E-02	2.4E-02	2.4E-02	2.6E-02	0.0E+00
Aromatic C_{17}-C_{34} group	annual	2.1E-06	2.1E-06	7.4E-06	7.4E-06	5.4E-06
Aromatic C_9-C_{16} group	annual	5.9E-03	5.9E-03	6.9E-03	1.3E-02	1.3E-03
Benzaldehyde	annual	2.0E-05	2.1E-05	5.0E-05	5.7E-05	3.2E-05
Biphenyl	annual	0.0E+00	0.0E+00	6.0E-09	6.0E-09	6.0E-09
Carbon disulphide group	annual	4.3E-03	4.3E-03	7.0E-03	1.1E-02	2.7E-03
Cyclohexane	annual	7.5E-04	7.5E-04	7.6E-04	7.8E-04	1.7E-06
Dichlorobenzenes	annual	4.0E-01	4.0E-01	4.0E-01	4.0E-01	2.7E-04
Diethanolamine	annual	0.0E+00	0.0E+00	2.2E-04	2.2E-04	2.2E-04
Ethylbenzene	annual	4.4E-03	4.5E-03	4.5E-03	5.7E-03	4.5E-05
H_2S	annual	2.2E-01	4.0E-01	8.5E-01	8.9E-01	6.9E-01
Hexane	annual	3.7E-03	3.9E-03	4.1E-03	4.9E-03	1.9E-03
Isopropylbenzene	annual	7.9E-06	7.9E-06	1.6E-05	2.5E-04	8.4E-06
Naphthalene	annual	8.4E-03	8.4E-03	9.0E-03	9.2E-03	4.6E-03
NO_2	annual	8.5E-02	9.8E-02	1.2E-01	2.0E-01	1.1E-02
PM	annual	1.1E-01	1.3E-01	1.5E-01	2.2E-01	5.5E-02
SO_2	annual	8.3E-02	1.5E-01	1.6E-01	4.0E-01	6.1E-02
Styrene	annual	5.4E-04	5.4E-04	5.4E-04	5.4E-04	5.8E-08
Toluene	annual	2.5E-03	2.5E-03	2.5E-03	3.4E-03	7.8E-05
Xylenes	annual	3.4E-02	3.4E-02	3.4E-02	5.0E-02	1.4E-03

Bold values represent exceedances of the exposure limit.

Table 4.7-16 Chronic Inhalation LCR and ILCR Values for the Industrial Receptor Group

COPC	Period	Background (LCR)	Baseline (LCR)	Application (LCR)	Cumulative (LCR)	Project (ILCR)
1,3-butadiene	annual	**1.2E+00**	**1.2E+00**	**1.2E+00**	**1.2E+00**	5.9E-01
Acetaldehyde	annual	1.2E+00	1.2E+00	1.2E+00	1.2E+00	6.8E-03
Benzene	annual	3.5E+00	3.5E+00	3.5E+00	3.8E+00	1.7E-01
Benzo(a)pyrene WMM	annual	1.1E-01	1.1E-01	2.5E-01	2.6E-01	1.6E-01
Benzo(a)pyrene IPM-TEQ	annual	3.7E-03	3.7E-03	3.8E-03	3.8E-03	1.7E-04
Formaldehyde	annual	3.5E+01	3.5E+01	3.5E+01	3.7E+01	1.4E-01
Methylene chloride	annual	6.6E-01	6.6E-01	6.6E-01	6.6E-01	2.5E-12
Propylene oxide	annual	3.2E-06	3.2E-06	1.5E-03	1.6E-03	1.5E-03
Regulatory Benchmark		*n/a*	*n/a*	*n/a*	*n/a*	*1 in 100,000*

Bold values represent exceedances of the exposure limit; n/a: not applicable.

Acrolein is the only COPC with a chronic RQ value above one. All other COPCs are associated with RQ values less than one, suggesting that the potential health risks to residential receptors from chronic inhalation of these substances are minimal.

All RQ values associated with the Project alone are less than one, indicating that the Project is expected to have a negligible impact on health.

The LCR estimates exceed one for 1,3-butadiene, acetaldehyde, benzene and formaldehyde, while none of the ICLR estimates exceed one, indicating that the Project-attributable cancer risk is essentially negligible. There is no clear regulatory benchmark for the interpretation of LCRs values, background cancer risks are described in more detail in Appendix 4D.

Acrolein

Predicted annual acrolein air concentrations are associated with a maximum RQ of 61 at the residential receptor locations for the Background, Baseline, Application and Cumulative cases. Long-term health risks appear to be due to the assumed indoor air concentrations of acrolein at the residential locations, as the background RQ for this receptor was about 61 compared to 0.07 for outdoor air. The Project's acrolein emissions are not expected to have an appreciable impact on background health risks.

As described in Section 4.6.1.2, given the degree of conservatism incorporated into the exposure limit and that the chronic risks to the residential receptors are similar to those estimated in other parts of Canada, adverse effects due to chronic inhalation of acrolein are not expected.

Acetaldehyde

There was no apparent change between the Background, Baseline, Application and Cumulative cases for the residential receptor. Background exposures contribute the risk to the development cases, and the exposure level in this assessment for background acetaldehyde represents both background indoor and outdoor exposures, and is dominated by indoor air exposure (LCR for indoor air is about 1.2 compared to 0.1 for outdoor air). Appendix 4D provides additional information.

Benzene

The LCR values for Baseline and Application were both 4.6, and a slight increase to 4.7 was observed in the Cumulative Case. Estimated background exposures to benzene appear to contribute the most risk, as the background LCR for the residential group is also 4.6. Similar to the agricultural receptor, indoor air appears to contribute the most risk. Potential future sources included in the Cumulative Case appear to contribute some additional risk. Appendix 4D provides additional information.

Formaldehyde

No change was apparent in the Baseline, Application and cumulative values. Existing sources contribute the most risk with negligible increases being associated with future developments. Appendix 4D provides additional information.

1,3-butadiene

No change was apparent in the Baseline, Application and cumulative values. Existing sources contribute the most risk with negligible increases being associated with future developments. Appendix 4D provides additional information.

4.7.3.3 Chronic Multi-Pathway Results for the Industrial Receptor Group

Tables 4.7-17 and 4.7-18 summarize the potential non-carcinogenic and carcinogenic risks associated with multiple routes of exposure.

Table 4.7-17 Chronic Multi-Pathway RQ Values for the Industrial Receptor

COPC	Background	Baseline	Application	Cumulative	Project
Aliphatic C_{17}-C_{34}	5.5E-07	5.5E-07	3.1E-06	3.1E-06	2.5E-06
Aliphatic C_5-C_8	2.9E-12	3.5E-12	4.5E-12	9.5E-12	1.6E-12
Aliphatic C_9-C_{16}	8.6E-07	2.1E-06	2.1E-06	1.5E-05	4.1E-07
Aromatic C_{17}-C_{34}	3.3E-07	3.3E-07	6.3E-07	6.3E-07	3.0E-07
Aromatic C_9-C_{16}	2.2E-08	2.4E-08	3.3E-08	8.8E-08	1.1E-08
Biphenyl	0.0E+00	0.0E+00	3.1E-14	3.1E-14	3.1E-14

All RQ values are less than one for the industrial receptor group, indicating that the health risks associated with long-term multi-media exposure to the non-carcinogenic COPCs are negligible.

Table 4.7-18 Chronic Multi-Pathway LCR and ILCR Values for the Industrial Receptor

COPC	Background (LCR)	Baseline (LCR)	Application (LCR)	Cumulative (LCR)	Project (ILCR)
Benzo(a)pyrene (WMM)	2.3E-04	2.3E-04	3.5E-04	3.5E-04	1.2E-04
Benzo(a)pyrene IPM TEF	1.3E-03	1.3E-03	2.4E-03	2.5E-03	1.1E-03
Regulatory Benchmark	*n/a*	*n/a*	*n/a*	*n/a*	*1 in 100,000*

n/a: not applicable.

The multi-media LCR values for the Baseline and Application cases are less than one. Further, the ILCR for the Project alone is associated with an essentially negligible level of cancer risk for the carcinogenic COPCs (i.e., less than 1 in 100,000).

4.7.4 Public Use Area Receptor Group

The acute and chronic health risks for the public use area receptor group are presented below. This receptor group considers individuals who may frequent public use areas within the study area, such as recreational lands or facilities, community buildings etc. It is assumed that these receptors do not live in the area, but may be exposed to emissions over several days.

4.7.4.1 Acute Inhalation Results for the Public Use Area Group

Table 4.7-19 presents the RQ values for the acute inhalation assessment for the public use areas. Baseline, Application and Cumulative cases are presented with background RQ values included. The risk estimates for the Baseline, Application and Cumulative cases include Background, while the Project risk estimates only represent Project emissions.

Table 4.7-19 Acute Inhalation RQ Values for the Public Use Area Group

COPC	Period	Background	Baseline	Application	Cumulative	Project
1,3-butadiene	1 h	1.3E-03	1.3E-03	1.5E-03	1.5E-03	1.4E-03
Acetaldehyde	1 h	8.1E-03	8.1E-03	8.1E-03	8.1E-03	5.5E-04
Acrolein	1 h	2.7E+00	2.7E+00	2.7E+00	2.7E+00	3.6E-01
Aliphatic alcohols group	1 h	2.4E-02	2.4E-02	2.4E-02	2.4E-02	5.0E-06
Aliphatic C_5-C_8 group	1 h	5.4E-04	7.0E-04	9.1E-04	2.2E-03	7.9E-04
Aliphatic C_9-C_{16} group	1 h	4.1E-03	4.1E-03	4.1E-03	5.0E-03	2.4E-04
Aliphatic ketones group	1 h	2.1E-04	2.1E-04	2.1E-04	2.1E-04	2.1E-05
Ammonia	1 h	1.6E-02	1.6E-02	1.6E-02	1.6E-02	0.0E+00
Aromatic C_9-C_{16} group	1 h	2.2E-03	2.2E-03	2.2E-03	2.2E-03	5.0E-04
Benzene	24 h	1.2E-01	1.2E-01	1.2E-01	1.4E-01	1.6E-02
Carbon disulphide group	1 h	1.2E-04	1.2E-04	6.0E-04	6.1E-04	6.0E-04
CO	1 h	2.1E-01	2.1E-01	2.1E-01	2.1E-01	1.7E-03
CO	8 h	4.6E-01	4.6E-01	4.6E-01	4.6E-01	2.6E-03
Cyclohexane	24 h	6.8E-06	7.0E-06	7.1E-06	1.7E-05	9.7E-07
Dichlorobenzene	24 h	1.42E-05	1.42E-05	1.68E-05	1.68E-05	2.74E-06
Ethylbenzene	24 h	2.7E-04	2.8E-04	2.8E-04	3.7E-04	4.9E-05
Formaldehyde	1 h	6.1E-01	6.1E-01	6.1E-01	7.8E-01	1.6E-02
H_2S	1 h	3.1E-02	6.2E-02	1.2E-01	1.3E-01	9.8E-02
Hexane	24 h	1.1E-03	1.1E-03	1.5E-03	1.8E-03	9.5E-04
Methylene chloride	24 h	5.0E-04	5.0E-04	5.0E-04	5.0E-04	7.2E-14
Naphthalene	1 h	2.5E-04	2.5E-04	2.5E-04	2.5E-04	4.9E-05
NO_2	1 h	3.4E-01	3.4E-01	3.4E-01	3.4E-01	1.4E-01
NO_2	24 h	4.4E-01	4.4E-01	4.4E-01	4.4E-01	9.5E-02
PM	24 h	7.4E-01	7.4E-01	7.7E-01	8.0E-01	5.1E-02
Propylene oxide	1 h	4.7E-07	4.7E-07	2.3E-05	2.3E-05	2.3E-05
SO_2	10 min	3.7E-01	4.5E-01	5.7E-01	8.4E-01	2.6E-01
SO_2	1 h	2.9E-01	3.5E-01	4.4E-01	6.5E-01	2.0E-01
SO_2	24 h	3.1E-01	3.5E-01	4.5E-01	7.7E-01	2.0E-01
Styrene	1 h	1.5E-04	1.5E-04	1.5E-04	1.5E-04	4.4E-08
Toluene	1 h	5.3E-04	5.3E-04	5.3E-04	5.3E-04	7.8E-05
Xylenes	1 h	1.3E-03	1.3E-03	1.3E-03	1.3E-03	1.8E-04

Bold values represent exceedances of the exposure limit.

Acrolein is the only COPC with predicted RQ values greater than one for the public use areas. The RQ values for all other COPCs are less than one, suggesting that the potential for acute health effects in the public use areas is generally negligible.

Acrolein

Predicted acrolein exposures are associated with an RQ value of 2.7 for the Baseline, Application and Cumulative cases. Given that the background RQ for acrolein is also 2.7, existing sources of acrolein appear to be contributing the most risk, with negligible amounts being contributed by future sources included in the Baseline, Application and Cumulative cases.

For the reasons outlined in Section 4.6.1.1, the background acrolein concentrations are considered to be conservative estimates of actual acrolein concentrations in the area. Given the degree of conservatism incorporated into the exposure limit, and that the predicted exposures are much lower than the threshold at which adverse effects might be observed, adverse effects in association with acute acrolein exposures at the public use areas are unlikely to occur.

4.7.4.2 Chronic Inhalation RQ, LCR and ILCR Values for the Public Use Area Receptor Group

Tables 4.7-20 and 4.7-21 present the RQ, LCR and ILCR values for the four development cases. Only the Baseline and Application values include Background while the Project values represent the risks associated with the Project emissions alone.

Table 4.7-20 Chronic Inhalation RQ Values for the Public Use Area Receptors

COPC	Period	Background	Baseline	Application	Cumulative	Project
2-chloronaphthalene	annual	1.8E-10	1.8E-10	1.8E-10	2.8E-09	0.0E+00
Acrolein	annual	**2.1E+00**	**2.1E+00**	**2.1E+00**	**2.1E+00**	8.7E-02
Aliphatic alcohols group	annual	2.5E-03	2.5E-03	2.5E-03	2.5E-03	8.8E-08
Aliphatic aldehydes group	annual	2.5E-04	2.5E-04	2.6E-04	2.6E-04	1.5E-05
Aliphatic C_{17}-C_{34} group	annual	1.2E-06	1.2E-06	1.3E-06	1.3E-06	6.5E-07
Aliphatic C_5-C_8 group	annual	1.6E-04	1.6E-04	2.6E-04	6.0E-04	9.9E-05
Aliphatic C_9-C_{16} group	annual	2.5E-03	2.5E-03	2.5E-03	3.5E-03	6.8E-05
Aliphatic ketones group	annual	2.5E-05	2.5E-05	2.5E-05	2.6E-05	9.3E-07
Ammonia	annual	2.4E-02	2.4E-02	2.4E-02	2.5E-02	0.0E+00
Aromatic C_{17}-C_{34} group	annual	1.5E-05	1.5E-05	1.5E-05	1.5E-05	9.2E-07
Aromatic C_9-C_{16} group	annual	4.6E-03	4.6E-03	4.6E-03	4.8E-03	5.0E-04
Benzaldehyde	annual	1.3E-04	1.3E-04	1.3E-04	1.3E-04	5.4E-06
Biphenyl	annual	0.0E+00	0.0E+00	1.3E-09	1.3E-09	1.3E-09
Carbon disulphide group	annual	1.2E-04	1.2E-04	5.8E-04	7.5E-04	5.3E-04
Byclohexane	annual	4.8E-06	5.7E-06	6.3E-06	1.9E-05	5.4E-07
Dichlorobenzenes	Annual	3.8E-04	3.8E-04	4.1E-04	4.1E-04	3.0E-05
Diethanolamine	annual	0.0E+00	0.0E+00	3.8E-05	3.8E-05	3.8E-05
Ethylbenzene	annual	1.3E-04	1.3E-04	1.4E-04	1.6E-04	1.2E-05
H_2S	annual	4.0E-01	4.7E-01	5.7E-01	6.2E-01	1.0E-01
Hexane	annual	9.5E-04	9.7E-04	1.1E-03	1.4E-03	4.0E-04
Isopropylbenzene	annual	2.4E-05	2.4E-05	2.6E-05	2.9E-05	2.6E-06
Naphthalene	annual	8.0E-03	8.0E-03	8.2E-03	8.2E-03	8.9E-04
NO_2	annual	3.7E-01	3.7E-01	3.7E-01	3.9E-01	7.5E-03
PM	annual	4.0E-01	4.1E-01	4.1E-01	4.4E-01	1.0E-02
SO_2	annual	1.4E-01	2.2E-01	2.3E-01	4.5E-01	1.7E-02
Styrene	annual	9.3E-05	9.3E-05	9.3E-05	9.3E-05	1.8E-08
Toluene	annual	1.9E-04	1.9E-04	1.9E-04	2.0E-04	1.4E-05
Xylenes	annual	5.4E-03	5.4E-03	5.4E-03	5.6E-03	3.4E-04

Bold values represent exceedances of the exposure limit.

Table 4.7-21 Chronic Inhalation LCR and ILCR Values for the Public Use Area Group

COPC	Period	Background (LCR)	Baseline (LCR)	Application (LCR)	Cumulative (LCR)	Project (ILCR)
1,3-butadiene	annual	9.6E-02	1.7E-01	1.7E-01	1.8E-01	7.5E-02
Acetaldehyde	annual	5.4E-01	5.4E-01	5.4E-01	5.4E-01	1.2E-03
Benzene	annual	3.1E-01	3.1E-01	3.2E-01	3.2E-01	2.7E-02
Benzo(a)pyrene WMM	annual	2.9E-01	2.9E-01	3.2E-01	3.3E-01	3.1E-02
Benzo(a)pyrene IPM-TEQ	annual	2.4E-04	2.4E-04	2.4E-04	2.4E-04	3.3E-05
Formaldehyde	annual	**1.2E+01**	**1.2E+01**	**1.2E+01**	**1.2E+01**	2.4E-02
Methylene chloride	annual	1.1E-02	1.1E-02	1.1E-02	1.1E-02	3.8E-13
Propylene oxide	annual	7.5E-06	7.5E-06	4.6E-04	5.7E-04	4.6E-04
Regulatory Benchmark		*n/a*	*n/a*	*n/a*	*n/a*	*1 in 100,000*

Bold values represent exceedances of the exposure limit, n/a – not applicable

Acrolein presents RQ values greater than one on a chronic basis. The RQ values for all other COPCs are less than one, indicating the potential health risks associated with long-term exposure to these COPCs are likely negligible.

The LCR estimates exceed one for formaldehyde, while none of the ICLR estimates exceed one, indicating that the Project-attributable cancer risk is acceptable when compared to the regulatory benchmark of one in 100,000. The LCR estimates relating to background are discussed in detail in Appendix 4D.

Acrolein

Predicted annual acrolein air concentrations are associated with a maximum RQ of 2.1 at the public use areas for the background, Baseline, Application and Cumulative cases. Long-term health risks appear to be due to the background outdoor air concentrations of acrolein. As shown in Table 4.7-9, the Project's acrolein emissions are not expected to have an appreciable impact on background health risks.

As described in Section 4.6.1.2, given the degree of conservatism incorporated into the exposure limit, adverse effects due to chronic inhalation of acrolein are not expected.

Formaldehyde

No change was apparent in the Baseline, Application and cumulative values. Existing sources contribute the most risk with negligible increases being associated with future developments. Appendix 4D provides additional information.

4.7.5 Monitoring Stations

This section presents the predicted acute and chronic health risks associated with predicted concentrations of the COPCs at various monitoring stations throughout the study area. As such, this group represents hypothetical exposure scenarios, and is included in the risk assessment for the purpose of evaluating future concentrations at these locations.

4.7.5.1 Acute Inhalation Results at the Monitoring Stations

Table 4.7-22 presents the RQ values for the acute inhalation assessment of the monitoring stations. Baseline, Application and Cumulative cases are presented with background RQ values included. The risk estimates for the Baseline, Application and Cumulative cases include Background, while the Project risk estimates only represent Project emissions.

Table 4.7-22 Acute Inhalation RQ Values for the Monitoring Receptors

COPC	Period	Background	Baseline	Application	Cumulative	Project
1,3-butadiene	1 h	1.7E-03	1.7E-03	3.3E-03	3.3E-03	3.2E-03
Acetaldehyde	1 h	9.4E-03	9.4E-03	9.4E-03	9.4E-03	1.5E-03
Acrolein	1 h	**3.5E+00**	**3.5E+00**	**3.5E+00**	**3.5E+00**	9.8E-01
Aliphatic alcohols group	1 h	2.5E-02	2.5E-02	2.5E-02	2.5E-02	1.3E-05
Aliphatic C_5-C_8 Group	1 h	3.2E-03	6.6E-03	6.7E-03	7.4E-03	2.2E-03
Aliphatic C_9-C_{16} group	1 h	5.3E-03	5.9E-03	5.9E-03	4.2E-02	6.2E-04
Aliphatic ketones group	1 h	2.7E-04	2.7E-04	2.7E-04	5.8E-04	5.4E-05
Ammonia	1 h	5.7E-02	5.7E-02	5.7E-02	5.7E-02	0.0E+00
Aromatic C_9-C_{16} Group	1 h	2.8E-03	2.8E-03	2.8E-03	2.8E-03	1.4E-03
Benzene	24 h	1.9E-01	1.9E-01	2.0E-01	2.5E-01	7.4E-02
Carbon disulphide Group	1 h	4.6E-04	4.6E-04	1.1E-03	1.1E-03	1.1E-03
CO	1 h	2.7E-01	2.7E-01	2.7E-01	2.7E-01	4.2E-03
CO	8 h	6.2E-01	6.2E-01	6.2E-01	6.2E-01	7.2E-03
Cyclohexane	24 h	4.2E-05	9.5E-05	9.5E-05	1.0E-04	4.0E-06
Dichlorobenzenes	24 h	1.4E-05	1.4E-05	2.3E-05	2.3E-05	8.9E-06
Ethylbenzene	24 h	8.6E-04	8.7E-04	8.8E-04	1.7E-03	1.8E-04
Formaldehyde	1 h	6.6E-01	6.6E-01	6.6E-01	**1.8E+00**	4.0E-02
H_2S	1 h	7.6E-02	1.2E-01	2.9E-01	2.9E-01	2.7E-01
Hexane	24 h	4.4E-03	9.3E-03	9.5E-03	9.6E-03	3.9E-03
Methylene chloride	24 h	5.0E-04	5.0E-04	5.0E-04	5.0E-04	2.6E-13
Naphthalene	1 h	3.3E-04	3.3E-04	3.3E-04	3.3E-04	1.2E-04
NO_2	1 h	4.1E-01	4.1E-01	4.1E-01	4.1E-01	2.4E-01
NO_2	24 h	4.9E-01	4.9E-01	4.9E-01	5.0E-01	2.4E-01
PM	24 h	**1.1E+00**	**1.1E+00**	**1.1E+00**	**1.1E+00**	9.4E-02
Propylene oxide	1 h	4.8E-07	4.8E-07	7.8E-05	7.8E-05	7.8E-05
SO_2	10-min	6.9E-01	9.6E-01	**1.1E+00**	**1.3E+00**	4.1E-01
SO_2	1 h	5.3E-01	7.4E-01	8.8E-01	1.0E+00	3.2E-01
SO_2	24 h	5.6E-01	6.6E-01	7.2E-01	**1.3E+00**	2.9E-01
Styrene	1 h	6.8E-04	6.8E-04	6.8E-04	6.8E-04	1.5E-07
Toluene	1 h	6.9E-04	6.9E-04	6.9E-04	1.3E-03	2.2E-04
Xylenes	1 h	1.7E-03	1.7E-03	1.7E-03	2.6E-03	5.7E-04

Bold values represent exceedances of the exposure limit.

Acrolein, fine Particulate Matter (PM), formaldehyde and sulphur dioxide are associated with acute RQ values greater than one at the monitoring stations. The RQ values for all other COPCs are less than one, suggesting that the potential for acute health effects at the monitoring stations is generally negligible.

It should be noted that the monitoring stations do not represent residences, farms or areas that people may necessarily frequent on a regular basis.

Acrolein

Predicted acrolein exposures are associated with an RQ value of 3.5 for both the Baseline and Application cases. Given that the background RQ for acrolein is also 3.5, existing sources of acrolein appear to be contributing the most risk, with negligible amounts being contributed by future sources included in the Baseline and Application cases.

For the reasons outlined in Section 4.6.1.1, the Background acrolein concentrations are considered to be conservative estimates of actual acrolein concentrations in the area. Given the degree of conservatism incorporated into the exposure limit, and that the predicted exposures are much lower than the threshold at which adverse effects might be observed, adverse effects in association with acute acrolein exposures to individuals at the monitoring locations are unlikely to occur.

Formaldehyde

The Cumulative Case acute RQ for formaldehyde is predicted to be 1.8 while the RQ value for the Project alone is much lower (0.04). There is no difference between the Background, Baseline and Application cases, suggesting that the Project will have a negligible impact on formaldehyde concentrations at the industrial locations.

For reasons presented in Section 4.6.1.1, the RQ values for the Cumulative Case are expected to be overestimates of actual risks to formaldehyde.

Particulate Matter

Acute exposures to fine particulate matter ($PM_{2.5}$) are associated with RQ values of 1.1 in the Baseline and Application cases. The background RQ for PM is also 1.1, suggesting that existing ambient sources of PM are “driving” the risks.

The RQ of 1.1 is associated with a 24-hour air concentration of 33 ug/m^3. Table 4.7-23 compares the maximum predicted $PM_{2.5}$ air concentration against background levels of PM in other areas in Canada.

Table 4.7-23 Ambient $PM_{2.5}$ Concentrations in Canada (2003-2005)

Location	Range in Ambient Air Concentrations[1] (ug/m^3)	Risk Quotient (RQ)[2]
Maximum predicted 24-hour $PM_{2.5}$ air concentration at the monitoring stations	33	1.1
Yukon and Northwest Territories	17 to 23	0.57 to 0.77
British Columbia	10 to 34	0.33 to 1.1
Alberta	11 to 22	0.37 to 0.73
Saskatchewan and Manitoba	9 to 15	0.30 to 0.50
Ontario	28 to 34	0.93 to 1.1
Quebec	23 to 40	0.77 to 1.3
Atlantic Canada	10 to 16	0.33 to 0.53

Notes:

1 Averaging times not evident from data source.

2 Risk quotients were calculated using the Health Canada CWS of 30 ug/m^3 (CCME, 2000)

Source: Environment Canada, 2006.

As shown, the maximum air concentration predicted at the monitoring stations falls within the range reported for other Canadian areas.

The health risks associated with the predicted $PM_{2.5}$ concentrations are characterized further in Appendix 4C.

Sulphur dioxide

Sulphur dioxide was associated with an RQ value 1.1 for the Application Case for the 10-minute averaging period, and an RQ of 1.3 in the Cumulative Case for both the 10-minute and 24-hour periods. These exceedances seem to be related to existing sources of sulphur dioxide combined with future sources in the Baseline, Application and Cumulative cases.

For reasons outlined in Section 4.6.3.1, the predicted short-term SO_2 concentrations are not expected to result in adverse health effects at the monitoring stations.

4.7.5.2 Chronic Inhalation Results at the Monitoring Stations

Tables 4.7-24 and 4.7-25 present the RQ, LCR and ILCR values for the four development cases for the monitoring group of receptors. Only the Baseline, Application and Cumulative values include Background while the Project values represent the risks associated with the Project emissions alone.

Table 4.7-24 Chronic Inhalation RQ Values at the Monitoring Stations

COPC	Period	Background	Baseline	Application	Cumulative	Project
2-chloronaphthalene	annual	2.8E-10	2.8E-10	2.8E-10	4.0E-09	0.0E+00
Acrolein	annual	**3.8E+00**	**3.8E+00**	**3.8E+00**	**3.8E+00**	2.6E-01
Aliphatic alcohols group	annual	2.6E-03	2.6E-03	2.6E-03	2.6E-03	3.3E-07
Aliphatic aldehydes group	annual	5.2E-04	5.2E-04	5.2E-04	5.2E-04	4.6E-05
Aliphatic C_{17}-C_{34} group	annual	2.5E-06	2.5E-06	2.9E-06	2.9E-06	2.4E-06
Aliphatic C_5-C_8 Group	annual	5.0E-04	1.1E-03	1.2E-03	2.1E-03	3.6E-04
Aliphatic C_9-C_{16} group	annual	5.1E-03	5.1E-03	5.1E-03	3.9E-02	2.3E-04
Aliphatic ketones group	annual	5.2E-05	5.2E-05	5.2E-05	1.1E-04	2.9E-06
Ammonia	annual	5.2E-02	5.2E-02	5.2E-02	5.5E-02	0.0E+00
Aromatic C_{17}-C_{34} group	annual	3.0E-05	3.0E-05	3.0E-05	3.0E-05	2.8E-06
Aromatic C_9-C_{16} Group	annual	9.4E-03	9.4E-03	9.5E-03	9.5E-03	1.8E-03
Benzaldehyde	annual	2.6E-04	2.6E-04	2.6E-04	2.6E-04	1.6E-05
Biphenyl	annual	0.0E+00	0.0E+00	4.7E-09	4.7E-09	4.7E-09
Carbon disulphide group	annual	5.2E-04	5.2E-04	1.2E-03	4.0E-03	1.1E-03
Cyclohexane	annual	2.6E-05	5.9E-05	5.9E-05	9.4E-05	2.3E-06
Dichlorobenzenes	annual	3.9E-04	3.9E-04	4.6E-04	4.7E-04	8.1E-05
Diethanolamine	annual	0.0E+00	0.0E+00	1.1E-04	1.1E-04	1.1E-04
Ethylbenzene	annual	2.7E-04	2.7E-04	2.7E-04	9.6E-04	4.8E-05
H_2S	annual	4.6E-01	5.6E-01	7.6E-01	8.2E-01	3.2E-01
Hexane	annual	1.9E-03	3.8E-03	3.9E-03	4.2E-03	1.4E-03
Isopropylbenzene	annual	2.4E-05	2.4E-05	3.4E-05	7.7E-05	1.0E-05
Naphthalene	annual	1.6E-02	1.6E-02	1.6E-02	1.6E-02	2.3E-03
NO_2	annual	5.9E-01	5.9E-01	6.0E-01	6.0E-01	1.7E-02
PM	annual	6.3E-01	6.4E-01	6.4E-01	6.6E-01	3.3E-02
SO_2	annual	2.2E-01	2.9E-01	3.0E-01	5.2E-01	3.2E-02
Styrene	annual	2.9E-04	2.9E-04	2.9E-04	2.9E-04	6.9E-08
Toluene	annual	3.8E-04	3.8E-04	3.8E-04	7.1E-04	5.0E-05
Xylenes	annual	1.1E-02	1.1E-02	1.1E-02	1.7E-02	1.3E-03

Bold values represent exceedances of the exposure limit.

Table 4.7-25 Chronic Inhalation LCR and ILCR Values for the Monitoring Stations

COPC	Period	Background (LCR)	Baseline (LCR)	Application (LCR)	Cumulative (LCR)	Project (ILCR)
1,3-butadiene	annual	5.1E-01	3.4E-01	3.4E-01	3.5E-01	2.1E-01
Acetaldehyde	annual	5.7E-01	5.7E-01	5.7E-01	5.7E-01	3.6E-03
Benzene	annual	6.0E-01	6.0E-01	6.0E-01	6.1E-01	9.4E-02
Benzo(a)pyrene WMM	annual	2.9E-01	2.9E-01	3.7E-01	3.8E-01	7.8E-02
Benzo(a)pyrene IPM-TEQ	annual	3.2E-04	3.2E-04	3.2E-04	3.3E-04	8.5E-05
Formaldehyde	annual	1.2E+01	1.2E+01	1.2E+01	1.6E+01	6.5E-02
Methylene chloride	annual	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.0E-12
Propylene oxide	annual	1.2E-05	1.2E-05	1.8E-03	1.9E-03	1.8E-03
Regulatory Benchmark		*n/a*	*n/a*	*n/a*	*n/a*	*1 in 100,000*

Bold values represent exceedances of the exposure limit; n/a: not applicable.

Acrolein presents RQ values greater than one on a chronic basis. The RQ values for all other COPCs are less than one, indicating the potential health risks associated with long-term exposure to these COPCs are likely negligible.

The LCR estimates exceed one for formaldehyde, while none of the ICLR estimates exceed one, indicating that the Project-attributable cancer risk is acceptable when compared to the regulatory benchmark of 1 in 100,000.

Acrolein

Predicted annual acrolein air concentrations are associated with a maximum RQ of 3.8 at the monitoring stations for the Background, Baseline, Application and Cumulative cases. Long-term health risks appear to be due to the background outdoor air concentrations of acrolein. As shown in Table 4.7-9, the Project's acrolein emissions are not expected to have an appreciable impact on background health risks.

As described in Section 4.6.1.2, given the degree of conservatism incorporated into the exposure limit, adverse effects due to chronic inhalation of acrolein are not expected.

Formaldehyde

The potential risks associated with formaldehyde were consistent between the background, Baseline and Application cases. Background exposures from existing ambient sources contribute the most risk. However, the Cumulative Case presented increase of 0.4 above the Baseline Case. This suggests that future sources other than the Project may contribute additional risks associated with formaldehyde.

4.7.6 Fenceline Receptor Group

The fenceline receptors represents a group of hypothetical, transient receptors that may be exposed to the COPCs on an acute basis as a result of being present close to the Project fenceline. No residences or farms are located at these sites. The intent of examining this group is to understand the maximum impact associated with COPC concentrations close to the site.

As the fenceline receptors will be exposed to COPCs on an occasional basis only and there are no residences at the fenceline, chronic inhalation and multi-pathway risks were not considered for this group.

4.7.6.1 Acute Inhalation Results for the Fenceline Receptor Group

Table 4.7-26 summarizes the acute inhalation RQ values for the Baseline, Application, Cumulative and Project cases for the fenceline group. Background values are provided for comparison purposes. The Baseline, Application and Cumulative values include Background, while the values associated with the Project do not.

Table 4.7-26 Acute Inhalation RQ Values for the Fenceline Receptor Group

COPC	Period	Background	Baseline	Application	Cumulative	Project
1,3-butadiene	1 h	**8.4E-04**	**8.4E-04**	**8.5E-03**	**8.5E-03**	**8.4E-03**
Acetaldehyde	1 h	6.5E-03	6.5E-03	1.2E-02	1.2E-02	7.9E-03
Acrolein	1 h	**1.7E+00**	**1.7E+00**	**5.2E+00**	**5.3E+00**	**5.1E+00**
Aliphatic alcohols group	1 h	2.4E-02	2.4E-02	2.4E-02	2.4E-02	3.4E-05
Aliphatic C_5-C_8 Group	1 h	5.1E-04	6.6E-04	5.3E-03	5.9E-03	5.3E-03
Aliphatic C_9-C_{16} group	1 h	2.5E-03	2.5E-03	2.8E-03	3.5E-03	1.4E-03
Aliphatic ketones group	1 h	1.3E-04	1.3E-04	2.7E-04	2.7E-04	2.6E-04
Ammonia	1 h	1.0E-02	1.0E-02	1.0E-02	1.0E-02	0.0E+00
Aromatic C_9-C_{16} Group	1 h	1.4E-03	1.4E-03	3.9E-03	4.0E-03	3.8E-03
Benzene	24 h	7.7E-02	7.7E-02	2.5E-01	2.7E-01	2.3E-01
CO	1 h	1.3E-01	1.3E-01	1.3E-01	1.3E-01	2.1E-02
CO	8 h	3.0E-01	3.0E-01	3.0E-01	3.0E-01	4.9E-02
Carbon disulphide Group	1 h	4.0E-05	4.0E-05	4.2E-03	4.2E-03	4.2E-03
Cyclohexane	24 h	6.3E-06	8.6E-06	1.4E-05	3.0E-05	1.1E-05
Dichlorobenzenes	24 h	1.4E-05	1.4E-05	5.5E-05	5.5E-05	4.1E-05
Ethylbenzene	24 h	2.1E-04	2.1E-04	6.4E-04	6.5E-04	5.5E-04
Formaldehyde	1 h	5.6E-01	5.6E-01	6.7E-01	9.3E-01	2.0E-01
H_2S	1 h	3.2E-02	4.7E-02	7.5E-01	7.6E-01	7.3E-01
Hexane	24 h	9.8E-04	1.1E-03	9.6E-03	9.6E-03	9.5E-03
Methylene chloride	24 h	5.0E-04	5.0E-04	5.0E-04	5.0E-04	9.6E-13
Naphthalene	1 h	1.6E-04	1.6E-04	1.6E-03	1.6E-03	1.6E-03
NO_2	1 h	2.5E-01	2.5E-01	4.3E-01	4.3E-01	4.2E-01
NO_2	24 h	2.7E-01	2.7E-01	5.9E-01	5.9E-01	5.5E-01
PM	24 h	4.9E-01	5.2E-01	5.4E-01	7.7E-01	3.6E-01
Propylene oxide	1 h	2.8E-07	2.8E-07	2.7E-04	2.7E-04	2.7E-04
SO_2	10-min	2.9E-01	3.6E-01	**1.7E+00**	**1.8E+00**	**1.6E+00**
SO_2	1 h	2.3E-01	2.8E-01	**1.3E+00**	**1.4E+00**	**1.2E+00**
SO_2	24 h	2.7E-01	3.3E-01	**1.2E+00**	**1.4E+00**	9.7E-01
Styrene	1 h	1.5E-04	1.5E-04	1.5E-04	1.5E-04	5.1E-07
Toluene	1 h	3.4E-04	3.4E-04	6.3E-04	7.1E-04	6.0E-04
Xylenes	1 h	8.2E-04	8.2E-04	1.7E-03	1.9E-03	1.6E-03

Predicted short-term air concentrations of acrolein and sulphur dioxide are associated with RQ values greater than one for the Baseline, Application and Cumulative cases. The Project emissions are associated with RQ values greater than one for acrolein and sulphur dioxide. These risks are discussed below.

Acrolein

Predicted acrolein exposures are associated with RQ values that range from 1.7 to 5.2 at the Project fenceline.

Given the degree of conservatism incorporated into the exposure limit (Section 4.6.1.1), and that the predicted exposures are much lower than the threshold at which adverse effects might be observed, adverse effects in association with acute acrolein exposures to transient persons exposed at the Project fenceline are unlikely to occur.

Sulphur Dioxide

Predicted short-term concentrations of sulphur dioxide are associated with RQ values of 1.7, 1.3 and 1.2 (10-min, 1-hour and 24-hour) for the Application Case. Baseline RQ values are all less than one for these averaging periods. These RQ values represent the maximum air concentrations (i.e., 850 ug/m^3, 585 ug/m^3 and 180 ug/m^3) predicted along the Project fenceline. It is unlikely that an individual would be located at the precise locations where these maximums occur, considering that the maximum out of all 327 fenceline locations was evaluated. These RQ values should be viewed as representing conservative estimates of risk.

For reasons outlined in Section 4.6.3.1, the predicted short-term SO_2 concentrations are not expected to result in adverse health effects at the Project fenceline.

4.7.7 Mixture Results for the Impact Assessment (Baseline, Application, Cumulative and Project)

This section summarizes the findings of the mixtures assessment for the various receptor groups. As discussed previously, COPCs were grouped into the chemical mixtures based on the exposure limits selected and the critical toxicological effect(s) upon which these exposure limits were based. Details regarding the chemical composition of the mixtures are provided in Appendix 4A.

All values presented in the acute and chronic inhalation mixture tables represent the maximum estimates for any particular mixture out of all the receptor locations in each receptor group. The Baseline, Application and Cumulative cases include Background, while the Project values represent mixtures associated with the Project emissions alone.

Due to the commonality in the results, the health risks for the mixtures are discussed after the presentation of the tables.

4.7.7.1 Inhalation Mixture Assessment Results for the Agricultural Receptor

Table 4.7-27 presents the maximum health risks to the agricultural receptors as a result of their concurrent inhalation of COPCs with common endpoints.

Table 4.7-27 Inhalation Mixture Results for the Agricultural Receptor

Mixture	**Background RQ**	**Baseline RQ**	**Application RQ**	**Cumulative RQ**	**Project RQ**
Acute Inhalation					
Irritants:					
Eye	**2.6E+00**	**2.6E+00**	**2.6E+00**	**3.1E+00**	**1.4E+00**
Nasal	6.0E-01	6.0E-01	6.0E-01	**1.5E+00**	5.1E-02
Respiratory	7.1E-01	9.0E-01	**1.4E+00**	**1.6E+00**	**1.2E+00**
Hepatotoxicants	2.2E-03	2.6E-03	4.7E-03	6.2E-03	4.4E-03
Nephrotoxicants	2.2E-03	2.6E-03	4.7E-03	6.2E-03	4.4E-03
Neurotoxicants	7.6E-03	4.8E-03	9.9E-03	1.0E-02	8.6E-03
Reproductive toxicants	1.3E-03	1.3E-03	5.5E-03	5.6E-03	5.4E-03

Mixture	**Background RQ**	**Baseline RQ**	**Application RQ**	**Cumulative RQ**	**Project RQ**
Chronic Inhalation					
Irritants:					
Eye	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nasal	**5.2E+01**	**5.2E+01**	**5.3E+01**	**5.3E+01**	7.5E-01
Respiratory	9.1E-02	1.6E-01	2.3E-01	5.1E-01	6.7E-02
Hepatotoxicants	6.5E-03	6.5E-03	8.5E-03	8.9E-03	2.1E-03
Nephrotoxicants	6.5E-03	6.5E-03	8.5E-03	9.0E-03	2.1E-03
Neurotoxicants	1.4E-01	1.5E-01	1.6E-01	1.6E-01	9.5E-03
Reproductive toxicants	7.0E-03	7.0E-03	7.1E-03	7.1E-03	9.1E-05
Carcinogenic Risks (by tumour type)					
	LCR	**LCR**	**LCR**	**LCR**	**ILCR**
Leukemia	4.7E+00	4.7E+00	5.0E+00	5.1E+00	4.0E-01
Nasal tumours	4.1E+01	4.1E+01	4.1E+01	4.4E+01	1.1E-01
Lung tumours	8.5E-01	8.5E-01	9.7E-01	0.0E+00	1.2E-01

Bold values represent exceedances of the exposure limit.

4.7.7.2 Inhalation Mixture Results for the Residential Receptor Group

Table 4.7-28 presents the maximum health risks to the residential receptors as a result of their concurrent inhalation of COPCs with common endpoints.

Table 4.7-28 Mixture Assessment Results for the Residential Receptor (Acute and Chronic Inhalation)

Mixture	**Background RQ**	**Baseline RQ**	**Application RQ**	**Cumulative RQ**	**Project RQ**
Acute Inhalation					
Irritants					
Eye	**2.7E+00**	**2.7E+00**	**2.7E+00**	**2.7E+00**	1.6E-01
Nasal	6.0E-01	6.0E-01	6.0E-01	6.3E-01	7.3E-03
Respiratory	5.8E-01	6.4E-01	7.9E-01	**1.1E+00**	3.7E-01
Hepatotoxicants	2.1E-03	2.1E-03	2.2E-03	2.4E-03	6.1E-04
Nephrotoxicants	2.1E-03	2.1E-03	2.2E-03	2.4E-03	6.1E-04
Neurotoxicants	7.7E-03	4.6E-03	4.8E-03	5.0E-03	1.3E-03
Reproductive toxicants	1.3E-03	1.3E-03	1.5E-03	1.5E-03	1.2E-03
Chronic Inhalation					
Irritants					
Eye	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nasal	**6.2E+01**	**6.2E+01**	**6.2E+01**	**6.2E+01**	1.5E-01
Respiratory	2.2E-02	7.3E-02	1.2E-01	3.1E-01	3.9E-02
Hepatotoxicants	7.2E-03	7.2E-03	7.5E-03	7.8E-03	3.2E-04
Nephrotoxicants	7.2E-03	7.2E-03	7.5E-03	7.8E-03	3.3E-04
Neurotoxicants	1.7E-01	1.8E-01	1.8E-01	1.8E-01	1.6E-03
Reproductive toxicants	7.8E-03	7.8E-03	7.8E-03	7.8E-03	8.1E-06
Carcinogens (by tumour type)					
	LCR	**LCR**	**LCR**	**LCR**	**ILCR**
Leukemia	**5.5E+00**	**5.6E+00**	**5.6E+00**	**5.6E+00**	7.3E-02
Nasal tumours	4.6E+01	4.6E+01	4.6E+01	**4.6E+01**	2.6E-02
Lung tumours	9.5E-01	9.5E-01	9.8E-01	9.9E-01	3.6E-02

Bold values indicate a potential risk of adverse effect due to mixture exposure

4.7.7.3 Inhalation Mixture Results for the Industrial Receptor Group

Table 4.7-29 presents the maximum health risks to the industrial receptors as a result of their concurrent inhalation of COPCs with common endpoints.

Table 4.7-29 Mixture Assessment Results for the Industrial Receptor (Acute and Chronic Inhalation

Mixture	**Background RQ**	**Baseline RQ**	**Application RQ**	**Cumulative RQ**	**Project RQ**
Acute Inhalation					
Irritants					
Eye	**2.4E+00**	**2.4E+00**	**2.4E+00**	**3.0E+00**	**1.2E+00**
Nasal	5.9E-01	5.9E-01	5.9E-01	**1.2E+00**	4.9E-02
Respiratory	**3.0E+00**	**3.0E+00**	**3.0E+00**	**3.1E+00**	**1.5E+00**
Hepatotoxicants	7.5E-03	8.2E-03	8.3E-03	9.2E-03	3.4E-03
Nephrotoxicants	7.5E-03	8.2E-03	8.3E-03	9.2E-03	3.4E-03
Neurotoxicants	1.8E-02	1.4E-02	1.4E-02	1.5E-02	6.6E-03
Reproductive toxicants	1.4E-03	1.5E-03	8.5E-03	8.6E-03	8.4E-03
Chronic Inhalation					
Irritants					
Eye	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nasal	**4.4E+01**	**4.4E+01**	**4.5E+01**	**4.6E+01**	**1.2E+00**
Respiratory	1.7E-01	2.5E-01	2.9E-01	6.1E-01	7.2E-02
Hepatotoxicants	5.9E-03	5.9E-03	6.9E-03	1.3E-02	1.3E-03
Nephrotoxicants	5.9E-03	5.9E-03	7.0E-03	1.3E-02	1.3E-03
Neurotoxicants	1.3E-01	1.4E-01	1.4E-01	2.3E-01	9.4E-03
Reproductive toxicants	6.4E-03	6.4E-03	6.4E-03	7.9E-03	5.3E-05
Carcinogens (by tumour type)					
	LCR	**LCR**	**LCR**	**LCR**	**ILCR**
Leukemia	**4.7E+00**	**4.0E+00**	**4.7E+00**	**4.8E+00**	7.6E-01
Nasal tumours	3.6E+01	3.6E+01	3.6E+01	**3.8E+01**	1.5E-01
Lung tumours	7.7E-01	7.7E-01	9.2E-01	9.2E-01	1.6E-01

Bold values indicate a potential risk of adverse effect due to mixture exposure.

4.7.7.4 Inhalation Mixture Results for the Public Use Area Receptor Group

Table 4.7-30 presents the maximum health risks at the public use area receptors as a result of their concurrent inhalation of COPCs with common endpoints.

Table 4.7-30 Mixture Assessment Results for the Public Use Area Receptor (Acute and Chronic Inhalation)

Mixture	**Background RQ**	**Baseline RQ**	**Application RQ**	**Cumulative RQ**	**Project RQ**
Acute Inhalation					
Irritants					
Eye	**3.3E+00**	**3.3E+00**	**3.3E+00**	**3.3E+00**	3.7E-01
Nasal	6.4E-01	6.4E-01	6.4E-01	8.1E-01	1.6E-02
Respiratory	7.3E-01	8.4E-01	**1.0E+00**	**1.3E+00**	5.1E-01
Hepatotoxicants	2.7E-03	2.7E-03	2.7E-03	3.5E-03	1.3E-03
Nephrotoxicants	2.7E-03	2.7E-03	2.7E-03	3.5E-03	1.3E-03
Neurotoxicants	9.7E-03	5.7E-03	5.8E-03	5.8E-03	2.3E-03
Reproductive toxicants	1.7E-03	1.7E-03	2.4E-03	2.5E-03	2.0E-03

Mixture	Background RQ	Baseline RQ	Application RQ	Cumulative RQ	Project RQ
Chronic Inhalation					
Irritants					
Eye	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nasal	**2.5E+00**	**2.5E+00**	**2.5E+00**	**2.5E+00**	1.9E-01
Respiratory	4.7E-01	4.8E-01	4.9E-01	7.9E-01	2.5E-02
Hepatotoxicants	4.6E-03	4.6E-03	4.6E-03	4.8E-03	5.0E-04
Nephrotoxicants	4.8E-03	4.8E-03	4.8E-03	4.9E-03	5.1E-04
Neurotoxicants	9.3E-03	1.4E-02	1.4E-02	1.5E-02	1.9E-03
Reproductive toxicants	2.7E-03	2.7E-03	2.7E-03	2.7E-03	1.4E-05
Carcinogens (by tumour type)					
	LCR	**LCR**	**LCR**	**LCR**	**ILCR**
Leukemia	3.4E-01	4.8E-01	4.9E-01	5.0E-01	1.0E-01
Nasal tumours	1.2E+01	1.2E+01	1.2E+01	1.3E+01	2.6E-02
Lung tumours	3.0E-01	3.0E-01	3.3E-01	3.4E-01	3.1E-02

Bold values indicate a potential risk of adverse effect due to mixture exposure.

4.7.7.5 Inhalation Mixture Results for the Monitoring Receptor Group

Table 4.7-31 presents the maximum health risks to the receptors at the monitoring stations as a result of their concurrent inhalation of COPCs with common endpoints.

Table 4.7-31 Mixture Assessment Results for the Monitoring Receptor (Acute and Chronic Inhalation Only)

Mixture	Background RQ	Baseline RQ	Application RQ	Cumulative RQ	Project RQ
Acute Inhalation					
Irritants					
Eye	**4.2E+00**	**4.2E+00**	**4.2E+00**	**4.2E+00**	1.0E+00
Nasal	6.8E-01	3.5E-02	3.5E-02	**1.8E+00**	1.7E-03
Respiratory	**1.1E+00**	**1.4E+00**	**1.6E+00**	**1.8E+00**	8.9E-01
Hepatotoxicants	4.4E-03	7.9E-03	8.0E-03	8.7E-03	3.6E-03
Nephrotoxicants	4.4E-03	0.0E+00	0.0E+00	8.7E-03	0.0E+00
Neurotoxicants	1.2E-02	1.2E-02	1.3E-02	1.3E-02	7.3E-03
Reproductive toxicants	2.1E-03	2.1E-03	4.7E-03	4.8E-03	4.6E-03
Chronic Inhalation					
Irritants					
Eye	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Nasal	**4.2E+00**	**4.2E+00**	**4.2E+00**	**4.2E+00**	5.8E-01
Respiratory	7.0E-01	7.1E-01	7.1E-01	9.0E-01	4.9E-02
Hepatotoxicants	9.4E-03	9.4E-03	9.5E-03	9.5E-03	1.8E-03
Nephrotoxicants	9.7E-03	9.7E-03	9.8E-03	9.9E-03	1.9E-03
Neurotoxicants	1.8E-02	2.7E-02	2.8E-02	7.1E-02	6.3E-03
Reproductive toxicants	2.9E-03	2.9E-03	2.9E-03	3.7E-03	5.3E-05
Carcinogens (by tumour type)					
	LCR	**LCR**	**LCR**	**LCR**	**ILCR**
Leukemia	7.7E-01	9.4E-01	9.5E-01	9.6E-01	3.1E-01
Nasal tumours	1.3E+01	1.3E+01	1.3E+01	1.7E+01	7.1E-02
Lung tumours	3.1E-01	3.1E-01	3.8E-01	3.9E-01	7.8E-02

Bold values indicate a potential risk of adverse effect due to mixture exposure.

4.7.7.6 Inhalation Mixture Results for the Fenceline Receptor Group

Table 4.7-32 presents the maximum health risks to the fenceline receptors as a result of their concurrent inhalation of COPCs with common endpoints.

Table 4.7-32 Mixture Assessment Results for the Fenceline Receptor (Acute Only)

Mixture	Background RQ	Baseline RQ	Application RQ	Cumulative RQ	Project RQ
Acute Inhalation					
Irritants					
Eye	**2.3E+00**	**2.3E+00**	**5.9E+00**	**6.1E+00**	**5.3E+00**
Nasal	5.8E-01	5.8E-01	7.0E-01	9.5E-01	2.0E-01
Respiratory	6.4E-01	7.2E-01	**2.8E+00**	**3.0E+00**	**2.6E+00**
Hepatotoxicants	1.8E-03	1.9E-03	9.3E-03	9.9E-03	9.1E-03
Nephrotoxicants	1.8E-03	1.9E-03	9.3E-03	9.9E-03	9.1E-03
Neurotoxicants	6.4E-03	3.9E-03	1.8E-02	1.8E-02	1.7E-02
Reproductive toxicants	1.1E-03	1.1E-03	1.3E-02	1.3E-02	1.3E-02

Bold values indicate a potential risk of adverse effect due to mixture exposure.

4.7.7.7 Multiple Exposure Pathway Mixture Results for the Agricultural Group

Table 4.7-33 presents the health risks to the agricultural group from multiple routes of exposure.

Table 4.7-33 Multi-Pathway Mixture Results (as RQ values) for the Agricultural Group

Mixture	Background	Baseline	Application	Cumulative	Project
Hepatotoxicants	8.9E-05	1.0E-04	3.2E-04	3.9E-04	2.2E-04
Nephrotoxicants	9.1E-04	9.3E-04	1.1E-03	1.4E-03	7.7E-05

4.7.7.8 Multiple Exposure Pathway Mixture Results for the Residential Group

Table 4.7-34 presents the health risks to the residential group from multiple routes of exposure.

Table 4.7-34 Multi-Pathway Mixture Results (as RQ values) for the Residential Group

Mixture	Background	Baseline	Application	Cumulative	Project
Hepatotoxicants	2.4E-06	2.5E-06	3.5E-06	6.7E-06	1.1E-06
Nephrotoxicants	3.9E-04	4.0E-04	4.7E-04	6.2E-04	3.5E-07

4.7.7.9 Multiple Exposure Pathway Mixture Results for the Industrial Group

Table 4.7-35 presents the health risks to the residential group from multiple routes of exposure.

Table 4.7-35 Multi-Pathway Mixture Results (as RQ values) for the Industrial Group

Mixture	Background	Baseline	Application	Cumulative	Project
Hepatotoxicants	1.4E-06	2.6E-06	5.2E-06	1.9E-05	2.9E-06
Nephrotoxicants	3.6E-07	3.6E-07	6.6E-07	7.2E-07	3.1E-07

4.7.7.10 Discussion of Mixture Results

The results for all receptor groups are discussed under the sub-headings below for chemical mixtures that presented values greater than one.

When considering inhalation alone, risks to chemical mixtures are described for acute eye irritation, acute nasal irritation, acute respiratory irritation, chronic nasal irritation and leukemia. None of the receptor groups presented risk estimates greater than one for the acute or chronic inhalation of hepatotoxicants, nephrotoxicants, neurotoxicants or reproductive toxicants.

All of the multi-pathway RQ mixture values for Baseline, Application and Project were less than one, signifying that the combined effect of the COPCs in these mixture are unlikely to cause adverse effects.

Acute Eye Irritants Mixture

Overall, the differences between the Baseline, Application and Cumulative Case risk estimates for the eye irritants are negligible, indicating the Project’s minor contribution to acute eye irritant risks in the region.

COPCs included in the acute eye irritants mixture are:

- Acetaldehyde;
- Acrolein;
- Aliphatic alcohols;
- Aliphatic ketones;
- Ammonia;
- Dichlorobenzenes;
- Formaldehyde;
- Naphthalene; and
- Styrene.

Acute health risks to the eye irritants appear to be primarily driven by the Background air concentrations of acrolein. Given the degree of conservatism built into the acrolein exposure limit (Section 4.6.1.1), and that the predicted air concentrations are much lower than the threshold at which adverse effects might be observed for acrolein (which is driving the eye irritant risk), adverse effects in association with acute exposures to eye irritants are unlikely to occur.

The eye irritants mixture for the agricultural receptor presented maximum RQ values of 2.6 for Baseline and Application, increasing to 3.1 in the Cumulative Case. An RQ of 1.4 was identified for the Project alone, occurring at agricultural location 538,

The eye irritants mixture for the industrial receptor presented maximum RQ values of 2.4 for the Baseline and Application cases, increasing to 3.0 in the Cumulative Case. For the Project at the industrial locations, the eye irritant mixture RQ was determined to be 1.2. This maximum occurred at industrial location 514, and the mixture component associated that is the primary determinant of the RQ is acrolein, which has an RQ of 1.1 at this location. It should be noted that this location is on the lease boundary and is very close to the emission source. It is not known whether this facility will continue to be in operation once the Project is operating.

No change in the RQ value was apparent between the Baseline, Application and Cumulative cases for the residential, public use or monitoring groups, and the Project RQs value were less than one.

Acute Nasal Irritants Mixture

Combined RQ values for the acute nasal irritants exceeded one at the maximum agricultural, industrial and monitoring locations for the Cumulative Case only. In all instances, the Project appears to have a negligible impact on the future acute nasal irritant risks.

COPCs included in the acute nasal irritant mixtures are:

- Aliphatic alcohols;
- Aliphatic ketones;
- Dichlorobenzenes;
- Formaldehyde; and
- Propylene oxide.

The maximum acute RQ values for the agricultural, industrial and monitoring stations are 1.5, 1.4 and 1.8, respectively. All of these exceedances occur in the Cumulative Case only. The acute nasal irritant risks appear to be due almost entirely to the predicted hourly formaldehyde concentrations at these locations, which are associated with RQ values of 1.4, 1.2 and 1.8, respectively. For the reasons presented in Section 4.6.1.1, the predicted acute health risks for the nasal irritants are likely overestimates of actual risks in the area.

Acute Respiratory Irritants Mixture

Combined RQ values for the acute respiratory irritants exceeded one for the agricultural group, industrial locations, public use areas, monitoring stations and fenceline receptors. Project only RQ values exceeded one for the agricultural, industrial and fenceline receptors.

COPCs included in the acute respiratory irritants mixture are:

- Acetaldehyde;
- Aliphatic alcohols;
- Aliphatic ketones;

- Ammonia;
- Hydrogen sulphide;
- Nitrogen dioxide;
- Sulphur dioxide;
- Styrene; and
- Xylenes.

For the Application, Cumulative and Project cases the mixture components contributing the most risk are sulphur dioxide (RQ 0.7), hydrogen sulphide (RQ 0.3) and nitrogen dioxide (RQ 0.2 – 0.3). While it is recognized that all three substances may cause respiratory effects, to assume that their effects are additive may be overly conservative.

The acute respiratory mixture for the industrial receptor is associated with an RQ of 3.0 in both the Baseline and Application cases, increasing to 3.1 in the Cumulative Case. As the Background mixture RQ value is approximately 3 as well, indicating that the risks in the Baseline and Application cases are related to existing emission sources. The maximum Project respiratory mixture RQ of 1.5 for this group occurs at a different industrial location than the one presenting the maximum background, Baseline and Application Case air concentrations. Of the mixture constituents, sulphur dioxide (RQ 0.9) and hydrogen sulphide (RQ 0.4) appear to contribute the most risk.

For the public use area group under the Cumulative Case, the respiratory irritants mixture is associated with an RQ value of 1.3. Sulphur dioxide (RQ 0.7), nitrogen dioxide (RQ 0.3) and hydrogen sulphide (RQ 0.13) contribute the most risk at this location. The substance-specific discussions regarding the conservatism incorporated into the exposure limits are described in Appendix 4A.

The acute respiratory irritants mixture for the monitoring receptor is associated with an RQ of 1.4 in the Baseline Case, 1.6 for the Application Case, increasing to 1.8 in the Cumulative Case. The mixture RQ associated with the Project alone was determined to be about 1.0. As the background RQ is 1.1 and the Baseline RQ is 1.4, existing ambient sources of the mixture components appear to contribute the most risk to Baseline. Of the mixture components, sulphur dioxide contributes the most risk to the Baseline RQ (RQ of 0.9) with some risk being attributable to nitrogen dioxide and hydrogen sulphide.

Overall, the primary contributors to the predicted risks for the respiratory irritant mixture are nitrogen dioxide and sulphur dioxide. However, the effect endpoints and the modes of action for each of these irritants differ. Nitrogen dioxide can be inhaled deeply into the lungs, acting as a deep-lung irritant, whereas sulphur dioxide is more soluble in water and is readily absorbed through the upper respiratory tract, inducing increases in airway resistance higher up in the respiratory tract (Calabrese, 1991). The dose-response relationships for these chemicals are somewhat independent in that the primary responses occur in different regions of the respiratory tract. For this reason, summing the RQ values for the constituents of the respiratory tract irritant mixture should be considered a conservative assumption.

Furthermore, it was conservatively assumed that the maximum predicted hourly air concentrations for each of the respiratory irritants would occur at precisely the same time for each location assessed in the receptor groups.

For these reasons, the health risks for the respiratory irritants are anticipated to be overestimates of actual respiratory health risks in the region.

Chronic Nasal Irritants Mixture

Combined RQ values for the chronic nasal irritants exceeded one for the agricultural group, industrial locations, public use areas, and monitoring stations. Project only RQ values exceeded one for the industrial receptor group only.

COPCs included in the chronic nasal irritant mixture are:

- Acrolein;
- Dichlorobenzenes;
- Hydrogen sulphide; and
- Naphthalene.

Background risks associated with nasal irritants contribute the most to the Baseline and Application case values, for all receptors. Review of the chronic inhalation results for acrolein alone (Section 4.6.1.2) suggests that acrolein is “responsible” for the vast majority of the chronic nasal irritant risk. The background RQ for acrolein is almost entirely due to the assumed indoor air concentrations. As such, the RQ values for the Background, Baseline and Application cases are all a result of the background indoor air value selected for acrolein in this assessment.

The mixture RQ for the agricultural group increased from 52 in the Background and Baseline cases to 53 in the Cumulative Case. Acrolein appears to be the mixture component contributing the most risk, with a background RQ of 52. This suggests that there is a slight increase in potential risks of nasal irritation due to future sources.

For the industrial group, the RQ value for the mixture increased from 44 in the Baseline Case to 45 in the Application case and 46 in the Cumulative Case. The primary mixture component associated with the most risk for all cases is acrolein (RQ of 44), with some contribution from dichlorobenzene and hydrogen sulphide. The background RQ values for acrolein contain an indoor air RQ of 43 and outdoor air RQ of about 0.3. Thus, the indoor air concentration of acrolein used in this assessment is associated with the majority of the mixture risk.

No changes in the mixture RQ was apparent between the background, Baseline, Application and Cumulative cases for the residential, industrial, public use or monitoring groups.

As described in Section 4.6.1.2, given the degree of conservatism incorporated into the chronic exposure limit for acrolein and that the annual average air concentrations of acrolein are similar to those measured in other parts of Canada, the predicted risks are expected to be overestimates of actual nasal irritant risks in the area.

Chronic Leukemia Mixture

The components of this mixture include:

- 1,3-butadiene; and
- Benzene.

As this mixture contains potential carcinogens, the difference between LCR and ILCR must be considered in the interpretation of risks. The Baseline, Application and Cumulative cases all contain background, thus, must be interpreted as LCRs, for which there is no clear regulatory benchmark. Appendix 4D provides additional information.

For the agricultural receptor group, chronic leukemia mixture was associated with LCR values of 4.7 (Baseline), 5.0 (Application), and 5.1 (Cumulative). The risks associated with the Project Case were less than one. The Background and Baseline mixture values are the same, and occur at the same location, thus Background exposures to the mixture are contributing the most risk (primarily benzene) to all development cases.

The mixture risk estimates for the residential receptor were unchanged across the Baseline, Application and Cumulative cases, with the mixture component contributing the most risk being background benzene exposures.

With respect to the industrial receptor, chronic leukemia mixture was associated with LCR values of 4.0 (Baseline), 4.7 (Application), and 4.8 (Cumulative). Background exposures to benzene appear to contribute the most risk to the mixture.

Chronic Nasal Tumours Mixture

The components of this mixture include:

- Acetaldehyde;
- Formaldehyde; and
- Propylene oxide.

As this mixture contains potential carcinogens, the difference between LCR and ILCR must be considered in the interpretation of risks. The Baseline, Application and Cumulative cases all contain background, thus, must be interpreted as LCRs, for which there is no clear regulatory benchmark. Appendix 4D provides additional information.

Slight changes between the Baseline, Application and Cumulative cases were observed for the agricultural, industrial, public use and monitoring groups. These increases above Baseline were about 0.3 (agricultural), 0.2 (industrial), 0.1 (public use) and 0.4 (monitoring), and appear to the result of increases in the formaldehyde emissions within the Cumulative Case for each group.

No change between the Background, Baseline, Application and cumulative values were observed for the residential group.

4.7.8 Mitigative Measures

Mitigation measures relevant to potential risks to public health are discussed in Section 2.6 of the Air Quality Assessment (Volume 2, Section 2). In an attempt to mitigate potential impacts to air quality, North American will control its construction emissions, operations emissions and greenhouse gas emissions.

Potential impacts to surface water quality will be mitigated through the implementation of a number of measures described in Section 7.6 of the Surface Water Quality Assessment (Volume 3, Section 7). These will include the implementation of a water management and sediment control plan during construction, the treatment of wastewater in an on-site facility, the control and treatment of stormwater and the containment and collection of spills.

Mitigative measures intended to protect groundwater quality are described in Section 5.6 of the Hydrogeology Assessment (Volume 3, Section 5).

The implementation of the planned mitigative measures for air quality, surface water quality and groundwater quality should ensure that the Project's chemical emissions will not adversely affect human health in the area.

4.8 Odour Impact Assessment and Mitigative Measures

Tables 4.8-1 to 4.8-3 summarize the odour concentration ratios (CRs) for the six receptor groups. Odour CRs are presented for those COPCs for which mean odour thresholds were available.

The Baseline, Application and Cumulative CRs all include Background values. The Project CRs exclude Background, and thus represent the Project emissions alone.

All CR values greater than 1 are presented in bold type-face, and indicate when the 3-minute or 1-hour concentration of a COPC exceeded an odour threshold. CR values less than 1 suggest that the COPCs are present at levels below the odour threshold, and are therefore unlikely to present nuisance odours.

Table 4.8-1 Odour Concentration Ratios for the Agricultural and Residential Receptors

Chemical	Period	Agricultural Group					Residential Group				
		Existing	Baseline	Application	Cumulative	Project	Existing	Baseline	Application	Cumulative	Project
1,3-Butadiene	3 min	4.1E-04	4.1E-04	6.3E-03	6.3E-03	6.1E-03	4.3E-04	4.3E-04	9.3E-04	9.4E-04	7.7E-04
Acetaldehyde	3 min	3.3E-01	3.3E-01	3.4E-01	3.4E-01	9.4E-02	3.3E-01	3.3E-01	3.3E-01	3.3E-01	1.1E-02
Acrolein	3 min	2.9E-03	2.9E-03	3.3E-03	3.3E-03	1.9E-03	3.0E-03	3.0E-03	3.0E-03	3.0E-03	2.2E-04
Aliphatic C_5-C_8 Group	3 min	3.7E-04	5.0E-04	1.4E-03	2.0E-03	1.2E-03	1.7E-04	1.9E-04	2.4E-04	3.7E-04	1.5E-04
Aliphatic C_9-C_{16} Group	1 h	1.3E-04	1.6E-04	1.9E-04	2.5E-04	1.4E-04	1.4E-04	1.4E-04	1.4E-04	3.1E-04	1.2E-05
Aliphatic alcohols group	3 min	1.1E-03	1.1E-03	1.1E-03	1.1E-03	9.0E-07	1.1E-03	1.1E-03	1.1E-03	1.1E-03	9.2E-08
Aliphatic ketones group	3 min	2.3E-04	2.3E-04	2.5E-04	2.6E-04	1.1E-04	2.4E-04	2.4E-04	2.4E-04	2.9E-04	1.4E-05
Ammonia	1 h	2.9E-02	2.9E-02	2.9E-02	3.0E-02	0.0E+00	1.8E-02	1.8E-02	1.8E-02	1.8E-02	0.0E+00
Aromatic C_9-C_{16} Group	3 min	6.1E-02	6.1E-02	7.6E-02	7.7E-02	5.1E-02	6.3E-02	6.3E-02	6.4E-02	9.0E-02	8.5E-03
Benzene	3 min	3.2E-04	3.4E-04	4.2E-04	5.5E-04	2.7E-04	2.9E-04	2.9E-04	3.0E-04	3.2E-04	3.6E-05
Biphenyl	3 min	0.0E+00	0.0E+00	3.4E-06	3.4E-06	3.4E-06	0.0E+00	0.0E+00	4.5E-07	4.5E-07	4.5E-07
Carbon disulphide group	1 h	1.8E-02	1.8E-02	3.7E-01	3.7E-01	3.6E-01	9.8E-03	9.8E-03	1.1E-01	1.1E-01	9.7E-02
CO	3 min	3.6E-05	3.6E-05	3.7E-05	3.7E-05	1.3E-06	3.8E-05	3.8E-05	3.8E-05	3.8E-05	2.4E-07
Cyclohexane	3 min	3.4E-05	4.8E-05	4.8E-05	1.5E-04	1.7E-05	1.2E-05	1.3E-05	1.4E-05	2.3E-05	1.2E-06
Dichlorobenzenes	3 min	2.9E-04	2.9E-04	1.2E-03	1.2E-03	9.7E-04	2.9E-04	2.9E-04	4.5E-04	4.6E-04	1.7E-04
Diethanolamine	3 min	0.0E+00	0.0E+00	4.1E-05	4.1E-05	4.1E-05	0.0E+00	0.0E+00	4.3E-06	4.3E-06	4.3E-06
Ethylbenzene	3 min	7.6E-04	7.9E-04	9.7E-04	1.0E-03	4.6E-04	4.0E-04	4.0E-04	4.0E-04	6.0E-04	4.1E-05
Formaldehyde	3 min	5.1E-02	5.1E-02	5.2E-02	1.3E-01	4.6E-03	5.2E-02	5.2E-02	5.2E-02	5.4E-02	6.5E-04
Hexane	3 min	4.7E-05	6.6E-05	2.0E-04	2.0E-04	1.8E-04	3.0E-05	3.1E-05	4.3E-05	4.6E-05	2.3E-05
H_2S	1 h	2.8E-01	4.2E-01	**2.4E+00**	**2.4E+00**	**2.2E+00**	2.5E-01	3.0E-01	5.6E-01	5.7E-01	3.2E-01
Isopropylbenzene	3 min	2.0E-04	2.0E-04	1.1E-03	1.1E-03	9.2E-04	2.0E-04	2.0E-04	2.9E-04	4.0E-04	8.3E-05
mercaptan	1 h	2.4E-04	2.4E-04	1.7E-01	1.7E-01	1.7E-01	3.4E-05	3.5E-05	2.2E-02	2.2E-02	2.2E-02
Methylene chloride	3 min	2.2E-06	2.2E-06	2.2E-06	2.2E-06	2.7E-15	2.2E-06	2.2E-06	2.2E-06	2.2E-06	3.8E-16
Naphthalene	3 min	1.6E-03	1.6E-03	2.2E-03	2.2E-03	1.5E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03	3.1E-04
NO_2	1 h	2.5E-01	2.6E-01	2.9E-01	2.9E-01	2.6E-01	2.9E-01	2.9E-01	3.0E-01	3.2E-01	7.2E-02
Propylene oxide	3 min	2.1E-08	2.1E-08	4.9E-06	4.9E-06	4.9E-06	1.0E-08	1.0E-08	4.6E-07	4.7E-07	4.6E-07
Styrene	3 min	1.1E-02	1.1E-02	1.1E-02	1.1E-02	4.9E-06	1.3E-03	1.3E-03	1.3E-03	1.3E-03	4.6E-07
SO_2	3 min	7.6E-02	1.2E-01	2.0E-01	2.4E-01	1.5E-01	4.3E-02	6.0E-02	1.0E-01	1.5E-01	5.5E-02
Toluene	3 min	2.5E-03	2.5E-03	3.1E-03	4.0E-03	2.0E-03	2.6E-03	2.6E-03	2.6E-03	3.0E-03	2.3E-04
Xylenes	3 min	3.2E-03	3.3E-03	4.0E-03	6.6E-03	2.5E-03	3.4E-03	3.4E-03	3.4E-03	3.9E-03	2.5E-04

Table 4.8-2 Odour Concentration Ratios for the Industrial and Public Use Area Receptor Groups

		Industrial Group					Public Use Areas Group				
Chemical	**Period**	**Existing**	**Baseline**	**Application**	**Cumulative**	**Project**	**Existing**	**Baseline**	**Application**	**Cumulative**	**Project**
1,3-Butadiene	3 min	3.6E-04	3.6E-04	4.9E-03	4.9E-03	4.8E-03	5.5E-04	5.5E-04	2.0E-03	2.0E-03	1.7E-03
Acetaldehyde	3 min	3.1E-01	3.1E-01	3.1E-01	3.1E-01	8.1E-02	3.8E-01	3.8E-01	3.8E-01	3.8E-01	2.6E-02
Acrolein	3 min	2.5E-03	2.5E-03	2.7E-03	2.6E-03	1.6E-03	3.8E-03	3.8E-03	3.8E-03	3.9E-03	5.1E-04
Aliphatic C_5-C_8 Group	3 min	2.4E-03	2.7E-03	3.4E-03	3.9E-03	1.0E-03	2.1E-04	3.0E-04	3.8E-04	8.9E-04	3.2E-04
Aliphatic C_9-C_{16} Group	1 h	2.5E-04	5.2E-04	5.2E-04	2.4E-03	1.6E-04	1.8E-04	2.0E-04	2.0E-04	3.0E-04	1.0E-05
Aliphatic alcohols group	3 min	1.1E-03	1.1E-03	1.1E-03	1.1E-03	5.2E-07	1.1E-03	1.1E-03	1.1E-03	1.1E-03	2.2E-07
Aliphatic ketones group	3 min	2.0E-04	2.0E-04	2.1E-04	1.1E-03	1.2E-04	3.1E-04	3.1E-04	3.1E-04	3.2E-04	3.2E-05
Ammonia	1 h	1.4E-01	1.4E-01	1.4E-01	1.5E-01	0.0E+00	3.8E-02	3.8E-02	3.8E-02	3.8E-02	0.0E+00
Aromatic C_9-C_{16} Group	3 min	5.5E-02	5.6E-02	5.9E-02	1.9E-01	3.0E-02	8.1E-02	8.1E-02	8.6E-02	8.9E-02	1.9E-02
Benzene	3 min	5.8E-04	6.2E-04	6.9E-04	9.6E-04	3.0E-04	3.8E-04	3.8E-04	3.8E-04	5.0E-04	7.5E-05
Biphenyl	3 min	0.0E+00	0.0E+00	3.0E-06	3.0E-06	3.0E-06	0.0E+00	0.0E+00	9.2E-07	9.2E-07	9.2E-07
Carbon disulphide group	1 h	1.9E-02	1.9E-02	5.0E-01	5.0E-01	4.8E-01	2.6E-02	2.6E-02	1.4E-01	1.5E-01	1.2E-01
CO	3 min	3.2E-05	3.3E-05	3.3E-05	3.3E-05	1.4E-06	4.9E-05	4.9E-05	4.9E-05	4.9E-05	4.0E-07
Cyclohexane	3 min	2.2E-04	2.5E-04	2.6E-04	2.9E-04	6.2E-06	3.3E-05	3.8E-05	3.8E-05	8.0E-05	3.5E-06
Dichlorobenzenes	3 min	2.9E-04	2.9E-04	1.2E-03	1.2E-03	8.7E-04	2.9E-04	2.9E-04	5.1E-04	5.2E-04	2.3E-04
Diethanolamine	3 min	0.0E+00	0.0E+00	5.0E-05	5.0E-05	5.0E-05	0.0E+00	0.0E+00	1.0E-05	1.0E-05	1.0E-05
Ethylbenzene	3 min	1.3E-03	1.5E-03	1.5E-03	3.9E-03	2.4E-04	5.1E-04	5.5E-04	5.5E-04	6.7E-04	1.0E-04
Formaldehyde	3 min	5.0E-02	5.0E-02	5.1E-02	1.1E-01	4.3E-03	5.5E-02	5.5E-02	5.5E-02	7.6E-02	1.4E-03
Hexane	3 min	3.3E-04	3.7E-04	4.7E-04	4.7E-04	1.6E-04	3.4E-05	3.9E-05	6.0E-05	6.1E-05	4.7E-05
H_2S	1 h	**1.0E+00**	**1.7E+00**	**3.7E+00**	**3.7E+00**	**2.7E+00**	2.1E-01	4.4E-01	8.6E-01	8.8E-01	6.9E-01
Isopropylbenzene	3 min	2.0E-04	2.0E-04	6.6E-04	8.8E-03	4.5E-04	2.0E-04	2.0E-04	4.2E-04	4.6E-04	2.2E-04
Mercaptan	1 h	1.6E-03	1.3E-03	1.5E-01	1.5E-01	1.5E-01	1.1E-04	1.1E-04	4.6E-02	4.7E-02	4.6E-02
Methylene chloride	3 min	2.2E-06	2.2E-06	2.2E-06	2.2E-06	3.5E-15	2.2E-06	2.2E-06	2.2E-06	2.2E-06	8.9E-16
Naphthalene	3 min	3.8E-03	3.8E-03	5.0E-03	5.0E-03	2.4E-03	2.1E-03	2.1E-03	2.1E-03	2.1E-03	4.1E-04
NO_2	1 h	3.0E-01	3.0E-01	3.3E-01	3.4E-01	2.3E-01	3.4E-01	3.5E-01	3.5E-01	3.7E-01	1.4E-01
Propylene oxide	3 min	2.9E-08	2.9E-08	2.8E-06	2.8E-06	2.8E-06	2.5E-08	2.5E-08	1.3E-06	1.3E-06	1.2E-06
Styrene	3 min	1.9E-02	1.9E-02	1.9E-02	1.9E-02	2.8E-06	4.1E-03	4.1E-03	4.1E-03	4.1E-03	1.2E-06
SO_2	3 min	5.4E-01	6.3E-01	7.2E-01	8.2E-01	2.0E-01	8.2E-02	1.0E-01	1.3E-01	1.9E-01	5.8E-02
Toluene	3 min	3.5E-03	3.9E-03	3.9E-03	1.1E-02	1.7E-03	3.3E-03	3.4E-03	3.4E-03	4.0E-03	4.8E-04
Xylenes	3 min	9.7E-03	1.0E-02	1.0E-02	1.8E-02	1.6E-03	4.3E-03	4.4E-03	4.4E-03	5.5E-03	6.1E-04

Table 4.8-3 Odour Concentration Ratios for the Monitoring and Fenceline Receptor Groups

		Monitoring Stations					**Fence-line Receptor Group**				
Chemical	**Period**	**Existing**	**Baseline**	**Application**	**Cumulative**	**Project**	**Existing**	**Baseline**	**Application**	**Cumulative**	**Project**
1,3-Butadiene	3 min	7.2E-04	7.2E-04	5.6E-03	5.6E-03	5.1E-03	3.5E-04	3.5E-04	1.6E-02	1.6E-02	1.6E-02
Acetaldehyde	3 min	4.4E-01	4.4E-01	4.5E-01	4.5E-01	7.1E-02	3.0E-01	3.0E-01	5.6E-01	5.6E-01	3.7E-01
Acrolein	3 min	4.9E-03	4.9E-03	5.2E-03	5.2E-03	1.4E-03	2.5E-03	2.5E-03	7.7E-03	7.8E-03	7.2E-03
Aliphatic C_5-C_8 Group	3 min	1.3E-03	2.6E-03	2.6E-03	3.2E-03	8.7E-04	2.0E-04	2.6E-04	2.2E-03	2.4E-03	2.1E-03
Aliphatic C_9-C_{16} Group	1 h	2.3E-04	3.3E-04	3.3E-04	1.9E-03	2.7E-05	1.1E-04	1.1E-04	1.3E-04	1.6E-04	6.1E-05
Aliphatic alcohols group	3 min	1.1E-03	1.1E-03	1.1E-03	1.1E-03	5.8E-07	1.1E-03	1.1E-03	1.1E-03	1.1E-03	1.5E-06
Aliphatic ketones group	3 min	4.0E-04	4.0E-04	4.1E-04	1.1E-03	8.1E-05	1.9E-04	1.9E-04	4.1E-04	4.2E-04	3.8E-04
Ammonia	1 h	1.3E-01	1.3E-01	1.3E-01	1.3E-01	0.0E+00	2.3E-02	2.3E-02	2.3E-02	2.4E-02	0.0E+00
Aromatic C_9-C_{16} Group	3 min	1.1E-01	1.1E-01	1.3E-01	1.5E-01	5.2E-02	5.1E-02	5.1E-02	1.5E-01	1.5E-01	1.4E-01
Benzene	3 min	4.9E-04	6.0E-04	6.1E-04	6.8E-04	2.0E-04	2.4E-04	2.5E-04	5.6E-04	6.0E-04	4.8E-04
Biphenyl	3 min	0.0E+00	0.0E+00	2.6E-06	2.6E-06	2.6E-06	0.0E+00	0.0E+00	5.9E-06	5.9E-06	5.9E-06
Carbon disulphide group	1 h	9.4E-02	1.0E-01	3.3E-01	3.3E-01	2.4E-01	8.2E-03	8.3E-03	8.7E-01	8.7E-01	8.6E-01
CO	3 min	6.3E-05	6.3E-05	6.9E-05	6.9E-05	9.9E-07	3.1E-05	3.1E-05	3.1E-05	3.1E-05	5.0E-06
Cyclohexane	3 min	1.2E-04	2.4E-04	2.4E-04	2.6E-04	1.2E-05	1.9E-05	2.5E-05	4.2E-05	7.4E-05	3.1E-05
Dichlorobenzenes	3 min	2.9E-04	2.9E-04	7.4E-04	7.4E-04	4.4E-04	2.9E-04	2.9E-04	2.4E-03	2.4E-03	2.1E-03
Diethanolamine	3 min	0.0E+00	0.0E+00	3.5E-05	3.5E-05	3.5E-05	0.0E+00	0.0E+00	1.2E-04	1.2E-04	1.2E-04
Ethylbenzene	3 min	1.2E-03	1.3E-03	1.3E-03	3.4E-03	3.4E-04	3.6E-04	3.8E-04	1.1E-03	1.2E-03	9.7E-04
Formaldehyde	3 min	5.9E-02	5.9E-02	5.9E-02	1.7E-01	3.5E-03	5.0E-02	5.0E-02	6.1E-02	8.3E-02	1.8E-02
Hexane	3 min	1.6E-04	3.0E-04	3.1E-04	3.1E-04	1.3E-04	2.8E-05	3.5E-05	3.2E-04	3.2E-04	3.1E-04
H_2S	1 h	5.3E-01	8.3E-01	2.4E+00	2.4E+00	1.9E+00	2.3E-01	3.5E-01	5.3E+00	5.3E+00	5.1E+00
Isopropylbenzene	3 min	2.0E-04	2.0E-04	9.2E-04	3.4E-03	7.1E-04	2.0E-04	2.0E-04	2.3E-03	2.4E-03	2.1E-03
Mercaptan	1 h	7.9E-04	1.2E-03	1.3E-01	1.3E-01	1.3E-01	1.3E-04	1.2E-04	3.2E-01	3.2E-01	3.2E-01
Methylene chloride	3 min	2.2E-06	2.2E-06	2.2E-06	2.2E-06	2.5E-15	2.2E-06	2.2E-06	2.2E-06	2.3E-06	8.2E-15
Naphthalene	3 min	2.7E-03	2.7E-03	3.0E-03	3.0E-03	9.9E-04	1.3E-03	1.3E-03	1.3E-02	1.3E-02	1.3E-02
NO_2	1 h	4.1E-01	4.2E-01	4.2E-01	4.6E-01	2.4E-01	2.5E-01	2.5E-01	4.5E-01	4.5E-01	4.2E-01
Propylene oxide	3 min	2.6E-08	2.6E-08	4.2E-06	4.2E-06	4.2E-06	1.5E-08	1.5E-08	1.4E-05	1.4E-05	1.4E-05
Styrene	3 min	1.9E-02	1.9E-02	1.9E-02	1.9E-02	4.2E-06	4.3E-03	4.3E-03	4.3E-03	4.3E-03	1.4E-05
SO_2	3 min	1.5E-01	2.1E-01	3.6E-01	4.0E-01	9.2E-02	6.5E-02	8.7E-02	3.9E-01	4.2E-01	3.5E-01
Toluene	3 min	4.3E-03	4.5E-03	4.6E-03	1.1E-02	1.4E-03	2.1E-03	2.1E-03	4.1E-03	4.5E-03	3.7E-03
Xylenes	3 min	5.6E-03	6.0E-03	6.0E-03	1.2E-02	1.9E-03	2.7E-03	2.7E-03	6.0E-03	6.5E-03	5.3E-03

Hydrogen sulphide was the only COPC that presented odour CRs greater than one. All other odour CRs were less than one, signifying a minimal overall risk of nuisance odours.

CR values for hydrogen sulphide range from 2.4 for the Application and Cumulative cases for the agricultural group while the maximum odour CR from the Project alone is 2.2. Thus, the emissions from the Project alone may contribute to nuisance odours.

The industrial CR values are 1.7 for Baseline, 3.7 for the Application and Cumulative cases, and 2.7 for the Project alone. These results suggest that sources included in the Baseline case are associated with potential nuisance odours.

The monitoring stations' CR values are 2.4 for both the Application and Cumulative cases, and 1.9 for the Project alone. The Project is expected to contribute to the Application and Cumulative cases.

The fenceline CR values are 5.3 for the Application and Cumulative cases and 5.1 for the Project alone. Given that the Baseline CR is about 0.3, the Project is expected to contribute to nuisance odours at the fenceline locations.

4.8.1 Mitigation Measures

Mitigation measures relevant to potential odours are discussed in Section 2.6 of the Air Quality Assessment (Volume 2, Section 2). In an attempt to mitigate potential impacts to air quality, North American will control its construction emissions, operations emissions and greenhouse gas emissions.

Relevant to the mitigation of potential odours, North American plans to implement a leak repair and detection program to identify and reduce fugitive emissions. Tanks with volatile contents will not be vented to the atmosphere, and vapours from these tanks will be recovered.

North American has designed and will operate the coker in order to minimize and control fugitifve emissions of RSCs to prevent offsite odours (Section 2.9.10).

4.9 Follow-up and Monitoring

The potential risks to public health and the possibility of odour occurrences will be addressed through the follow-up activities and monitoring initiatives described in the Air Quality assessment (Volume 2, Section 2.8), in the Hydrogeology assessment (Volume 3, Section 5.8) and in the Surface Water Quality assessment (Volume 3, Section 7.8).

In accordance with the respective AENV environmental approval, North American will undertake the following emission source monitoring and ambient air quality monitoring:

- Source monitoring of sulphur dioxide and RSCs;
- Source monitoring of nitrogen oxides;
- Implementation of a leak detection and repair (LDAR) program;
- Participation in the FAP ongoing ambient air monitoring program; and
- Implementation of a formal process to identify and respond to odour complaints.

Groundwater follow-up and monitoring is described in Section 5.8 of the Hydrogeology Assessment (Volume 3, Section 5). The planned groundwater monitoring program will be used to enable early detection of changes in groundwater conditions. As described, in the event that significant changes in groundwater quality are detected, North American will develop and implement an incident-specific groundwater response plan.

Follow-up and monitoring with respect to surface water quality is summarized in Volume 3, Section 7.8. As described, water contained in the stormwater ponds will be monitored before it is discharged to the NSR to ensure it complies with regulatory discharge criteria.

The Project's operational wastewater effluent also will be monitored before it is discharged to the NSR to ensure it complies with regulatory discharge criteria. Monitoring will consist of continuous temperature, pH and flow measurements, while other water quality variables will be measured through composite sampling. The effluent discharge limits and specific monitoring requirements will be established by AENV

Air and water monitoring will contribute to addressing human health concerns through the detection and subsequent response to releases of concern. Ambient air monitoring will help reduce uncertainties associated with environmental exposures and risks and allow North American to verify its impact predictions for human health and project odours.

4.10 Summary

Emissions from Baseline, Project and future sources are predicted to result in potentially elevated health risks for certain individual chemicals and mixtures of chemicals (described below). However, due to the conservative nature of the HHRA, the predicted risk estimates are not expected to result in measurable health effects in the region.

The Project emissions on their own and in combination with other area emissions are expected to result in some odours being perceived by residents in the area.

4.10.1 Acute Assessment Summary

The predicted short-term air concentrations generally met health-based exposure limits for the COPCs. However, exceedances of the acute exposure limits are predicted for certain COPCs.

Generally, the Project's contribution to acute health risks was negligible, as shown by the similarities in risks between the Baseline and Application cases. Short-term exceedances are predicted for acrolein, sulphur dioxide, the respiratory irritants and eye irritants for Project alone. The exceedances for the eye irritants were primarily due to acrolein while the exceedances for the respiratory irritants were due to sulphur dioxide and, to a lesser extent, nitrogen dioxide.

Given the probable overestimation of background exposure levels, the degree of conservatism incorporated into the different exposure limits, and the use of maximum concentrations to characterize risks, the results of the acute inhalation assessment are likely conservative.

4.10.2 Chronic Assessment Summary

Potential long-term health risks for the Project emissions were evaluated for non-carcinogens (expressed as RQs) and carcinogens (expressed as incremental lifetime cancer risks or ILCR). Predicted long-term air concentrations met health-based exposure limits for the COPCs in most cases.

Generally, the Project's contribution to chronic health risks was negligible, as shown by the similarities in risks between the Baseline and Application cases. Long-term exceedances are predicted for acrolein and the nasal irritants for the Project only at the maximum of the industrial locations. The acrolein exceedance is largely due to the conservative nature of the exposure limit. Because the exceedance for the nasal irritants is primarily due to acrolein, it can be said that the exceedance for the nasal irritants is due to the conservative nature of the acrolein exposure limit as well.

Given the degree of conservatism built into the HHRA, the results of the chronic inhalation assessment are likely conservative.

None of the exposure estimates for the multiple exposure pathway assessment exceeded their health-based exposure limits. The results suggest that the Project's air emissions are not expected to adversely affect the quality of the area's locally grown foods.

4.10.3 Odour Assessment Results

An odour assessment was completed for the COPCs on an acute basis, using peak 3-minute or 1-hour concentrations. A CR of 1.0 or less indicates that the odour threshold for the COPC is not exceeded.

With the exception of hydrogen sulphide, maximum predicted short-term air concentrations were less than mean odour thresholds for all development cases. As indicated by the results of the odour assessment, the Project's emissions may result in nuisance odours in the immediate vicinity of the Project area.

Overall, the majority of the area residents are not expected to detect any odours as a result of the Project's emissions.

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APPENDIX 2A: SOURCE AND EMISSION INVENTORY

TABLE OF CONTENTS

TABLES

FIGURES

2A1 INTRODUCTION

The Project site is located in an airshed that is shared by other industrial and residential users. In order to assess the air quality effects associated with the Project, it is necessary to identify and document other industrial and non-industrial emission sources. This technical Appendix identifies and characterizes emission sources in the vicinity of the Project site.

The Project information is presented for the application case (243,000 bpsd of bitumen processing capacity). The other industrial source information is presented for a Baseline Case (existing and approved operations) and for a Cumulative Case (Baseline Case plus disclosed but not yet approved operations, including the Project). The non-industrial sources focus on traffic emissions and emission from domestic/commercial heating units.

2A2 APPROACH

2A2.1 Study Area

The preparation of a source and emission inventory involves the systematic identification and characterization of relevant sources within a specified geographic region that discharge gaseous or particulate emissions to the atmosphere. While the proposed Project is located in Strathcona County, there are four other administrative jurisdictions adjacent to Strathcona County that include: Sturgeon County to the north, Lamont County to the west, the City of Fort Saskatchewan to the southwest, and the City of Edmonton further to the southwest (Figure 2A-1).

Previous air quality assessments in the region focused on 50 x 50 km study areas centered on the respective facilities (e.g., BA Energy (2004) Heartland Upgrader, Shell Scotford (2005) Upgrader SE1 Expansion, North West Upgrading (2006) Upgrader, and Synenco (2006) Northern Lights Upgrader). The focus for these assessments was the identification and characterization of all significant industry sources within a nominal 20 to 25 km radius of the facilities being assessed. The Heartland and Scotford assessments also included traffic and residential/commercial heating sources explicitly, while the North West and Northern Lights assessments included these other sources implicitly by adding a background concentration term to the model predictions.

The Petro-Canada Oil Sands Inc. (2006) Sturgeon Upgrader and the Shell (2007) Scotford SU2 Expansion considered a larger 100 by 100 km area for identifying industry sources, and also included the City of Edmonton traffic and domestic/commercial heating unit emissions. The SU2 Expansion also considered the larger industrial sources in the east Edmonton area. The rationale for selecting a larger area for these assessments was associated with the need to be more rigorous with additional industrial developments being proposed in the region.

The urban and industrial emissions for the Project assessment are provided for the larger area for the same reason. Specifically, the emission sources for the 100 by 100 km area shown in Figure 2A-1 were identified and reviewed. Sources were identified for inclusion in the assessment using the following selection method.

2A2.2 Existing Industry Sources - Review and Selection

The (NPRI was used as a starting point to identify the industrial emission sources in the Project study area. The 2005 NPRI database identifies a number of industrial facilities in the Edmonton (77), Fort Saskatchewan (14), Sturgeon County (26), Strathcona County (25), and Lamont County (7) regions (resulting in a total of 149 facilities). However, only 136 of these facilities are located in the 100 x 100 km study area shown in Figure 2A-1 [namely: Edmonton (73), Fort

Saskatchewan (14), Sturgeon County (21), Strathcona County (25), and Lamont County (3)]. Some of the facilities are significant emission sources, while others are small sources.

In order to evaluate overlapping effects of these emissions with the proposed Project emissions, it is important that other significant sources be included. Significance is qualitatively defined as "large magnitude" sources or those sources that are "near the proposed Project site". A tiered selection approach was adopted to identify significant NPRI sources:

- Tier 1 facilities are located near the Project site and were characterized using the most recent data. For the most part, the Tier 1 facilities are within a 20 to 25 km radius of the Project site.
- Tier 2 facilities are the more distant or smaller facilities, and the associated information was not as recent as for the Tier 1 facilities. For the most part, the east Edmonton industrial sources fall in this category.
- Tier 3 facilities are not included as they are either small facilities or are sufficiently distant from the Project site; that is, their influence is minimal to providing an overall understanding of Project emissions on regional air quality.

Tables 2A-1 to 2A-6 identify the facilities located inside the 100 by 100 km study area for the respective regions and provides the associated criteria air contaminant (CAC) emission rates. The NPRI CAC emission rates are provided on an annual bases in various units (e.g., t, kg), depending on the magnitude of the emissions. The values in Tables 2A-1 through 2A-6 are based on the 2005 NPRI inventory and are all expressed on a t/d emission rate basis. The following comments can be made with respect to each region:

- **Strathcona County (Table 2A-1)**: NPRI identifies 25 facilities in Strathcona County. The Project assessment includes nine of the facilities that account for 100% and 96% of the SO_2 and NO_X emissions, respectively. The Petro-Canada Edmonton terminal (37.5 km from the centre of the Project site) and the Shell Sherwood terminal (28.6 km from the centre of the Project site) have relatively high VOC emissions but were not included as the emission data were not readily available from the databases used. The excluded sites are both more than 30 km from the Project site.
- **Sturgeon County (Table 2A-2)**: NPRI identifies 26 facilities in Sturgeon County. Only 21 of the facilities are located in the 100 km x 100 km study area. The Project assessment includes seven of the facilities that account for 96% and 72% of the SO_2 and NO_X emissions, respectively. Excluded sources include several sweet gas facilities and compressor stations that are located about 55 km from the Project site. The two Baytex facilities that have relatively high NOx emissions were not included in the Project assessment as the emission data were not readily available from the databases used.
- **Lamont County (Table 2A-3)**: NPRI identifies 7 facilities in Lamont County. Three of the sources are located in the 100 by 100 km study area. The Project assessment includes one of these facilities. The other two facilities are located more than 30 km from the centre of the Project site.
- **Fort Saskatchewan (Table 2A-4)**: NPRI identifies 14 facilities in Fort Saskatchewan. All 14 facilities are located in the 100 by 100 km study area. The Project assessment includes 10 of these facilities that account for virtually 100% of the industrial emissions. Three facilities have no CACs emissions and the other one is a small emission source.

- **Edmonton (Table 2A-5)**: NPRI identifies 77 facilities in Edmonton. Four of the facilities are located outside the 100 by 100 km study area. The Project assessment includes five facilities that account for 23 and 8% of the SO_2 and NO_X emissions, respectively. Several sweet gas and compressor stations facilities that are located 49.9 to 54.1 km from the Project site are excluded. The other sources that are excluded are small emissions sources compared to the others.

A summary of the existing facilities that are included for each region is provided in Table 2A-6. The following are noted with respect to the industrial sources that were included:

- The facilities that are included in the Project assessment account for 99% of the identified industrial SO_2 emissions (i.e., 55 out of 55 t/d) in the 100 by 100km study area. When urban emissions (5.25 t/d for SO_2) are accounted for, the indicated facilities include <u>99% of the regional SO_2 emissions</u>.

- The facilities that are included in the Project assessment account for 85% of the industrial NO_X emissions (i.e., 45 out of 52 t/d, 86.5%) in the 100 by 100 km study area. When urban emissions (177 t/d for NO_x) are accounted for, the indicated facilities include <u>97% of the regional NO_x emissions</u>.

- The facilities that are included account for <u>77% of the industrial CO emissions</u> (i.e., 23 out of 29 t/d, 79%) in the study area. When urban emissions (916 t/d for CO) are accounted for, the indicated facilities include <u>99% of the regional CO emissions</u>.

- The facilities that are included account for 75% of the industrial $PM_{2.5}$ emissions (i.e., 2.1 out of 2.8 t/d) in the study area. When urban emissions (12 t/d for $PM_{2.5}$) are accounted for, the indicated facilities include <u>95% of the regional $PM_{2.5}$ emissions</u>.

- The facilities that are included account for 60% of the industrial VOC emissions (i.e., 12 out of 20 t/d) in the study area. When urban emissions (73 t/d for VOC) are accounted for, the indicated facilities include <u>92% of the regional VOC emissions</u>.

While there was some subjectivity in determining inclusion of the more distant sources, the indicated sources capture most of the 100 by 100 km study area emissions, especially those that are in closer proximity to the Project site. In conclusion, the inventory is viewed as being sufficiently complete to evaluate the overlapping effects of the Project emissions with those from other sources.

2A2.3 Future Industry Sources - Review and Selection

The NPRI database refers to facilities that were operating in 2005, and does not include facilities that have received approvals to operate and are not currently operating. The NPRI database also excludes facilities that are proposed and have filed, or are filing applications for approvals to operate. The identified facilities that fall into these two categories are indicated in Table 2A-7.

2A2.4 Other Facility Changes

The CE Alberta BioClean facility received approval from AENV (Approval 00046706-00-00) in 1998, and the predicted emissions from this facility have been included in previous air quality assessments for the region. However, the approval was cancelled by AENV on July 18, 2006. The company was required to start construction by May 1, 1999. The approval was cancelled after several unsuccessful attempts by AENV to determine the status of the project, which was not started. For this reason, the proposed emissions for this project are not included for the Project assessment.

The OxyVinyls Scotford Plant near Fort Saskatchewan discontinued production in January 2006. Subsequently, the facility began a decommissioning process and was planned to be fully shutdown by the end of March 2006. As the facility is not currently operating, the emissions for this facility are not included for the Project assessment.

The Sulzer Metco (Canada) Inc. is located about 14.8 km to the southwest of the Project site. While the plant is identified in various databases, no CAC emissions are identified with this plant. As this plant is only a source of NH_3, it was not included for the Project assessment.

2A2.5 Traffic and Community Sources

Urban emissions sources were included in the Sturgeon and Shell SU2 application assessments. The information for the 100 by 100 km study area was obtained from the EC 2000 emission database and was supplied via Shell Canada through RWDI West Inc. The urban emissions sources were grouped as either “traffic” sources that were assumed to have a diurnal variation, or as “domestic/commercial heating” sources that were assumed to have a seasonal variation. This temporal variation is in contrast to the industrial sources that are assumed to operate on a continuous basis.

2A2.6 Source and Emission Databases

The NPRI emission database does not have the detailed information required for a dispersion modelling assessment; therefore the NPRI database is not sufficient for the purposes of evaluating the Project. For this reason other information sources have been used:

- The data provided in recently filed regulatory applications for the BA Energy Heartland Upgrader, the Shell Scotford Upgrader SE1 Expansion, the North West Upgrader, the Synenco Northern Lights Upgrader, the Petro-Canada Sturgeon Upgrader and the Shell Scotford Upgrader SU2 Project. While there were many similarities among these emission databases, there are some differences.

- For this reason, the FAP commissioned a study to prepare a common source and emission database for the currently operating industries in the FAP region. The FAP emission information was supplied for this assessment by FAP through AMEC Earth and Environmental (Rudolph R, pers. comm., 2007).

- Source and emission data for the Edmonton area industrial emissions were obtained from the Petro-Canada Refinery Conversion Project (RCP) application (Petro-Canada 2004). The application provided emission data for a number of the industrial facilities near the refinery.

The emission data used for the Project assessment is a blend of the FAP and non-FAP data as the non-FAP data also provide a more detailed fugitive emission estimates and information for proposed facilities.

2A2.7 Required Emission Data

Emission sources types can be defined by the following parameters:

- **Conventional stacks** are defined by location, base elevation, stack height, stack diameter, gas exit velocity, gas exit temperature and contaminant emission rate. These stacks typically operate on a continuous basis with relatively constant emission rates.

- **Flare stacks** typically discharge low volumes of gas to the atmosphere under normal operating conditions. Under plant start-up, shut-down, upset or emergency conditions; these stacks can discharge high volumes of gas to the atmosphere. Under these latter conditions, the release durations tend to be relatively short (approximately 1 hour or less) and infrequent (e.g., one event per year). The composition and flow rates of the gas streams to the flare are required to characterize the flare stacks. Conventional stack parameters were used to characterize the flare stacks once adjustments were made according to the AENV Calculation Sheet for Flares.xls (reference need here).

- **Fugitive emissions** result from small leaks, which while individually very small, can collectively be substantial for large, complex facilities. These leaks include pipeline flanges, valve packing, rotating seals, vents, and drains. Fugitive emissions are typically defined as area sources resulting from an individual process area or from an entire facility.

- **Urban/community emission sources** include traffic from local roadways and highways, and heating units used in residential and commercial buildings. These sources were represented as area sources for a 4 km by 4 km grid.

- Combustion sources produce trace compounds such as SO_2, NO_x, CO, and $PM_{2.5}$ as well as various VOC, RSC, and PAH compounds. Fugitive emission sources produce VOC and RSC compounds.

- Information for existing facilities can be obtained from measurements, and information for future sources can be obtained from a combination of extrapolation, engineering mass balance considerations, and process-specific emission factors. Extensive use of process-specific emission factors was extensively used to estimate VOC and PAH emission for combustion and fugitive sources.

- This assessment focused on chemical compounds or chemical compound groups that are expected to be emitted in meaningful quantities from the Project.

- All spatial information characterizing the locations of the emission sources are referenced to the UTM NAD 83 coordinate system.

2A2.8 Temporal Variability

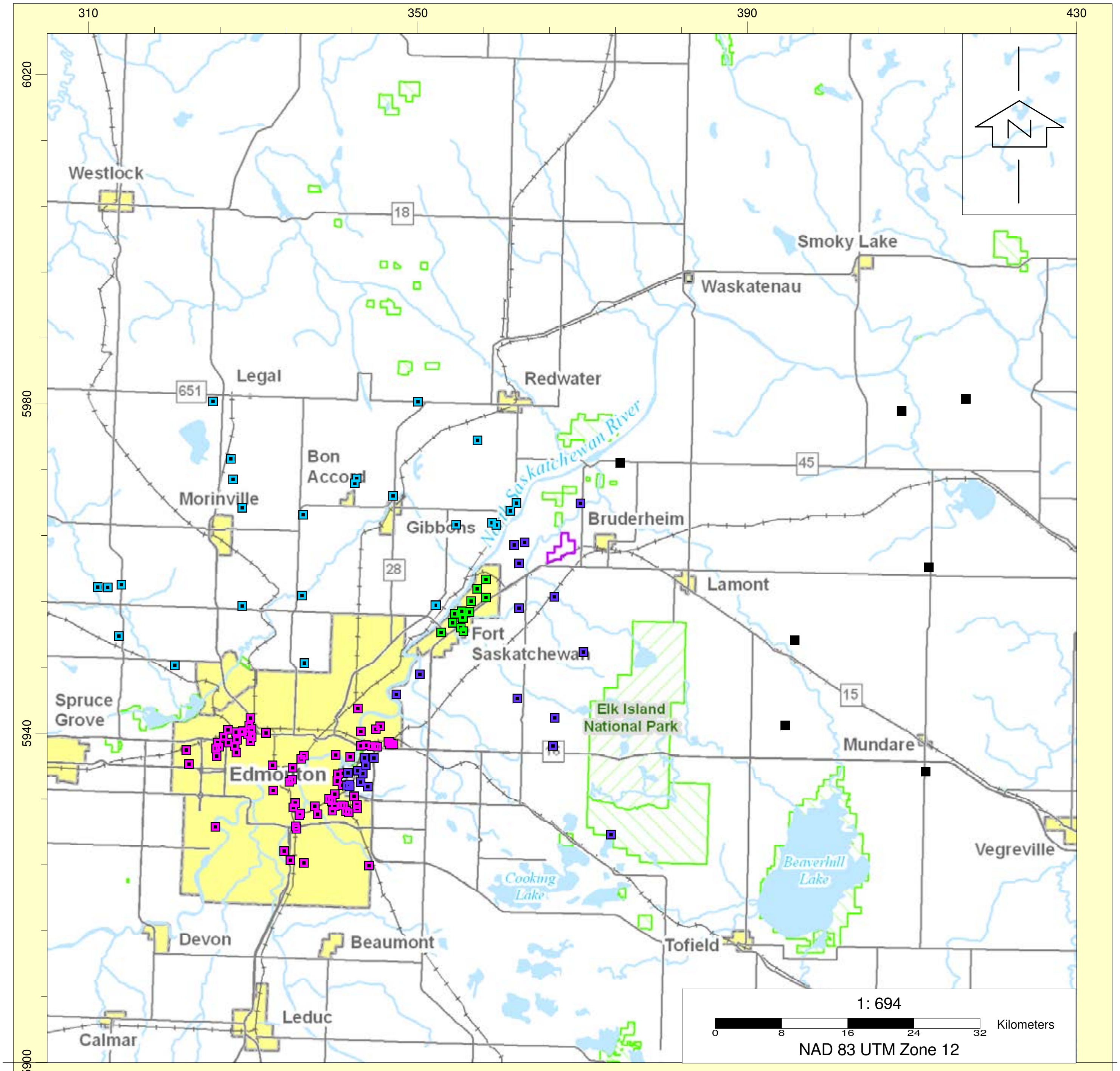
For SO_2 emissions, there can be a considerable difference between normal emissions (i.e., annual average values) and maximum approved emissions (i.e., short term peak values) for a given facility. The following are noted relative to this difference:

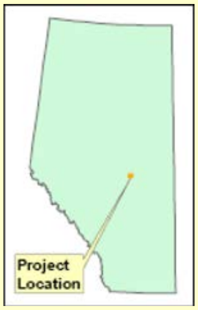
- This assessment has the primary focus to evaluate the implications of the Project on local and regional air quality. For this reason annual average emission rates were used to predict annual average concentrations, and higher short-term emission rates were used to predict 1-h and 24-h average concentrations. Upset emission profiles specific to the Project are also evaluated.

- For non-project Upgrader facilities, annual average SO_2 emission rates were used to predict annual average SO_2 concentrations. For some of the more significant sources, higher rates are used to predict 1-h and 24-h average concentrations. The maximum approved values are not necessarily used as it is unlikely that all SO_2 emitting facilities will be emitting at maximum approved rates simultaneously.

- There is also some temporal variability for NO_X emissions. The assumed emission rates are based on those provided by the operators and were viewed as representing average emissions instead of maximum approved emissions.

The source and emission inventory preparation for this assessment focused on characterizing the Project's emission sources and other emission sources in the region.





Legend

▭ Project Property Line

▭ Community/Town

▭ Natural Area

▣ Facilities in Sturgeon

┼ Railway

▣ Facilities in Edmonton

▣ Facilities in Strathcona

▣ Facilities in Fort Saskatchewan

■ Facilities in Lamont

Title:

INDUSTRIAL FACILITIES IN EDMONTON, FORT SASKATCHEWAN, STURGEON, STRATHCONA AND LAMONT COUNTIES

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 17/10/2007

File:
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Table 2A-1 Summary of the Strathcona County Industrial Facilities and Associated CAC Emissions

Operator	Facility Name	NPRI 2005 Emissions (t/d)					Tier	In FAP?	Distance (km)	Comments
		SO_2	NO_X	CO	$PM_{2.5}$	VOC				
Air Liquide Canada	**Scotford Complex**	**-**	**0.471**	**0.149**	**0.016**	**-**	**1**	**Y**	**4.7**	
Alberta Capital Region	Wastewater Plant	-	-	-	0.007	-	3		26.9	small source
Alberta Envirofuels	**Alberta Envirofuels**	**0.022**	**1.116**	**0.368**	**-**	**0.149**	**2**		**37.5**	
Alcan Inc.	**Strathcona Works**	**11.375**	**0.622**	**-**	**-**	**-**	**2**		**34.3**	
Altasteel	**Altasteel**	**0.165**	**0.417**	**1.312**	**0.149**	**0.179**	**2**		**38.6**	
Aquest Energy Ltd.	Aquest Cooking Lake	-	0.270	-	-	-	3		35.2	small source and > 35 km
Canexus Ltd.	**Bruderheim**	**-**	**0.010**	**-**	**-**	**-**	**1**	**Y**	**9.0**	
Daylight Energy Trust	Fort Saskatchewan	-	0.110	-	-	-	3		12.8	small source
Genalta Recycling	Edmonton	-	-	-	-	-	3		38.9	no CACs emitted
Husky Energy	Redwater O.B.	0.000	0.122	0.000	0.002	0.000	3		5.9	small source
Imperial Oil	**Strathcona Refinery**	**11.872**	**5.586**	**4.937**	**0.776**	**2.881**	**1**		**37.7**	
Kinder Morgan Canada	Edmonton Terminal	-	-	-	-	0.094	3		36.6	small source and > 35 km
Lafarge Canada, Inc.,	Villeneuve A&P Plant	-	--	-	0.015	-	3		23.1	small source
Northrock Resources	2-31-52-23W4	-	-	-	0.005	-	3		38.8	small source and > 35 km
Oxy Vinyls Canada	Scotford Plant	-	-	-	0.017	-	3		5.6	shut down
Petro Canada	**Edmonton Refinery**	**3.781**	**4.579**	**2.532**	**0.157**	**1.812**	**2**		**35.6**	
Petro Canada	Edmonton Terminal	-	-	-	-	2.285	3		35.0	> 35 km
Petrofund Corp.	Ft.Sask. Bremner	-	0.137	-	-	-	3		24.0	small source
Petrofund Corp.	Ft.Sask. Partridge Hill	-	0.160	-	-	-	3		19.0	small source
Shaw Pipe Protection	21 Street, Edmonton	-	-	-	-	0.042	3		36.7	small source and > 35 km
Shell Canada	**Shell Scotford Refinery**	**0.269**	**2.199**	**1.275**	**0.029**	**0.296**	**1**	**Y**	**5.9**	
Shell Canada	Sherwood Terminal	-	-	-	-	1.299	3		37.4	> 35 km
Shell Canada Limited	**Scotford Upgrader**	**19.099**	**2.542**	**1.738**	**0.039**	**0.776**	**1**	**Y**	**5.9**	
Shell Chemicals	**Scotford Chemical Plant**	**0.006**	**1.152**	**0.457**	**0.033**	**0.270**	**1**	**Y**	**5.9**	
Signalta Resources	Signalta Fort Sask 11-27	-	0.067	-	-	-	3		20.6	small source
Total Emissions: Tier (1+2+3)		**46.59**	**19.56**	**12.77**	**1.23**	**10.08**	**25**	**Facilities that are included in the Project assessment are shown in bold**		
Emissions Included: Tier (1+2) (% of Total Emissions)		**46.59 (100)**	**18.70 (96)**	**12.77 (100)**	**1.20 (98)**	**6.36 (63)**	**10 (40)**			

Table 2A-2 Summary of the Sturgeon County Industrial Facilities and Associated CAC Emissions

Operator	Facility Name	NPRI 2005 Emissions (t/d)					Tier	In FAP?	distance (km)	Comments
		SO_2	NO_X	CO	$PM_{2.5}$	VOC				
Acclaim Energy Inc.	Norcen Campbell Namao	-	0.140				3		40.9	> 20 km
Agricore United	Fort Saskatchewan CPC	-					3		16.8	no CAC emitted
Agrium	**Redwater Fertilizer Operations**	**4.399**	**3.278**	**1.356**	**0.268**	**0.586**	**1**	**Y**	**13.3**	
Agrium	**Fort Sask. Nitrogen Operations**	**-**	**2.322**	**1.554**	**0.014**	**0.036**	**1**	**Y**	**7.9**	
Alliance Pipeline	Morinville Compressor Station	-	0.277	0.169	0.005	-	3		39.3	> 20 km
ATCO MIDSTREAM	Carbondale	-	0.111	-	0.002	-	3		39.6	> 20 km
ATCO MIDSTREAM	Legal	-	0.216	0.364	0.001	-	3		46.1	> 20 km
ATCO Pipelines	FBA	-	0.054	-	0.001	-	3		26.5	small source
ATCO Pipelines	Villeneuve	-	0.058	0.066	-	-	3		49.2	small source and > 20 km
Baytex Energy Trust	Baytex Excelsior Battery	0.226	0.570	0.208	0.011	0.000	3		31.8	> 20 km
Baytex Energy Trust	Baytex Opal Compressor	0	0.326	0.000	0.000	0.000	3		25.1	> 20 km
Bunge Canada	**Fort Sask. Plant**	**-**	**-**	**-**	**0.042**	**0.325**	**1**		**16.9**	
Daylight Energy Trust	Bon Accord 16-15-56-23-4	-	0.310	0.000	-	-	3		21.6	> 20 km
Degussa Canada	**Gibbons Site**	**-**	**0.055**	**0.046**	**0.001**		**1**	**Y**	**7.9**	
Dept. of National Defense	Canadian Forces Base	-	-	-	-	0.000	3		34.3	no CAC emitted
Encana	Wild River Sweet Gas Plant	-	0.094	0.146	-	-	3		26.5	small source
Prospec Chemicals	**Sturgeon County**	**0.082**	**0.003**	**0.007**	**-**	**-**	**1**	**Y**	**32.2**	
Provident Energy Trust	**Redwater Fractionation and Storage**	**0.740**	**0.065**	**0.078**	**0.002**	**0.085**	**1**	**Y**	**8.6**	
Signalta Resources	Signalta Fairydell-Bon Accord 5-35	-	0.109	-	-	-	3		41.8	small source and > 20 km
TransCanada Energy	**Redwater Power Plant**	**-**	**0.345**	**0.104**	**0.008**	**-**	**1**	**Y**	**9.2**	
Total Emissions: Tier (1+2+3)		**5.45**	**8.33**	**4.10**	**0.36**	**1.03**	**20**	**Facilities that are included in the Project assessment are shown in bold**		
Emissions Included: Tier (1+2) (% of Total Emissions)		**5.22 (95.9)**	**6.07 (72.8)**	**3.14 (76.8)**	**0.34 (94.4)**	**1.03 (100)**	**7 (35)**			

Table 2A-3 Summary of the Lamont County Industrial Facilities and Associated CAC Emissions

Operator	Facility Name	NPRI 2005 Emissions (t/d)					Tier	In FAP?	Distance (km)	Comments
		SO_2	NO_X	CO	$PM_{2.5}$	VOCs				
Altagas Services	Mundare Plant	-	0.184	0.029	0.001	-	3		34.5	> 30 km
Daylight Energy Trust	Chipman (13-27-54-18-4)	-	0.097	0.074	-	-	3		30.2	> 30 km
Erco Worldwide	**Bruderheim Plant**	**-**	**-**	**-**	**0.005**		**1**		**12.5**	
Total Emissions: Tier (1+2+3)		**0.00**	**0.28**	**0.10**	**0.01**	**0.00**	**3**	**Facilities that are included in the Project assessment are shown in bold.**		
Emissions Included: Tier (1+2) (% of Total Emissions)		**0.00 -**	**- -**	**0.00 -**	**0.005 (84)**	**0.00 -**	**1 (33)**			

Table 2A-4 Summary of the Fort Saskatchewan Industrial Facilities and Associated CAC Emissions

Operator	Facility Name	NPRI 2005 Emissions (t/d)					Tier	In FAP?	Distance (km)	Comments
		SO_2	NO_X	CO	$PM_{2.5}$	VOC				
ATCO Midstream	**Fort Sask. Sour Gas Plant**	**-**	**-**	**-**	**-**	**-**	**1**			**No NPRI Data**
BP CANADA	**Fort Sask. Storage and Fractionation**		**0.320**	**0.277**	**0.007**	**0.255**	**1**	**Y**	**10.1**	
Dow Chemical Canada Inc.	**Western Canada Operations**	**0.130**	**3.581**	**2.279**	**0.044**	**1.087**	**1**	**Y**	**12.9**	
Guardian Chemicals Inc.	Fort Sask.	-	-	-	-	-	3		16.1	no CACs emitted
KEYERA Energy Ltd.	**Fort Sask. Plant**	**0.454**	**0.128**	**0.093**	**0.005**	**1.541**	**1**	**Y**	**11.5**	
Lafarge Canada, Inc.,	Ft. Sask. Conc. Plan						3		15.7	no CACs emitted
Marsulex Inc.	Customer Service Centre	0.000	0.000	0.000			3		15.7	small source
Marsulex Inc.	**Marsulex Sulphides**	**0.987**	**0.004**	**0.003**	**0.000**	**0.006**	**1**	**Y**	**13.7**	
MEGlobal Canada Inc.	Fort Sask. EOEG					0.036	3		11.1	small source
Nucryst Pharmaceuticals	Nucryst Pharmaceuticals						3		14.8	no CACs emitted
Sherritt International Corporation	**Fort Sask.**	**1.049**	**7.303**	**0.496**	**0.020**		**1**	**Y**	**14.5**	
Sulzer Metco (Canada) Inc.	**Fort Sask. Operations**				**0.001**		**1**	**Y**	**14.8**	
The Cobalt Refinery Company Inc.	**Fort Sask.**				**0.009**		**1**		**14.5**	
Transalta Cogen Lp	**Fort Sask. Cogeneration Plant**		**0.230**	**0.235**	**0.019**		**1**	**Y**	**17.9**	
Umicore Canada	**Fort Sask. Production Facility**				**0.002**		**1**	**Y**	**15.3**	
Total Emissions: Tier (1+2+3)		**2.62**	**11.57**	**3.38**	**0.11**	**2.93**	**15**	**Facilities that are included in the Project assessment are shown in bold The ATCO Midstream facility is included in the Project assessment despite the lack of NPRI data.**		
Emissions Included: Tier (1+2) (% of Total Emissions)		**2.62 (100)**	**11.57 (100)**	**3.38 (100)**	**0.11 (100)**	**2.89 (99)**	**10 (67)**			

Table 2A-5 Summary of the Edmonton Industrial Facilities and Associated CAC Emissions

Operator	Facility Name	NPRI 2005 Emissions (t/d)					Tier	In FAP?	Distance (km)	Comments
		SO_2	NO_X	CO	$PM_{2.5}$	VOC				
ABCgroup Inc.	Polybottle Group						3		43.9	no CACs emitted
AEP Canada	Edmonton Resinite						3		45.0	no CACs emitted
Alberta Plywood Ltd	A Division Of West Fraser Mills		0.058	0.185		0.220	3		45.4	> 35 km
All Brite Metal Finishing-	Edmonton						3		41.6	no CACs emitted
Armor Wood Products-	Armor Wood Products			0.000			3		31.4	no CACs emitted
Ashland Canada	Edmonton						3		36.1	no CACs emitted
AT PLASTICS	**Edmonton Site**		**1.142**	**0.888**	**0.035**	**1.140**	**2**		**38.7**	
ATCO Pipelines	Cloverbar		0.420	0.444	0.001	0.067	3		30.9	beyond 30 km
BEAVER PLASTICS	BEAVER PLASTICS					0.246	3		45.9	beyond 35 km
Canada Bread	Edmonton Bakery					0.337	3		45.9	beyond 35 km
CEDA REACTOR	CEDA-Reactor Ltd						3		31.6	no CACs emitted
Celanese Canada	**Edmonton Facility**	**0.009**	**2.435**	**1.129**	**0.038**	**0.233**	**2**		**33.8**	
City of Edmonton	**Gold Bar Wastewater Treatment**	**0.223**					**2**		**37.3**	
Edmonton Waste Management Branch	Composting Facility						3		31.6	no CACs emitted
ClearTech Industries Inc	Edmonton						3		48.1	no CACs emitted
Cloverdale Paint	Edmonton Factory					0.027	3		46.8	beyond 35 km
Colgate	Palmolive Canada-Edmonton						3		44.6	no CACs emitted
Continental Cylinder Inc.	Continental Cylinder Inc.						3		49.0	no CACs emitted
Custom Environmental Services Ltd.	Edmonton Waste Brokerage Facility						3		31.6	no CACs emitted
Daam Galvanizing	Edmonton				0.002		3		39.3	small source and far away
Data Business Forms Limited	Edmonton					0.050	3		47.0	small source and far away
EMCO Building Products Corp.	BP Edmonton Plant	0.171	0.069	0.054	0.073		3		38.2	beyond 35 km
Endura Manufacturing	Endura Manufacturing						3		44.4	no CACs emitted
Epcor Generation	Clover Bar Thermal Generating Station		0.063				3		33.1	Decommissioned
Epcor Generation	**Rossdale Thermal Generating Station**		**3.900**	**1.270**			**2**		**43.2**	
Epcor Water Services	E. L. Smith Water Treatment Plant	0.000	0.006	0.005	0.000	0.000	3		43.6	small source and far away
Federated Co-Operatives	Edmonton Feed Plant				0.002	0.000	3		31.6	small source
Ge Betz	Edmonton						3		43.7	no CACs emitted
Georgia-Pacific Canada	Edmonton Gypsum				0.049	0.045	3		32.9	small source
Grace Canada	GRACE CONSTRUCTION PRODUCTS - 3			0.086	0.003		3		44.2	small source and far away

Table 2A-5 Summary of the Edmonton Industrial Facilities and Associated CAC Emissions (continued ….)

Operator	Facility Name	NPRI 2005 Emissions (t/d)					Tier	In FAP?	Distance (km)	Comments
Great Western Containers	Edmonton South Plant					0.082	3		33.1	small source and far away
Great Western Containers	Edmonton North Plant						3		40.2	no CACs emitted
Hexion Specialty Chemicals	Edmonton			0.164		0.394	3		44.7	beyond 35 km
Imperial Oil	Edmonton Terminal					2.156	3		39.3	beyond 35 km
Labatt Breweries Of Canada	Alberta				0.004	0.087	3		46.8	small source and beyond 35 km
Lafarge North America	ETM Concrete plant				0.001		3		39.9	small source and beyond 35 km
Lafarge Canada, Inc.	Winterburn A&P Plant				0.002		3		40.3	small source and beyond 35 km
Lafarge Canada, Inc.	Stadium Rd. Concrete				0.002		3		45.1	small source and beyond 35 km
Lafarge Canada, Inc.	Cloverbar A&P Plant				0.003		3		31.6	small source
Lafarge Canada, Inc.	Aggregate Wash Plant				0.016		3		40.8	small source and beyond 35 km
Lehigh Inland Cement	Inland Cement	0.228	3.428	4.429	0.095		3		45.5	beyond 35 km
Maple Leaf Metal Industries	Edmonton						3		41.8	no CACs emitted
MASTERFEEDS INC	Masterfeeds Edmonton				0.003		3		31.7	small source
Molson Canada	Edmonton					0.043	3		44.0	beyond 35 km
Ostrem Chem.	Ostrem Chem. Co. Ltd					0.000	3		39.3	beyond 35 km
Owens Corning Canada	**Edmonton Plant**		**0.642**		**0.362**	**0.120**	**2**		**33.4**	
Parmalat Dairy & Bakery Inc.	Edmonton	0.000	0.000	0.000	0.000	0.000	3		42.4	small source
Praxair Canada Inc.	Edmonton						3		41.3	no CACs emitted
Procor Limited	Edmonton					0.044	3		42.3	small source and beyond 35 km
Quadra Chemicals Ltd	Edmonton						3		43.7	no CACs emitted
Quebecor World	Edmonton					0.073	3		48.6	small source and beyond 35 km
Raylo Chemicals	Argyll Road					0.025	3		43.4	small source and beyond 35 km
Raylo Chemicals	Clover Bar Site					0.063	3		34.3	small source
Rbw Waste management Ltd.							3		41.2	no CACs emitted
Russel metals	Edmonton						3		44.9	no CACs emitted
Russel Metals	RUSSELL METALS INC						3		41.6	no CACs emitted
Saputo Foods Ltd	EDMONTON				0.001		3		46.5	small source and beyond 35 km
Shaw Pipe Protection	34 St EDMONTON				0.001		3		41.2	small source and beyond 35 km
Solomon Coatings	SOLOMON COATINGS				0.001	0.038	3		42.4	small source and beyond 35 km
Standard General Inc.	Yellowhead				0.373		3		47.1	small source and beyond 35 km
Steel-Craft Door Products	Main Plant						3		43.2	no CACs emitted
Trimay Wear Plate	TRIMAY WEAR PLATE						3		40.7	no CACs emitted
Unifeed	Unifeed Mill - Edmonton				0.000		3		31.6	small source
Univar Canada Limited	Edmonton						3		47.0	no CACs emitted
University of Alberta	University Heating Plant		0.401	0.334	0.008		3		45.8	beyond 35 km
Waste Management Of Canada	West Edmonton Landfill	0.080			0.002		3		46.2	beyond 35 km

Table 2A-5 Summary of the Edmonton Industrial Facilities and Associated CAC Emissions (continued ….)

Operator	Facility Name	NPRI 2005 Emissions (t/d)					Tier	In FAP?	Distance (km)	Comments
West Coast Reduction Ltd.	Northern Alberta Processing Company						3		31.6	no CACs emitted
Western Hard Chrome Plating	Edmonton						3		45.5	no CACs emitted
Wilkinson Steel and Metals	Edmonton						3		45.3	no CACs emitted
ZCL Composites	Edmonton Plant					0.116	3		41.0	small source and beyond 35 km
ZEP Manufacturing Of Canada	Edmonton						3		48.2	no CACs emitted
Total Emissions: Tier (1+2+3)		**0.71**	**12.57**	**8.99**	**1.08**	**5.61**	**71**	**Facilities that are included in the Project assessment are shown in bold.**		
Emissions Included: Tier (1+2) (% of Total Emissions)		**0.23 (33)**	**8.12 (65)**	**3.29 (37)**	**0.43 (40)**	**1.49 (27)**	**5 (7)**			

Table 2A-6 Summary of Industrial Emissions for the Five NPRI Regions

NPRI Region	Tier	Number of Facilities	NPRI 2005 Emission Summary									
			SO_2		NO_X		CO		$PM_{2.5}$		VOCs	
			(t/d)	(%)	(t/d)	(%)	(t/d)	(%)	(t/d)	(%)	(t/d)	(%)
Strathcona County	Tier 1+2+3	25	46.59	84	19.56	37	12.77	44	1.24	45	10.08	51
	Tier 1+2	8	46.59	85	18.70	42	12.77	57	1.22	58	6.36	54
	Tier 1+2	32%	100		96		100		98		63	
Sturgeon County	Tier 1+2+3	21	5.45	10	8.33	16	4.10	14	0.36	13	1.03	5
	Tier 1+2	7	5.22	10	6.07	14	3.14	14	0.34	16	1.03	9
	Tier 1+2	33%	96		73		77		94		100	
Lamont County	Tier 1+2+3	3	0.00	0	0.28	1	0.10	0	0.01	0	0.00	0
	Tier 1+2	1	0.00	0		0	0.00	0	0.00	0	0.00	0
	Tier 1+2	33%					0		84			
Fort Saskatchewan	Tier 1+2+3	14	2.62	5	11.57	22	3.38	12	0.11	4	2.93	15
	Tier 1+2	10	2.62	5	11.57	26	3.38	15	0.11	5	2.89	25
	Tier 1+2	71%	100		100.00		100.00		100.00		98.77	
Edmonton	Tier 1+2+3	73	0.71	1	12.57	24	8.99	31	1.08	39	5.61	29
	Tier 1+2	2	0.23	0	8.12	18	3.29	15	0.43	21	1.49	13
	Tier 1+2	3%	33		65		37		40		27	
All industrial Sources	**Total Emissions: Tier (1+2+3)**	**136**	**55.37**	100	**52.31**	100	**29.34**	100	**2.79**	100	**19.65**	100
	Emissions Included: Tier (1+2) (% of Total Emissions)	**28**	**54.66**	100	**44.45**	100	**22.58**	100	**2.10**	100	**11.78**	100
		21	**99**		**85**		**77**		**75**		**60**	
Industrial plus Urban Sources	**Urban**		**5.25**		**177.43**		**916.00**		**12.10**		**73.25**	
	Urban + Tier (1+2+3)		**60.62**		**229.74**		**945.34**		**14.87**		**92.90**	
	Emissions Included: Urban + Tier (1+2) (% of Total Emissions)		**59.91**		**221.88**		**938.58**		**14.18**		**85.03**	
			99		**97**		**99**		**95**		**92**	

Table 2A-7 Approved and Proposed Facilities.

Operator	Facility	Region	Approved but not Operating	Proposed but not Approved
BA Energy	Heartland Upgrader	Strathcona	Yes	-
Shell Canada Ltd.	Scotford Upgrader SE1	Strathcona	Yes	-
	Scotford Upgrader SU2	Strathcona	-	Yes
North West Upgrading Inc.	North West Upgrader	Sturgeon	-	Yes
Synenco Energy	Northern Lights Upgrader	Sturgeon	-	Yes
Petro-Canada Oil Sands Inc.	Sturgeon Upgrader	Sturgeon	-	Yes
Aux Sable	Heartland Offgas	Strathcona	-	Yes
	Confidential Project	Strathcona	-	Yes
Access Pipeline	Redwater Trim Blending Facility	Sturgeon	-	Yes
Hazco Environmental Services	Bruderheim Sulphur Forming Facility	Lamont	-	Yes
Kinder Morgan (Terasen)	Heartland Storage Tank Terminal	Strathcona	-	Yes

2A3 EMISSION SUMMARY

2A3.1 Industrial Facilities

Figure 2A-2 identifies the major industrial emission sources within the 100 km by 100 km study area that were included in the air quality assessment. The facilities include FAP area facilities and Edmonton area facilities. Table 2A-8 summarizes the industrial facilities and their status (existing, approved or planned). In this context, existing refers to a facility that is currently operating, approved refers to a facility that has regulatory approval but is not yet operating, and planned refers to a facility that is proposed but does not yet have regulatory approval.

2A3.1.1 Baseline Case Summary

Table 2A-9 provides a summary of Baseline Case (i.e., existing and approved) emissions. The following are noted with respect to the FAP region industrial sources:

- There are two main industrial sources of SO_2 emissions in region; the existing Scotford Upgrader (31.30 t/d) and the approved BA Energy Heartland Upgrader (19.44 t/d). These two sources account for about 80 percent of the study area SO_2 emissions.

- The industrial NO_x emissions in the region are 45.0 t/d. The major NO_x emitting facilities in the study area are the Shell Scotford Upgrader (9.26 t/d), the Sherritt Fort Saskatchewan Complex (7.667 t/d), the Dow Chemical Fort Saskatchewan Plant (5.528 t/d), the Agrium Redwater Fertilizer Plant (5.11 t/d) and the BA Energy Heartland Upgrader (4.67 t/d).

- The industrial CO emissions in the 1region are 24.7 t/d. The largest emissions sources are the Shell Scotford Upgrader (9.19 t/d), and the Dow Chemical Fort Saskatchewan Plant (6.26 t/d).

- $PM_{2.5}$ emissions in the region are 3.39 t/d, with the largest source being the Dow Chemical Fort Saskatchewan Plant (0.89 t/d).

- VOC emissions in the region are 1.96 t/d, with the largest regional source being the Dow Chemical Fort Saskatchewan Plant (1.87 t/d).

- H_2S emissions in the region are 0.663 t/d, with the largest regional source being the BA Energy Heartland Upgrader (0.47 t/d).

Table 2A-9 also provides emission information for the Edmonton industrial sources and for urban sources. More details describing the Baseline Case industrial sources are provided in Section 2A.5 for the FAP industry sources, Section 2A.6 for the Edmonton Industry sources and in Section 2A.8 for the non-industrial sources.

2A3.1.2 Application Case Summary

Table 2A-10 provides a summary of Project emissions associated with the full development phase. The SO_2 emissions are provided for expected maximum (t/h and t/d) emission rates and average (t/d) emission rates to coincide with the averaging periods associated with the regulatory process. More details regarding the individual stack sources, potential upset flaring sources, and fugitive sources associated with the Project are provided in Section 2A.4. Table 2A-11 provides a summary of emissions from other sources associated with the Application Case.

2A3.1.3 Cumulative Case Summary

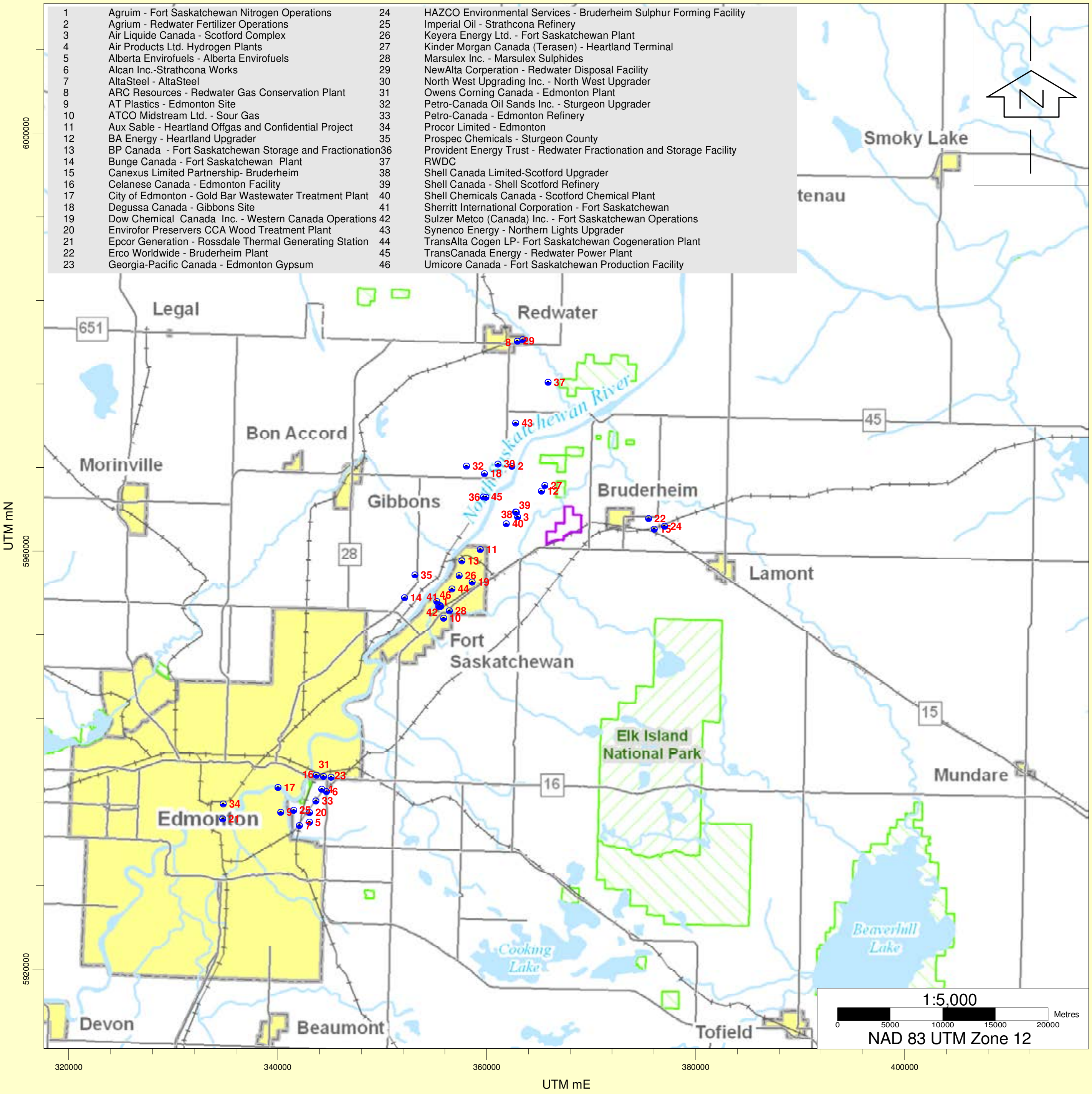
Table 2A-12 provides a summary of emission for a future planned scenario that includes the existing and approved facilities as well as future planned facilities that have not yet received approval.

2A3.1.4 SO_2 Emission Variability

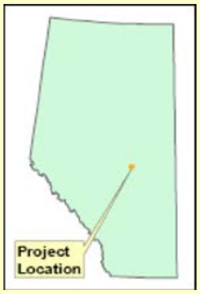
Table 2A-13 compares the SO_2 emissions from different information sources. The SO_2 emissions from many of the larger facilities tend to vary time. Typically, the actual emissions are less than the maximum approved values contained in the Alberta EPEA approvals. The table indicates the values that were used in this assessment to represent short-term (i.e., 1-h and 24-h) averaging periods and long-term (i.e., annual) averaging periods. More details discussing SO_2 emission variability for the FAP industry sources are provided in Section 2A.5.

2A3.1.5 Fugitive Emissions

Table 2A-14 provides an overview summary of fugitive emission in the region. Fugitive emission data are more difficult to obtain and values are not available for all the facilities in the region. More details describing fugitive emissions are provided in Section 2A.7 for industrial sources and in Section 2A.8 for urban sources.



1	Agruim - Fort Saskatchewan Nitrogen Operations	24	HAZCO Environmental Services - Bruderheim Sulphur Forming Facility
2	Agrium - Redwater Fertilizer Operations	25	Imperial Oil - Strathcona Refinery
3	Air Liquide Canada - Scotford Complex	26	Keyera Energy Ltd. - Fort Saskatchewan Plant
4	Air Products Ltd. Hydrogen Plants	27	Kinder Morgan Canada (Terasen) - Heartland Terminal
5	Alberta Envirofuels - Alberta Envirofuels	28	Marsulex Inc. - Marsulex Sulphides
6	Alcan Inc.-Strathcona Works	29	NewAlta Corporation - Redwater Disposal Facility
7	AltaSteel - AltaSteel	30	North West Upgrading Inc. - North West Upgrader
8	ARC Resources - Redwater Gas Conservation Plant	31	Owens Corning Canada - Edmonton Plant
9	AT Plastics - Edmonton Site	32	Petro-Canada Oil Sands Inc. - Sturgeon Upgrader
10	ATCO Midstream Ltd. - Sour Gas	33	Petro-Canada - Edmonton Refinery
11	Aux Sable - Heartland Offgas and Confidential Project	34	Procor Limited - Edmonton
12	BA Energy - Heartland Upgrader	35	Prospec Chemicals - Sturgeon County
13	BP Canada - Fort Saskatchewan Storage and Fractionation	36	Provident Energy Trust - Redwater Fractionation and Storage Facility
14	Bunge Canada - Fort Saskatchewan Plant	37	RWDC
15	Canexus Limited Partnership- Bruderheim	38	Shell Canada Limited-Scotford Upgrader
16	Celanese Canada - Edmonton Facility	39	Shell Canada - Shell Scotford Refinery
17	City of Edmonton - Gold Bar Wastewater Treatment Plant	40	Shell Chemicals Canada - Scotford Chemical Plant
18	Degussa Canada - Gibbons Site	41	Sherritt International Corporation - Fort Saskatchewan
19	Dow Chemical Canada Inc. - Western Canada Operations	42	Sulzer Metco (Canada) Inc. - Fort Saskatchewan Operations
20	Envirofor Preservers CCA Wood Treatment Plant	43	Synenco Energy - Northern Lights Upgrader
21	Epcor Generation - Rossdale Thermal Generating Station	44	TransAlta Cogen LP- Fort Saskatchewan Cogeneration Plant
22	Erco Worldwide - Bruderheim Plant	45	TransCanada Energy - Redwater Power Plant
23	Georgia-Pacific Canada - Edmonton Gypsum	46	Umicore Canada - Fort Saskatchewan Production Facility



Legend

🟪 Project Property Line

● Industrial Facility

🟨 Community/Town

🟩 Natural Area

Title:

MAJOR INDUSTRIAL FACILITIES IN THE REGIONAL STUDY AREA

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 11/05/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 Other Emissions/Industrial inclusion_05Nov07.srf

Drawn by: XC	Checked: MD	Fig. No.: 2A-2

Table 2A-8 Identification and Status of Industrial Emission Sources in the Air Quality Assessment 100 km by 100 km Study Area

	Operator	Facility	Status		
			Existing	**Approved but not Operating**	**Planned but not Approved**
1	Acess Pipeline	Redwater Trim Blending Facility			×
2	Agrium	Fort Sask. Nitrogen Operations	×		
3	Agrium	Redwater Fertilizer Operations	×		
4	Air LIQUIDE CANADA	Scotford Complex	×		
5	Air Products Ltd.	Hydrogen Plants	×		
6	Alberta Envirofuels	Alberta Envirofuels	×		
7	Alcan Inc.	Strathcona Works	×		
8	Altasteel	Altasteel	×		
9	ARC Resources	Redwater Gas Conservation Plant	×		
10	AT Plastics	Edmonton Site		×	
11	Atco Midstream Ltd.	Sour Gas	×		
12	Aux Sable	Heartland Offgas And Confidential Project		×	×
13	BA Energy	Heartland Bitumen Upgrader		×	
14	BP Canada	Fort Sask. Storage And Fractionation	×		
15	Bunge Canada	Bunge Canada-Fort Saskatchewan Plant	×		
16	Canexus Ltd Partnership	Bruderheim	×		
17	Celanese Canada	Edmonton Facility	×		
18	City Of Edmonton	Gold Bar Wastewater Treatment Plant	×		
19	Degussa Canada	Gibbons Site	×		
20	Dow Chemical Canada Inc.	Western Canada Operations	×		
21	Envirofor Preservers CCA Wood Treatment Plant	Envirofor Preservers CCA Wood Treatment Plant	×		
22	EPCOR Generation	Rossdale Thermal Generating Station	×		
23	ERCO Worldwide	Bruderheim Plant	×		
24	Georgia-Pacific Canada	Edmonton Gypsum	×		
25	HAZCO Environmental Services	Butimen Sulphur Forming			×
26	Imperial Oil	Strathcona Refinery	×		
27	Keyera Energy Ltd.	Fort Sask. Plant	×		
28	Kinder Morgan(Terasen)	Heartland Terminal			×
29	Marsulex Inc.	Marsulex Sulphides	×		
30	Newalta Corperation	Redwater Disposal Facility	×		
31	North West Upgrading Inc.	North West Upgrader			×
32	Owens-Corning Canada	Edmonton Plant	×		
33	Petro-Canada Oil Sands Inc.	Sturgeon Upgrader			×
34	Petro-Canada	Edmonton Refinery	×		
35	Procor Limited	Edmonton	×		
36	Prospec Chemicals	Prospec Chemicals - Sturgeon County	×		
37	Provident Energy Trust	Redwater Fractionation And Storage Facility	×		
38	RWDC	RWDC	×		
39	Shell Canada Limited	Scotford Upgrader	×	×	×
40	Shell Canada	Shell Scotford Refinery	×		

Table 2A-8 Identification and Status of Industrial Emission Sources in the Air Quality Assessment 100 by 100km Study Area

	Operator	Facility	Status		
			Existing	Approved but not Operating	Planned but not Approved
41	Shell Chemicals Canada	Scotford Chemical Plant	×		
42	Sherritt International Corporation	Fort Saskatchewan	×		
43	Synenco Energy	Northern Lights Upgrader			×
44	Transalta Cogen Lp	Fort Sask. Cogeneration Plant	×		
45	Transcanada Energy	Redwater Power Plant	×		
46	Umicore Canada	Fort Sask. Production Facility	×		

Table 2A-9 Summary of Emissions Associated with Baseline Case Sources

Operator	Facility	Emission Rate (t/d)						
		SO_2 (short)	SO_2 (long)	NO_x	CO	$PM_{2.5}$	VOC/PAH	H_2S
Agrium Products	Fort Sask. Nitrogen Operations	0.0045	0.0045	3.1680	0.6999	0.0169	0.0443	0.0000
Agrium Products	Redwater Fertilizer Operations	7.6580	4.1299	5.1060	1.2613	0.3847	0.3005	0.0000
Air Liquide Canada	Scotford Complex	0.0000	0.0000	0.4658	0.1476	0.0154	0.0209	0.0000
ARC Resources	Redwater Gas Conservation Plant	0.8001	0.8001	2.5759	1.8290	0.0280	0.0403	0.0062
ATCO Midstream	Fort Sask. Sour Gas Plant	0.0007	0.0070	0.0174	0.0030	0.0013	0.0010	0.0000
Aux Sable	Heartland Offgas	0.0000	0.0000	0.1770	0.1490	0.0120	0.0097	0.0000
BA Energy	Heartland Bitumen Upgrader	19.4400	19.4400	4.6656	1.5600	0.4700	0.2566	0.4700
BP Canada Energy	Fort Sask. Storage and Fractionation	1.0410	0.1294	0.2941	0.2474	0.0055	0.0162	0.0000
Canexus Limited Partnership	Bruderheim	0.0000	0.0000	0.0380	0.0030	0.0156	0.0021	0.0000
Degussa Canada	Gibbons Site	0.0004	0.0004	0.0580	0.0480	0.0040	0.0032	0.0000
Dow Chemical Canada Inc.	Western Canada Operations	0.1342	0.1342	5.5283	6.2630	0.8900	0.1865	0.0000
ERCO Worldwide	Bruderheim Plant	0.0000	0.0000	0.0116	0.0098	0.0010	0.0006	0.0000
Keyera Energy Ltd.	Fort Sask. Fractionation Plant	2.4000	2.4000	0.8350	0.0260	0.0250	0.0107	0.0002
Marsulex Inc.	Marsulex Sulphides	0.6420	0.6420	0.0040	0.0030	0.0002	0.0060	0.0000
Newalta Corporation	Redwater Disposal Facility	0.0000	0.0000	0.0200	0.0170	0.0020	0.0011	0.0000
Prospec Chemicals	Sturgeon County	0.0818	0.0818	0.0034	0.0500	0.0000	0.0002	0.0000
Provident Energy Trust	Redwater Fractionation and Storage Facility	0.7143	0.7143	0.2530	0.0580	0.0191	0.0139	0.0000
Redwater Water Disposal Company	Redwater Waste Disposal Facility	0.2740	0.2740	0.0000	0.0000	0.0000	0.0000	0.0000
Shell Canada Ltd.	Scotford Upgrader	31.2990	31.2990	9.2645	9.1941	0.8226	0.5095	0.1927
Shell Canada	Scotford Refinery	0.0040	0.0040	1.4320	1.0121	0.1970	0.0975	0.0000
Shell Chemicals Canada	Scotford Chemical Plant	0.1168	0.1168	2.7336	1.1970	0.3496	0.1503	0.0000
Sherritt International Corporation	Fort Sask.	0.9044	0.9044	7.6667	0.5913	0.0280	0.2579	0.0000
TransAlta Cogeneration LP	Fort Sask. Cogeneration Plant	0.0300	0.0300	0.2900	0.2600	0.0200	0.0200	0.0000
TransCanada Energy	Redwater Power Plant	0.0000	0.0000	0.3451	0.1200	0.0100	0.0081	0.0000
Umicore Canada	Fort Sask. Production Facility	0.0000	0.0000	0.0000	0.0000	0.0300	0.0000	0.0000
FAP Industrial Fugitive Emissions	All	0.0000	0.0000	0.0000	0.0000	0.039	3.262	0.0307
Sub-Total FAP (t/d)		**65.55**	**61.11**	**44.95**	**24.75**	**3.39**	**5.22**	**0.70**
Edmonton Industrial Sources	All (See Section 2A.5)	31.8	31.8	26.7	38.1	3.72	-	-
Sub-Total FAP and Edmonton Industrial (t/d)		**97.35**	**92.91**	**71.65**	**62.85**	**7.11**	**5.22**	**0.70**
Urban Sources	Traffic and Heating	5.25	5.25	177.4	916.1	12.1	73.3	0.0
Baseline Case Total (FAP and Edmonton Industrial and Urban Sources) (t/d)		**102.595**	**98.162**	**249.053**	**978.950**	**19.207**	**78.519**	**0.700**

Notes:
This table does not include the North West Upgrader that received conditional approval after the assessment was undertaken.
Short = SO_2 emission rates used to evaluate 1-h and 24-h concentrations.
Long = SO_2 emission rates used to evaluate annual average concentrations and deposition.

Table 2A-10 Summary of Emissions Associated with the Project

Substance (t/d)	Conventional Stacks	Flare Stacks	Sub-total Stacks	Storage Tanks	Process Areas	Sub-total Fugitive	Cooling Tower	Total
Common Air Contaminants								
SO_2 (1-h and 24-h) (t/d)	18.13	0.00077	18.13	0.0	0.0090	0.0090	0.0	18.14
SO_2 (Annual average) (t/d)	7.34	0.00077	7.34	0.0	0.00032	0.00032	0.0	7.34
NO_x (t/d)	2.99	0.031	3.02	0.0	0.428	0.428	0.0	3.45
CO (t/d)	2.33	0.025	2.36	0.0	0.127	0.127	0.0	2.48
$PM_{2.5}$ (t/d)	0.41	0.00056	0.411	0.0	0.0127	0.0127	0.0	0.42
HC and RSC Substances								
VOC/PAH (t/d)	0.19	0.063	0.253	0.39	0.26	0.65	0.0	0.90
H_2S (t/d)	0.20	0.00	0.20	0.020	0.043	0.063	0.0	0.26
RSC (t/d)	0.68	0.00	0.68	0.027	0.060	0.087	0.0	0.77
Water Vapour								
H_2O (t/d)	4019	26.65	4046	0.0	0.0	0.0	8360	12406
Greenhouse Gas Emissions								
CO_2 (t/d)	8035	46.87	8082	0.0	30.877	30.877	0.0	8113
Methane (t/d)	0.16	0.0009	0.16	0.060	0.950	1.01	0.0	1.17
N_2O (t/d)	0.14	0.0008	0.14	0	0.0004	0.0004	0	0.14
CO_{2e} (t/d)	8,082	47.1	8129	1.3	51.0	52.2	0	8,181

Note: Emissions from Process areas include the sulphur handling area emissions..

Table 2A-11 Summary of Emissions Associated with Application Case Sources

Operator	Facility	Emission Rate (t/d)						
		SO_2 (short)	SO_2 (long)	NO_x	CO	$PM_{2.5}$	VOC/PAH	H_2S
Agrium Products	Fort Sask. Nitrogen Operations	0.0045	0.0045	3.1680	0.6999	0.0169	0.0443	0.0000
Agrium Products	Redwater Fertilizer Operations	7.6580	4.1299	5.1060	1.2613	0.3847	0.3005	0.0000
Air Liquide Canada	Scotford Complex	0.0000	0.0000	0.4658	0.1476	0.0154	0.0209	0.0000
ARC Resources	Redwater Gas Conservation Plant	0.8001	0.8001	2.5759	1.8290	0.0280	0.0403	0.0062
ATCO Midstream	Fort Sask. Sour Gas Plant	0.0007	0.0070	0.0174	0.0030	0.0013	0.0010	0.0000
Aux Sable	Heartland Offgas	0.0000	0.0000	0.1770	0.1490	0.0120	0.0097	0.0000
BA Energy	Heartland Bitumen Upgrader	19.4400	19.4400	4.6656	1.5600	0.4700	0.2566	0.4700
BP Canada Energy	Fort Sask. Storage and Fractionation	1.0410	0.1294	0.2941	0.2474	0.0055	0.0162	0.0000
Canexus Limited Partnership	Bruderheim	0.0000	0.0000	0.0380	0.0030	0.0156	0.0021	0.0000
Degussa Canada	Gibbons Site	0.0004	0.0004	0.0580	0.0480	0.0040	0.0032	0.0000
Dow Chemical Canada Inc.	Western Canada Operations	0.1342	0.1342	5.5283	6.2630	0.8900	0.1865	0.0000
ERCO Worldwide	Bruderheim Plant	0.0000	0.0000	0.0116	0.0098	0.0010	0.0006	0.0000
Keyera Energy Ltd.	Fort Sask. Fractionation Plant	2.4000	2.4000	0.8350	0.0260	0.0250	0.0107	0.0002
Marsulex Inc.	Marsulex Sulphides	0.6420	0.6420	0.0040	0.0030	0.0002	0.0060	0.0000
Newalta Corporation	Redwater Disposal Facility	0.0000	0.0000	0.0200	0.0170	0.0020	0.0011	0.0000
North American Oil Sands	***Project (stack emissions)***	***18.13***	***7.34***	***3.02***	***2.355***	***0.411***	***0.253***	***0.20***
	Project (fugitive emissions)	***0.0090***	***0.00032***	***0.428***	***0.127***	***0.0127***	***0.65***	***0.063***
Prospec Chemicals	Sturgeon County	0.0818	0.0818	0.0034	0.0500	0.0000	0.0002	0.0000
Provident Energy Trust	Redwater Fractionation and Storage Facility	0.7143	0.7143	0.2530	0.0580	0.0191	0.0139	0.0000
Redwater Water Disposal Company	Redwater Waste Disposal Facility	0.2740	0.2740	0.0000	0.0000	0.0000	0.0000	0.0000
Shell Canada Ltd.	Scotford Upgrader	31.2990	31.2990	9.2645	9.1941	0.8226	0.5095	0.1927
Shell Canada	Scotford Refinery	0.0040	0.0040	1.4320	1.0121	0.1970	0.0975	0.0000
Shell Chemicals Canada	Scotford Chemical Plant	0.1168	0.1168	2.7336	1.1970	0.3496	0.1503	0.0000
Sherritt International Corporation	Fort Sask.	0.9044	0.9044	7.6667	0.5913	0.0280	0.2579	0.0000
TransAlta Cogeneration LP	Fort Sask. Cogeneration Plant	0.0300	0.0300	0.2900	0.2600	0.0200	0.0200	0.0000
TransCanada Energy	Redwater Power Plant	0.0000	0.0000	0.3451	0.1200	0.0100	0.0081	0.0000
Umicore Canada	Fort Sask. Production Facility	0.0000	0.0000	0.0000	0.0000	0.0300	0.0000	0.0000
FAP Industrial Fugitive Emissions	All without Project	0.0000	0.0000	0.0000	0.0000	0.039	3.262	0.0307
Sub-Total FAP (t/d)		**83.684**	**68.452**	**48.411**	**27.232**	**3.811**	**6.337**	**0.992**
Edmonton Industrial Sources	All (See Section 2A.5)	31.8	31.8	26.7	38.1	3.72	-	-
Sub-Total FAP and Edmonton Industrial (t/d)		**115.484**	**100.252**	**75.111**	**65.332**	**7.531**	**6.337**	**0.992**
Urban Sources	Traffic and Heating	5.25	5.25	177.4	916.1	12.1	73.3	-
Application Case Total (FAP and Edmonton Industrial and Urban Sources) (t/d)		**120.73**	**105.50**	**252.51**	**981.43**	**19.63**	**79.42**	**0.96**

Notes: This table does not include the North West Upgrader that received conditional approval after the assessment was undertaken.
Short = SO_2 emission rates used to evaluate 1-h and 24-h concentrations.
Long = SO_2 emission rates used to evaluate annual average concentrations and deposition.
Project emissions are shown in ***bold face, italic*** font.

Table 2A-12 Summary of Emissions Associated with Cumulative Case Sources

Operator	Facility	Emission Rate (t/d)						
		SO$_2$ (short)	**SO$_2$ (long)**	**NO$_x$**	**CO**	**PM$_{2.5}$**	**VOC/PAH**	**H$_2$S**
Agrium Products	Fort Sask. Nitrogen Operations	0.0045	0.0045	3.1680	0.6999	0.0169	0.0443	0.0000
Agrium Products	Redwater Fertilizer Operations	7.6580	4.1299	5.1060	1.2613	0.3847	0.3005	0.0000
Air Liquide Canada	Scotford Complex	0.0000	0.0000	0.4658	0.1476	0.0154	0.0209	0.0000
ARC Resources	Redwater Gas Conservation Plant	0.8001	0.8001	2.5759	1.8290	0.0280	0.0403	0.0062
ATCO Midstream	Fort Sask. Sour Gas Plant	0.0007	0.0070	0.0174	0.0030	0.0013	0.0010	0.0000
Aux Sable	*Confidential Project*	*0.0000*	*0.0000*	*2.1870*	*1.8380*	*0.1480*	*0.1203*	*0.0000*
Aux Sable	Heartland Offgas Project	0.0000	0.0000	0.1770	0.1490	0.0120	0.0097	0.0000
BA Energy	Heartland Bitumen Upgrader	19.4400	19.4400	4.6656	1.5600	0.4700	0.2566	0.4700
BP Canada Energy	Fort Sask. Storage and Fractionation	1.0400	0.1294	0.2941	0.2474	0.0055	0.0162	0.0000
Canexus Limited Partnership	Bruderheim	0.0000	0.0000	0.0380	0.0030	0.0156	0.0021	0.0000
Degussa Canada	Gibbons Site	0.0004	0.0004	0.0580	0.0480	0.0040	0.0032	0.0000
Dow Chemical Canada Inc.	Western Canada Operations	0.1342	0.1342	5.5283	6.2620	0.8900	0.1865	0.0000
ERCO Worldwide	Bruderheim Plant	0.0000	0.0000	0.0116	0.0098	0.0010	0.0006	0.0000
HAZCO Environmental	Bruderheim Sulphur Forming Facility	0.0000	0.0000	0.0090	0.0110	0.0190	0.0005	0.0000
Keyera Energy Ltd.	Fort Sask. Fractionation Plant	2.4000	2.4000	0.8350	0.3450	0.0250	0.0107	0.0002
Marsulex Inc.	Marsulex Sulphides	0.6420	0.6420	0.0040	0.0030	0.0002	0.0060	0.0000
Newalta Corporation	Redwater Disposal Facility	0.0000	0.0000	0.0200	0.0170	0.0020	0.0011	0.0000
North American Oil Sands	***Project (stack emissions)***	***18.13***	***7.34***	***3.02***	***2.355***	***0.411***	***0.253***	***0.20***
	Project (fugitive emissions)	***0.0090***	***0.00032***	***0.428***	***0.127***	***0.0127***	***0.65***	***0.063***
North West Upgrading Inc.	*North West Upgrader*	*19.5505*	*17.7000*	*2.1090*	*17.5507*	*0.1769*	*0.5877*	*0.0000*
Petro-Canada Oil Sands Inc.	*Sturgeon Upgrader*	*23.7191*	*10.1191*	*14.3766*	*9.5073*	*0.4397*	*0.9966*	*0.1540*
Prospec Chemicals	Sturgeon County	0.0818	0.0818	0.0034	0.0500	0.0000	0.0002	0.0000
Provident Energy Trust	Redwater Fractionation and Storage	0.7143	0.7143	0.2530	0.0580	0.0191	0.0139	0.0000
Redwater Water Disposal Company	Redwater Waste Disposal Facility	0.2740	0.2740	0.0000	0.0000	0.0000	0.0000	0.0000
Shell Canada Ltd.	*Scotford Upgrader (Base+SE1+SU2)*	*39.1894*	*39.1894*	*25.6593*	*19.1473*	*1.7618*	*1.4113*	*0.4905*
Shell Canada	Scotford Refinery	0.0040	0.0040	1.4320	1.0121	0.1970	0.0975	0.0000
Shell Chemicals Canada	Scotford Chemical Plant	0.1168	0.1168	2.7336	1.1970	0.3496	0.1503	0.0000
Sherritt International Corp.	Fort Sask.	0.9044	0.9044	7.6667	0.5913	0.0280	0.2579	0.0000
Synenco Energy	*Northern Lights Upgrader*	*28.8501*	*28.8501*	*3.1109*	*4.5600*	*0.2075*	*0.2986*	*0.0000*
TransAlta Cogeneration LP	Fort Sask. Cogeneration Plant	0.0300	0.0300	0.2900	0.2600	0.0200	0.0200	0.0000
TransCanada Energy	Redwater Power Plant	0.0000	0.0000	0.3451	0.1200	0.0100	0.0081	0.0000
Umicore Canada	Fort Sask. Production Facility	0.0000	0.0000	0.0000	0.0000	0.0300	0.0000	0.0000
FAP Industrial Fugitive Emissions	All without Project	0.0000	0.0000	0.0000	0.0000	0.039	3.262	0.0307
Sub-total FAP Industrial (t/d)		**163.69**	**133.01**	**86.60**	**70.97**	**5.74**	**9.03**	**1.41**
Edmonton Industrial Sources	All (See Section A1.6)	31.8	31.8	26.7	38.1	3.72	-	-
Sub-Total FAP and Edmonton Industrial (t/d)		**195.49**	**164.81**	**113.30**	**109.07**	**9.46**	**9.03**	**1.41**
Urban Sources	Traffic and Heating	5.25	5.25	177.4	916.1	12.1	73.3	-
Cumulative Case Total (FAP and Edmonton Industrial and Urban Sources) (t/d)		**200.74**	**170.06**	**290.70**	**1025.17**	**21.56**	**82.33**	**1.41**

Notes: This table does not include the proposed Total E&P Upgrader as emissions were not available at the time of the assessment.
Short = SO$_2$ emission rates used to evaluate 1-h and 24-h concentrations.
Long = SO$_2$ emission rates used to evaluate annual average concentrations and deposition.
Project emissions are shown in ***bold face, italic*** font and other planned emissions are shown in *italic* font.

Table 2A-13 Comparison of FAP Industrial SO_2 Emissions

Operator	Facility	SO_2 Emissions					
		Alberta Approval		NPRI 2005	FAP Data	Project Assessment	
		1-h (t/h)	24-h (t/d)	(t/d)	(t/d)	Short Term	Long term
Agrium Products	Fort Sask. Plant	-	-	-	0.0045	0.0045	0.0045
Agrium Products	Redwater Fertilizer Plant	0.477	-	4.4	4.13	7.66	4.13
ARC Resources	Redwater Gas Conservation Plant	0.14	2.4	0.58	0.8	0.8	0.8
ATCO Midstream	Fort Sask. Sour Gas Plant	-	-	-	-	0.001	0.001
BA Energy	Heartland Bitumen Upgrader	1.4	28.1	-	19.44	19.44	19.44
BP Canada Energy	Fort Sask. Fractionation Plant	-	0.89	-	0.259	1.04	0.129
Deguss Canada Inc.	Gibbons Hydrogen Peroxide Plant	-	-	-	0.0004	0.0004	0.0004
Dow Chemical Canada	Fort Sask. Chemical Plant	-	-	0.13	0.134	0.134	0.134
Keyera Energy	Fort Sask. Fractionation Facility	-	2.4	0.45	2.4	2.4	2.4
Marsulex	Fort Sask. Chemical Plant	0.08	-	0.987	0.642	0.642	0.642
North West Upgrading	North West Upgrader Project	-	-	-	19.55	19.55	17.7
Petro-Canada	Sturgeon Upgrader (Phase 2/3)	-	-	-	9.224	23.72	10.12
Prospec Chemicals	Fort Sask. Xanthate Plant	-	-	0.08	0.082	0.082	0.082
Provident Energy	Redwater Fractionation Facility	-	1.98	0.74	0.714	0.714	0.714
Redwater Water Disposal Company	Redwater Waste Disposal Facility	-	-	0.29	0.274	0.274	0.274
Shell Canada	Scotford Bitumen Upgrader (Existing/Approved)	2	28	18.95	45.86	31.3	31.3
	Scotford Bitumen Upgraders (Cumulative)	-	-	-		39.2	39.2
Shell Chemical Canada	Scotford Chemical Plant	-	-	0.01	0.004	0.004	0.004
Shell Canada Products	Scotford Oil Refinery	-	-	0.27	0.117	0.117	0.117
Sherritt International Corp.	Fort Sask. Fertilizer Plant	0.117	-	1.05	0.904	0.904	0.904
Synenco Energy	Northern Lights Upgrader Project	-	-	-	28.85	28.85	28.85
TransAlta Cogeneration	Fort Sask. Cogeneration Power Plant	-	-	-	0.03	0.03	0.03
Total (Baseline Case)		**-**	**-**	**-**		**65.5**	**61.1**
Total (Cumulative Case)		**-**	**-**	**-**	**-**	**146**	**126**

Table 2A-14 Summary of Available Fugitive Emissions for Industrial Sources in the Region

Operator	Facility	Emission Rate (t/d)					
		Baseline Case			Cumulative Case		
		$PM_{2.5}$	VOC	H_2S	$PM_{2.5}$	VOC	H_2S
Access Pipeline	Redwater Trim Blending Facility	0.00	0.00	0.00	0.00	0.0239	0.0000011
Agrium Products	Fort Sask. Fertilizer Plant	0.00	0.0362	0.00	0.00	0.0362	0.00
Agrium Products	Redwater Fertilizer Plant	0.00	0.586	0.00	0.00	0.586	0.00
Air Liquide Canada	Scotford Cogeneration Power Plant	N/A	N/A	N/A	N/A	N/A	N/A
ARC Resources	Redwater Gas Conservation Plant	0.00	0.208	0.0028	0.00	0.208	0.0028
ATCO Midstream	Fort Sask. Sour Gas Plant	N/A	N/A	N/A	N/A	N/A	N/A
Aux Sable Canada	Heartland Offgas Project	N/A	N/A	N/A	N/A	N/A	N/A
BA Energy	Heartland Bitumen Upgrader	0.00	0.082	0.0067	0.00	0.082	0.0067
BP Canada Energy	Fort Sask. Fractionation Plant	0.00	0.238	0.00	0.00	0.238	0.00
Bunge Canada	Fort Sask. Oilseed Processing Plant	0.039	0.0226	0.00	0.039	0.0226	0.00
Canexus Chemicals Canada	Bruderheim Sodium Chlorate Plant	N/A	N/A	N/A	N/A	N/A	N/A
Degussa Canada	Gibbons Hydrogen Peroxide Plant	N/A	N/A	N/A	N/A	N/A	N/A
Dow Chemical Canada	Fort Sask. Chemical Plant	0.00	0.157	0.00	0.00	0.157	0.00
Enbridge	Stonefell Storage Tank Terminal	0.00	0.00	0.00	0.00	0.00	0.0000319
ERCO Worldwide	Bruderheim Sodium Chlorate Plant	N/A	N/A	N/A	N/A	N/A	N/A
HAZCO Environmental Services	Bruderheim Sulphur Forming Facility	N/A	N/A	N/A	N/A	N/A	N/A
Keyera Energy	Fort Sask. Fractionation Facility	0.00	1.53	0.000384	0.00	1.53	0.000384
Marsulex	Fort Sask. Chemical Plant	0.00	0.00	0.0000383	0.00	0.00	0.0000383
Newalta Corporation	Redwater Disposal Facility	0.00	0.00	0.00	0.00	0.00	0.00
North West Upgrading	North West Upgrader Project	0.00	0.00	0.00	0.00	0.00	1.15
Petro-Canada Oil Sands Inc.	Sturgeon Upgrader Project	0.00	0.00	0.00	0.00	1.10	0.0362
Prospec Chemicals	Fort Sask. Xanthate Plant	N/A	N/A	N/A	N/A	N/A	N/A
Provident Energy	Redwater Fractionation Facility	0.00	0.0714	0.00	0.00	0.0714	0.00
Redwater Water Disposal Company	Redwater Waste Disposal Facility	N/A	N/A	N/A	N/A	N/A	N/A
Shell Canada	Scotford Bitumen Upgrader	0.00	0.00	0.0177	0.00	0.00	0.02239
Shell Canada Products	Scotford Oil Refinery	0.00	0.262	0.00266	0.00	0.262	0.00266
Shell Chemicals Canada	Scotford Styrene & MEG Plant	0.00	0.07	0.00	0.00	0.07	0.00
Sherritt International Corporation	Fort Sask. Fertilizer Plant	N/A	N/A	N/A	N/A	N/A	N/A
Synenco Energy	Northern Lights Upgrader Project	0.00	0.00	0.00	0.00	1.11	0.00777
Kinder Morgan (Terasen)	Heartland Storage Tank Terminal	0.00	0.00	0.00	0.00	0.105	0.000108
TransAlta Cogeneration	Fort Sask. Cogeneration Power Plant	N/A	N/A	N/A	N/A	N/A	N/A
TransCanada Energy	Redwater Cogeneration Power Plant	N/A	N/A	N/A	N/A	N/A	N/A
Industry Sub-total (t/d)		**0.039**	**3.262**	**0.0307**	**0.039**	**2.337**	**1.20**

Operator	Facility	Emission Rate (t/d)					
		Baseline Case			Cumulative Case		
		$PM_{2.5}$	VOC	H_2S	$PM_{2.5}$	VOC	H_2S
Industry Sub-total Baseline Case (t/d)		**0.039**	**3.262**	**0.0307**			
North American	Upgrader (the Project)	0.0127	0.865	0.093			
Industry Sub-total Application Case (t/d)		**0.0517**	**4.127**	**0.124**			
Industry Sub-total Cumulative Case (t/d)		**0.039**	**2.337**	**1.20**			
Urban	Traffic and heating	12.1	73.25	0.00			
Total Baseline Case (t/d)		12.14	76.51	0.0307			
Total Application Case (t/d)		12.15	77.375	0.124			
Total Cumulative Case (t/d)		12.15	76.452	1.293			

NOTE: N/A = Not Available.

2A4 PROJECT EMISSIONS

The Jacques Whitford AXYS Ltd. (JWA) air quality team worked closely with North American engineering staff to define the emission parameters required to characterize air quality due to the operation of the Upgrader. Clearstone Engineering Ltd. also worked the North American engineering staff to develop a fugitive emission profile for the Upgrader.

The following sections present full development emission profile for the Upgrader. While most of the identified sources operate on a continuous basis, there are a few sources that are only used for start-up or maintenance operations. In order to be conservative, these latter sources are assumed to operate continuously. Upset or emergency conditions were evaluated separately and in isolation due to the associated short-term and intermittent values.

For the purposes of assessment, the Project's emission sources were grouped into the following categories:

- Conventional stacks
- Flare stacks
- Storage tanks
- Process areas
- Cooling towers

The conventional stacks are the main sources of emissions from the Upgrader, with flare stacks being used primarily for plant maintenance, upset or emergency operations. Emissions from storage tanks and process areas are classified as fugitive emissions. North American plans to design, construct and operate the Project in phases, however, the air quality assessment focused on the final development of all phases of the Project.

2A4.1 Stack Emissions

Table 2A-15 provides a summary of the emission sources associated with the conventional (27) and flare (11) stacks. Figure 2A-3 is a plot plan showing the location of the stacks.

2A4.1.1 Heaters, Furnace and Boiler Stacks

The stack parameters (location, stack height, exit temperature, and exit velocity) were provided by North American engineering staff. The following comments can be made relative to the parameters and emissions associated with the conventional stacks:

- The SO_2, NO_x, CO, $PM_{2.5}$ and VOC emissions associated with heaters, furnaces and boilers were provided by North American.
- The heaters, furnaces and boilers are fired with a fuel gas whose composition is given in Table 2A-16. This fuel gas is comprised of 37 percent methane, 20 percent ethane, and 12 percent hydrogen.
- The sensitivity of SO_2 emission rates to sulphur recovery efficiencies is presented in Table 2A-17 and in Figure 2A-4.
- VOC and PAH emissions are based on the application of EPA and CARB emission factors. These are identified in Table 2A-18. The selected compound groupings are based on classification by the HHRA team to reflect potential human health effects.
- The five utility boilers (Stacks 9, 10, 28, 29 and 30) are expected to be used one week every two years at maximum capacity of 273 GJ/h each. These boilers were assumed to

operate on a continuous basis at maximum capacity for the purposes of the Project assessment to be conservative.

Tables 2A-19 to 2A-24 provides the emission parameters for the furnace, heater and boiler stacks.

2A4.1.1.1 SRU/TGTU Stacks

The major SO_2 emission sources at the Project are the incinerator stacks that service the three SRU/TGTU complexes for the Upgrading facilities (referred to as UP1, UP2, and UP3) and two SRU/TGTU complexes for the gasification facilities (referred to as GAS1 and GAS2). The SO_2 emission rate from each SRU/TGTU complex depends on the equivalent inlet sulphur feed rate and on the sulphur recovery efficiency, which is expressed as a percentage of the inlet to each SRU/TGTU complex. The SO_2 emission rate can vary with time, depending on the individual performance of each SRU/TGTU complex. The variations can change slowly with time depending on factors such as an aging catalyst with decreasing effectiveness, or over a short period (i.e., several hours) depending on factors such as fluctuations in the air to acid gas ratio.

The EUB and AENV have specified minimum sulphur recovery guidelines based on the equivalent inlet sulphur rate to the SRU/TGTU system (EUB Interim Directive 2001-3). Higher sulphur recoveries are required for larger sulphur inlet rates. The proposed sulphur inlet rate for the Project is 1,796 t/d. The design or long-term sulphur recovery can be derived from the equation: Recovery (%) = 98.18185 + 0.187259 $\log_{10}$ (Sulphur Inlet Rate (t/d)).

This value is typically interpreted as the minimum expected sulphur recovery on an annual basis. For a sulphur inlet rate of 1,796 t/d, the associated recovery efficiency is 99.79%. On a quarterly basis, the minimum sulphur recovery rate is this value minus 0.3%, which is equal to 99.49%. AENV typically bases the maximum 24-h emission rate in the EPEA approval on the 0.3% difference. AENV has also accepted an additional operating headroom factor of 1.4 for specifying a maximum 1-hour SO_2 emission rate in the EPEA approval.

Notwithstanding these minimum requirements, North American proposes to adopt a more efficient sulphur recovery to lower the SO_2 emissions from the proposed upgrader. The long-term (i.e., annual average) sulphur recovery for each complex is expected to be in the 99.9% (for new catalyst) to 99.8% (for spent catalyst) range. The expected long-term performance guarantee from the Project vendors is 99.8%.

The AAAQO for SO_2 are specified for annual, 24-h and 1-h averaging periods. To provide a realistic estimate of Project SO_2 emissions on ambient air quality, it is desirable to select SO_2 emission rates that are appropriate to each averaging period. For a facility serviced by a single SRU/TGTU complex, the maximum 24-h SO_2 emission rate can be derived from a 99.5% sulphur recovery (a 0.3% decrease for a quarterly sulphur recovery). Similarly, the maximum 1-h SO_2 emission rate can be based on the 24-h rate times 1.4.

However, for a facility that is serviced by five independent SRU/TGTU complexes, adopting this approach for all complexes is viewed as unrealistic as it is unlikely that all five complexes will simultaneously experience abnormal operating conditions. Figure 2A-4 and Table 2A-17 show the estimated SO_2 emissions for the following cases:

- Based on the EUB ID 2001-3 guidelines, the maximum permissible annual and 24-h average SO_2 emissions are 43.47 t/d and 54.25 t/d, respectively. This is based on overall sulphur recovery efficiencies of 98.79 and 98.49%, respectively.

- Based on the design, the annual SO_2 emission is expected to be 7.18 t/d based on a sulphur recovery efficiency of 99.8 %.

- A range of various abnormal cases based on the application of the 0.3% sulphur recovery difference so some and several complexes, and the application of the 1.4 factor. The corresponding SO_2 emissions range from 8.34 t/d to 17.98 t/d, depending on the assumption for each individual SRU/TGTU complex.

The preceding discussion has focused solely on the SO_2 emissions from the SRU/TGTU incinerator stacks and is not applicable to the sulphur content of the fuel used to fire the various heaters, furnaces and boilers. The SO_2 emission from these units will overlap with the SO_2 emissions from the five SRU/TGTU incinerator stacks

Given the variability in the SO_2 emission depending on the assumed SRU/TGTU sulphur recovery efficiency, the following SO_2 emission rates were selected to provide an indication of the Project impact on ambient air quality:

- For the purposes of estimating annual average SO_2 concentrations and PAI deposition, the annual average SO_2 emission rate is based on the 99.8% sulphur recovery assumption. The corresponding SO_2 emission rate from the five SRU/TGTU facilities operating at this rate is 7.18 t/d.

- For the purposes of estimating 24-h and 1-h average SO_2 concentrations, the 24-h and 1h average SO_2 emission rates are based on the 99.5% sulphur recovery assumption. The corresponding SO_2 emission rate from the five SRU/TGTU facilities is operating at this rate is 17.96 t/d. This is viewed as conservative (i.e., overstating the SO_2 emissions) as it is unlikely that all SRU/TGTU complexes will simultaneously be operating as low as 99.5% sulphur recovery.

The preceding discussion has focused solely on the SO_2 emissions from the SRU/TGTU incinerator stacks and is not applicable to the sulphur content of the fuel used to fire the various heaters, furnaces and boilers. The SO_2 emissions from these units will overlap with the SO_2 emissions from the five SRU/TGTU incinerator stacks.

The total reduced sulphur (TRS) compound emissions are based on a maximum expected concentration of 25 ppm in the flue gas and 16 ppm in the natural gas. NO_x and CO emissions were provided by North American. $PM_{2.5}$, VOC and PAH emissions were estimated based on the ratio of their emission rates in terms of NO_x.

Sulphuric acid (H_2SO_4) emissions were estimated from the CPPI (2005) Code of Practice. Specifically 2% (wt.) conversion of SO_2 to SO_3 was first assumed. Then the conversion of SO_3 to H_2SO_4 is based on exit stack temperature and gas water composition. For tail gas incinerators, the estimated SO_3 to H_2SO_4 conversion is 6% (vol.) based on a stack temperature of 538°C and a flue gas water vapour composition of 14%. For the gasification TGTU thermal oxidizers, the estimated SO_3 to H_2SO_4 conversion is 5% (vol.) based on a stack temperature of 538°C and a flue gas water vapour composition of 12%.

2A4.1.2 Flare Stacks

Under normal operating conditions, small volumes of purge and pilot gases are directed to the flares. The associated flare parameters and emissions for normal operating conditions are provided in Tables 2A-26 to 2A-28. Under upset conditions, which will be infrequent and of a short-term nature, larger volumes of gas will be directed to the flares. The associated flare parameters and emissions for emergency conditions are provided in Tables 2A-29, 2A-30 and 2A-31. The following are noted relative to flaring:

The normal operating conditions are evaluated for the suite of compounds listed in Table 2A-14 since the HHRA addresses long-term exposures. The upset emergency cases are only evaluated to determine maximum 1-h average SO_2 concentrations given the high H_2S content of some of the upset cases that could occur.

The largest SO_2 emissions are associated with the H_2S flare that services the SRU/TGTU complexes. Three intermittent emergency scenarios have been identified. Under these conditions, SO_2 emissions will not be occurring from the thermal oxidizer stack. The natural gas addition represents the maximum amount of natural gas that would be available at the plant. The acid gas stream might contain ammonia; the ammonia is assumed to be completely oxidized to NOx.

Two extreme High Pressure (HP) and Low Pressure (LP) flare events are identified. While the volumes of gas to flare can be relatively large, the H_2S content is lower than that associated with the SRU/TGTU acid gas streams,

As dispersion models are not set up to evaluate flare stacks, the flare data has to be processed to produce “effective” parameters that can be used by the models. These parameters are provided in Tables 2A-29 to 2A-31.

2A4.2 Storage Tank Emissions

Table 2A-31 identifies the 45 storage tanks associated with the Project. Figure 2A-5 is a plot plan showing the location of the tanks. Fugitive emissions result from emptying and filling operations (referred to as working losses) and from diurnal heating and cooling of the tanks (referred to as breathing losses). Clearstone Engineering estimated the losses and the provided associated speciation information. The following are noted:

- The EPA TANKS emission estimation program was used to calculate total hydrocarbon emissions based on the tank properties and the tank contents.
- For tanks that are tied into a vapour recovery system, a control efficiency of 95 percent was assumed. These tanks include the amine surge tanks, amine storage tanks, sludge tanks, bitumen diluent feed tanks, distillate product sure tanks, cdu feed tanks, nhtu tanks, dhtu tanks, reject tanks, and amine storage makeup tanks.
- The compositions of the fugitive emissions are based on the application of speciation profiles derived from fugitive emission measurements conducted at similar facilities.
- The estimated fugitive VOC emissions due to the tanks are 260.55 t/y. The largest sources are the four diluted bitumen tanks (48.8 percent). Tables 2A-33 to 2A-43 provide representative emissions for each tank. Emissions that fall in the “other” category (~0 to 53.6 percent) include the lighter hydrocarbons (C_2 to $C_{4,}$) that do not have health consequences of significance.

2A4.3 Process Area Emissions

Large volumes of gases are handled in the different process areas, and fugitive emissions will result from the numerous valves, flanges, rotating seals, and drains that are associated with these areas. Figure 2A-6 is a plot plan showing the location of the process areas. Clearstone Engineering estimated the fugitive emissions and provided representative speciation profiles. The magnitude and composition of the fugitive emissions were based on measurements at similar facilities. Tables 2A-44 to 47 provide a summary of the process area parameters and emissions. The total VOC emissions due to these sources are estimated to be 537.5 t/y.

2A4.3.1 Sulphur Handling (Area J)

The Project will be serviced by on-site facilities that handle the produced sulphur, which can include sulphur forming and sulphur pastille storage and loading components (see Figure 2A-7). In this case, liquid sulphur would be delivered by pipeline to the sulphur handling facility from SRU underground storage tanks. Above-ground liquid sulphur tanks would be located adjacent to the rotoforming units. Overall storage volume is based on turnaround time required for maintenance of the rotoforming units.

Figure 2A-7 is a plot plan showing the proposed layout of he sulphur handling area.

The sulphur would then be pumped from the feed tank through a duplex filter and a conditioning unit which cools the sulphur to an optimal forming temperature of 125^0C. The cooled liquid would be fed to the Rotoform drop forming equipment. Resulting pastilles with typical diameters of about 3 mm would be conveyed into a storage silo with an open top that has a capacity of 18,900 t. During shipping operations, the pastilles would be loaded directly from the storage area onto rail cars through a 2,520 t/h loader conveyor. In some unexpected situations, sulphur will be moved by a front-end loader from the emergency storage area to the train. The assessment is based on the maximum sulphur capacity of 1,822 t/d.

The potential emission sources include:

- two liquid storage tanks;
- two vent stacks from the rotoform building;
- conveyors;
- locomotive during shipping operations; and
- emergency storage area.

The following outlines assumptions to estimate the emissions from each of these sources.

2A4.3.1.1 Liquid Storage Tanks

The two insulated, heated, above-ground sulphur tanks are assumed to be 12.2 m in diameter and 18.3 m in height. The maximum emission rate is based on displacing the headspace in the tanks at the maximum sulphur production rate of 1,822 t/d. The degassed liquid sulphur was assumed to be delivered to the forming facility with a maximum H_2S content of 10 ppmv. Mitigation to reduce H_2S emissions assumes the displaced headspace gas is vented through a Sulfa Treat process to reduce the H_2S concentrations vented to the atmosphere to 1 ppmv.

Table 2A-47 presents the emission parameters associated with sulphur liquid tanks based on these assumptions. For the purpose of comparison, the emissions supplied by Clearstone Engineering are also presented in Table 2A-47. These latter estimates are based on the extrapolation of fugitive emissions measurements from similar facilities. The JWA 10 ppm values (no mitigation) are about one-half the Clearstone values.

2A4.3.1.2 Rotoform Stacks

There will be seven rotoforming trains in the building and each train is capable of processing 12 t/h of sulphur. The size of building is assumed to be 30.5 x 48.5 x 13.4 m (i.e., width x length x height). Emissions from the two rotoform building stacks typically contain H_2S and $PM_{2.5}$ and are treated as point sources.

Table 2A-48 presents the stack and emission parameters associated with these point sources. Stack parameters were based on JWA archive data from facilities similar to those for the Project. The maximum H_2S and $PM_{2.5}$ emissions from each of two vent stacks are based on 5 ppmv and 0.05 g/kg, respectively. The 0.05 g/kg value is based on the Shell Canada Shantz rotoformer exhaust vent limit (Alberta Environment Approval 00011379-01-00).

2A4.3.1.3 Conveyor

To reduce fugitive emissions, all conveyer systems to transport pastilles to the silo, rail cars or emergency storage areas are assumed to be covered and dust control is assumed at all transfer points. Therefore, fugitive emissions from conveyor system 3 should be and are assumed to be insignificant. Dust suppression in the rail-out area can be achieved with the use of a proprietary dust suppression agent, release aid, and water. Dust suppression agents are assumed to be applied to all transfer covered conveyor points, surge bins, the diverter, the weigh bins and at the rail out.

2A4.3.1.4 Locomotive

A GE AC4400 CW locomotive is used for sulphur shipping activities. This locomotive has an engine of 4400 hp. Train loading is assumed to take 6 hours, and occur once every 7 days. The main emissions from the locomotive are combustion components from the diesel engine exhaust and they are treated as an area source represented by the distribution of the rail track system. The sulphur content for the diesel fuel consumed by the locomotive engine was assumed to be 500 ppm. The emission factors for locomotive are based on EPA emission factors for locomotives. The greenhouse gas emissions are based on Canada's Greenhouse Gas Inventory- Annex 7 (Emission Factors, August 2003) for locomotives. Tables 2A-50 and 2A-51 present emission parameters associated with locomotive operation. The emissions were assumed to be uniformly originated from a 40 by 160 m area.

2A4.3.1.5 Emergency Storage Area

During unexpected situations, pastilles will be loaded directly to an open asphalted emergency storage pad. The storage area is expected to have 20 days storage capacity (36,440t) Accumulated sulphur will be moved as quickly as possible through unit train loading of 12,600t/train. Loading will be limited by the front-end loader capacity (assuming 8 hours maximum to load train). A Cat 980H Wheel Loader is used for loading during this period. This loader has a 355 hp and a maximum bucket capacity of 6.1 m^3.

Table 2A-50 presents emission parameters associated with emergency loading area. The emissions were assumed to be uniformly originated from a 10 by 30 m area. The sulphur content for the diesel fuel consumed by the front-end loader engines was assumed to be 15 ppm. Emissions from the asphalt pavement were obtained from estimation methods recommended by the EPA (2006) with the assumption that the silt covering the asphalt would be similar to that found in areas of sand and gravel operations.

2A4.4 Cooling Tower Emissions

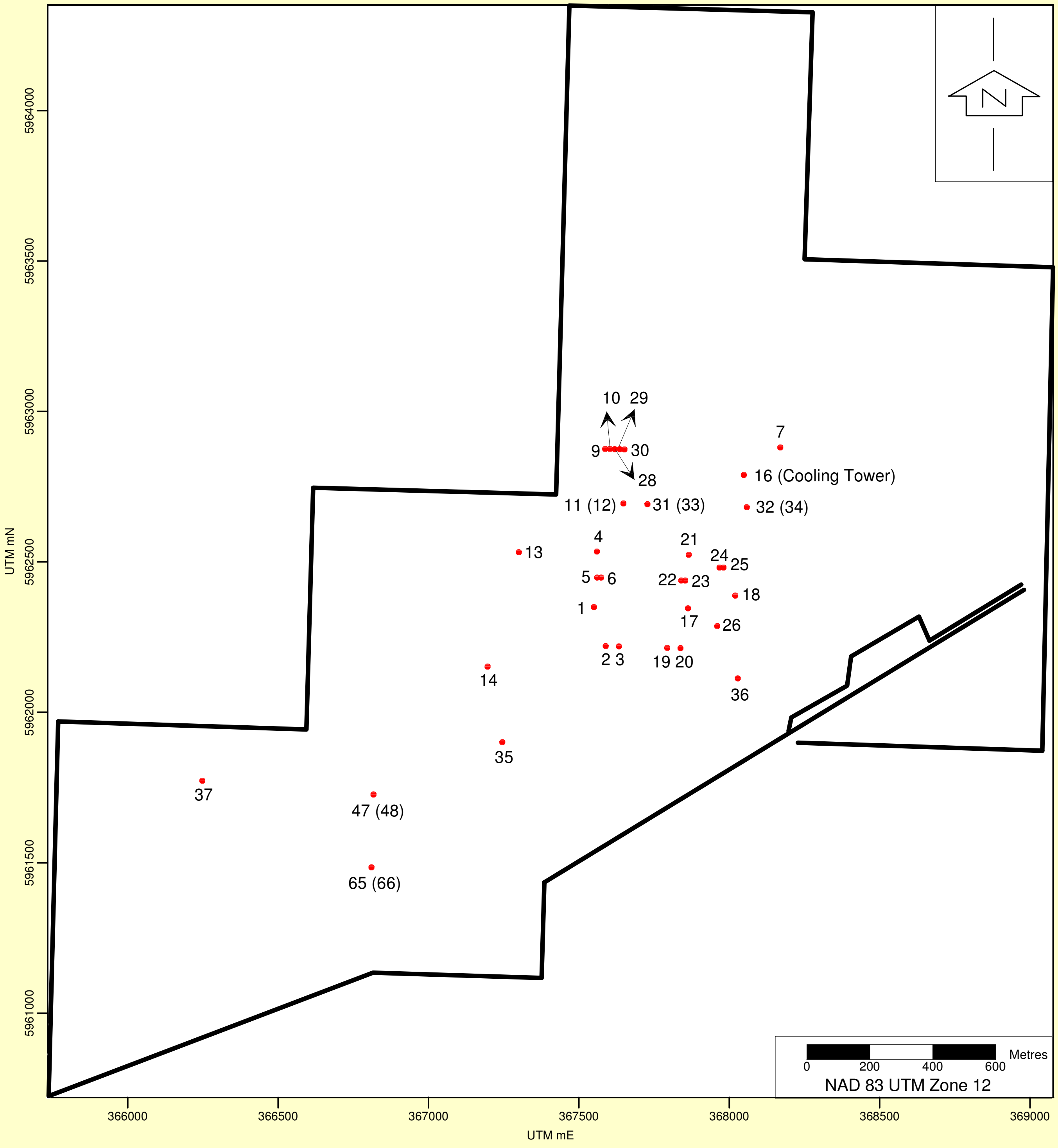
Regulatory Phase of the Project will be serviced by one eight-cell forced draft cooling tower to provide the cooling requirements of the Project. The cooling tower locations are shown in Figure 2A-3. The cooling water circulation rate for each cell is 2,130 m^3/h or 2,130,000 kg/h, and the expected water vapour release rate for each cell is 43,540 kg/h. Table 2A-51 provides the parameters associated with the cooling tower. The total water vapour emission due to the cooling tower is 8,359.7 t/d. For the purpose of comparison, the total water vapour emission from combustion sources is 4046 t/d. The distribution of water vapour emission for the Project is therefore 67.4 percent due to cooling towers and 32.6 percent due to combustion sources.

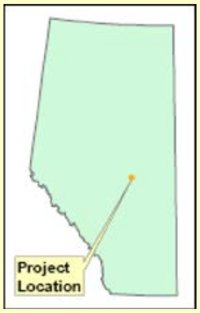
2A4.5 Greenhouse Gas Emissions

The greenhouse gas (GHG) emissions are mainly from two sources (CO_2 and CH_4) from combustion and fugitive sources. The total CO_2, CH_4, and N_2O emissions for the Project are 8,113 t/d, 1.01 t/d, and 0.0004 t/d respectively. The GHG emissions are normally reported as CO_2-equivalents (CO_2e) and the global warming potential for CH_4 is 21 and for N_2O is 310. Therefore, the maximum CO_2e emission rate for the Project, based on all the combustion equipment operating at full capacity, is 8,181 t/d.

Table 2A-15 Summary of Project Emission Sources (Stacks)

Identification Number	Identification	Description
Conventional Stacks		
1	DRU-1 Heater	Diluent Recovery Unit
2	DCU 1- Coker Heater 1	Delayed Coking
3	DCU 1- Coker Heater 2	Delayed Coking
4	NHT Heater 1	Naphtha Hydrotreater
5	DHT Heater 1	Distillate Hydrotrater
6	DHT Heater 2	Distillate Hydrotrater
7	Hydrogen Plant	Hydrogen Reformer
9	Utility Boiler 1	Steam Generation Unit
10	Utility Boiler 2	Steam Generation Unit
11	SRU incinerator 1 (UP1)	Sulphur Recovery Incinerator Stack
17	DRU-2 Heater	Diluent Recovery Unit
18	DRU-3 Heater	Diluent Recovery Unit
19	DCU 2 – Coker Heater 1	Delayed Coking
20	DCU-2 – Coker Heater 2	Delayed Coking
21	NHT Heater 2	Naphtha Hydrotreater
22	GO HT/HK Heater 1	Gas Oil Hydrotreater/Hydrocracker
23	GO HT/HK Heater 2	Gas Oil Hydrotreater/Hydrocracker
24	VGO HT/HK Heater 1	Vacuum Gas Oil Hydrotreater/Hydrocracker
25	VGO HT/HK Heater 2	Vacuum Gas Oil Hydrotreater/Hydrocracker
26	Vacuum Heater	Vacuum Recovery Unit
28	Utility Boiler 1	Steam Generation Unit
29	Utility Boiler 2	Steam Generation Unit
30	Utility Boiler 3	Steam Generation Unit
33	SRU incinerator 2 (UP2)	Sulphur Reduction Unit
34	SRU incinerator 3 (UP3)	Sulphur Recovery Incinerator Stack
47	Gas incinerator 1 (GAS1)	Sulphur Recovery Incinerator Stack
65	Gas incinerator 2 (GAS2)	Sulphur Recovery Incinerator Stack
Flare Stacks		
12	-	Acid Gas Flare
13	-	PH1 Atmospheric Flare Stack
14	-	PH1 Hydrocarbon Flare Stack
31	-	Acid Gas Flare
32	-	Acid Gas Flare
35	-	Future Atmospheric Flare Stack
36	-	Hydrocarbon Flare Stack
37	-	Gasification Flare Stack
48	-	Sour Gas Flare
55	-	Gasification Flare Stack
66	-	Sour Gas Flare





Legend

● Point Source

Title:

PROJECT PLOT PLAN SHOWING STACK LOCATIONS

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 17/10/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 NAOSC Emissions /JW-AXYS Emissions/Stack Sources

Drawn by:	Checked:	Fig. No.:
HZ	MD	**2A-3**

Table 2A-16 Plant Fuel Gas and Natural Gas Composition (mole %)

Component	Plant Fuel Gas	Natural Gas
Hydrogen	11.62	0.00
Nitrogen	0.00	0.93
CO_2	0.00	0.68
Methane	36.64	96.88
Ethane	20.07	1.06
Ethylene	2.60	0.00
Propane	12.12	0.32
Propene	4.00	0.00
n-Butane	5.86	0.07
i-Butane	3.19	0.07
Butylene	3.90	0.00
H_2S (ppm)	25	16
Total	100.00	100.00
Molecular Mass	27.98	16.64
Low Heating Value (MJ/m^3)	57.26	33.95

Table 2A-17 Sensitivity of SO_2 Emission Rates to Sulphur Recovery Efficiencies

Case	SO_2 Emission Rate (t/d)						Comment
	UP1	UP2	UP3	GAS1	GAS2	All	
A	1.89	1.89	1.89	0.76	0.76	7.18	Annual Project Case = 99.8%
B	1.89	1.89	1.89	1.91	0.76	8.34	1 GAS = 99.5%, others = 99.8%
C	1.89	1.89	1.89	2.67	0.76	9.10	1 GAS = 99.5%x1.4, others = 99.8%
D	4.72	1.89	1.89	0.76	0.76	10.02	1 SRU = 9 9.5%, others = 99.8%
E	4.72	1.89	1.89	1.91	0.76	11.17	1 SRU and 1 GAS = 99.5%, others = 99.8%
F	6.60	1.89	1.89	0.76	0.76	11.90	1 SRU = 99.5%x1.4, others = 99.8%
G	6.60	1.89	1.89	2.67	0.76	13.81	1 SRU and 1 GAS = 99.5%x1.4, others = 99.8%
H	4.72	4.72	4.72	1.91	1.91	17.98	1-h and 24-h Project Case = 99.5%
I	11.42	11.42	11.42	4.61	4.61	43.48	EUB 2003, Everything = 98.79% (Long-term)
J	14.25	14.25	14.25	5.75	5.75	54.25	EUB 2003, Everything = 98.49% (Quarterly)

Note:

- Case A where all SRU/TGTU complexes are operating at 99.8% is used to represent the Project when calculating annual average SO_2 concentrations and PAI deposition.
- Case H where all SRU/TGTU complexes are operating at 99.5% is used to represent the Project when calculating 1-h and 24-h average SO_2 concentrations.

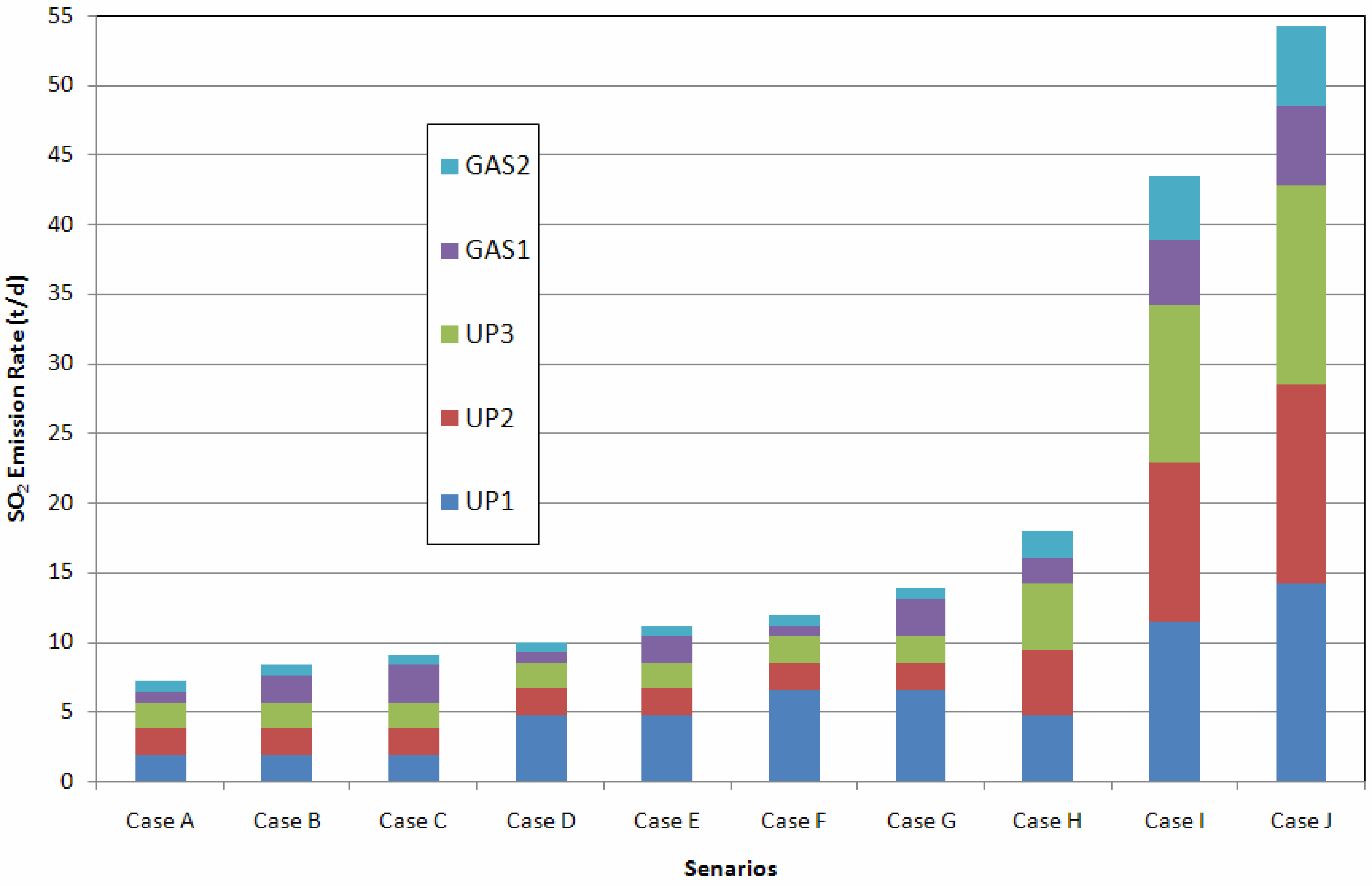


Figure 2A-4 Sensitivity of SO_2 Emission Rates to the Sulphur Recovery Cases Described in Table 2A-17

Table 2A-18 Emission Factors Used to Estimate Combustion Source Emissions

Substance	Type of Combustion Equipment	
	Heater, Boiler and Steam Generator	Flare (Landfill Gas)
	lb/MMBTU	lb/MMBTU
CO_2	104.04	104.04
H_2O	59.16	59.16
SO_2	0.0034	-
NO_x	0.07 (delayed coking) 0.035 (Other units)	0.068
CO	0.03	-
VOC	0.0023	0.14
$PM_{2.5}$	0.007	0.00124
Acenaphthene Group	0.0000000222	0.0000729
Acetaldehyde	0.0000325	0.000425
Acrolein	0.0000144	0.0000607
Anthracene	0.00000000156	0.0000364
Benzaldehyde	0.0000177	0.00
Benzene	0.0000260	0.000559
Benzo(a)anthracene	0.00000000185	0.0000364
Benzo(a)pyrene	0.000000000781	0.0000364
Benzo(b)fluoranthene	0.00000000117	0.0000364
Benzo(e)pyrene	0.00	0.0000000487
Benzo(g,h,i)perylene	0.000000000924	0.0000364
Benzo(k)fluoranthene	0.00000000117	0.0000364
C_5-C_8 Aliphatics	0.00169	0.00
C_{17}-C_{34} Aromatics	0.0000000116	0.0000000487
Chrysene	0.00000000119	0.0000364
Dibenz(a,h)anthracene	0.000000000781	0.0000364
Dichlorobenzene	0.000000781	0.00
Ethylbenzene	0.00000146	0.00
Fluoranthene	0.0000000116	0.0000364
Fluorene	0.00000000379	0.0000364
Formaldehyde	0.000437	0.0439
Hexane	0.00117	0.00
Indeno(1,2,3-cd)pyrene	0.00000000117	0.0000364
2-Methylnaphthalene	0.0000000156	0.0000107
Naphthalene	0.00000161	0.023
Phenanthrene	0.0000000308	0.0000364
Pyrene	0.00000000755	0.0000364
Toluene	0.0000486	0.0709
Xylenes	0.0000193	0.000518

Table 2A-19 Combustion Source Parameters and Emissions (Stacks 1, 2, 3, and 4)

Source identification #		**1**	**2**	**3**	4
Unit Name/Description		Diluent Recovery Unit	Delayed Coking		Naphtha Hydrotreater
		DRU-1 Heater	DCU 1- Coker Heater 1	DCU 1- Coker Heater 2	NHT Heater 1
Temporal Variation		Continuous	Continuous	Continuous	Continuous
Rating					
Capacity - Heat Input (FIRED)	GJ/h	310.7	268.7	268.7	15.7
	mmBTU/h	294.5	254.7	254.7	14.9
Efficiency	%	90	92	92	84
Fuel Type		Fuel Gas	Fuel Gas	Fuel Gas	Fuel Gas
Fuel Consumption	10^3 Nm^3/d	130.21	112.60	112.60	6.60
Stack Location					
UTM NAD 83	m N	5962349.5632	5962220.3568	5962219.0660	5962534.4307
UTM NAD 83	m E	367549.8663	367589.0927	367633.0738	367560.2942
Base Elevation of Stack	m ASL	626.0	625.0	624.4	627.0
Stack Dimensions					
Height Above Base Elevation	m	30	61	61	30
Stack Exit Diameter	m	1.95	1.70	1.55	0.45
Exhaust Parameters					
Exit Velocity	m/s	15.33	15.72	15.95	18.00
Exit Temperature	C	177	132	132	282
Exit Temperature	K	450	405	405	555
Emission Rate					
CO_2	t/d	333.54	288.42	288.42	16.89
H_2O	t/d	189.64	163.99	163.99	9.61
SO_2	t/d	0.012	0.010	0.010	0.0010
NO_x	t/d	0.123	0.213	0.213	0.0060
CO	t/d	0.106	0.091	0.091	0.0054
VOC	t/d	0.011	0.0090	0.0090	0.0010
$PM_{2.5}$	t/d	0.025	0.021	0.021	0.0010
Acenaphthene Group	t/y	0.000026	0.000022	0.000022	0.0000013
Acetaldehyde	t/y	0.038	0.033	0.033	0.0019
Acrolein	t/y	0.017	0.015	0.015	0.00086
Anthracene	t/y	0.0000018	0.0000016	0.0000016	0.000000093
Benzaldehyde	t/y	0.021	0.018	0.018	0.0010
Benzene	t/y	0.030	0.026	0.026	0.0015
Benzo(a)anthracene	t/y	0.0000022	0.0000019	0.0000019	0.00000011
Benzo(a)pyrene	t/y	0.00000091	0.00000079	0.00000079	0.000000046
Benzo(b)fluoranthene	t/y	0.0000014	0.0000012	0.0000012	0.00000007
Benzo(g,h,i)perylene	t/y	0.0000011	0.00000093	0.00000093	0.000000055
Benzo(k)fluoranthene	t/y	0.0000014	0.0000012	0.0000012	0.000000069
C5-C8 Aliphatics	t/y	1.98	1.71	1.71	0.10
C17-C34 Aromatics	t/y	0.000014	0.000012	0.000012	0.00000069
Chrysene	t/y	0.0000014	0.0000012	0.0000012	0.000000071
Dibenz(a,h)anthracene	t/y	0.0000009	0.0000008	0.0000008	0.000000046
Dichlorobenzene	t/y	0.00091	0.00079	0.00079	0.000046
Ethylbenzene	t/y	0.0017	0.0015	0.0015	0.00009
Fluoranthene	t/y	0.000014	0.000012	0.000012	0.0000007
Fluorene	t/y	0.0000044	0.0000038	0.0000038	0.00000022
Formaldehyde	t/y	0.51	0.44	0.44	0.03
Hexane	t/y	1.37	1.19	1.19	0.07
Indeno(1,2,3-cd)pyrene	t/y	0.0000014	0.0000012	0.0000012	0.00000007
2-Methylnaphthalene	t/y	0.000018	0.000016	0.000016	0.00000093
Naphthalene	t/y	0.0019	0.0016	0.0016	0.00010
Phenanthrene	t/y	0.000036	0.000031	0.000031	0.0000018
Pyrene	t/y	0.0000088	0.0000076	0.0000076	0.00000045
Toluene	t/y	0.057	0.049	0.049	0.0029
Xylenes	t/y	0.023	0.020	0.020	0.0011

Table 2A-20 Combustion Source Parameters and Emissions (Stacks 5, 6, 7, and 9, 10)

Source identification #		5	**6**	**7**	**9**	**10**
Unit Name/Description		Distillate Hydrotreater		Hydrogen Reformer Stack	Steam Generation Unit	
		DHT Heater 1	DHT Heater 2		Utility Boiler 1	Utility Boiler 2
Temporal Variation		Continuous	Continuous	Continuous	1 week/ 2 years	1 week/ 2 years
Rating						
Capacity - Heat Input (FIRED)	GJ/h	34.1	34.1	850.5	272.6	272.6
	mmBTU/h	32.34	32.34	806.2	258.4	258.4
Efficiency	%	84	84	92	90	90
Fuel Type		Fuel Gas	Fuel Gas	FG/PSA	Fuel Gas	Fuel Gas
Fuel Consumption	10^3 Nm^3/d	14.30	14.30	356.49	114.26	114.26
Stack Location						
UTM NAD 83	m N	5962448.2859	5962447.8677	5962880.6075	5962875.6909	5962875.2216
UTM NAD 83	m E	367560.7672	367573.7605	368169.7122	367587.3173	367603.3104
Base Elevation of Stack	m ASL	626.5	626.5	621.1	622.4	624.7
Stack Dimensions						
Height Above Base Elevation	m	30	30	61	30	30
Stack Exit Diameter	m	0.70	0.70	3.2	1.80	1.80
Exhaust Parameters						
Exit Velocity	m/s	16.29	16.29	15.27	15.79	15.79
Exit Temperature	C	288	288	138	177	177
Exit Temperature	K	561	561	411	450	450
Emission Rate						
CO_2	t/d	36.63	36.63	2544.59	292.67	292.67
H_2O	t/d	20.83	20.83	960.24	166.40	166.40
SO_2	t/d	0.0010	0.0010	0.0040	0.011	0.011
NO_x	t/d	0.014	0.014	0.343	0.108	0.108
CO	t/d	0.012	0.012	0.294	0.093	0.093
VOC	t/d	0.0010	0.0010	0.029	0.0090	0.0090
$PM_{2.5}$	t/d	0.003	0.003	0.069	0.022	0.022
Acenaphthene Group	t/y	0.0000029	0.0000029	0.000071	0.000023	0.000023
Acetaldehyde	t/y	0.0042	0.0042	0.104	0.033	0.033
Acrolein	t/y	0.0019	0.0019	0.046	0.015	0.015
Anthracene	t/y	0.00000020	0.00000020	0.0000050	0.0000016	0.0000016
Benzaldehyde	t/y	0.0023	0.0023	0.057	0.018	0.018
Benzene	t/y	0.0033	0.0033	0.083	0.027	0.027
Benzo(a)anthracene	t/y	0.00000024	0.00000024	0.0000059	0.0000019	0.0000019
Benzo(a)pyrene	t/y	0.00000010	0.00000010	0.0000025	0.00000080	0.00000080
Benzo(b)fluoranthene	t/y	0.00000015	0.00000015	0.00000375	0.0000012	0.0000012
Benzo(g,h,i)perylene	t/y	0.00000012	0.00000012	0.0000030	0.00000095	0.00000095
Benzo(k)fluoranthene	t/y	0.00000015	0.00000015	0.0000038	0.0000012	0.0000012
C5-C8 Aliphatics	t/y	0.22	0.22	5.42	1.74	1.74
C17-C34 Aromatics	t/y	0.0000015	0.0000015	0.000037	0.000012	0.000012
Chrysene	t/y	0.00000015	0.00000015	0.0000038	0.0000012	0.0000012
Dibenz(a,h)anthracene	t/y	0.00000010	0.00000010	0.0000025	0.00000080	0.00000080
Dichlorobenzene	t/y	0.00010	0.00010	0.0025	0.00080	0.00080
Ethylbenzene	t/y	0.00019	0.00019	0.0047	0.0015	0.0015
Fluoranthene	t/y	0.0000015	0.0000015	0.000037	0.000012	0.000012
Fluorene	t/y	0.00000049	0.00000049	0.000012	0.0000039	0.0000039
Formaldehyde	t/y	0.056	0.056	1.40	0.45	0.45
Hexane	t/y	0.15	0.15	3.75	1.20	1.20
Indeno(1,2,3-cd)pyrene	t/y	0.00000015	0.00000015	0.0000038	0.0000012	0.0000012
2-Methylnaphthalene	t/y	0.0000020	0.0000020	0.000050	0.000016	0.000016
Naphthalene	t/y	0.00021	0.00021	0.0051	0.0017	0.0017
Phenanthrene	t/y	0.0000040	0.0000040	0.00010	0.000032	0.000032
Pyrene	t/y	0.0000010	0.0000010	0.000024	0.0000077	0.0000077
Toluene	t/y	0.006	0.006	0.16	0.050	0.050
Xylenes	t/y	0.0025	0.0025	0.062	0.020	0.020

Table 2A-21 Combustion Source Parameters and Emissions (Stacks 17, 18, 19, and 20)

Source identification #		**17**	**18**	**19**	**20**
Unit Name/Description		Diluent Recovery Unit		Delayed Coking	
		DRU-2 Heater	DRU-3 Heater	DCU 2- Coker Heater 1	DCU 2- Coker Heater 2
Temporal Variation		Continuous	Continuous	Continuous	Continuous
Rating					
Capacity - Heat Input (FIRED)	GJ/h	354.0	174.9	322.6	322.6
	mmBTU/h	335.5	165.7	305.8	305.8
Efficiency	%	90	90	92	92
Fuel Type		Fuel Gas	Fuel Gas	Fuel Gas	Fuel Gas
Fuel Consumption	10^3 Nm^3/d	148.35	73.29	135.22	135.22
Stack Location					
UTM NAD 83	m N	5962345.3786	5962387.7676	5962214.3428	5962213.0519
UTM NAD 83	m E	367862.8783	368020.1895	367794.0045	367837.9855
Base Elevation of Stack	m ASL	623.5	624.6	624.2	625.0
Stack Dimensions					
Height Above Base Elevation	m	30	30	61	61
Stack Exit Diameter	m	2.10	1.45	1.75	2.20
Exhaust Parameters					
Exit Velocity	m/s	15.06	15.41	15.03	15.44
Exit Temperature	C	177	171	132	282
Exit Temperature	K	450	444	405	555
Emission Rate					
CO_2	t/d	380.00	187.73	346.36	346.36
H_2O	t/d	216.06	106.74	196.93	196.93
SO_2	t/d	0.014	0.007	0.012	0.012
NO_x	t/d	0.14	0.069	0.26	0.26
CO	t/d	0.120	0.060	0.11	0.11
VOC	t/d	0.012	0.0060	0.011	0.011
$PM_{2.5}$	t/d	0.028	0.014	0.026	0.026
Acenaphthene Group	t/y	0.000030	0.000015	0.000027	0.000027
Acetaldehyde	t/y	0.043	0.021	0.040	0.040
Acrolein	t/y	0.0193	0.0095	0.0176	0.0176
Anthracene	t/y	0.0000021	0.0000010	0.0000019	0.0000019
Benzaldehyde	t/y	0.024	0.012	0.022	0.022
Benzene	t/y	0.035	0.017	0.032	0.032
Benzo(a)anthracene	t/y	0.0000025	0.0000012	0.0000023	0.0000023
Benzo(a)pyrene	t/y	0.0000010	0.00000051	0.00000095	0.00000095
Benzo(b)fluoranthene	t/y	0.0000016	0.00000077	0.00000142	0.00000142
Benzo(g,h,i)perylene	t/y	0.0000012	0.00000061	0.00000112	0.00000112
Benzo(k)fluoranthene	t/y	0.0000016	0.00000077	0.00000142	0.00000142
C5-C8 Aliphatics	t/y	2.26	1.11	2.06	2.06
C17-C34 Aromatics	t/y	0.000015	0.0000076	0.000014	0.000014
Chrysene	t/y	0.0000016	0.00000078	0.0000014	0.0000014
Dibenz(a,h)anthracene	t/y	0.0000010	0.00000051	0.00000095	0.00000095
Dichlorobenzene	t/y	0.0010	0.00051	0.00095	0.00095
Ethylbenzene	t/y	0.0020	0.00096	0.00178	0.00178
Fluoranthene	t/y	0.000016	0.0000077	0.0000142	0.0000142
Fluorene	t/y	0.0000050	0.0000025	0.0000046	0.0000046
Formaldehyde	t/y	0.58	0.29	0.53	0.53
Hexane	t/y	1.56	0.77	1.42	1.42
Indeno(1,2,3-cd)pyrene	t/y	0.0000016	0.00000077	0.00000142	0.00000142
2-Methylnaphthalene	t/y	0.000021	0.000010	0.000019	0.000019
Naphthalene	t/y	0.0021	0.0011	0.0020	0.0020
Phenanthrene	t/y	0.000041	0.000020	0.000037	0.000037
Pyrene	t/y	0.000010	0.0000050	0.0000092	0.0000092
Toluene	t/y	0.065	0.032	0.059	0.059
Xylenes	t/y	0.026	0.013	0.023	0.023

Table 2A-22 Combustion Source Parameters and Emissions (Stacks 21 to 25)

Source identification #		21	22	23	24	25
Unit Name/Description		Naphtha Hydrotreater	Gas Oil Hydrotreater/ Hydrocracker		Vacuum Gas Oil Hydrotreater/Hydrocracker	
		NHT Heater 2	GO HT/HK Heater 1	GO HT/HK Heater 2	VGO HT/HK Heater 1	VGO HT/HK Heater 2
Temporal Variation		Continuous	Continuous	Continuous	Continuous	Continuous
Rating						
Capacity - Heat Input (FIRED)	GJ/h	16.7	33.7	33.7	24.0	24.0
	mmBTU/h	15.9	31.90	31.90	22.73	22.73
Efficiency	%	84	80	80	80	80
Fuel Type		Fuel Gas	Fuel Gas	Fuel Gas	Fuel Gas	Fuel Gas
Fuel Consumption	10^3 Nm^3/d	7.01	14.10	14.10	10.05	10.05
Stack Location						
UTM NAD 83	m N	5962523.4525	5962438.0725	5962437.6911	5962481.3558	5962480.9744
UTM NAD 83	m E	367865.1015	367840.5880	367853.5824	367967.9126	367980.9070
Base Elevation of Stack	m ASL	623.0	623.0	623.0	623.3	623.7
Stack Dimensions						
Height Above Base Elevation	m	30	30	30	30	30
Stack Exit Diameter	m	0.50	0.75	0.75	0.6	0.6
Exhaust Parameters						
Exit Velocity	m/s	15.51	15.66	15.66	17.44	17.44
Exit Temperature	C	282	354	354	354	354
Exit Temperature	K	555	627	627	627	627
Emission Rate						
CO_2	t/d	17.97	36.13	36.13	25.74	25.74
H_2O	t/d	10.22	20.54	20.54	14.64	14.64
SO_2	t/d	0.0010	0.0010	0.0010	0.0010	0.0010
NO_x	t/d	0.0067	0.013	0.013	0.010	0.010
CO	t/d	0.0057	0.011	0.011	0.0082	0.0082
VOC	t/d	0.0010	0.0012	0.0012	0.0010	0.0010
$PM_{2.5}$	t/d	0.0010	0.0027	0.0027	0.002	0.0020
Acenaphthene Group	t/y	0.000001	0.000003	0.000003	0.000002	0.000002
Acetaldehyde	t/y	0.002	0.004	0.004	0.003	0.003
Acrolein	t/y	0.0009	0.0018	0.0018	0.0013	0.0013
Anthracene	t/y	0.00000010	0.00000020	0.00000020	0.00000014	0.00000014
Benzaldehyde	t/y	0.001	0.002	0.002	0.002	0.002
Benzene	t/y	0.002	0.003	0.003	0.002	0.002
Benzo(a)anthracene	t/y	0.00000012	0.00000024	0.00000024	0.00000017	0.00000017
Benzo(a)pyrene	t/y	0.00000005	0.00000010	0.00000010	0.00000007	0.00000007
Benzo(b)fluoranthene	t/y	0.00000007	0.00000015	0.00000015	0.00000011	0.00000011
Benzo(g,h,i)perylene	t/y	0.00000006	0.00000012	0.00000012	0.000000083	0.000000083
Benzo(k)fluoranthene	t/y	0.00000007	0.00000015	0.00000015	0.00000011	0.00000011
C5-C8 Aliphatics	t/y	0.11	0.21	0.21	0.15	0.15
C17-C34 Aromatics	t/y	0.00000073	0.0000015	0.0000015	0.0000010	0.0000010
Chrysene	t/y	0.000000075	0.00000015	0.00000015	0.00000011	0.00000011
Dibenz(a,h)anthracene	t/y	0.00000005	0.00000010	0.00000010	0.000000071	0.000000071
Dichlorobenzene	t/y	0.00005	0.00010	0.00010	0.00007	0.00007
Ethylbenzene	t/y	0.00009	0.00019	0.00019	0.00013	0.00013
Fluoranthene	t/y	0.0000007	0.0000015	0.0000015	0.0000011	0.0000011
Fluorene	t/y	0.0000002	0.0000005	0.0000005	0.0000003	0.0000003
Formaldehyde	t/y	0.03	0.06	0.06	0.04	0.04
Hexane	t/y	0.07	0.15	0.15	0.11	0.11
Indeno(1,2,3-cd)pyrene	t/y	0.00000007	0.00000015	0.00000015	0.00000011	0.00000011
2-Methylnaphthalene	t/y	0.0000010	0.0000020	0.0000020	0.0000014	0.0000014
Naphthalene	t/y	0.00010	0.00020	0.00020	0.00015	0.00015
Phenanthrene	t/y	0.0000019	0.0000039	0.0000039	0.0000028	0.0000028
Pyrene	t/y	0.00000048	0.0000010	0.0000010	0.00000068	0.00000068
Toluene	t/y	0.0031	0.0062	0.0062	0.0044	0.0044
Xylenes	t/y	0.0012	0.0024	0.0024	0.0017	0.0017

Table 2A-23 Combustion Source Parameters and Emissions (Stacks 26, 28, 29, and 30)

Source identification #		**26**	**28**	**29**	**30**
Unit Name/Description		Vacuum Recovery Unit	Steam Generation Unit		
		Vacuum Heater	Utility Boiler 1	Utility Boiler 2	Utility Boiler 3
Temporal Variation		Continuous	1 week/2 years	1 week/2 years	1 week/2 years
Rating					
Capacity - Heat Input (FIRED)	GJ/h	248.1	272.6	272.6	272.6
	mmBTU/h	235.2	258.4	258.4	258.4
Efficiency	%	90	90	90	90
Fuel Type		Fuel Gas	Fuel Gas	Fuel Gas	Fuel Gas
Fuel Consumption	10^3 Nm^3/d	103.99	114.26	114.26	114.26
Stack Location					
UTM NAD 83	m N	5962286.4984	5962874.7522	5962874.2828	5962873.8134
UTM NAD 83	m E	367960.1928	367619.3035	367635.2966	367651.2897
Base Elevation of Stack	m ASL	624.0	625.5	625.3	625
Stack Dimensions					
Height Above Base Elevation	m	30	30	30	30
Stack Exit Diameter	m	1.75	1.8	1.8	1.8
Exhaust Parameters					
Exit Velocity	m/s	15.20	15.79	15.79	15.79
Exit Temperature	C	177	177	177	177
Exit Temperature	K	450	450	450	450
Emission Rate					
CO_2	t/d	266.37	292.67	292.67	292.67
H_2O	t/d	151.45	166.40	166.40	166.40
SO_2	t/d	0.010	0.011	0.011	0.011
NO_x	t/d	0.098	0.108	0.108	0.108
CO	t/d	0.084	0.093	0.093	0.093
VOC	t/d	0.0080	0.0090	0.0090	0.0090
$PM_{2.5}$	t/d	0.020	0.022	0.022	0.022
Acenaphthene Group	t/y	0.000021	0.000023	0.000023	0.000023
Acetaldehyde	t/y	0.030	0.033	0.033	0.033
Acrolein	t/y	0.013	0.015	0.015	0.015
Anthracene	t/y	0.0000015	0.0000016	0.0000016	0.0000016
Benzaldehyde	t/y	0.017	0.018	0.018	0.018
Benzene	t/y	0.024	0.027	0.027	0.027
Benzo(a)anthracene	t/y	0.0000017	0.0000019	0.0000019	0.0000019
Benzo(a)pyrene	t/y	0.00000073	0.00000080	0.00000080	0.00000080
Benzo(b)fluoranthene	t/y	0.00000109	0.00000120	0.00000120	0.00000120
Benzo(g,h,i)perylene	t/y	0.00000086	0.00000095	0.00000095	0.00000095
Benzo(k)fluoranthene	t/y	0.00000109	0.00000120	0.00000120	0.00000120
C_5-C_8 Aliphatics	t/y	1.58	1.74	1.74	1.74
C_{17}-C_{34} Aromatics	t/y	0.0000108	0.0000119	0.0000119	0.0000119
Chrysene	t/y	0.00000111	0.00000122	0.00000122	0.00000122
Dibenz(a,h)anthracene	t/y	0.00000073	0.00000080	0.00000080	0.00000080
Dichlorobenzene	t/y	0.00073	0.00080	0.00080	0.00080
Ethylbenzene	t/y	0.0014	0.0015	0.0015	0.0015
Fluoranthene	t/y	0.000011	0.000012	0.000012	0.000012
Fluorene	t/y	0.0000035	0.0000039	0.0000039	0.0000039
Formaldehyde	t/y	0.41	0.45	0.45	0.45
Hexane	t/y	1.09	1.20	1.20	1.20
Indeno(1,2,3-cd)pyrene	t/y	0.0000011	0.0000012	0.0000012	0.0000012
2-Methylnaphthalene	t/y	0.000015	0.000016	0.000016	0.000016
Naphthalene	t/y	0.0015	0.0017	0.0017	0.0017
Phenanthrene	t/y	0.000029	0.000032	0.000032	0.000032
Pyrene	t/y	0.0000071	0.0000077	0.0000077	0.0000077
Toluene	t/y	0.045	0.050	0.050	0.050
Xylenes	t/y	0.018	0.020	0.020	0.020

Table 2A-24 Thermal Oxidizer Parameters and Emissions

Source identification #			**11**	**33**	**34**	**47**	**65**
Unit Name/Description			**SRU 1**	**SRU 2**	**SRU 3**	**Gas 1**	**Gas 2**
Temporal Variation			Continuous	Continuous	Continuous	Continuous	Continuous
Sulphur Recovery							
Inlet Sulphur Equivalent		t/d	472	472	472	191	191
Annual S Recovery		%	99.8	99.8	99.8	99.8	99.8
Quarterly S Recovery		%	99.5	99.5	99.5	99.5	99.5
Stack Location	UTM NAD 83	m N	5962693.8322	5962691.4853	5962681.8666	5961726.7868	5961484.8909
	UTM NAD 83	m E	367648.0083	367727.9738	368057.8318	366817.2808	366810.1813
Base Elevation of Stack		m ASL	625.3	623.6	621.2	622	622.3
Stack Dimensions							
Height Above Base Elevation		m	90	90	90	90	90
Inside Tip Diameter		m	2.13	2.13	2.13	1.219	1.219
Exhaust Parameters							
Exit Velocity		m/s	16.92	16.92	16.92	16.02	16.02
Exit Temperature		C	538	538	538	538	538
Exit Temperature		K	811	811	811	811	811
Emission Rate							
CO_2		t/d	166.55	166.55	166.55	428.96	428.96
H_2O		t/d	197.01	197.01	197.01	58.90	58.90
SO_2 average (c)		t/d	1.89	1.89	1.89	0.76	0.76
SO_2 24 h max (d)		t/d	4.72	4.72	4.72	1.91	1.91
SO_2 1 h (e)		t/h	0.197	0.197	0.197	0.0796	0.0796
TRS		t/d	0.134	0.134	0.134	0.046	0.046
H_2S		t/d	0.0536	0.0536	0.0536	0.018	0.018
COS		t/d	0.142	0.142	0.142	0.027	0.027
NOx		t/d	0.181	0.181	0.181	0.056	0.056
CO		t/d	0.22	0.22	0.22	0.034	0.034
VOC		t/d	0.0071	0.0071	0.0071	0.0022	0.0022
$PM_{2.5}$		t/d	0.0025	0.0025	0.0025	0.00076	0.00076
Acenaphthene Group		t/y	0.000016	0.000016	0.000016	0.000005	0.000005
Acetaldehyde		t/y	0.024	0.024	0.024	0.0073	0.0073
Acrolein		t/y	0.0105	0.0105	0.0105	0.0032	0.0032
Anthracene		t/y	0.0000011	0.0000011	0.0000011	0.00000035	0.00000035
Benzaldehyde		t/y	0.013	0.013	0.013	0.0040	0.0040
Benzene		t/y	0.019	0.019	0.019	0.0058	0.0058
Benzo(a)anthracene		t/y	0.0000013	0.0000013	0.0000013	0.00000042	0.00000042
Benzo(a)pyrene		t/y	0.00000057	0.00000057	0.00000057	0.00000018	0.00000018
Benzo(b)fluoranthene		t/a	0.00000085	0.00000085	0.00000085	0.00000026	0.00000026
Benzo(g,h,i)perylene		t/y	0.00000067	0.00000067	0.00000067	0.00000021	0.00000021
Benzo(k)fluoranthene		t/y	0.00000085	0.00000085	0.00000085	0.00000026	0.00000026
C5-C8 Aliphatics		t/y	1.23	1.23	1.23	0.38	0.38
C17-C34 Aromatics		t/y	0.0000084	0.0000084	0.0000084	0.0000026	0.0000026
Chrysene		t/y	0.00000086	0.00000086	0.00000086	0.00000027	0.00000027
Dibenz(a,h)anthracene		t/y	0.00000057	0.00000057	0.00000057	0.00000018	0.00000018
Dichlorobenzene		t/y	0.00057	0.00057	0.00057	0.00018	0.00018
Ethylbenzene		t/y	0.0011	0.0011	0.0011	0.00033	0.00033
Fluoranthene		t/y	0.0000084	0.0000084	0.0000084	0.0000026	0.0000026
Fluorene		t/y	0.0000027	0.0000027	0.0000027	0.00000085	0.00000085
Formaldehyde		t/y	0.32	0.32	0.32	0.098	0.098
Hexane		t/y	0.85	0.85	0.85	0.26	0.26
Indeno(1,2,3-cd)pyrene		t/y	0.00000085	0.00000085	0.00000085	0.00000026	0.00000026
2-Methylnaphthalene		t/y	0.000011	0.000011	0.000011	0.0000035	0.0000035
Naphthalene		t/y	0.0012	0.0012	0.0012	0.00036	0.00036
Phenanthrene		t/y	0.000022	0.000022	0.000022	0.0000069	0.0000069
Pyrene		t/y	0.0000055	0.0000055	0.0000055	0.0000017	0.0000017
Toluene		t/y	0.035	0.035	0.035	0.011	0.011
Xylenes		t/y	0.0140	0.0140	0.0140	0.0043	0.0043
Sulphuric Acid		t/y	1.27	1.27	1.27	0.42	0.42

Table 2A-25 Flare Stack Parameters and Emissions (Normal, Stacks 12, 13 and 14)

Source identification #		**12**	**13**	**14**
Unit Name/Description		Acid Gas Flare	PH1 Atmos Flare Stack	PH1 Hydrocarbon Flare Stack
Event		Normal	Normal	Normal
Frequency		Continuous	Continuous	Continuous
Duration		Continuous	Continuous	Continuous
Flow Rate				
Inlet Gas Stream		Natural Gas	Natural Gas	Natural Gas
Inlet Flow Rate	10^3 Nm^3/d	0.3	0.2	6.96
Stack Location				
UTM NAD 83	m N	5,962,693.8322	5,962,531.9687	5,962,151.8325
UTM NAD 83	m E	367,648.0083	367,300.1100	367,196.3136
Base Elevation of Stack	m ASL	625.3	622.0	622.2
Stack Dimensions				
Height Above Base Elevation	m	90	16	137.2
Inside Tip Diameter	m	0.356	0.305	1.524
Effective Parameters				
Stack Height	m	90.6	16.50	139.9
Stack Diameter	m	3.44	2.95	14.72
Exit Velocity	m/s	0.035	0.032	0.044
Exit Temperature	C	1000	1000	1000
Exit Temperature	K	1273	1273	1273
Emission Rate				
CO_2	t/d	0.78	0.52	18.00
H_2O	t/d	0.48	0.32	11.08
SO_2	t/d	0.000013	0.0000085	0.000296
NO_x	t/d	0.00051	0.00034	0.0118
CO	t/d	0.00041	0.00027	0.0095
VOC	t/d	0.0010	0.00070	0.024
$PM_{2.5}$	t/d	0.0000092	0.0000061	0.00021
Acenaphthene Group	t/y	0.00020	0.00013	0.0046
Acetaldehyde	t/y	0.0012	0.00077	0.027
Acrolein	t/y	0.00017	0.00011	0.0038
Anthracene	t/y	0.000099	0.000066	0.0023
Benzene	t/y	0.0015	0.0010	0.035
Benzo(a)anthracene	t/y	0.000099	0.000066	0.0023
Benzo(a)pyrene	t/y	0.000099	0.000066	0.0023
Benzo(b)fluoranthene	t/y	0.000099	0.000066	0.0023
Benzo(e)pyrene	t/y	0.00000013	0.000000088	0.0000031
Benzo(g,h,i)perylene	t/y	0.000099	0.000066	0.0023
Benzo(k)fluoranthene	t/y	0.000099	0.000066	0.0023
C_{17}-C_{34} Aromatics	t/y	0.00000013	0.000000088	0.0000031
Chrysene	t/y	0.00010	0.000066	0.0023
Dibenz(a,h)anthracene	t/y	0.00010	0.000066	0.0023
Fluoranthene	t/y	0.00010	0.000066	0.0023
Fluorene	t/y	0.00010	0.000066	0.0023
Formaldehyde	t/y	0.12	0.080	2.77
Indeno(1,2,3-cd)pyrene	t/y	0.000099	0.000066	0.0023
2-Methylnaphthalene	t/y	0.000029	0.000019	0.00067
Naphthalene	t/y	0.063	0.042	1.45
Phenanthrene	t/y	0.000099	0.000066	0.0023
Pyrene	t/y	0.000099	0.000066	0.0023
Toluene	t/y	0.19	0.13	4.48
Xylenes	t/y	0.0014	0.00094	0.033

Table 2A-26 Flare Stack Parameters and Emissions (Normal, Stacks 31, 32, 35 and 36)

Source Identification #		**31**	**32**	**35**	**36**
Unit Name/Description		Acid Gas Flare	Acid Gas Flare	Future Atmos Flare Stack	Hydrocarbon Flare Stack
Event		Normal	Normal	Normal	Normal
Frequency		Continuous	Continuous	Continuous	Continuous
Duration		Continuous	Continuous	Continuous	Continuous
Flow Rate					
Inlet Gas Stream		Natural Gas	Natural Gas	Natural Gas	Natural Gas
Inlet Flow Rate	10^3 Nm^3/d	0.3	0.3	0.3	6.96
Stack Location					
UTM NAD 83	m N	5,962,691.4853	5,962,681.8666	5,961,900.3598	5,962,112.4015
UTM NAD 83	m E	367,727.9738	368,057.8318	367,245.5530	368,028.1150
Base Elevation of Stack	m ASL	623.6	621.2	623.0	624.0
Stack Dimensions					
Height Above Base Elevation	m	90	90	16	152.4
Inside Tip Diameter	m	0.356	0.356	0.305	1.524
Effective Parameters					
Stack Height	m	90.6	90.6	16.6	155.1
Stack Diameter	m	3.44	3.44	2.95	14.72
Exit Velocity	m/s	0.035	0.035	0.048	0.044
Exit Temperature	C	1000	1000	1000	1000
Exit Temperature	K	1273	1273	1273	1273
Emission Rate					
CO_2	t/d	0.78	0.78	0.78	18.00
H_2O	t/d	0.48	0.48	0.48	11.08
SO_2	t/d	0.000013	0.000013	0.000013	0.000296
NO_x	t/d	0.00051	0.00051	0.00051	0.0118
CO	t/d	0.00041	0.00041	0.00041	0.0095
VOC	t/d	0.0010	0.0010	0.0010	0.024
$PM_{2.5}$	t/d	0.0000092	0.0000092	0.0000092	0.00021
Acenaphthene Group	t/y	0.00020	0.00020	0.00020	0.0046
Acetaldehyde	t/y	0.0012	0.0012	0.0012	0.027
Acrolein	t/y	0.00017	0.00017	0.00017	0.0038
Anthracene	t/y	0.000099	0.000099	0.000099	0.0023
Benzene	t/y	0.0015	0.0015	0.0015	0.035
Benzo(a)anthracene	t/y	0.000099	0.000099	0.000099	0.0023
Benzo(a)pyrene	t/y	0.000099	0.000099	0.000099	0.0023
Benzo(b)fluoranthene	t/y	0.000099	0.000099	0.000099	0.0023
Benzo(e)pyrene	t/y	0.00000013	0.00000013	0.00000013	0.0000031
Benzo(g,h,i)perylene	t/y	0.000099	0.000099	0.000099	0.0023
Benzo(k)fluoranthene	t/y	0.000099	0.000099	0.000099	0.0023
C_{17}-C_{34} Aromatics	t/y	0.00000013	0.00000013	0.00000013	0.0000031
Chrysene	t/y	0.00010	0.00010	0.000099	0.0023
Dibenz(a,h)anthracene	t/y	0.00010	0.00010	0.000099	0.0023
Fluoranthene	t/y	0.00010	0.00010	0.000099	0.0023
Fluorene	t/y	0.00010	0.00010	0.000099	0.0023
Formaldehyde	t/y	0.12	0.12	0.12	2.77
Indeno(1,2,3-cd)pyrene	t/y	0.000099	0.000099	0.000099	0.0023
2-Methylnaphthalene	t/y	0.000029	0.000029	0.000029	0.00067
Naphthalene	t/y	0.063	0.063	0.063	1.45
Phenanthrene	t/y	0.000099	0.000099	0.000099	0.0023
Pyrene	t/y	0.000099	0.000099	0.000099	0.0023
Toluene	t/y	0.19	0.19	0.19	4.48
Xylenes	t/y	0.0014	0.0014	0.0014	0.033

Table 2A-27 Flare Stack Parameters and Emissions (Normal, Stacks 37, 48, 55 and 66)

Source identification #		**37**	**48**	**55**	**66**
Unit Name/Description		Gas. Flare Stack	Sour Gas Flare	Gas. Flare Stack	Sour Gas Flare
Event		Normal	Normal	Normal	Normal
Frequency		Continuous	Continuous	Continuous	Continuous
Duration		Continuous	Continuous	Continuous	Continuous
Flow Rate					
Inlet Gas Stream		Natural Gas	Natural Gas	Natural Gas	Natural Gas
Inlet Flow Rate	10^3 Nm^3/d	1.2	0.2	1.2	0.2
Stack Location					
UTM NAD 83	m N	5,961,772.4962	5,961,706.7954	5,961,572.6448	5,961,464.8995
UTM NAD 83	m E	366,248.3769	366,816.6940	366,242.5095	366,809.5946
Base Elevation of Stack	m ASL	625.2	621.6	623.0	622.8
Stack Dimensions					
Height Above Base Elevation	m	34	90	34	90
Inside Tip Diameter	m	0.914	0.305	0.914	0.305
Effective Parameters					
Stack Height	m	35.2	90.5	35.2	90.5
Stack Diameter	m	8.83	2.95	8.83	2.95
Exit Velocity	m/s	0.021	0.032	0.021	0.032
Exit Temperature	C	1000	1000	1000	1000
Exit Temperature	K	1273	1273	1273	1273
Emission Rate					
CO_2	t/d	3.10	0.52	3.10	0.52
H_2O	t/d	1.91	0.32	1.91	0.32
SO_2	t/d	0.000051	0.0000085	0.000051	0.0000085
NO_x	t/d	0.0020	0.00034	0.0020	0.00034
CO	t/d	0.0016	0.00027	0.0016	0.00027
VOC	t/d	0.0042	0.00070	0.0042	0.00070
$PM_{2.5}$	t/d	0.000037	0.0000061	0.000037	0.0000061
Acenaphthene Group	t/y	0.00079	0.00013	0.00079	0.00013
Acetaldehyde	t/y	0.0046	0.00077	0.0046	0.00077
Acrolein	t/y	0.00066	0.00011	0.00066	0.00011
Anthracene	t/y	0.00040	0.000066	0.000397	0.000066
Benzene	t/y	0.0061	0.0010	0.0061	0.0010
Benzo(a)anthracene	t/y	0.00040	0.000066	0.00040	0.000066
Benzo(a)pyrene	t/y	0.00040	0.000066	0.00040	0.000066
Benzo(b)fluoranthene	t/y	0.00040	0.000066	0.00040	0.000066
Benzo(e)pyrene	t/y	0.00000053	0.000000088	0.00000053	0.000000088
Benzo(g,h,i)perylene	t/y	0.00040	0.000066	0.000397	0.000066
Benzo(k)fluoranthene	t/y	0.00040	0.000066	0.000397	0.000066
C_{17}-C_{34} Aromatics	t/y	0.00000053	0.000000088	0.00000053	0.000000088
Chrysene	t/y	0.00040	0.000066	0.00040	0.000066
Dibenz(a,h)anthracene	t/y	0.00040	0.000066	0.00040	0.000066
Fluoranthene	t/y	0.00040	0.000066	0.00040	0.000066
Fluorene	t/y	0.00040	0.000066	0.00040	0.000066
Formaldehyde	t/y	0.48	0.080	0.48	0.080
Indeno(1,2,3-cd)pyrene	t/y	0.00040	0.000066	0.00040	0.000066
2-Methylnaphthalene	t/y	0.00012	0.000019	0.00012	0.000019
Naphthalene	t/y	0.25	0.042	0.25	0.042
Phenanthrene	t/y	0.00040	0.000066	0.00040	0.000066
Pyrene	t/y	0.00040	0.000066	0.00040	0.000066
Toluene	t/y	0.77	0.13	0.77	0.13
Xylenes	t/y	0.0056	0.00094	0.0056	0.00094

Table 2A-28 Flare Stack Parameters and Emissions (Emergency, Stacks 12, 13 and 14)

Source identification #		**12**	**13**	**14**	
Unit Name/Description		Acid Gas Flare	PH1 Atmos Flare Stack	PH1 Hydrocarbon Flare Stack	
Event		Power Failure/Startup	VRU Failure	Power Failure	Blower Failure
Frequency		once/2 years	once/2 years	once/5 years	once/2 years
Duration		1 day	15 minutes	20 minutes	20 minutes
Flow Rate					
Inlet Gas Stream		Acid Gas	Acid Gas	Acid Gas	Acid Gas
Inlet Flow Rate	10^3 Nm^3/d	96.8	293	16536.8	685.82
Maximum Natural Gas Flow Rate	10^3 Nm^3/d	1120	1120	1120	1120
Inlet Gas Composition					
H_2	Mole %	0.00	0.00	35.38	0.00
N_2	Mole %	0.00	0.19	0.33	0.00
Ar	Mole %	0.00	0.00	0.00	0.00
CO	Mole %	0.00	0.00	1.01	0.00
CO_2	Mole %	0.00	0.13	6.49	1.35
H_2S	Mole %	38.20	2.95	4.21	46.25
COS	Mole %	0.00	0.00	0.00	0.00
C_1	Mole %	0.70	18.93	6.54	0.00
C_2	Mole %	0.00	8.93	2.41	0.00
C_3	Mole %	0.00	19.44	1.64	0.00
C_4	Mole %	0.00	25.83	2.07	0.00
C_{5+}	Mole %	0.00	21.68	27.09	0.00
H_2O	Mole %	22.91	1.92	12.37	52.40
NH_3	Mole %	38.20	0.00	0.46	0.00
Total	*Mole %*	*100.00*	*100.00*	*100.00*	*100.00*
Acid Gas Properties					
Molecular Mass	kg/kmole	*23.76*	*49.45*	*33.73*	*25.8*
Heating Value	MJ/m^3	*15.22*	*93.78*	*56.61*	*10.13*
Combined Gas Properties					
Molecular Mass	kg/kmole	*17.21*	*23.44*	*33.58*	*20.12*
Heating Value	MJ/m^3	*32.46*	*46.36*	*55.17*	*24.90*
Stack Location					
UTM NAD 83	m N	5,962,693.8322	5,962,531.9687	5,962,151.8325	
UTM NAD 83	m E	367,648.0083	367,300.1100	367,196.3136	
Base Elevation of Stack	m ASL	625.3	622.0	622.2	
Stack Dimensions					
Height Above Base Elevation	m	90	16	137.2	
Inside Tip Diameter	m	0.356	0.305	1.524	
Effective Parameters					
Stack Height	m	121.7	56.4	284.1	171.0
Stack Diameter	m	3.36	3.44	18.77	12.61
Exit Velocity	m/s	141.5	223.84	112.03	11.46
Exit Temperature	C	1000	1000	1000	1000
Exit Temperature	K	1273	1273	1273	1273
Emission Rate					
SO_2 (flare period)	t/d	98.14	22.94	1847.7	841.8
SO_2 (equivalent 1-h)	t/d	98.14	5.74	615.9	280.6

Table 2A-29 Flare Stack Parameters and Emissions (Emergency, Stacks 31, 32, 35 and 36)

Source identification #		**31**	**32**	**35**	**36**	
Unit Name/Description		Acid Gas Flare	Acid Gas Flare	Future Atmos Flare Stack	Hydrocarbon Flare Stack	
Event		Power Failure/Startup	Power Failure/Startup	VRU Failure	Power Failure	Blower Failure
Frequency		once/2 years	once/2 years	once/2 years	once/5 years	once/2 years
Duration		1 day	1 day	15 minutes	20 minutes	20 minutes
Flow Rate						
Inlet Gas Stream		Acid Gas	Acid Gas	Acid Gas	Acid Gas	Acid Gas
Inlet Flow Rate	10^3 Nm^3/d	96.8	96.8	440	11885.8	685.82
Maximum Natural Gas Flow Rate	10^3 Nm^3/d	1120	1120	1120	1120	1120
Inlet Gas Composition						
H_2	Mole %	0.00	0.00	0.00	12.34	0.00
N_2	Mole %	0.00	0.00	0.19	0.09	0.00
Ar	Mole %	0.00	0.00	0.00	0.00	0.00
CO	Mole %	0.00	0.00	0.00	0.00	0.00
CO_2	Mole %	0.00	0.00	0.13	0.14	1.35
H_2S	Mole %	38.20	38.20	2.95	4.02	46.25
COS	Mole %	0.00	0.00	0.00	0.00	0.00
C_1	Mole %	0.70	0.70	18.93	6.61	0.00
C_2	Mole %	0.00	0.00	8.93	4.12	0.00
C_3	Mole %	0.00	0.00	19.44	2.77	0.00
C_4	Mole %	0.00	0.00	25.83	3.47	0.00
C_{5+}	Mole %	0.00	0.00	21.68	45.18	0.00
H_2O	Mole %	22.91	22.91	1.92	20.69	52.40
NH_3	Mole %	38.20	38.20	0.00	0.57	0.00
Total	*Mole %*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*
Acid Gas Properties						
Molecular Mass	kg/kmole	*23.76*	*23.76*	*49.45*	*50.00*	25.8
Heating Value	MJ/m^3	*15.22*	*15.22*	*93.78*	*87.39*	*10.13*
Combined Gas Properties						
Molecular Mass	kg/kmole	*17.21*	*17.21*	*25.89*	*47.13*	*20.12*
Heating Value	MJ/m^3	*32.46*	*32.46*	*50.83*	*82.79*	*24.90*
Stack Location						
UTM NAD 83	m N	5,962,691.4853	5,962,681.8666	5,961,900.3598	5,962,112.4015	
UTM NAD 83	m E	367,727.9738	368,057.8318	367,245.5530	368,028.1150	
Base Elevation of Stack	m ASL	623.6	621.2	623.0	624.0	
Stack Dimensions						
Height Above Base Elevation	m	90	90	16	152.4	
Inside Tip Diameter	m	0.356	0.356	0.305	1.524	
Effective Parameters						
Stack Height	m	121.7	121.7	60.3	306.5	186.2
Stack Diameter	m	3.36	3.36	3.61	22.99	12.61
Exit Velocity	m/s	141.5	141.5	247.1	82.52	11.46
Exit Temperature	C	1000	1000	1000	1000	1000
Exit Temperature	K	1273	1273	1273	1273	1273
Emission Rate						
SO_2 (flare period)	t/d	98.1	98.1	34.45	1268.1	841.8
SO_2 (equivalent 1-h)	t/d	98.1	98.1	8.61	422.7	280.6

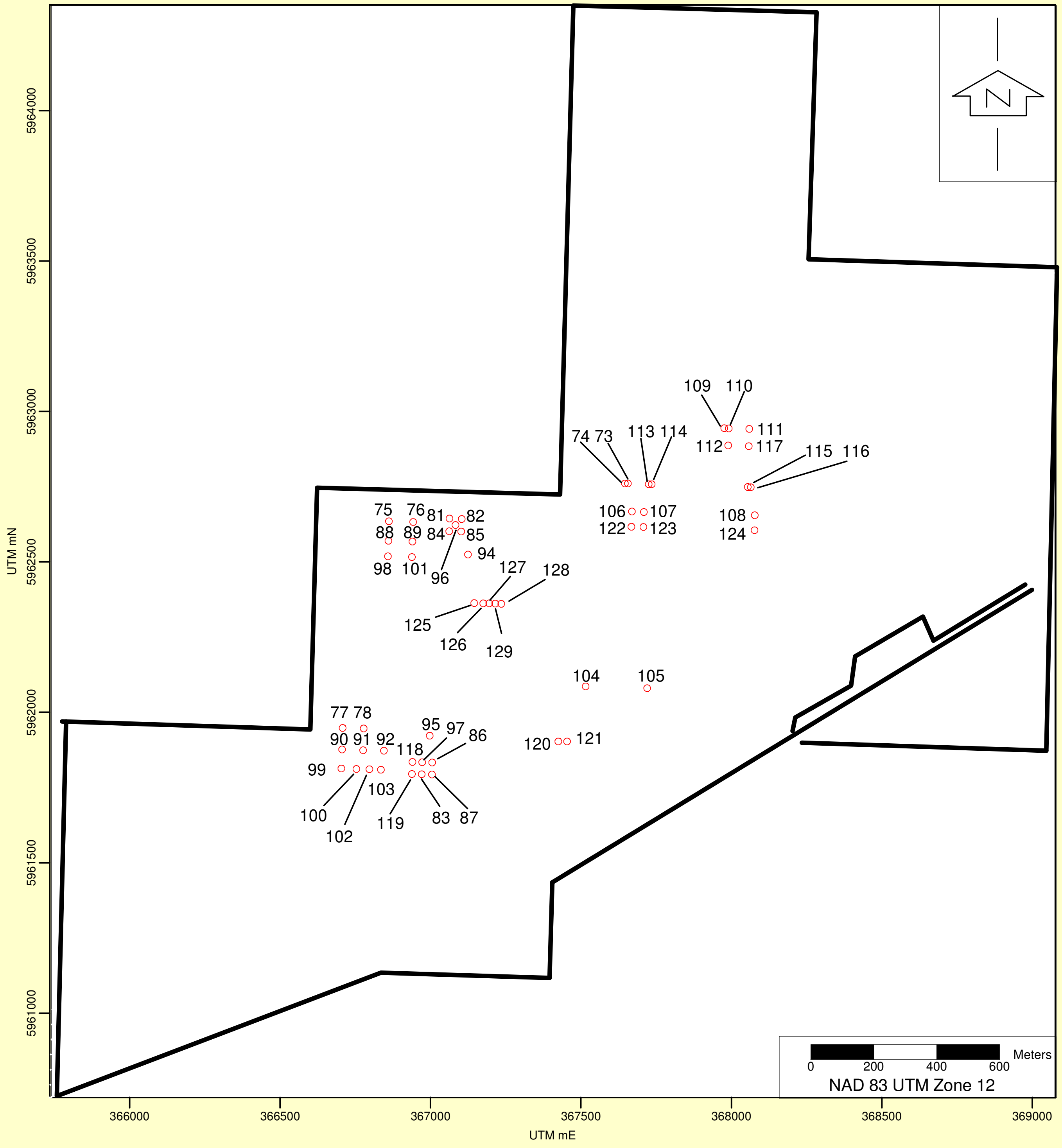
Table 2A-30 Flare Stack Parameters and Emissions (Emergency, Stacks 37, 48, 55 and 66)

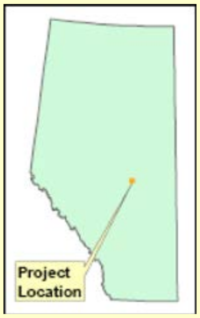
Source identification #		**37**		**48**	**55**		**66**
Unit Name/Description		Gas. Flare Stack		Sour Gas Flare	Gas. Flare Stack		Sour Gas Flare
Event		Blocked Outlet	Start-up	Emergency	Emergency	Start-up	Emergency
Frequency		Once/ 25 years	Once/ 2 years	Once/ 2 years	Once/ 25 years	Once/ 2 years	Once/ 2 years
Duration		15 minutes	12 hours	24 hours	15 minutes	12 hours	24 hours
Flow Rate							
Inlet Gas Stream		Acid Gas	Acid Gas	Acid Gas	Acid Gas	Acid Gas	Acid Gas
Inlet Flow Rate	10^3 Nm^3/d	286.1	69.9	37.68	255.5	69.9	37.68
Maximum Natural Gas	10^3 Nm^3/d	1120	1120	1120	1120	1120	1120
Inlet Gas Composition							
H_2	Mole %	53.82	54.45	0.24	48.27	54.45	0.24
N_2	Mole %	0.44	0.44	0.00	0.47	0.44	0.00
Ar	Mole %	0.00	0.00	0.00	0.00	0.00	0.00
CO	Mole %	1.59	1.61	0.71	15.61	1.61	0.71
CO_2	Mole %	42.74	43.27	49.97	33.87	43.27	49.97
H_2S	Mole %	1.28	0.10	42.12	1.14	0.10	42.12
COS	Mole %	0.00	0.00	0.00	0.07	0.00	0.00
C_1	Mole %	0.02	0.02	0.00	0.39	0.02	0.00
C_2	Mole %	0.00	0.00	0.00	0.00	0.00	0.00
C_3	Mole %	0.00	0.00	0.00	0.00	0.00	0.00
C_4	Mole %	0.00	0.00	0.00	0.00	0.00	0.00
C_{5+}	Mole %	0.00	0.00	0.00	0.00	0.00	0.00
H_2O	Mole %	0.11	0.11	6.96	0.18	0.11	6.96
NH_3	Mole %	0.00	0.00	0.00	0.00	0.00	0.00
Total	*Mole %*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*
Acid Gas Properties							
Molecular Mass	kg/kmole	*20.92*	*20.78*	*37.8*	*20.91*	*20.78*	*37.80*
Heating Value	MJ/m^3	*5.98*	*5.79*	*9.34*	*7.19*	*5.79*	*9.34*
Combined Gas Properties							
Molecular Mass	kg/kmole	*17.51*	*16.88*	*17.33*	*16.88*	*17.43*	*17.33*
Heating Value	MJ/m^3	*28.26*	*32.29*	*33.15*	*32.29*	*28.98*	*33.15*
Stack Location							
UTM NAD 83	m N	5,961,772.4962		5,961,706.7954	5,961,572.6448		5,961,464.8995
UTM NAD 83	m E	366,248.3769		366,816.6940	366,242.5095		366,809.5946
Base Elevation of Stack	m ASL	625.2		621.6	623.0		622.8
Stack Dimensions							
Height Above Base Elevation	m	34		90	34		90
Inside Tip Diameter	m	0.914		0.305	0.914		0.305
Effective Parameters							
Stack Height	m	65.8	65.3	121.3	65.3	65.9	121.3
Stack Diameter	m	8.06	8.61	2.91	8.61	8.16	2.91
Exit Velocity	m/s	24.8	20.99	183.4	20.99	24.26	183.4
Exit Temperature	C	1000	1000	1000	1000	1000	1000
Exit Temperature	K	1273	1273	1273	1273	1273	1273
Emission Rate							
SO_2 (flare period)	t/d	9.72	0.18	42.12	0.18	7.73	42.12
SO_2 (equivalent 1-h)	t/d	2.43	0.18	42.12	0.045	7.73	42.12

Table 2A-31 Summary of Tank Emission Sources

Tank ID	Description	Tank ID	Description
73	TK 1501 Amine Surge Tank	103	TK3109C Future Reject Tank
74	TK 1502 Amine Surge Tank	104	TK3110A Sludge Storage Tank
75	TK3101A Diluted Bitumen Feed Storage Tank	105	Future Sludge Storage Tank
76	TK3101B Diluted Bitumen Feed Storage Tank	106	TK1001 (ISBL) Sour Water Tank
77	TK3101C Diluted Bitumen Feed Storage Tank	107	Future Sour Water Tank
78	TK3101D Future Diluted Bitumen Feed Storage Tank	108	Future Sour Water Tank
81	TK3102A Dilutent Storage Tank	*109*	*TK3901 Sodium Hypochlorite Storage Tank*
82	TK3102B Dilutent Storage Tank	*110*	*TK3902 Sodium Hydroxide Storage Tank*
83	TK3102C Dilutent Storage Tank	111	TK3903 Diesel Storage Tank
84	TK3103A Naptha Product Storage Tank	*112*	*D3901 Sulfuric Acid Storage Drum*
85	TK3103B Naptha Product Storage Tank	113	Future Amine Surge Tank
86	TK3103C Future Naptha Product Storage Tank	114	Future Amine Surge Tank
87	TK3103D Future Naptha Product Storage Tank	115	Future Amine Surge Tank
88	TK3104A Distillate Product Storage Tank	116	Future Amine Storage Tank
89	TK3104B Distillate Product Storage Tank	*117*	*D3904 Gasoline Storage Drum*
90	TK3104C Distillate Product Storage Tank	118	TK3102D Future Diluent Storage Tank
91	TK3104D Future Distillate Product Storage Tank	119	TK3102E Future Diluent Storage Tank
92	TK3104E Future Distillate Product Storage Tank	120	TK1301A Liquid Sulfur Storage Tank
94	TK3106A DCU Feed Tank	121	TK1301B Future Liquid Sulfur Storage Tank (Gas.)
95	TK3106B DCU Feed Tank	122	TK901 Amine Storage Make-up Tank
96	TK3107A Naptha Hydro. Feed Tank	123	Future Amine Storage Make-up Tank
97	TK3107B Naptha Hydro. Feed Tank	124	Future Amine Storage Make-up Tank
98	TK31008A Bulk Hydrotreater Feed Tank	*125*	*TK901 Equalization Tank*
99	TK31008B Future Bulk Hydrotreater Feed Tank	*126*	*TK3701A Skims Tank*
100	TK31008C Future Bulk Hydrotreater Feed Tank	*127*	*TK3701B Skims Tank*
101	TK3109A Reject Tank	*128*	*TK3710 Aerobic Digester*
102	TK3109B Future Reject Tank	*129*	*TK3701C Skim Tank*

NOTES:
Tanks labeled in *italic font* were not included in the emissions inventory based on *de minimus* considerations.





Legend

○ Tank

Title:

**PROJECT PLOT PLAN
SHOWING TANK LOCATIONS**

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date: 30/11/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix/N8897 NAOSC Emissions /JW-AXYS Emissions/Tanks

Drawn by:	Checked:	Fig. No.:
HZ	MD	2A-5

Table 2A-32 Summary of Tank Parameters and Emissions (Tanks 73 to 76)

Source identification #		73	74	75	76
Tank ID		TK1501A	TK1502A	TK3101A	TK3101B
Unit Name/Description		Amine Surge Tank	Amine Storage Tank	Diluted Bitumen Feed Storage Tank	Diluted Bitumen Feed Storage Tank
Temporal Variation		Continuous	Continuous	Continuous	Continuous
Volume Source Locations	m E	367655.8712	367645.8756	366861.9401	366941.9057
	m N	5962760.6273	5962760.9207	5962634.8675	5962632.5205
Base Elevation of Source	m ASL	625.2	625.4	622.9	622.0
Release Dimensions					
Tank Height	m	6.1	5.4	14.6	14.6
Tank Diameter	m	6.0	3.6	42.7	42.7
Sigma Y	m	1.40	0.84	9.92	9.92
Sigma Z	m	2.85	2.51	6.80	6.80
Emission Rate					
Total Emission	t/y	0.0030	0.000030	30.06	30.06
Acenaphthene	t/y	0.00	0.00	0.00000011	0.00000011
Anthracene	t/y	0.00	0.00	0.0000000023	0.0000000023
Benzene	t/y	0.00	0.00	0.11	0.11
Biphenyl	t/y	0.00	0.00	0.00000064	0.00000064
C17+ aliphatic group	t/y	0.00	0.00	0.0065	0.0065
C5-C8 aliphatic group	t/y	0.00	0.00	14.98	14.98
C9-C16 aliphatic group	t/y	0.00	0.00	0.32	0.32
C9-C16 aromatic group	t/y	0.00	0.00	0.069	0.069
Diethanolamine	t/y	0.0030	0.000030	0.00	0.00
Ethylbenzene	t/y	0.00	0.00	0.0020	0.0020
Fluorene	t/y	0.00	0.00	0.00000062	0.00000062
Hexane	t/y	0.00	0.00	2.54	2.54
Hydrogen sulphide	t/y	0.00	0.00	0.85	0.85
Mercaptan group	t/y	0.00	0.00	0.18	0.18
Naphthalene	t/y	0.00	0.00	0.000014	0.000014
Phenanthrene	t/y	0.00	0.00	0.000000026	0.000000026
C_2-C_4	t/y	0.00	0.00	10.94	10.94
Toluene	t/y	0.00	0.00	0.049	0.049
Xylenes	t/y	0.00	0.00	0.0095	0.0095

Table 2A-33 Summary of Tank Parameters and Emissions (Tanks 81, 82, 84 and 85)

Source identification #		81	82	84	85
Tank ID		TK3102A	TK3102B	TK3103A	TK3103B
Unit Name/Description		Diluent Storage Tank	Diluent Storage Tank	Naptha Product Storage Tank	Naptha Product Storage Tank
Temporal Variation		Continuous	Continuous	Continuous	Continuous
Volume Source Locations	m E	367063.2936	367103.2764	367062.0615	367102.0443
	m N	5962643.9643	5962642.7909	5962601.9824	5962600.8089
Base Elevation of Source	m ASL	621.6	622.3	622.0	622.0
Release Dimensions					
Tank Height	m	12.2	12.2	11.0	11.0
Tank Diameter	m	18.3	18.3	18.3	18.3
Sigma Y	m	4.25	4.25	4.25	4.25
Sigma Z	m	5.67	5.67	5.10	5.10
Emission Rate					
Total Emission	t/y	2.51	2.51	3.60	3.60
1,3-butadiene	t/y	0.00	0.00	0.077	0.077
Aliphatic aldehydes	t/y	0.00	0.00	0.022	0.022
Aliphatic ketones	t/y	0.00	0.00	0.0085	0.0085
Acenaphthene	t/y	0.0000000030	0.0000000030	0.00	0.00
Anthracene	t/y	0.000000000062	0.000000000062	0.00	0.00
Benzene	t/y	0.0139	0.0139	0.066	0.066
Biphenyl	t/y	0.000000017	0.00	0.00	0.00
C17+ aliphatic group	t/y	0.00066	0.00066	0.00	0.00
C5-C8 aliphatic group	t/y	1.31	1.31	0.92	0.92
C9-C16 aliphatic group	t/y	0.036	0.036	0.063	0.063
C9-C16 aromatic group	t/y	0.012	0.012	0.00	0.00
CS2	t/y	0.00	0.00	0.00084	0.00084
Ethylbenzene	t/y	0.00027	0.0000000030	0.0082	0.0082
Fluorene	t/y	0.000000017	0.000000000062	0.00	0.00
Furan	t/y	0.00	0.00	0.0028	0.0028
Hexane	t/y	0.31	0.31	0.069	0.069
Hydrogen sulphide	t/y	0.013	0.013	0.063	0.063
Isopropylbenzene	t/y	0.00	0.00	0.00011	0.00011
Mercaptan group	t/y	0.00	0.00	0.0035	0.0035
Methane (C_1)	t/y	0.00	0.00	0.75	0.75
Naphthalene	t/y	0.00000037	0.0000000030	0.00	0.00
Phenanthrene	t/y	0.00000000070	0.000000000062	0.00	0.00
C_2-C_4	t/y	0.81	0.81	1.41	1.41
Thiophene group	t/y	0.00	0.00	0.0082	0.0082
Toluene	t/y	0.0070	0.0070	0.13	0.13
Xylenes	t/y	0.0014	0.0014	0.0098	0.0098

Table 2A-34 Summary of Tank Parameters and Emissions (Tanks 88, 89, 94 and 96)

Source identification #		88	89	94	96
Tank ID		TK3104A	TK3104B	TK3106A	TK3107A
Unit Name/Description		Distillate Product Storage Tank	Distillate Product Storage Tank	DCU Feed Tank	NHTU Feed Tank
Temporal Variation		Continuous	Continuous	Continuous	Continuous
Volume Source Locations	m E	366860.0332	366939.9988	367124.8039	367082.6690
	m N	5962569.8954	5962567.5485	5962524.1082	5962622.3866
Base Elevation of Source	m ASL	623.0	622.4	622.0	622.0
Release Dimensions					
Tank Height	m	12.2	12.2	16.5	11.0
Tank Diameter	m	30.5	30.5	30.5	18.3
Sigma Y	m	7.09	7.09	7.09	4.25
Sigma Z	m	5.67	5.67	7.66	5.10
Emission Rate					
Total Emission	t/y	0.22	0.22	17.22	0.21
1,3-butadiene	t/y	0.00	0.00	0.00	0.0048
Aliphatic alcohols	t/y	0.0011	0.0011	0.00	0.00055
Aliphatic ketones	t/y	0.00	0.00	0.00	0.0010
Acenaphthene	t/y	0.00	0.00	0.000000065	0.00
Anthracene	t/y	0.00	0.00	0.0000000013	0.00
Benzene	t/y	0.00	0.00	0.0627	0.0016
Biphenyl	t/y	0.00	0.00	0.00000036	0.00
C17+ aliphatic group	t/y	0.0013	0.0013	0.0037	0.0014
C5-C8 aliphatic group	t/y	0.0011	0.0011	8.58	0.0099
C9-C16 aliphatic group	t/y	0.11	0.11	0.19	0.050
C9-C16 aromatic group	t/y	0.0062	0.0062	0.0397	0.0072
Ethylbenzene	t/y	0.00060	0.00060	0.0011	0.0012
Fluorene	t/y	0.00	0.00	0.00000036	0.00
Hexane	t/y	0.00	0.00	1.46	0.0011
Hydrogen sulphide	t/y	0.00	0.00	0.49	0.00
Isopropylbenzene	t/y	0.00	0.00	0.00	0.00055
Mercaptan group	t/y	0.00	0.00	0.103	0.00
Methane (C_1)	t/y	0.022	0.022	0.00	0.00
Naphthalene	t/y	0.00	0.00	0.0000078	0.00
Phenanthrene	t/y	0.00	0.00	0.000000015	0.00
C_2-C_4	t/y	0.049	0.049	6.27	0.12
Thiophene group	t/y	0.00	0.00	0.00	0.0016
Toluene	t/y	0.029	0.029	0.0283	0.0044
Xylenes	t/y	0.0033	0.0033	0.00545	0.0055

Table 2A-35 Summary of Tank Parameters and Emissions (Tanks 98, 101, 104 and 106)

Source identification #		98	101	104	106
Tank ID		TK3108A	TK3109A	TK304A	Tk1001A
Unit Name/Description		Bulk Hydrotreater Feed tank	Reject Tank	Sludge Storage Tank	Sour Water Feed Tank
Temporal Variation		Continuous	Continuous	Continuous	Continuous
Volume Source Locations	m E	366858.5370	366938.5026	367515.1330	367669.2360
	m N	5962518.9174	5962516.5705	5962086.4689	5962667.1980
Base Elevation of Source	m ASL	623.6	623.0	623.0	625.0
Release Dimensions					
Tank Height	m	12.2	11.0	4.9	14.6
Tank Diameter	m	30.5	24.4	3.8	18.3
Sigma Y	m	7.09	5.67	0.89	4.25
Sigma Z	m	5.67	5.10	2.27	6.80
Emission Rate					
Total Emission	t/y	11.41	9.23	0.00029	0.68
1,3-butadiene	t/y	0.00	0.00	0.00	0.00
Aliphatic aldehydes	t/y	0.00	0.0038	0.00	0.00
Acenaphthene	t/y	0.00	0.00	0.0000000000011	0.00
Anthracene	t/y	0.00	0.00	0.000000000000022	0.00
Benzene	t/y	0.1937	0.12	0.0000011	0.00
Biphenyl	t/y	0.00	0.00	0.0000000000062	0.00
C17+ aliphatic group	t/y	0.18	0.00	0.000000063	0.00
C5-C8 aliphatic group	t/y	1.56	1.63	0.00015	0.00
C9-C16 aliphatic group	t/y	1.08	0.050	0.0000031	0.00
C9-C16 aromatic group	t/y	0.032	0.0018	0.00000067	0.00
CS2	t/y	0.022	0.014	0.00	0.00
Cyclohexane	t/y	0.00	0.017	0.00	0.00
Ethylbenzene	t/y	0.24	0.012	0.000000019	0.00
Fluorene	t/y	0.00	0.00	0.0000000000060	0.00
Hexane	t/y	0.260	0.084	0.000025	0.00
Hydrogen sulphide	t/y	0.082	0.45	0.0000082	0.25
Isopropylbenzene	t/y	0.029	0.00071	0.00	0.00
Mercaptan group	t/y	0.00	0.11	0.0000017	0.00
Methane (C_1)	t/y	5.31	0.46	0.00	0.27
Naphthalene	t/y	0.00	0.00023	0.00000000013	0.00
Phenanthrene	t/y	0.00	0.00	0.00000000000025	0.00
Propylene oxide	t/y	0.00	0.052	0.00	0.00
C_2-C_4	t/y	1.02	5.91	0.00011	0.10
Styrene	t/y	0.00	0.00067	0.00	0.00
Thiophene group	t/y	0.074	0.17	0.00	0.053
Toluene	t/y	0.72	0.12	0.00000048	0.00
Xylenes	t/y	0.62	0.028	0.000000092	0.00

Table 2A-36 Summary of Tank Parameters and Emissions (Tanks 120, 122 and 111)

Source identification #		120	122	111
Tank ID		TK1301A	TK901A	TK3903
Unit Name/Description		Liquid Sulphur Storage Tank	Amine Storage Make-up Tank	Diesel Storage Tank
Temporal Variation		Continuous	Continuous	Continuous
Volume Source Locations	m E	367424.7042	367667.7692	368059.4619
	m N	5961903.1053	5962617.2195	5962941.8683
Base Elevation of Source	m ASL	623.9	625.5	
Release Dimensions				
Tank Height	m	18.3	7.2	10.1
Tank Diameter	m	12.2	10.0	7.0
Sigma Y	m	2.84	2.33	1.63
Sigma Z	m	8.51	3.36	4.68
Emission Rate				
Total Emission	t/y	0.042	0.00031	0.38
1,4-Dichlorobenzene	t/y	0.00	0.00	0.000033
Aliphatic alcohols	t/y	0.00	0.00	0.0106
Benzene	t/y	0.00	0.00	0.000014
C5-C8 aliphatic group	t/y	0.00	0.00	0.016
C9-C16 aliphatic group	t/y	0.00	0.00	0.175
C9-C16 aromatic group	t/y	0.00	0.00	0.040
CS2	t/y	0.032	0.00	0.00
Diethanolamine	t/y	0.00	0.00031	0.00
Ethylbenzene	t/y	0.00	0.00	0.0039
Hydrogen sulphide	t/y	0.010	0.00	0.000071
Isopropylbenzene	t/y	0.00	0.00	0.0022
Methane (C_1)	t/y	0.000027	0.00	0.00061
C_2-C_4	t/y	0.00	0.00	0.00010
Toluene	t/y	0.00	0.00	0.00058
Xylenes	t/y	0.00	0.00	0.020

Table 2A-37 Summary of Tank Parameters and Emissions (Tanks 77, 78, 83, 86 and 87)

Source identification #		77	78	83	86	87
Tank ID		TK3101C	TK3101D	TK3102C	TK3103C	TK3103D
Unit Name/Description		Diluted Bitumen Feed Storage tank	Diluted Bitumen Feed Storage tank	Dilutent Storage Tank	Naphtha Product Surge Tank	Naphtha Product Surge Tank
Temporal Variation		Continuous	Continuous	Continuous	Continuous	Continuous
Volume Source Locations	m E	366707.7261	366777.696	366970.5779	367005.4869	367004.3134
	m N	5961948.0960	5961946.0424	5961794.3186	5961833.3113	5961793.3285
Base Elevation of Source	m ASL	627.3	626.1	624.7	624.2	624.4
Release Dimensions						
Tank Height	m	17.1	17.1	14.6	14.6	14.6
Tank Diameter	m	42.7	42.7	18.3	18.3	18.3
Sigma Y	m	9.92	9.92	4.25	4.25	4.25
Sigma Z	m	7.94	7.94	6.80	6.80	6.80
Emission Rate						
Total Emission	t/y	33.52	33.52	2.87	3.70	3.70
1,3-butadiene	t/y	0	0	0.00	0.079	0.079
Aliphatic aldehydes	t/y	0	0	0.00	0.023	0.023
Aliphatic ketones	t/y	0	0	0.00	0.0088	0.0088
Acenaphthene	t/y	0.00000013	0.00000013	0.0000000035	0.00	0.00
Anthracene	t/y	0.0000000026	0.0000000026	0.000000000071	0.00	0.00
Benzene	t/y	0.12	0.12	0.016	0.067	0.067
Biphenyl	t/y	0.00000071	0.00000071	0.000000020	0.00	0.00
C17+ aliphatic group	t/y	0.0072	0.0072	0.00076	0.00	0.00
C5-C8 aliphatic group	t/y	16.71	16.71	1.50	0.94	0.94
C9-C16 aliphatic group	t/y	0.36	0.36	0.041	0.065	0.065
C9-C16 aromatic group	t/y	0.077	0.077	0.014	0.00	0.00
CS2	t/y	0.00	0.00	0.00	0.00086	0.00086
Ethylbenzene	t/y	0.0022	0.0022	0.00031	0.0084	0.0084
Fluorene	t/y	0.00000069	0.00000069	0.000000019	0.00	0.00
Furan	t/y	0.00	0.00	0.00	0.0029	0.0029
Hexane	t/y	2.83	2.83	0.35	0.071	0.071
Hydrogen sulphide	t/y	0.95	0.95	0.015	0.065	0.065
Isopropylbenzene	t/y	0.00	0.00	0.00	0.00011	0.00011
Mercaptan group	t/y	0.20	0.20	0.00	0.0036	0.0036
Methane (C_1)	t/y	0.00	0.00	0.00	0.77	0.77
Naphthalene	t/y	0.000015	0.000015	0.00000042	0.00	0.00
Phenanthrene	t/y	0.000000029	0.000000029	0.00000000080	0.00	0.00
C_2-C_4	t/y	12.20	12.20	0.92	1.45	1.45
Thiophene group	t/y	0.00	0.00	0.00	0.0084	0.0084
Toluene	t/y	0.055	0.055	0.0081	0.13	0.13
Xylenes	t/y	0.011	0.011	0.0016	0.010	0.010

Table 2A-38 Summary of Tank Parameters and Emissions (Tanks 90, 91, 95 and 97)

Source identification #		90	91	95	97
Tank ID		Tk3104C	Tk3104D	Tk3106B	TK3107B
Unit Name/Description		Distillate Product Storage Tank	Distillate Product Storage Tank	DCU Feed Tank	Naphtha Hydro. Feed Tank
Temporal Variation		Continuous	Continuous	Continuous	Continuous
Volume Source Locations	m E	366705.6139	366775.5837	366997.1026	366972.5011
	m N	5961876.1270	5961874.0734	5961922.5957	5961834.2794
Base Elevation of Source	m ASL	624.3	624.1	623.4	624.4
Release Dimensions					
Tank Height	m	14.6	14.6	16.5	14.6
Tank Diameter	m	31.1	31.1	33.5	18.3
Sigma Y	m	7.23	7.23	7.80	4.25
Sigma Z	m	6.80	6.80	7.66	6.80
Emission Rate					
Total Emission	t/y	0.27	0.27	20.84	0.22
1,3-butadiene	t/y	0.00	0.00	0.00	0.0049
Aliphatic alcohols	t/y	0.0013	0.0013	0.00	0.00055
Aliphatic ketones	t/y	0.00	0.00	0.00	0.0010
Acenaphthene	t/y	0.00	0.00	0.000000078	0.00
Anthracene	t/y	0.00	0.00	0.0000000016	0.00
Benzene	t/y	0.00	0.00	0.076	0.0016
Biphenyl	t/y	0.00	0.00	0.00000044	0.00
C17+ aliphatic group	t/y	0.0016	0.0016	0.0045	0.0015
C5-C8 aliphatic group	t/y	0.0014	0.0014	10.38	0.010
C9-C16 aliphatic group	t/y	0.13	0.13	0.22	0.050
C9-C16 aromatic group	t/y	0.0077	0.0077	0.048	0.0072
Ethylbenzene	t/y	0.00074	0.00074	0.0014	0.0012
Fluorene	t/y	0.00	0.00	0.00000043	0.00
Hexane	t/y	0.00	0.00	1.76	0.0011
Hydrogen sulphide	t/y	0.00	0.00	0.59	0.00
Isopropylbenzene	t/y	0.00	0.00	0.00	0.00055
Mercaptan group	t/y	0.00	0.00	0.13	0.00
Methane (C_1)	t/y	0.027	0.027	0.00	0.00
Naphthalene	t/y	0.00	0.00	0.0000095	0.00
Phenanthrene	t/y	0.00	0.00	0.000000018	0.00
C_2-C_4	t/y	0.061	0.061	7.58	0.125
Thiophene group	t/y	0.00	0.00	0.00	0.0016
Toluene	t/y	0.036	0.036	0.034	0.0044
Xylenes	t/y	0.0042	0.0042	0.0066	0.0055

Table 2A-39 Summary of Tank Parameters and Emissions (Tanks 99, 102, 105 and 107)

Source identification #		99	102	105	107
Tank ID		TK3108B	TK3109B	TK304B	TK1001B
Unit Name/Description		Bulk Hydrotreater Feed Tank	Reject Tank	Sludge Tank	Sour Water Feed Tank
Temporal Variation		Continuous	Continuous	Continuous	Continuous
Volume Source Locations	m E	366703.7657	366796.7256	367720.0448	367709.2188
	m N	5961813.1541	5961810.4258	5962080.4549	5962666.0245
Base Elevation of Source	m ASL	623.4	623.2	623.3	624.2
Release Dimensions					
Tank Height	m	14.6	11.0	4.9	14.6
Tank Diameter	m	31.1	24.4	3.8	18.3
Sigma Y	m	7.23	5.67	0.89	4.25
Sigma Z	m	6.80	5.10	2.27	6.80
Emission Rate					
Total Emission	t/y	14.25	9.23	0.00029	0.68
1,3-butadiene	t/y	0.00	0.00	0.00	0.00
Aliphatic aldehydes	t/y	0.00	0.0038	0.00	0.00
Acenaphthene	t/y	0.00	0.00	0.0000000000011	0.00
Anthracene	t/y	0.00	0.00	0.000000000000022	0.00
Benzene	t/y	0.24	0.12	0.0000011	0.00
Biphenyl	t/y	0.00	0.00	0.0000000000062	0.00
C17+ aliphatic group	t/y	0.23	0.00	0.000000063	0.00
C5-C8 aliphatic group	t/y	1.95	1.63	0.00015	0.00
C9-C16 aliphatic group	t/y	1.35	0.050	0.00000314	0.00
C9-C16 aromatic group	t/y	0.040	0.0018	0.00000067	0.00
CS2	t/y	0.028	0.014	0.00	0.00
Cyclohexane	t/y	0.00	0.017	0.00	0.00
Ethylbenzene	t/y	0.30	0.012	0.000000019	0.00
Fluorene	t/y	0.00	0.00	0.0000000000060	0.00
Hexane	t/y	0.32	0.084	0.000025	0.00
Hydrogen sulphide	t/y	0.10	0.45	0.0000082	0.25
Isopropylbenzene	t/y	0.036	0.00071	0.00	0.00
Mercaptan group	t/y	0.00	0.11	0.0000017	0.00
Methane (C_1)	t/y	6.62	0.46	0.00	0.27
Naphthalene	t/y	0.00	0.00023	0.00000000013	0.00
Phenanthrene	t/y	0.00	0.00	0.00000000000025	0.00
Propylene oxide	t/y	0.00	0.052	0.00	0.00
C_2-C_4	t/y	1.27	5.91	0.00011	0.10
Styrene	t/y	0.00	0.00067	0.00	0.00
Thiophene group	t/y	0.092	0.17	0.00	0.053
Toluene	t/y	0.90	0.12	0.00000048	0.00
Xylenes	t/y	0.77	0.028	0.000000092	0.00

Table 2A-40 Summary of Tank Parameters and Emissions (Tanks 113, 114, 118 and 123)

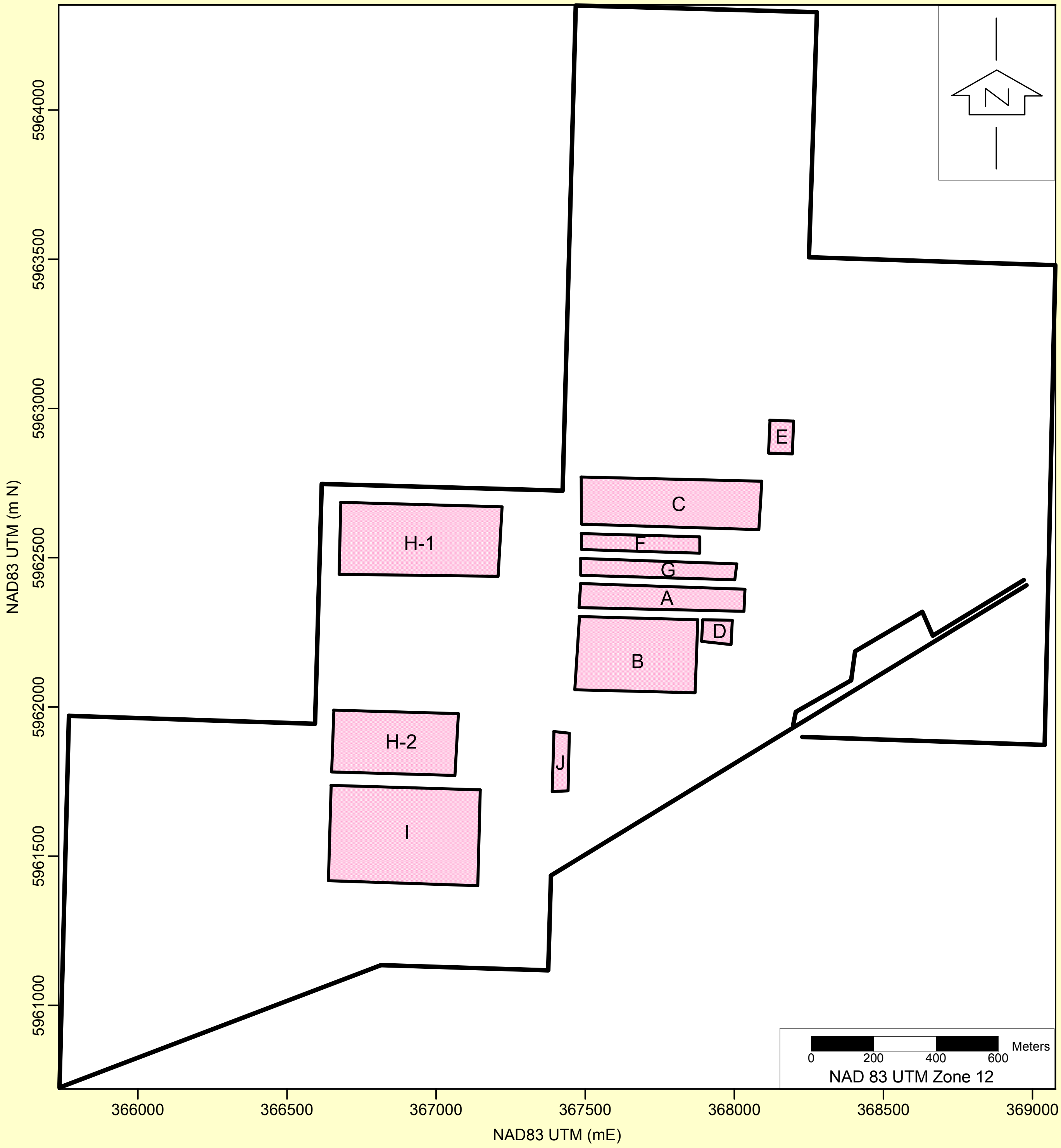
Source identification #		113	114	118	123
Tank ID		TK1501B	TK1502B	TK3102D	Tk901B
Unit Name/Description		Amine Surge Tank	Amine Storage Tank	Diluent Storage Tank	Amine Storage Make-up Tank
Temporal Variation					
Volume Source Locations	m E	367724.9415	367734.9372	366940.1210	367707.7520
	m N	5962758.6031	5962758.3097	5961835.2197	5962616.0460
Base Elevation of Source	m ASL	623.1	623.1	624.6	624.3
Release Dimensions					
Tank Height	m	6.1	5.4	14.6	7.22
Tank Diameter	m	6.0	3.6	18.3	10.0
Sigma Y	m	1.40	0.84	4.25	2.33
Sigma Z	m	2.85	2.51	6.80	3.36
Emission Rate					
Total Emission	t/y	0.0030	0.000030	2.87	0.00031
Acenaphthene	t/y	0.00	0.00	0.0000000035	0.00
Anthracene	t/y	0.00	0.00	0.000000000071	0.00
Benzene	t/y	0.00	0.00	0.016	0.00
Biphenyl	t/y	0.00	0.00	0.000000020	0.00
C17+ aliphatic group	t/y	0.00	0.00	0.00076	0.00
C5-C8 aliphatic group	t/y	0.00	0.00	1.50	0.00
C9-C16 aliphatic group	t/y	0.00	0.00	0.041	0.00
C9-C16 aromatic group	t/y	0.00	0.00	0.014	0.00
Diethanolamine	t/y	0.0030	0.000030	0.00	0.00031
Ethylbenzene	t/y	0.00	0.00	0.00031	0.00
Fluorene	t/y	0.00	0.00	0.000000019	0.00
Hexane	t/y	0.00	0.00	0.35	0.00
Hydrogen sulphide	t/y	0.00	0.00	0.015	0.00
Naphthalene	t/y	0.00	0.00	0.00000042	0.00
Phenanthrene	t/y	0.00	0.00	0.00000000080	0.00
C_2-C_4	t/y	0.00	0.00	0.92	0.00
Toluene	t/y	0.00	0.00	0.0081	0.00
Xylenes	t/y	0.00	0.00	0.0016	0.00

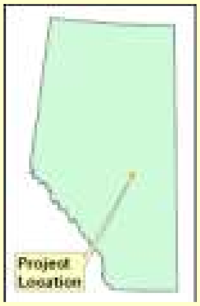
Table 2A-41 Summary of Tank Parameters and Emissions (Tanks 79, 92, 100, 103 and 108

Source identification #		92	100	103	108
Tank ID		TK3104E	TK3108C	TK3109C	TK1001C
Unit Name/Description		Distillate Product Surge Tank	Bulk Hydrotreater Feed Tank	Reject Tank	Sour Water Tank
Temporal Variation		Continuous	Continuous	Continuous	Continuous
Volume Source Locations	m E	366844.5540	366753.7441	366834.7093	368078.0600
	m N	5961872.0582	5961811.6873	5961809.3110	5962655.1993
Base Elevation of Source	m ASL	624.5	622.8	623.5	621.6
Release Dimensions					
Tank Height	m	14.6	12.8	11.0	14.6
Tank Diameter	m	31.1	27.4	24.4	18.3
Sigma Y	m	7.23	6.38	5.67	4.25
Sigma Z	m	6.80	5.95	5.10	6.80
Emission Rate					
Total Emission	t/y	0.19	9.71	9.23	0.68
1,3-butadiene	t/y	0.00	0.00	0.00	0.00
Aliphatic alcohols	t/y	0.00090	0.00	0.00	0.00
Aliphatic aldehydes	t/y	0.00	0.00	0.0038	0.00
Acenaphthene	t/y	0.00	0.00	0.00	0.00
Anthracene	t/y	0.00	0.00	0.00	0.00
Benzene	t/y	0.00	0.16	0.12	0.00
Biphenyl	t/y	0.00	0.00	0.00	0.00
C17+ aliphatic group	t/y	0.0011	0.15	0.00	0.00
C5-C8 aliphatic group	t/y	0.0010	1.33	1.63	0.00
C9-C16 aliphatic group	t/y	0.091	0.92	0.050	0.00
C9-C16 aromatic group	t/y	0.0053	0.027	0.0018	0.00
CS2	t/y	0.00	0.019	0.014	0.00
Cyclohexane	t/y	0.00	0.00	0.017	0.00
Ethylbenzene	t/y	0.00051	0.20	0.012	0.00
Fluorene	t/y	0.00	0.00	0.00	0.00
Hexane	t/y	0.00	0.22	0.084	0.00
Hydrogen sulphide	t/y	0.00	0.070	0.45	0.25
Isopropylbenzene	t/y	0.00	0.025	0.00071	0.00
Mercaptan group	t/y	0.00	0.00	0.11	0.00
Methane (C_1)	t/y	0.018	4.51	0.46	0.27
Naphthalene	t/y	0.00	0.00	0.00023	0.00
Phenanthrene	t/y	0.00	0.00	0.00	0.00
Propylene oxide	t/y	0.00	0.00	0.052	0.00
C_2-C_4	t/y	0.042	0.87	5.91	0.10
Styrene	t/y	0.00	0.00	0.00067	0.00
Thiophene group	t/y	0.00	0.063	0.17	0.053
Toluene	t/y	0.024	0.61	0.12	0.00
Xylenes	t/y	0.0028	0.52	0.028	0.00

Table 2A-42 Summary of Tank Parameters and Emissions (Tanks 115, 116, 119, 121 and 124)

Source identification #		115	116	119	121	124
Tank ID		TK1501C	TK1502C	TK3102E	TK1301B	TK901C
Unit Name/Description		Amine Surge Tank	Amine Storage Tank	Diluent Storage Tank	Liquid Sulphur Tank	Amine Storage Make-up Tank
Temporal Variation		Continuous	Continuous	Continuous	Continuous	Continuous
Volume Source Locations	m E	368054.7995	368064.7952	366938.3418	367454.042	368076.5932
	m N	5962748.9220	5962748.6286	5961795.2647	5961903.1104	5962605.2208
Base Elevation of Source	m ASL	621.1	621.5	624.4	625.0	621.8
Release Dimensions						
Tank Height	m	6.13	5.4	14.6	18.3	7.2
Tank Diameter	m	6.0	3.6	18.3	12.2	10.0
Sigma Y	m	1.40	0.84	4.25	2.84	2.33
Sigma Z	m	2.85	2.51	6.80	8.51	3.36
Emission Rate						
Total Emission	t/y	0.0030	0.000030	2.87	0.042	0.00031
Acenaphthene	t/y	0.00	0.00	0.0000000035	0.00	0.00
Anthracene	t/y	0.00	0.00	0.000000000071	0.00	0.00
Benzene	t/y	0.00	0.00	0.016	0.00	0.00
Biphenyl	t/y	0.00	0.00	0.000000020	0.00	0.00
C17+ aliphatic group	t/y	0.00	0.00	0.00076	0.00	0.00
C5-C8 aliphatic group	t/y	0.00	0.00	1.50	0.00	0.00
C9-C16 aliphatic group	t/y	0.00	0.00	0.041	0.00	0.00
C9-C16 aromatic group	t/y	0.00	0.00	0.014	0.00	0.00
CS2	t/y	0.00	0.00	0.00	0.032	0.00
Diethanolamine	t/y	0.0030	0.000030	0.00	0.00	0.00031
Ethylbenzene	t/y	0.00	0.00	0.00031	0.00	0.00
Fluorene	t/y	0.00	0.00	0.000000019	0.00	0.00
Hexane	t/y	0.00	0.00	0.35	0.00	0.00
Hydrogen sulphide	t/y	0.00	0.00	0.015	0.010	0.00
Isopropylbenzene	t/y	0.00	0.00	0.00	0.00	0.00
Methane (C_1)	t/y	0.00	0.00	0.00	0.000027	0.00
Naphthalene	t/y	0.00	0.00	0.00000042	0.00	0.00
Phenanthrene	t/y	0.00	0.00	0.00000000080	0.00	0.00
C_2-C_4	t/y	0.00	0.00	0.92	0.00	0.00
Toluene	t/y	0.00	0.000	0.0081	0.00	0.00
Xylenes	t/y	0.00	0.000	0.0016	0.00	0.00





Legend

▨ Area Sources

Title:

Project Plot Plan - Locations of the Area Source

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date: 30/11/2007

File:

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Drawn by:	Checked:	Fig. No.:
HZ	MD	**2A-6**

Table 2A-43 Summary of Process Area Parameters and Emissions (Areas A and B)

Source identification #		**A**		**B**	
Unit Name/Description		Desalter	Diluent Recovery Unit (DRU)	Delayed Coker Unit	Gas Recovery Unit
Temporal Variation		continuous	continuous	continuous	continuous
Number of Units		5	3	4	2
Area Source Locations					
Northwest	m E	367485.008		367481.608	
	m N	5962413.534		5962302.834	
Northeast	m E	368034.908		367877.008	
	m N	5962394.334		5962291.634	
Southeast	m E	368032.908		367868.808	
	m N	5962319.734		5962048.034	
Southwest	m E	367481.308		367464.908	
	m N	5962333.134		5962057.834	
Base Elevation of Source	m ASL	624.7		624.2	
Release Dimensions					
Release Height	m	6.0		6.0	
Initial Sigma Z	m	10.0		10.0	
Emission Rate					
Total Emission	t/y	16.19	61.18	69.535	15.45
Acenaphthene	t/y	0.000000061	0.00000023	0.00	0.00
Aliphatic alcohols	t/y	0.00	0.00	0.00	0.00024
Aliphatic aldehydes	t/y	0.00	0.00	0.099	0.00
Anthracene	t/y	0.0000000012	0.0000000047	0.00	0.00
Benzene	t/y	0.059	0.223	0.36	0.0036
Biphenyl	t/y	0.00000034	0.0000013	0.00	0.00
Aliphatics C17-C34	t/y	0.0035	0.013	0.00	0.00
C5-C8 aliphatic group	t/y	8.07	30.49	2.63	0.14
C9-C16 aliphatic group	t/y	0.17	0.66	0.45	0.00045
C9-C16 aromatic group	t/y	0.037	0.14	0.13	0.00
CS2	t/y	0.00	0.00	0.95	0.00017
Cyclohexane	t/y	0.00	0.00	0.00	0.00061
Ethylbenzene	t/y	0.0011	0.0040	0.00	0.00038
Fluorene	t/y	0.00000033	0.0000013	0.00	0.00
Hexane	t/y	1.37	5.17	0.00	0.0027
Hydrogen sulphide	t/y	0.46	1.73	7.21	0.086
Mercaptan group	t/y	0.097	0.37	0.00	0.0033
Methane (C_1)	t/y	0.00	0.00	52.86	11.80
Naphthalene	t/y	0.0000073	0.000028	0.00	0.00
Phenanthrene	t/y	0.000000014	0.000000053	0.00	0.00
C_2-C_4	t/y	5.89	22.27	0.00	3.41
Thiophene group	t/y	0.00	0.00	4.22	0.0024
Toluene	t/y	0.027	0.10	0.43	0.0030
Xylenes	t/y	0.0051	0.019	0.20	0.0012

Table 2A-44 Summary of Process Area Parameters and Emissions (Areas C and D)

Source identification #		**C**			**D**
Unit Name/Description		Gas Sweetening Unit	Sulphur Recovery Unit	Tail Gas Treatment Unit	Vacuum Distillation Unit
Temporal Variation		continuous	continuous	continuous	continuous
Number of Units		2	5	3	1
Area Source Locations					
Northwest	m E	367487.008			367894.708
	m N	5962770.434			5962292.234
Northeast	m E	368091.908			367992.708
	m N	5962756.134			5962291.034
Southeast	m E	368082.308			367989.108
	m N	5962593.634			5962209.734
Southwest	m E	367489.308			367889.908
	m N	5962612.734			5962220.534
Base Elevation of Source	m ASL	623.2			624.2
Release Dimensions					
Release Height	m	6.0			6.0
Initial Sigma Z	m	10.0			10.0
Emission Rate					
Total Emission	t/y	6.04	98.53	9.06	27.18
1,3-butadiene	t/y	0.0123	0.20	0.018	0.58
Aliphatic aldehydes	t/y	0.00	0.00	0.00	0.170
Aliphatic ketones	t/y	0.00	0.00	0.00	0.064
Benzene	t/y	0.000030	0.00050	0.000046	0.49
C5-C8 aliphatic group	t/y	0.0019	0.031	0.0029	6.61
C9-C16 aliphatic group	t/y	0.00	0.00	0.00	0.78
CS2	t/y	0.00012	0.0020	0.00018	0.0064
Ethylbenzene	t/y	0.0000019	0.000032	0.0000029	0.062
Furan	t/y	0.00	0.00	0.00	0.021
Hexane	t/y	0.000027	0.00043	0.000040	0.52
Hydrogen sulphide	t/y	0.101	1.65	0.15	0.48
Isopropylbenzene	t/y	0.00	0.00	0.00	0.00082
Mercaptan group	t/y	0.0052	0.0855	0.0079	0.027
Methane (C_1)	t/y	3.96	64.57	5.94	5.62
Methylene chloride	t/y	0.0000000000065	0.00000000011	0.0000000000098	0.00
C_2-C_4	t/y	1.96	31.98	2.94	10.63
Thiophene group	t/y	0.00078	0.013	0.0012	0.062
Toluene	t/y	0.000022	0.00035	0.000033	0.98
Xylenes	t/y	0.0000068	0.00011	0.000010	0.074

Table 2A-45 Summary of Process Area Parameters and Emissions (Areas E, F and G)

Source identification #		**E**	**F**	**G**	
Unit Name/Description		H_2 Plant	Naphtha Hydrotreater	Hydrotreater	Medium Gas Oil Hydrotreater
Temporal Variation		continuous	continuous	continuous	continuous
Number of Units		1	2	1	2
Area Source Locations					
Northwest	m E	368119.708	367488.008	367485.608	
	m N	5962960.734	5962581.834	5962498.234	
Northeast	m E	368198.708	367885.008	368008.108	
	m N	5962958.334	5962569.934	5962479.134	
Southeast	m E	368195.108	367885.008	368002.108	
	m N	5962848.434	5962514.934	5962425.334	
Southwest	m E	368115.008	367486.808	367485.608	
	m N	5962850.834	5962528.134	5962442.034	
Base Elevation of Source	m ASL	621.6	623.8	624.4	
Release Dimensions					
Release Height	m	6.0	6.0	6.0	
Initial Sigma Z	m	10.0	10.0	10.0	
Emission Rate					
Total Emission	t/y	48.82	52.68	26.12	65.23
1,3-butadiene	t/y	0.68	0.00	0.12	0.29
Aliphatic ketones	t/y	0.0056	0.0010	0.0057	0.014
Benzene	t/y	0.0023	0.043	0.0041	0.010
C17-C34 aromatic group	t/y	0.00	0.0016	0.00012	0.00029
C5-C8 aliphatic group	t/y	0.20	0.47	0.11	0.27
C9-C16 aliphatic group	t/y	0.0049	0.025	0.0075	0.019
C9-C16 aromatic group	t/y	0.00	0.014	0.00077	0.0019
CS2	t/y	0.0095	0.35	0.000012	0.000029
Cyclohexane	t/y	0.00094	0.024	0.00	0.00
Ethylbenzene	t/y	0.00058	0.0051	0.0071	0.018
Hexane	t/y	0.0165	0.078	0.0066	0.016
Hydrogen sulphide	t/y	0.000039	3.83	0.0000037	0.0000093
Isopropylbenzene	t/y	0.00	0.00088	0.00	0.00
Mercaptan group	t/y	0.0046	0.0038	0.00034	0.00084
Methane (C_1)	t/y	26.23	42.55	19.10	47.70
Methylene chloride	t/y	0.00000000012	0.00	0.000000000065	0.00000000016
C_2-C_4	t/y	19.94	5.23	6.72	16.79
Thiophene group	t/y	0.0030	0.018	0.013	0.032
Toluene	t/y	0.0032	0.028	0.011	0.027
Xylenes	t/y	0.0013	0.016	0.015	0.038

Table 2A-46 Summary of Process Area Parameters and Emissions (Areas H, I and J)

Source identification #		H-1	H-2	**I**	**J**
Unit Name/Description		Tank Farm	Tank Farm	Gasifier	
Temporal Variation		continuous	continuous	continuous	continuous
Number of Units		1		2	
Area Source Locations					
Northwest	m E	366681.108	366658.108	366648.708	367395.408
	m N	5962685.634	5961988.334	5961738.034	5961917.434
Northeast	m E	367221.708	367075.308	367148.408	367448.008
	m N	5962671.334	5961977.634	5961722.534	5961912.634
Southeast	m E	367207.408	367063.408	367138.908	367442.108
	m N	5962437.134	5961770.834	5961402.234	5961719.034
Southwest	m E	366674.908	366650.908	366638.008	367389.508
	m N	5962444.234	5961781.634	5961417.834	5961715.534
Base Elevation of Source	m ASL	622.7	624.7	624.2	624.2
Release Dimensions					
Release Height	m	6.0		6.0	6.0
Initial Sigma Z	m	10.0		10.0	10.0
Emission Rate					
Total Emission	t/y	9.88	9.88	21.76	
1,3-butadiene	t/y	0.015	0.015	0.31	
Aliphatic alcohols	t/y	0.0094	0.0094	0.00	
Aliphatic ketones	t/y	0.00	0.00	0.0026	
Benzene	t/y	0.11	0.11	0.0011	
C5-C8 aliphatic group	t/y	6.05	6.05	0.094	
C9-C16 aliphatic group	t/y	0.74	0.74	0.0023	
C9-C16 aromatic group	t/y	0.034	0.034	0.00	
CS2	t/y	0.00087	0.00087	0.0044	
Cyclohexane	t/y	0.13	0.13	0.00044	
Ethylbenzene	t/y	0.22	0.22	0.00027	
Fluorene	t/y	0.00	0.00	0.00	
Furan	t/y	0.00	0.00	0.00	
Hexane	t/y	0.21	0.21	0.0076	
Hydrogen sulphide	t/y	0.018	0.018	0.000018	
Isopropylbenzene	t/y	0.013	0.013	0.000000000054	
Mercaptan group	t/y	0.0022	0.0022	0.0021	
Methane (C_1)	t/y	0.40	0.40	12.12	
Methylene chloride	t/y	0.00	0.00	0.00	
C_2-C_4	t/y	0.74	0.74	9.21	
Thiophene group	t/y	0.019	0.019	0.0014	
Toluene	t/y	0.68	0.68	0.0015	
Xylenes	t/y	0.5005	0.5005	0.00061	

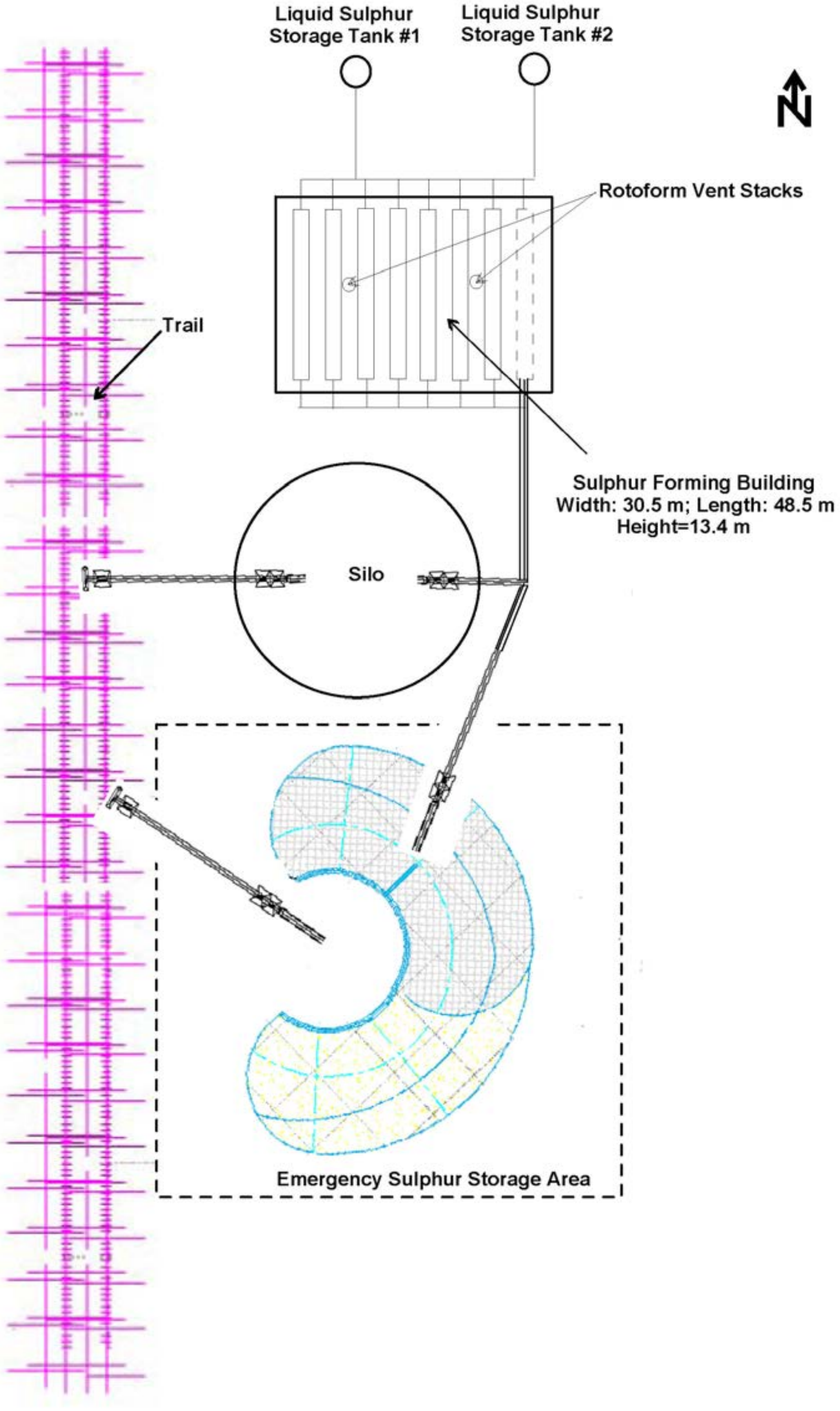


Figure 2A-7 Conceptual Plot Plan for the Project Sulphur Forming and Shipping Facility

Table 2A-47 Stack and Emission Parameters for Sulphur Liquid Tanks at the Proposed North American Sulphur Forming Facility

Source identification #		120	121	120	121
		Clearstone		JWA	
Tank ID		TK1301A	TK1301B	TK1301A	TK1301B
Unit Name/Description		Liquid Sulphur Tank	Liquid Sulphur Tank	Liquid Sulphur Tank	Liquid Sulphur Tank
Temporal Variation		Continuous	Continuous	Continuous	Continuous
Volume Source Locations	m E	367424.704	367454.042	367424.704	367454.042
	m N	5961903.1053	5961903.1	5961903.1053	5961903.1
Base Elevation of Source	m ASL	625.0	625.0	625.0	625.0
Release Dimensions					
Tank Height	m	18.3	18.3	18.3	18.3
Tank Diameter	m	12.2	12.2	12.2	12.2
Sigma Y	m	2.84	2.84	2.84	2.84
Sigma Z	m	8.51	8.51	8.51	8.51
Emission Rate					
Total VOC	t/y	0.042	0.042	-	-
CS_2	t/y	0.032	0.032	-	-
Hydrogen sulphide	t/y	0.010	0.010	0.0052 (10 ppm)	0.0052 (10 ppm)
		-	-	0.00052 (1 ppm)	0.00052 (1 ppm)
Methane	t/y	0.000027	0.000027	-	-

Notes:
Source identification numbers are per the EIA design numbering scheme.
Clearstone values are based on measurements at a surrogate facility.
JWA values are based on assumptions provided in the text.
Sigma Y and Sigma Z are dispersion modelling parameters.
The JWA 10 ppm emission values assume no additional mitigation.
The JWA 1 ppm emission values assume mitigation.

Table 2A-48 Stack and Emission Parameters for Continuous Point Sources at the Proposed NAOSC Sulphur Forming Facility

Parameter		**Rotoform Stack #1**	**Rotoform Stack #2**
Event		Normal	Normal
Frequency		Continuous	Continuous
Duration		Continuous	Continuous
Stack Location			
UTM NAD83	m E	367419	367446
	m N	5961860	5961860
Base Elevation of Stack	m ASL	624.5	624.5
Stack Dimensions			
Stack Height Above Elevation	m	18.5	18.5
Inside Tip Diameter	m	0.41	0.41
Exhaust Parameters			
Actual Exhaust Volume Flow Rate	m^3/h	7820	7820
Exit Velocity	m/s	16.7	16.7
Exit Temperature	^oC	36	36
	K	309	309
Emission Rates			
H_2S (Based on Max 5 ppmv)	g/s	0.0144	0.0144
	t/d	0.0012	0.0012
	t/y	0.454	0.454
$PM_{2.5}$ (Based on Max 0.05 g/kg)	g/s	0.1202	0.1202
	t/d	0.010	0.010
	t/y	3.79	3.79

Table 2A-49 VOC Speciation Profile for Locomotive Emissions

Substance Group		Portion of VOC Due to Locomotive (%)
8	1,3-butadiene	0.1677
10	2-methylnaphthalene	0.3306
11	Acenaphthene group	0.0483
12	Acetaldehyde	22.6161
13	Acrolein	1.8396
15	Aliphatic Aldehydes	24.8346
16	Aliphatic Ketones	4.0579
18	Anthracene	0.0124
19	Benzaldehyde	2.056
20	Benzene	1.4825
21	Benzo(a)anthracene	0.0016
28	C17+ aliphatic group	0.6591
29	C17-C34 Aromatics	0.1154
30	C5-C8 aliphatics	7.2502
31	C9-C16 Aromatics	1.8064
32	C9-C18 aliphatics	2.148
33	Chrysene	0.0018
34	Cyclohexane	0.1136
38	Ethylbenzene	0.2543
39	Fluoranthene	0.0287
40	Fluorene	0.0353
41	Formaldehyde	12.0656
43	Hexane	0.0134
47	Naphthalene	0.3338
48	Phenanthrene	0.0504
52	Toluene	2.1534
53	Xylenes	1.7098
	Total	86.19

Table 2A-50 Emission Parameters for Area Sources at the Proposed Sulphur Forming Facility

Unit Name/Description		**Locomotive Exhaust [a]**	**Loader Engine Exhaust [a]**	**Pastille Loading Operation Area [b]**
Temporal Variation		Once/week	Abnormal	Abnormal
Duration		6 hours/day	Intermittent	Intermittent
Area Source Locations		624.5	624.5	624.5
Northwest	m E	367352.308	367382.308	367382.308
	m N	5961888.934	5961766.934	5961766.934
Northeast	m E	367392.308	367412.308	367412.308
	m N	5961888.934	5961766.934	5961766.934
Southeast	m E	367392.308	367412.308	367412.308
	m N	5961728.934	5961756.934	5961756.934
Southwest	m E	367352.308	367382.308	367382.308
	m N	5961728.934	5961756.934	5961756.934
Base Elevation of Source	m	624.5	624.5	624.5
Release Dimensions				
Release Height	m	6.0	3.6	1.0
Initial Sigma Z	m	10	10	10
1-h Max Emission Rate				
CO_2	g/s	357.37	28.83	-
	t/h	1.29	0.10	-
SO_2	g/s	0.105	0.00000091	-
	t/h	0.00038	0.00000084	-
NO_x	g/s	4.95	0.34	-
	t/h	0.018	0.0012	-
CO	g/s	1.47	0.13	-
	t/h	0.0053	0.00046	-
VOC	g/s	0.37	0.049	-
	t/h	0.0013	0.00018	-
$PM_{2.5}$	g/s	0.147	0.0074	0.241
	t/h	0.00053	0.000027	0.00087
Annual Emission Rate				
CO_2	g/s	12.73	-	-
	t/y	401.4	-	-
SO_2	g/s	0.0037	-	-
	t/y	0.12	-	-
NO_x	g/s	0.18	-	-
	t/y	5.56	-	-
CO	g/s	0.052	-	-
	t/y	1.65	-	-
VOC	g/s	0.013	-	-
	t/y	0.41	-	-
$PM_{2.5}$	g/s	0.0052	-	-
	t/y	0.16	-	-

Notes:

[a] More detailed speciation profiles are available for the locomotive and loader engines exhaust emissions.

[b] Emissions from Pastille Loading area is based on U.S. EPA AP-42 Equation 13.2.1.3 (1)

$$E=k(sL/2)^{0.65}*(W/3)^{1.5}-C$$

Where: E = Particulate emission factor(having units matching the units of k),
k = particle size multiplier for particle size range and units of interest
sL= road surface silt loading (g/m^2)
W = average weight (tons) of the vehicles traveling the road, and
C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear.

Table 2A-51 Summary of the Eight-cell Cooling Tower Parameters and Water Vapour Emissions

Source identification #		16								
Cell Number		1	2	3	4	5	6	7	8	All
Circulating Water Flow Rate										
Per Cell	m^3/h	2,130	2,130	2,130	2,130	2,130	2,130	2,130	2,130	17,040
	kg/h	2,130,000	2,130,000	2,130,000	2,130,000	2,130,000	2,130,000	2,130,000	2,130,000	17,040,000
Location										
UTM NAD 83	m N	5962789	5962789	5962789	5962789	5962789	5962789	5962789	5962789	-
UTM NAD 83	m E	368006	368018	368030	368042	368054	368066	368078	368090	-
Base Elevation	m ASL	621.3	621.3	621.3	621.3	621.3	621.3	621.3	621.3	-
Dimensions										
Cell Height (including fan stack)	m	20	20	20	20	20	20	20	20	20
Cell Top Internal Diameter	m	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Cell Structure Height	m	15	15	15	15	15	15	15	15	15
Cell Structure Width	m	24	24	24	24	24	24	24	24	24
Cell Structure Length	m	12	12	12	12	12	12	12	12	96
Exhaust Parameters										
Cell Exit Temperature	°C	31	31	31	31	31	31	31	31	-
Cell Exit Temperature	K	304	304	304	304	304	304	304	304	-
Cell Exit Velocity	m/s	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	-
Water Vapour Emission Rate	kg/h	43540	43540	43540	43540	43540	43540	43540	43540	348,320

2A5 OTHER INDUSTRIAL STACK SOURCES

This section provides a brief discussion identifying each facility and provides a comparison of the emissions provided by FAP with those obtained from the Scotford SU2, Sturgeon Upgrader Project and NPRI (2004 and 2005) database. The NPRI database is only applicable to existing facilities. In some cases, the maximum approved emission limits identified in the Alberta EPEA approvals are compared to the average values. Detailed emission data are summarized at the end of this section in Tables 2A-84 and 2A-85 for the Baseline and the Cumulative Case, respectively. Table 2A-83 provides the emission data for the Baseline Case emission data for the facilities that are located in the East Edmonton area.

2A5.1 Agrium. Fort Saskatchewan Nitrogen Operations

The Agrium Inc. Fort Saskatchewan Nitrogen Operations is located about 7.9 km to the southwest of the Project site. The facility produces anhydrous ammonia and urea. Emission information for this facility was supplied by Agrium. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to both the Baseline and Cumulative cases.

Table 2A-52 compares the emission information provided by the various data sources. For CO, the FAP data are less than the NPRI values. The Project assessment is based on the FAP emissions.

Table 2A-52 Summary of the Agrium Fort Saskatchewan Facility Emissions based on Various Data Sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.003	**0.0045**	0.00	N/R	N/R	0.0045	0.0045
NO_x	3.080	**3.1680**	3.08	2.59	2.32	3.168	3.168
CO	1.080	0.6999	0.68	0.76	**1.55**	0.6999	0.6999
$PM_{2.5}$	**0.040**	0.0169	0.00	0.041	0.014	0.0169	0.0169
VOC	N/R	**0.0400**	0.08	0.050	0.036	0.0443	0.0443

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.2 Agrium, Redwater Fertilizer Operations

The Agrium Redwater Fertilizer Operations is located about 13.3 km to the east of centre of the Project site. The facility produces ammonia, ammonium nitrate, ammonium sulphate, urea ammonium nitrate solutions and urea. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to both the Baseline and Cumulative cases.

The SO_2 emission results primarily from two stacks: the sulphur acid tail gas stack #1 (4.07 t/d) and the sulfur acid tail gas stack #2 (3.58 t/d). The maximum approved SO_2 emission rates for these two stacks are 6.768 t/d and 4.680 t/d, respectively for a total of 11.448 t/d. The maximum approved NO_x emission from the two ammonia units and the nitric acid unit is equal to 13.44 t/d (AENV Approval 00000210-01-00). The maximum approved SO_2 and NO_x rates are expressed in a kg/h basis.

Table 2A-53 compares the emission information for the Agrium Redwater Fertilizer Operations provided by the various data sources. The FAP and NPRI SO_2 and NO_x emissions are less than the respective maximum approved values of 11.448 t/d and 13.44 t/d, respectively. The Project assessment is based primarily on the FAP emissions that are listed in Table 2A-53. The short term SO_2 emission rate included in the Project assessment is based on the SU2 and Sturgeon assessments.

Table 2A-53 Summary of the Agrium Redwater Facility Emissions based on various data sources (for Baseline and Cumulative Cases).

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	7.658	4.13	**7.66**	4.87	4.40	7.66	4.13
NO_x	5.085	**5.11**	5.09	3.68	3.28	5.11	5.11
CO	1.336	1.26	1.34	1.18	**1.36**	1.26	1.26
$PM_{2.5}$	**0.419**	0.38	0.42	1.40	0.27	0.38	0.38
VOC	N/R	0.02	0.63	**0.66**	0.59	0.30	0.30

NOTE:
N/R = Not Reported
Maximum values shown in **bold.**

2A5.3 Air Liquide Canada, Scotford Cogeneration Power Plant

Air Liquide operates a cogeneration power plant at the Scotford Complex. The cogeneration plant has a capacity of 200t of steam per hour and 80 MW of electricity supplying the Shell Chemical and Air Liquide facilities. The plant is located adjacent to Shell Chemical facilities, which is about 4.7 km southeast of the Project site. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to both the Baseline and Cumulative cases.

Table 2A-54 compares the emission information provided by the various data sources. The maximum approved NO_x emission from the gas turbine/HRSG exhaust stack is 1.512 t/d (or 63 kg/h, Alberta Environment Approval 68179-00-00). A value of 0.70 t/d results from an auxiliary boiler exhaust stack that does not have a maximum approved limit. The Project assessment is based on the FAP emissions.

Table 2A-54 Summary of the Air Liquide Facility Emissions based on Various Data Sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.000	0.00	0.00	N/R	N/R	0.00	0.00
NO_x	2.208	0.466	**2.21**	0.58	0.47	0.466	0.466
CO	**0.914**	0.148	0.91	0.183	0.149	0.148	0.148
$PM_{2.5}$	0.076	0.015	**0.08**	0.017	0.016	0.015	0.015
VOC	N/R	0.021	**0.20**	N/R	N/R	0.021	0.021

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.4 ARC Resource, Gas Conversation Plant

ARC Resources Redwater gas conservation plant is located about 18.2 km to the northwest of the Project site. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-55 compares the emission information provided by the various data sources. The maximum approved SO_2 emissions are 0.14 t/h and 2.4 t/d (Alberta Environment Approval 150-02-00). The Project assessment is based on the FAP emissions that are listed in the table. For CO, the SU2 and Sturgeon rate is used.

Table 2A-55 Summary of the ARC Facility Emissions based on various data sources (for Baseline and Cumulative Cases).

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.590	**0.800**	0.59	0.58	0.58	0.800	0.800
NO_x	1.071	**2.576**	1.07	1.12	0.76	2.576	2.576
CO	**1.830**	N/R	**1.83**	0.070	0.539	1.830	1.830
$PM_{2.5}$	0.013	**0.280**	0.01	0.004	0.003	0.280	0.280
VOC	N/R	0.040	0.22	**0.222**	0.014	0.040	0.040

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.5 ATCO Midstream Inc., Fort Saskatchewan Sour Gas Plant

The ATCO Midstream Fort Saskatchewan sour gas plant is located about 14.7 km to the southwest of the Project site. ATCO Midstream provides gas gathering, processing, storage and natural gas liquids to the Canadian natural gas producing sector. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-56 summaries the emission information provided by the various data sources. The maximum approved SO_2 emissions are 0.044 t/d (Alberta Environment Approval 240-02-00). The Project assessment is based on the SU2 emissions that are listed in the table.

Table 2A-56 Summary of the ATCO Facility Emissions based on various data sources (for Baseline and Cumulative Cases).

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	**0.001**	N/R	0.00	N/R	N/R	0.001	0.001
NO_x	0.017	N/R	**0.02**	N/R	N/R	0.017	0.017
CO	0.003	N/R	**0.01**	N/R	N/R	0.003	0.003
$PM_{2.5}$	**0.001**	N/R	0.00	0.001	N/R	0.001	0.001
VOC	N/R	N/R	0.00	N/R	N/R	0.001	0.001

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.6 Aux Sable Canada, Heartland Offgas Project

The Aux Sable Canada Heartland offgas plant site is located about 8.6 km to the southwest of the Project site. Aux Sable proposes to extract the natural gas liquids created from the upgrading process and sell them to petrochemical and NGL industries located in the Fort Saskatchewan area as feedstocks. The Heartland Offgas Project has received regulatory approval, while the Confidential Projects No. 1, 2 and 3 (designated as such by Aux Sable Canada) are in the planning stage. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative Cases. respectively.

Table 2A-57 summarizes the Heartland Offgas Project emission information obtained from SU2 and Sturgeon projects. No data are available from FAP. The facility is a small source of NO_x, CO, $PM_{2.5}$ and VOC emissions. The Project assessment is based on the SU2 emissions.

Table 2A-58 summarizes the Confidential Projects No. 1, 2 and 3 emission information obtained from SU2 project. The facility is a source of NO_x, CO, $PM_{2.5}$ and VOC emissions. The Project assessment is based on the SU2 emissions.

Table 2A-57 Summary of the Aux Sable Heartland Offgas Project Emissions based on various data sources (for Baseline Case).

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.000	N/R	0.00	N/R	N/R	0.000	0.000
NO_x	**0.177**	N/R	0.13	N/R	N/R	0.177	0.177
CO	**0.149**	N/R	0.11	N/R	N/R	0.149	0.149
$PM_{2.5}$	**0.012**	N/R	0.01	N/R	N/R	0.012	0.012
VOC	N/R	N/R	0.01	N/R	N/R	0.01	0.01

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

Table 2A-58 Summary of the Aux Sable Confidential Projects No. 1, 2 and 3 Emissions based on various data sources (for Cumulative Case).

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.00	N/R	N/R	N/R	N/R	0.000	0.000
NO_x	**2.187**	N/R	N/R	N/R	N/R	2.187	2.187
CO	**1.838**	N/R	N/R	N/R	N/R	1.838	1.838
$PM_{2.5}$	**0.148**	N/R	N/R	N/R	N/R	0.148	0.148
VOC	N/R	N/R	N/R	N/R	N/R	0.120	0.120

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.7 BA Energy Heartland Upgrader

The Heartland Upgrader is located about 4.5 km to the northwest of the Project site. This Project represents the next generation of bitumen upgrading technology, which will upgrade extra-heavy asphaltic crude oils from the oil sands into lighter synthetic crude oil blends. The Project will be designed to process up to 41,400 m^3 per stream day of oil sands bitumen blend. Light, residue-free synthetic crude oil blends and medium blends with low asphaltene content will be produced and transported by pipeline to refinery markets. The plant has been approved and is currently under construction. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-59 compares the emission information provided by the various data sources. The facility is a large source of SO_2 emissions. The maximum approved emissions for SO_2 are 1.4 t/h or 28.1 t/d, and for NO_x are 4.7 t/d (Alberta Environment Approval 203303-00-00). The Project assessment is based on the FAP emissions. For CO, the SU2 and Sturgeon value is used.

Table 2A-59 Summary of the BA Energy Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	19.440	19.440	**28.10**	N/R	N/R	19.440	19.440
NO_x	4.670	4.670	**4.70**	N/R	N/R	4.670	4.670
CO	**1.560**	N/R	1.56	N/R	N/R	1.560	1.560
$PM_{2.5}$	**0.470**	**0.470**	**0.47**	N/R	N/R	0.470	0.470
VOC	N/R	N/R	**0.2566**	N/R	N/R	0.2566	0.2566

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.8 BP Canada Energy Fort Saskatchewan Fractionation Plant

The BP Canada Energy Fort Saskatchewan fractionation plant is located in the northern portion of Section 14 and southern portion of Section 23 of Township 55, Range 22, West of the 4th Meridian, which is about 10.1 km to the south of the Project site. The plant is the hub for the processing, transportation, and marketing of natural gas liquids. Natural gas liquids are received by pipeline, stored in hydrocarbon storage caverns, fractionated, treated and dried for shipment to market. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-60 compares the emission information provided by the various data sources. The maximum approved SO_2 emissions are 0.892 t/d (Alberta Environmental Approval 10081-01-00). The Project assessment is based on the FAP emissions.

Table 2A-60 Summary of the BP Canada Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	**1.041**	0.259	1.04	N/R	N/R	1.041	0.129
NO_x	**0.643**	0.294	0.64	0.32	0.32	0.294	0.294
CO	**0.544**	0.247	0.54	0.253	0.277	0.247	0.247
$PM_{2.5}$	**0.023**	0.006	0.02	0.006	0.007	0.006	0.006
VOC	N/R	**0.255**	0.25	0.591	0.255	0.016	0.016

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.9 Canexus Chemicals Canada Ltd., Partnership Bruderheim Sodium Chlorate Plant

The Canexus Chemicals sodium chlorate plant is located about 9 km to the east of the Project site. The Bruderheim Operation produces sodium chlorate which is used for bleaching purposes by the pulp and paper industry and is also a major distribution terminal for hydrochloric acid. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-61 compares the emission information provided by the various data sources. The Canexus Canada facility is a small source of NO_x emissions. The Project assessment is based on the FAP emissions that are listed in the table.

Table 2A-61 Summary of the Canexus Canada Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.000	0.000	0.00	N/R	N/R	0.000	0.000
NO_x	0.017	**0.038**	0.02	0.02	0.01	0.038	0.038
CO	0.003	**0.003**	0.01	N/R	N/R	0.003	0.003
$PM_{2.5}$	0.001	**0.016**	0.00	N/R	N/R	0.016	0.016
VOC	N/R	0.000	0.00	N/R	N/R	**0.0021**	0.0021

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.10 Degussa Canada Inc., Gibbons Hydrogen Peroxide Plant

The Degussa Canada Inc. Gibbons hydrogen peroxide manufacturing plant is located about 7.9 km to the east of the Project site. Degussa Gibbons Site is the largest Hydrogen Peroxide facility in Canada. Hydrogen Peroxide is sold to the pulp and paper, mining, textile, detergent, cosmetic, chemical synthesis, electronics, environmental, food and space industries. Substance releases reported from the site are low-level ammonia and chlorine (NPRI 2004). The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-62 compares the emission information provided by the various data sources. The maximum approved NO_x emission from the hydrogen plant reformer stack is 0.0207 t/d (or 0.24 g/s, Alberta Environment Approval 1034-02-00). The Project assessment is based on the FAP emissions supplemented with the SU2 data.

Table 2A-62 Summary of the Degussa Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.000	**0.0004**	0.00	N/R	N/R	0.0004	0.0004
NO_x	0.058	0.058	0.05	**0.06**	0.05	0.058	0.058
CO	**0.048**	N/R	0.01	0.050	0.046	0.048	0.048
$PM_{2.5}$	0.004	N/R	**0.01**	0.001	0.001	0.004	0.004
VOC	N/R	N/R	0.00	N/R	N/R	**0.003**	0.003

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.11 Dow Chemical Canada Inc., Fort Saskatchewan Chemical Plant

The Dow chemical Canada Inc. Fort Saskatchewan chemical plant is located about 12.9 km to the southwest of the Project site. Dow Chemical operates the largest petrochemical manufacturing site at its Fort Saskatchewan location. The plant produces caustic soda, polyethylene, ethylene, ethylene dichloride, vinyl chloride monomer, power generation.

Natural gas liquids are separated, producing ethane, propane-plus, propane, butane and pentane-plus. The ethane remains on site to make ethylene More than three million tonnes of product leave the Fort Saskatchewan site each year. A cogeneration plant at Dow Chemical uses combined gas and steam turbines to generate approximately 300 megawatts of power. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-63 compares the emission information provided by the various data sources. The NO_x emission is consistent with the maximum approved value (698 kg/h or 16.752 t/d, Alberta Environment Approval 236-01-04).The NPRI database indicates the Fort Saskatchewan facility is also a source of HCFC-142b (0.30 and 0.38 t/d for 2004 and 2005, respectively). The Project assessment is based on the FAP emissions supplemented with the SU2 emissions.

Table 2A-63 Summary of the Dow Chemical Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	**0.600**	0.134	**0.60**	0.14	0.13	0.134	0.134
NO_x	11.422	5.528	**11.85**	5.81	3.58	5.528	5.528
CO	6.263	N/R	**6.31**	2.960	2.278	6.263	6.263
$PM_{2.5}$	0.992	0.890	**1.10**	0.200	0.044	0.890	0.890
VOC	N/R	N/R	**0.53**	1.244	1.085	0.187	0.187

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.12 ERCO Worldwide, Bruderheim Sodium Chlorate Plant

The ERCO Bruderheim sodium chlorate plant is located about 12.5 km to the east of the Project site. The Bruderheim plant produces approximately 80,000 tonnes of sodium chlorate per year. Sodium chlorate is used primarily in the bleaching of kraft pulp and water treatment and is shipped to pulp mills throughout North America. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-64 summaries the emission information provided by the various data sources. The Project assessment is based on the SU2 emissions

Table 2A-64 Summary of the ERCO Facility Emissions based on various data sources (for Baseline and Cumulative Cases).

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.000	N/R	0.00	N/R	N/R	0.000	0.000
NO_x	**0.012**	N/R	0.01	N/R	N/R	0.012	0.012
CO	**0.010**	N/R	0.01	N/R	N/R	0.010	0.010
$PM_{2.5}$	0.001	N/R	**0.02**	0.011	0.005	0.001	0.001
VOC	N/R	N/R	0.00	N/R	N/R	0.001	0.001

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.13 HAZCO Environmental Service Ltd., Bruderheim Sulphur Forming Facility

The HAZCO Bruderheim sulphur forming facility site is located about 9.6 km to the east of the Project site. HAZCO utilizes a sulphur management facility to process sulphur generated by oil and gas related refining operations in Bruderheim. The Project includes facilities for sulphur forming and shipping, as well as facilities for storage of manufactured product (i.e., sulphur pellets). The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Cumulative Case.

Table 2A-65 summarizes the emission information obtained from SU2 and Sturgeon projects. The Project assessment is based on these emissions.

Table 2A-65 Summary of the HAZCO Facility Emissions based on various data sources (for Cumulative Case)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.000	N/R	0.00	N/R	N/R	0.000	0.000
NO_x	0.009	N/R	**0.01**	N/R	N/R	0.009	0.009
CO	**0.011**	N/R	0.01	N/R	N/R	0.011	0.011
$PM_{2.5}$	0.019	N/R	**0.02**	N/R	N/R	0.019	0.019
VOC	N/R	N/R	0.00	N/R	N/R	0.001	0.001

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.14 Keyera Energy Ltd., Fort Saskatchewan Fractionation Facility

The Keyera Energy Ltd. Fort Saskatchewan fractionation facility is located about 11.5 km to the southwest of the Project site. The Keyera Energy operated Fort Saskatchewan Fractionation and Storage Facility receives natural gas liquids from connected pipeline systems and truck offloading. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-66 compares the emission information provided by the various data sources. The maximum approved SO_2 emission is 2.4 t/d (Alberta Environment Approval 10235-01-01). The Project assessment is based on the FAP emissions. For long term SO_2 emission the NPRI data are used.

Table 2A-66 Summary of the Keyera Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	1.900	**2.400**	1.90	0.41	0.45	2.400	2.400
NO_x	0.837	0.835	**0.84**	0.13	0.13	0.835	0.835
CO	**0.343**	0.026	0.34	0.080	0.093	0.345	0.345
$PM_{2.5}$	**0.048**	0.025	0.05	0.002	0.005	0.025	0.025
VOC	N/R	0.010	1.54	0.860	1.540	0.011	0.011

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.15 Marsulex Inc., Fort Saskatchewan Chemical Plant

The Marsulex Inc. Fort Saskatchewan Chemical Plant is located about 13.7 km to the southwest of the Project site. The plant produces aluminum sulphate (Alum), sodium, bisulphate, carbon disulphite and hydrogen sulphide. The range of chemicals is used in a variety of industrial applications such as water and sewage treatment, pulp and paper, power generation and oil and gas production. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-67 compares the emission information provided by the various data sources. The maximum approved SO_2 emission is 1.92 t/d (or 80 kg/h, Alberta Environment Approval 1636-01-00). The Project assessment is based on the SU2 and Sturgeon emissions.

Table 2A-67 Summary of the Marsulex Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.292	0.642	0.99	0.716	0.987	**0.642**	0.642
NO_x	**0.004**	N/R	0.00	0.005	0.004	0.004	0.004
CO	**0.003**	N/R	0.00	0.004	0.003	0.003	0.003
$PM_{2.5}$	0.000	N/R	0.00	0.0002	0.0002	0.0002	0.0002
VOC	N/R	N/R	0.00	0.007	0.006	0.006	0.006

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.16 NewAlta Corporation, Redwater Disposal Facility

The Newalta Redwater disposal facility is located about 18.4 km to the northwest of the Project site. Newalta is an industrial waste management company operating an incinerator and two boilers on the Dow Chemical site. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-68 compares the emission information provided by the various data sources. The Project assessment is based on the FAP and SU2 emissions

Table 2A-68 Summary of the NewAlta Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.000	0.000	0.00	N/R	N/R	0.000	0.000
NO_x	**0.020**	0.020	0.02	N/R	N/R	0.020	0.020
CO	0.017	N/R	**0.02**	N/R	N/R	0.017	0.017
$PM_{2.5}$	**0.002**	N/R	0.00	N/R	N/R	0.002	0.002
VOC	N/R	N/R	0.00	N/R	N/R	0.001	0.001

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.17 North West Upgrading Inc., North West Upgrader

The North West Upgrader facility site is located about 8.8 km to the northwest of the Project site. North West Upgrading is a Calgary-based company planning to build a heavy oil Upgrader in Sturgeon County. The plant will produce synthetic crude oil with a planned capacity of 50,000 barrels per day (bpd) per phase (three phases). The first phase of the Project is expected to come on stream in 2010. Two additional phases are expected to be built by 2015 to meet market demand for merchant upgrading services. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Cumulative Case.

Table 2A-69 compares the emission information provided by provided by the various data sources. The Project assessment is based on the North West Upgrader supplemental information responses to AENV and the EUB (North West Upgrading, 2006).

Table 2A-69 Summary of the North West Facility Emissions based on various data sources (for Cumulative Case)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	19.510	19.551	**26.28**	N/R	N/R	19.551	17.700
NO_x	2.130	2.109	**19.42**	N/R	N/R	2.109	2.109
CO	17.540	**17.551**	0.28	N/R	N/R	17.551	17.551
$PM_{2.5}$	0.150	0.177	**1.16**	N/R	N/R	0.177	0.177
VOC	N/R	0.588	**1.14**	N/R	N/R	0.588	0.588

NOTE:
N/R = Not Reported
The short term SO_2 emissions assume 1096 t/sd sulphur inlet and 99.1% sulphur recovery efficiency.
The long term SO_2 emissions assume 991 t/cd sulphur inlet and 99.1% sulphur recovery efficiency.
Maximum values shown in **bold face** text.

2A5.18 Petro-Canada Oil Sands Inc., (Fort Hills) Sturgeon Upgrader (Planned)

The Petro-Canada Oil Sands Inc., Sturgeon Upgrader is located about 11.4 km to the west of the Project site. The Sturgeon Upgrader produces synthetic crude oil. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Cumulative cases.

Table 2A-70 compares the emission information provided by the various data sources. The Project assessment is based on the Sturgeon Upgrader EIA assessment (PCOSI, 2006).

Table 2A-70 Summary of the Petro-Canada (Fort Hills) Sturgeon Upgrader Emissions based on various data sources (for Cumulative Case)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	23.716	9.224	**23.72**	N/R	N/R	23.72	10.119
NO_x	**14.387**	3.495	14.36	N/R	N/R	14.38	14.38
CO	**9.515**	2.146	9.507	N/R	N/R	9.507	9.507
$PM_{2.5}$	0.440	**0.065**	0.440	N/R	N/R	0.440	0.440
VOC	N/R	0.218	**0.997**	N/R	N/R	0.997	0.997

NOTE:
N/R = Not Reported
The short term SO_2 emissions assume 2265 t/d sulphur inlet and 99.5% sulphur recovery efficiency.
The long term SO_2 emissions assume 2265 t/d sulphur inlet and 99.8% sulphur recovery efficiency.
Maximum values shown in **bold face** text.

2A5.19 Prospec Chemicals, Fort Saskatchewan Xanthate Plant

The Prospec Chemicals Fort Saskatchewan Xanthate Plant is located about 32.2 km to the southwest of the Project site. The Fort Saskatchewan plant produces 7000 t/y of xanthates. The facility also produces Thionocarbamates and Xanthogen Formates. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-71 compares the emission information provided by the various data sources. The Project assessment is based on the FAP and SU2 emissions.

Table 2A-71 Summary of the Prospec Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	**SU2**	**FAP**	**Sturgeon**	**NPRI (2004)**	**NPRI (2005)**	**Project Assessment**	
						Short term	**Annual**
SO_2	0.161	0.082	0.16	0.08	0.08	0.082	0.082
NO_x	0.004	0.003	0.00	0.002	0.003	0.003	0.003
CO	0.050	N/R	0.05	0.027	0.007	0.050	0.050
$PM_{2.5}$	0.000	N/R	0.00	N/R	N/R	0.000	0.000
VOC	N/R	N/R	0.00	N/R	N/R	0.00002	0.00002

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.20 Provident Energy Ltd., Redwater Fractionation Facility

The Provident Energy Limited Redwater Fractionation Facility is located about 8.6 km to the southeast of the Project site. The Redwater Fractionation and Storage Facility is equipped to collect, extract, transport, fractionate, store, distribute and market natural gas liquids, as well as fractionate olefin's, such as propylene, for William's Energy. The facility has an annual production capacity of approximately 65,000 bpd. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-72 compares the emission information provided by the various data sources. The maximum approved SO_2 emission is 1.98 t/d (AENV Approval 9995-01-01). The Project assessment is based primarily on the FAP emissions.

Table 2A-72 Summary of the Provident Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	**SU2**	**FAP**	**Sturgeon**	**NPRI (2004)**	**NPRI (2005)**	**Project Assessment**	
						Short term	**Annual**
SO_2	0.769	0.714	**0.77**	0.63	0.74	0.714	0.714
NO_x	0.099	**0.253**	0.10	0.08	0.065	0.253	0.253
CO	0.**083**	N/R	0.08	0.15	0.078	0.058	0.058
$PM_{2.5}$	0.008	**0.019**	0.01	0.003	0.002	0.019	0.019
VOC	N/R	N/R	0.08	0.114	0.085	0.014	0.014

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.21 Redwater Water Disposal Company

The Redwater Company has a number of facilities that produce SO_2 and NO_x emissions. One is located about 8.4 km to the north of the Project site. The other two are located about 13 and 21 km to the north of the site, respectively. Emissions are primarily generated from incinerators or pump stations. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-73 compares the emission information provided by the various data sources. The Project assessment is based on the FAP emissions.

Table 2A-73 Summary of the Redwater Disposal Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	**0.290**	0.274	0.29	0.50	0.29	0.274	0.274
NO_x	0.000	0.000	0.00	N/R	N/R	0.000	0.000
CO	0.000	0.000	0.00	N/R	N/R	0.000	0.000
$PM_{2.5}$	0.000	0.000	0.00	N/R	N/R	0.000	0.000
VOC	N/R	0.000	0.00	N/R	N/R	0.000	0.000

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.22 Shell Canada, Scotford Bitumen Upgrader

The Shell Canada Scotford Bitumen Upgrader is located about 5.9 km to the west of the Project site. The Scotford plant has recently applied to increase bitumen production, which will change the emission profile. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases, respectively.

Tables 2A-74 and 2A-75 compare the emission information provided by the various data sources. For the Project assessment, the Baseline Case Scotford Upgrader emissions are based on the existing baseline plant plus the approved SE1 expansion (Table 2A-69) and the emission profile is obtained from the SU2 application (Shell 2007). The Cumulative Case emissions are based on the baseline plant plus the approved Baseline plant plus the SE1 expansion plus the SU2 Project emissions (Table 2A-75) and the emission profile is obtained from the SU2 application.

Table 2A-74 Summary of the Shell Scotford Facility (After Expansion SE1) Emissions based on various data sources (for Baseline Case)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	31.30	45.858	**52.592**	18.14	18.95	31.299	31.299
NO_x	9.265	**23.830**	14.150	3.12	2.54	9.2645	9.2645
CO	9.194	**19.406**	8.655	2.884	1.738	9.1941	9.1941
$PM_{2.5}$	0.823	**1.773**	0.988	0.070	0.04	0.8226	0.8226
VOC	N/R	N/R	N/R	1.013	0.775	0.510	0.510

NOTE:
N/R = Not Reported
FAP, Sturgeon and NPRI values represent Baseline Plant prior to SE1.
Maximum values shown in **bold face** text.

Table 2A-75 Summary of the Shell Scotford Facility (After SU2 Project) Emissions based on various data sources (for Cumulative Case).

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	**39.19**	N/R	N/R	18.14	18.95	39.1894	39.1894
NO_x	**25.66**	N/R	N/R	3.12	2.54	25.6593	25.6593
CO	**19.15**	N/R	N/R	2.884	1.738	19.1473	19.1473
$PM_{2.5}$	**1.762**	N/R	N/R	0.070	0.04	1.7618	1.7618
VOC	N/R	N/R	N/R	1.013	0.775	1.4113	1.4113

NOTE:
N/R = Not Reported
NPRI values represent Baseline Plant prior to SE1.
Maximum values shown in **bold face** text.

2A5.23 Shell Canada Products, Scotford Oil Refinery

The Shell Canada Products Scotford Oil Refinery is located about 5.9 km to the west of the Project site. The Scotford plant refines synthetic crude from the Alberta oil sands into a wide range of petroleum products including jet fuel, gasoline, diesel, propane, butane and petrochemicals. The refinery produces 100,000 barrels per day of refined products. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-76 compares the emission information provided by the various data sources. The Project assessment is based on the FAP emissions.

Table 2A-76 Summary of the Shell Oil Refinery Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.117	0.117	**0.12**	0.19	0.27	0.117	0.117
NO_x	2.734	**2.734**	2.73	2.35	2.20	2.734	2.734
CO	1.197	1.197	**1.20**	1.348	1.275	1.197	1.197
$PM_{2.5}$	0.350	N/R	**0.35**	0.030	0.029	0.350	0.350
VOC	N/R	N/R	**0.41**	0.314	0.296	0.150	0.150

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.24 Shell Chemicals Canada, Scotford Chemical Plant

The Shell Chemicals Canada Scotford Chemical Plant is located about 5.9 km to the west of the Project site. The chemical plant manufactures principally styrene monomers and mono-ethylene glycols. On site storage of benzene, styrene residues and ethyl benzene also occurs. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-77 compares the emission information provided by the various data sources. The Project assessment is based on the FAP and SU2 emissions.

Table 2A-77 Summary of the Shell Chemicals Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	**0.004**	0.004	0.00	0.01	0.01	0.004	0.004
NO_x	**1.432**	1.432	1.43	1.28	1.15	1.432	1.432
CO	**1.013**	1.012	1.01	0.451	0.457	1.012	1.012
$PM_{2.5}$	0.197	0.197	**0.20**	0.039	0.033	0.197	0.197
VOC	N/R	0.097	**0.37**	0.287	0.141	0.097	0.097

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.25 Sherritt International Corporation, Fort Saskatchewan Fertilizer Plant

The Sherritt International Corporation Fort Saskatchewan Fertilizer Plant is located about 14.5 km to the southwest of the Project site. The Sherritt plant produces ammonia, urea and ammonium sulphate. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases, respectively.

Table 2A-78 compares the emission information provided by the various data sources. The maximum approved SO_2 emission is 2.808 t/d (or 117 kg/h, AENV Approval 211-01-00). The Project assessment is based on the FAP emissions.

Table 2A-78 Summary of the Sherritt Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.904	0.904	**1.04**	0.89	1.05	0.904	0.904
NO_x	7.643	**7.667**	7.64	5.92	7.30	7.667	7.667
CO	**2.169**	0.591	2.09	0.466	0.496	0.591	0.591
$PM_{2.5}$	**0.171**	0.028	0.16	0.020	0.020	0.028	0.028
VOC	N/R	0.000	**0.25**	N/R	N/R	0.258	0.258

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.26 Synenco Energy, Northern Lights Upgrader Project

The Synenco Energy Northern Lights Upgrader project site is located about 11.0 km to the northwest of the Project site. The Project proposes to produce a high grade synthetic crude oil product. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Cumulative Case.

Table 2A-79 compares the emission information provided by the various data sources. The Project assessment is based on the FAP emissions.

Table 2A-79 Summary of the Synenco Facility Emissions based on various data sources (for Cumulative Case)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	28.840	28.850	**31.08**	N/R	N/R	28.840	28.840
NO_x	3.100	3.111	**9.39**	N/R	N/R	3.111	3.111
CO	4.580	4.560	**9.57**	N/R	N/R	4.560	4.560
$PM_{2.5}$	0.209	0.208	**0.43**	N/R	N/R	0.208	0.208
VOC	N/R	0.299	**2.17**	N/R	N/R	0.299	0.299

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.27 TransAlta Cogeneration L.P., Fort Saskatchewan Cogeneration Power Plant

The TransAlta Fort Saskatchewan Cogeneration Power Plant is located about 17.9 km to the southwest of the Project site. The cogeneration facility uses natural gas to produce 120 megawatts of electricity and 100 tonnes of steam per hour. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-80 compares the emission information provided by the various data sources. The NO_x emission is consistent with the maximum approved value (1.872 t/d or 78 kg/h, AENV Approval 48325-00-00). The Project assessment is based on the FAP emissions.

Table 2A-80 Summary of the TransAlta Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.03	0.030	**0.03**	N/R	N/R	0.030	0.030
NO_x	0.29	0.290	**1.87**	0.32	0.23	0.290	0.290
CO	0.26	N/R	**0.69**	0.248	0.235	0.260	0.260
$PM_{2.5}$	0.02	0.020	**0.02**	0.048	0.019	0.020	0.020
VOC	N/R	0.020	**0.02**	N/R	N/R	0.020	0.020

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.28 TransCanada Cogeneration L.P., Fort Saskatchewan Cogeneration Power Plant

The TransCanada Fort Saskatchwan Cogeneration Power Plant is located about 9.2 km to the southwest of the Project site. The plant operates a 40-megawatt natural gas-fired cogeneration plant. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-81 compares the emission information provided by the various data sources. The maximum approved NO_X emission is 0.8323 t/d (or 34.3 kg/h, AENV Approval 136951-00-00). The Project assessment is based on the FAP and SU2 emissions.

Table 2A-81 Summary of the TransCanada Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.000	N/R	0.00	N/R	N/R	0.000	0.000
NO_x	**0.523**	0.345	0.52	0.30	0.35	0.345	0.345
CO	**0.120**	N/R	0.12	0.115	0.104	0.120	0.120
$PM_{2.5}$	**0.010**	N/R	0.01	0.009	0.008	0.010	0.010
VOC	N/R	N/R	0.00	N/R	N/R	0.008	0.008

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.29 Umicore Canada, Fort Saskatchewan Metal Plant

The Umicore Canada Fort Saskatchewan Metal Plant is located about 15.3 km to the southwest of the Project site. The plant mainly produces spherical fine Cobalt, Nickel and Copper powders. The detailed emission parameters provided in Tables 2A-84 and 2A-85 are applicable to the Baseline and Cumulative cases.

Table 2A-82 compares the emission information provided by the various data sources. The maximum approved Particular Matter emission is 0.20g/kg effluent (or 40% opacity, AENV Approval 0080865-00-00). The Project assessment is based on the SU2 emissions.

Table 2A-82 Summary of the Umicore Facility Emissions based on various data sources (for Baseline and Cumulative Cases)

Emission Rate (t/d)	SU2	FAP	Sturgeon	NPRI (2004)	NPRI (2005)	Project Assessment	
						Short term	Annual
SO_2	0.000	N/R	N/R	N/R	N/R	0.000	0.000
NO_x	0.000	N/R	N/R	N/R	N/R	0.000	0.000
CO	0.000	N/R	N/R	N/R	N/R	0.000	0.000
$PM_{2.5}$	0.030	N/R	N/R	N/R	N/R	0.030	0.030
VOC	N/R	N/R	N/R	N/R	N/R	0.000	0.000

NOTE:
N/R = Not Reported
Maximum values shown in **bold face** text.

2A5.30 Detailed Emission Parameters (Baseline Case)

Table 2A-83 provides the detailed emission parameters for the Baseline Case on a stack-by-stack basis that were used for this assessment. The Baseline Case includes existing and approved industrial facilities.

2A5.31 Detailed Emission Parameters (Cumulative Case)

For new facilities or for facilities that are proposing an expansion, the detailed emission parameters for the additional Cumulative Case facilities are provided in Table 2A-84 on a stack by stack basis. The parameters in Table 2A-84 replace the parameters in Table 2A-83 for the identified facilities; for all other facilities, the Baseline Case parameters are still applicable.

Table 2A-83 Detailed Stack and Emission Parameters for the Baseline Case Stack Emissions

Company/Facility/Unit	UTM E (m)	UTM N (m)	Elevation (m ASL)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (K)	SO_2 (t/d)	NO_X (t/d)	CO (t/d)	$PM_{2.5}$ (t/d)
Ammonia Primary Reformer Stack	355209	5955267	619	36.6	3.4	17.6	445.0	0.0040	3.0000	0.6220	0.0141
Package Boiler Flue Gas Stack	355217	5955190	616	30.2	1.5	7.1	351.5	0.0005	0.0900	0.0760	0.0017
Urea Stack	355269	5955112	621	67.1	2.7	23.0	324.0		0.0780	0.0019	0.0011
Sum: Agrium-Ft Sask. Nitrogen Operations								**0.0045**	**3.1680**	**0.6999**	**0.0169**
Ammonia-1 CO2 Vent	362449	5968058	624	45.0	0.6	21.5	375.0				
Ammonia-1 Primary Reformer Stack A (North)	362478	5968060	623	29.0	1.5	20.0	475.0	0.0010	1.4700		0.0045
Ammonia-1 Primary Reformer Stack B	362478	5968053	624	29.0	1.5	20.0	475.0	0.0010	1.4700	0.2000	0.0045
Ammonia-2 CO2 Vent	362449	5967950	626	85.0	0.6	23.1	375.0				
Ammonia-2 Primary Reformer Stack	362448	5967838	626	25.9	3.7	15.0	460.0	0.0060	1.9100	0.8674	0.0290
Ammonium Nitrate Prill Tower Fan #1	362364	5968096	623	36.1	1.8	17.0	304.0				0.0121
Ammonium Nitrate Prill Tower Fan #2	362366	5968096	623	36.1	1.8	17.0	304.0	0.0159			
Ammonium Nitrate Prill Tower Fan #3	362366	5968094	623	36.1	1.8	17.0	304.0				0.0121
Ammonium Nitrate Prill Tower Fan #4	362366	5968092	623	36.1	1.8	17.0	304.0				0.0121
Ammonium Nitrate Prill Tower Fan #5	362364	5968092	623	36.1	1.8	17.0	304.0				0.0121
Ammonium Nitrate Prill Tower Fan #6	362362	5968092	623	36.1	1.8	17.0	304.0				0.0121
Ammonium Nitrate Prill Tower Fan #7	362362	5968094	623	36.1	1.8	17.0	304.0				0.0121
Ammonium Nitrate Prill Tower Fan #8	362362	5968096	622	36.1	1.8	17.0	304.0				0.0121
Ammonium Nitrate Process Vent	362357	5968100	622	42.7	1.4	19.7	331.0				0.0180
Boiler 1	362529	5968090	623	19.0	1.2	1.0	408.0		0.0024	0.0176	
Boiler 2	362541	5968090	623	19.0	1.2	1.0	408.0		0.0024	0.0155	
Boiler 3	362551	5968090	623	18.0	1.5	1.0	393.0		0.0140	0.0617	0.0014
CGT-902 Compressor	362418	5967855	626	25.9	3.2	2.5	810.0		0.0460	0.0378	
Dryer Scrubber East Stack	362375	5968320	624	35.1	2.7	12.6	325.0		0.0290		0.0054
Dryer Scrubber West Stack	362329	5968302	626	35.1	2.1	8.0	330.0		0.0190		0.0048
Nitric Acid Tail Gas Stack	362340	5968040	624	45.4	1.2	24.9	442.0		0.1200	0.0157	
Phosphoric Acid South Filter L-602 Scrubber Stack	362502	5968397	624	28.7	1.2	18.0	300.0				0.0220
Phosphoric Acid Attack Tank Scrubber Stack	362502	5968339	625	28.7	1.1	8.0	305.0				0.0180
Phosphoric Acid Filter Scrubber Stack	362499	5968312	626	28.7	1.2	14.1	301.0				0.0180
Phosphoric Acid Granulation East Baghouse	362361	5968323	625	30.5	1.0	9.5	345.0			0.0283	0.0259
Phosphoric Acid Granulation West Baghouse	362343	5968323	626	30.5	1.0	6.0	345.0			0.0131	0.0259
Reactor/Granulator Scrubber East Stack	362372	5968321	624	30.5	1.5	13.1	352.0				0.0018
Reactor/Granulator Scrubber West Stack	362328	5968320	626	30.5	1.5	19.5	341.0				0.0030
Sulphuric Acid Tail Gas Stack #1	362551	5968342	625	76.2	2.3	13.2	346.0	4.0700			0.0246
Sulphuric Acid Tail Gas Stack #2	362553	5968290	625	45.1	2.1	6.6	341.0	0.0360	0.0184		0.0272
Urea D-419 Relief Vent	362332	5967920	623	55.0	0.9	6.0	422.0				

Company/Facility/Unit	UTM E (m)	UTM N (m)	Elevation (m ASL)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (K)	SO$_2$ (t/d)	NO$_X$ (t/d)	CO (t/d)	PM$_{2.5}$ (t/d)
Urea Granulation Scrubber Stack	362346	5967879	624	54.9	3.5	12.8	316.0				0.0660
Urea Process Scrubber Vent	362332	5967921	623	55.0	0.3	20.3	325.0				
Utilities Ammonia Flare	362706	5967896	620	15.2	0.3	5.0	1273.0		0.0048	0.0041	
Sum: Agrium-Redwater Fertilizer Operations								**4.1299**	**5.1060**	**1.2613**	**0.3847**
Sum: Agrium-Redwater Fertilizer Operations (short term) (4.07+3.58=7.66 t/d)								**7.6580**	**5.1060**	**1.2613**	**0.3847**
Auxiliary Boiler Exhaust Stack	362952	5963270	622	22.9	1.8	24.1	468.0		0.0384	0.0384	0.0021
Gas Turbine/HRSG Exhaust Stack	362942	5963258	622	32.3	5.6	16.6	438.0		0.4274	0.1092	0.0133
Sum: Air Liquide-Scotford Complex								**0.0000**	**0.4658**	**0.1476**	**0.0154**
#1 Fieldgate Treater V105	363439	5980298	615	8.7	0.6	6.8	753.2		0.0074	0.0100	0.0010
Compressor K50RAh	363446	5980252	615	10.0	0.3	57.2	919.0		0.8986	0.5200	0.0080
Compressor K50RBh	363434	5980252	615	10.0	0.3	57.2	919.0		0.8986	0.5200	0.0080
Compressor K8R	363472	5980265	615	10.0	0.2	48.0	844.0		0.3620	0.3610	0.0040
Compressor K9R	363460	5980265	615	6.6	0.2	48.0	844.0		0.3620	0.3760	0.0040
Glycol Tracing Boiler F91R	363467	5980173	616	5.1	0.5	1.1	693.0		0.0008		
Heating & Bent Boiler F92R l	363489	5980175	615	4.6	0.5	10.0	693.0		0.0083	0.0100	0.0010
Hot Oil Heater F90R	363464	5980181	616	21.2	1.5	4.2	633.0		0.0344	0.0300	0.0020
Incinerator Stack	363470	5980160	616	45.7	0.9	5.1	719.0	0.8001	0.0039	0.0020	
Sum: ARC Resources-Redwater Gas Conversation Plant								**0.8001**	**2.5759**	**1.8290**	**0.0280**
Regenerator Gas Heater (466 kW)	355890	5953580	622	7.2	0.4	3.2	876.0		0.0106	0.0020	0.0008
Glycol Heater (170 kW)	355830	5953605	622	4.9	0.4	3.1	529.0		0.0067	0.0010	0.0005
Continuous Flare	355910	5953600	622	30.1	0.4	0.1	1273.0	0.0070			
Sum: ATCO Midstream Ltd.- Fort Sask. Sour Gas Plant								**0.0070**	**0.0174**	**0.0030**	**0.0013**
Heat Medium Heater (14 MMBtu/h)	359370	5960305	631	4.6	0.6	8.3	406.0		0.0590	0.0497	0.0040
Heat Medium Heater (14 MMBtu/h)	359370	5960310	631	4.6	0.6	8.3	406.0		0.0590	0.0497	0.0040
Heat Medium Heater (14 MMBtu/h)	359370	5960315	631	4.6	0.6	8.3	406.0		0.0590	0.0497	0.0040
Sum: Aux Sable Canada Ltd.-Heartland Offgas Project								**0.0000**	**0.1770**	**0.1490**	**0.0120**
Heartland Upgrader Main Stack	365239	5965736	626	100.0	5.0	16.0	423.0	19.4400	4.6656	1.5600	0.4700
Sum: BA Energy-Heartland Bitumen Upgrader								**19.4400**	**4.6656**	**1.5600**	**0.4700**
CORP Acid Gas Incinerator	357733	5959215	623	27.4	0.6	12.0	863.0	0.0845			
PSU Acid Gas Incinerator	357729	5959066	627	27.4	0.6	12.0	863.0	0.0449			
Debutanizer Hot Oil Heater Exhaust Debut 1	357706	5959011	627	24.0	1.4	3.3	491.0		0.0390	0.0329	0.0007
Depropanizer Hot Oil Heater Depropanizer	357629	5959017	625	44.7	2.1	3.1	453.0		0.1140	0.0957	0.0021
Glycol Heater Exhaust CORP	357526	5959023	623	17.3	1.2	1.5	653.0		0.0233	0.0196	0.0004
Glycol Heater Exhaust CORP	357632	5959097	623	18.0	1.2	4.0	553.0		0.0143	0.0120	0.0003
Hot Oil Heater Exhaust Debut 2	357529	5959110	620	28.2	1.8	4.4	463.0		0.0781	0.0658	0.0015
Other Heaters/Boilrs	357611	5959130	621	17.3	1.2	1.5	653.0		0.0233	0.0196	0.0004
Regeneration Gas Heater H-62	357590	5959069	623	9.1	0.4	1.5	493.0		0.0021	0.0018	0.0000
Sum: BP Canada-Fort Sask. Storage and Fractionation								**0.1294**	**0.2941**	**0.2474**	**0.0055**

Company/Facility/Unit	UTM E (m)	UTM N (m)	Elevation (m ASL)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (K)	SO_2 (t/d)	NO_X (t/d)	CO (t/d)	$PM_{2.5}$ (t/d)
Sum: BP Canada-Fort Sask. Storage and Fractionation (Short Term)								**1.0410**	**0.2941**	**0.2474**	**0.0055**
Baghouse#1(W)	376045	5962135	645	20.4	0.1	3.0	313.0				
Baghouse#2(E)	376053	5962135	646	20.4	0.1	4.6	313.0				
Boiler Exhaust Vent	376025	5962106	645	9.0	0.6	4.1	467.0	0.0000	0.0102	0.0030	0.0001
Dust Scrubber Vent	376041	5962083	645	23.5	0.5	20.0	313.0				0.0155
Flare	375822	5962070	644	18.3	0.1	20.0	1273.0				
HCL Storage Tank Scrubber	376045	5962083	645	23.5	0.2	1.9	313.0				
Hydrogen vent	376043	5962068	645	23.5	0.2	48.3	313.0		0.0278		
Retention tank fume scrubber	376057	5962069	645	11.3	0.1	2.6	313.0				
Salt hopper baghouse	376037	5962135	645	20.4	0.1	2.6	313.0				
Vaculoader#1 (W)	376047	5962143	645	10.7	0.1	23.0	313.0				
Vaculoader#2 (E)	376054	5962143	646	10.7	0.1	25.7	313.0				
Sum: Canexus Ltd. Partnership-Bruderheim								**0.0000**	**0.0380**	**0.0030**	**0.0156**
Boiler 1 Stack	359779	5967407	631	18.3	0.6	12.6	449.0	0.0002	0.0248	0.0100	0.0010
Boiler 2 Stack	359750	5967431	631	10.0	0.9	6.7	489.0	0.0001	0.0208	0.0170	0.0010
Hydrogen Plant Stack	359818	5967432	630	21.1	0.8	13.3	455.0	0.0001	0.0124	0.0210	0.0020
Sum: Degussa-Gibbons Hydrogen Peroxide								**0.0004**	**0.0580**	**0.0480**	**0.0040**
Brine Degas Incinerator	360242	5957340	628	20.4	1.2	3.0	1033.0	0.0000	0.0163	0.0300	
CO2 Incinerator	358773	5957339	627	22.9	1.4	8.6	1073.0	0.1100	0.0102	0.0340	0.0500
Ethylene Cracking Furnace #1	359035	5957312	637	40.0	1.8	11.0	394.0	0.0015	0.2536	0.0270	0.0200
Ethylene Cracking Furnace #10	359144	5957371	636	40.0	1.8	11.0	394.0	0.0015	0.2531	0.0270	0.0200
Ethylene Cracking Furnace #11	359157	5957378	635	40.0	1.8	11.0	394.0	0.0016	0.2630	0.0270	0.0200
Ethylene Cracking Furnace #2	359041	5957315	637	40.0	1.8	11.0	394.0	0.0015	0.2407	0.0270	0.0200
Ethylene Cracking Furnace #3	359060	5957325	638	40.0	1.8	11.0	394.0	0.0015	0.2407	0.0270	0.0200
Ethylene Cracking Furnace #4	359067	5957328	639	40.0	1.8	11.0	394.0	0.0014	0.2328	0.0270	0.0200
Ethylene Cracking Furnace #5	359086	5957338	639	40.0	1.8	11.0	394.0	0.0014	0.2357	0.0270	0.0200
Ethylene Cracking Furnace #6	359092	5957340	640	40.0	1.8	11.0	394.0	0.0015	0.2419	0.0270	0.0200
Ethylene Cracking Furnace #7	359105	5957352	639	40.0	1.8	11.0	394.0	0.0016	0.2628	0.0270	0.0200
Ethylene Cracking Furnace #8	359118	5957359	638	40.0	1.8	11.0	394.0	0.0014	0.2335	0.0270	0.0200
Ethylene Cracking Furnace #9	359131	5957365	637	40.0	1.8	11.0	394.0	0.0016	0.2538	0.0270	0.0200
Fractionator Flare (intermittent)				59.5	2.6			0.0002	0.0229		
HCS Wells Dowtherm Furnace	357602	5957168	626	14.5	0.8	2.2	603.0	0.0000	0.0126		
LHC Cooling Towers	359176	5957925	629	20.4	19.8	10.7	295.0				0.0200
LHC Flare (intermittent)				74.7	1.2				0.0945		
Loading Incinerator	358910	5957030	626	17.1	1.9	1.0	1173.0		0.0043	0.0020	0.0100
New furnace	357314	5955731	629	45.0	1.5	8.2	493.0	0.0004	0.0767	0.0680	0.0200
NGL Dryer Regen Heater (intermittent)				20.4	0.8	1.3	508.0		0.0007		
Package Boilers #1	359071	5957416	632	15.2	2.1	3.8	453.0	0.0005	0.0762	0.0180	0.0100

Company/Facility/Unit	UTM E (m)	UTM N (m)	Elevation (m ASL)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (K)	SO_2 (t/d)	NO_X (t/d)	CO (t/d)	$PM_{2.5}$ (t/d)
Package Boilers #2	359081	5957397	634	15.2	2.1	3.8	453.0	0.0002	0.0356	0.0180	0.0100
Poly Flare (intermittent)	357267	5955950	626	42.7	0.9	34.0	1003.0	0.0000	0.0101	0.0080	
Polyethylene Expansion Furnace	357321	5955766	630	48.0	1.5	7.1	493.0	0.0003	0.0877	0.0580	0.0200
Polyethylene Furnace	357297	5955769	630	32.0	1.1	7.9	493.0	0.0002	0.0584	0.0360	0.0100
Power and Utilities Gas Turbine and Heat Recovery Unit #1	356676	5956358	627	30.5	4.6	18.7	392.0	0.0023	0.9184	2.8385	0.2400
Power and Utilities Gas Turbine and Heat Recovery Unit #2	356690	5956330	627	30.5	4.6	18.7	392.0	0.0035	1.3724	2.8385	0.2400
Spent Caustic Incinerator	359092	5957374	636	40.0	0.6	12.3	356.0	0.0001	0.0111	0.0100	0.0200
Tank Vent Incinerator	359307	5957338	630	17.1	1.3	3.1	1173.0		0.0073	0.0070	0.0200
Wells Flare (intermittent)				30.5	1.4				0.0013		
Sum: DOW Chemical-Fort Sask. Chemical Plant								**0.1342**	**5.5283**	**6.2630**	**0.8900**
Boiler Exhaust Vent	375474	5963118	634	13.5	0.9	14.1	472.0		0.0116	0.0098	0.0010
Scrubber Vent 1 (horizontal)	375490	5963086	634	12.0	0.8	1.0	310.0				
Scrubber Vent 2 (horizontal)	375496	5963104	634	17.8	0.8	1.0	311.0				
Silo Baghouse A	375490	5963088	634	27.0	0.3	1.6	313.0				
Sum: ERCO Worldwide-Bruderheim Sodium Chlorate Plant								**0.0000**	**0.0116**	**0.0098**	**0.0010**
BO-10.01 Napanee	357322	5957632	630	6.7	0.3	35.8	653.0		0.0080	0.0010	0.0010
HR-15.01 Maloney Steel Craft Ltd.	357373	5957640	631	6.1	0.9	35.3	603.0		0.0040		
HR-15.02 Born Engineering Co.	357331	5957706	631	41.1	1.9	15.0	421.0	2.4000	0.2080	0.0150	0.0140
PM-18.03 Solar Turbine	357380	5957660	631	6.1	0.9	43.3	593.0		0.1230	0.0020	0.0020
PM-18.04 Solar Turbine	357390	5957660	631	6.1	0.9	43.3	593.0		0.1230	0.0020	0.0020
PM-18.05 Solar Turbine	357400	5957660	631	6.1	0.9	43.3	593.0		0.1230	0.0020	0.0020
PM-18.14 Solar Turbine	357370	5957660	631	6.1	0.9	43.3	593.0		0.1230	0.0020	0.0020
PM-18.17 Solar Turbine	357410	5957660	631	6.1	0.9	43.3	593.0		0.1230	0.0020	0.0020
Sum: Keyera Energy-Fort Sask. Plant								**2.4000**	**0.8350**	**0.0260**	**0.0250**
Waste Gas Incinerator Stack	356423	5954300	622	64.0	1.1	3.4	597.0	0.6420	0.0040	0.0030	0.0002
Sum: Malsulex-Fort Sask. Sulphides								**0.6420**	**0.0040**	**0.0030**	**0.0002**
Cleaver Brooks Boiler	362927	5980096	621	4.9	0.5	7.1	523.0		0.0100	0.0085	0.0010
Volcano Boiler	362927	5980101	621	4.6	0.5	4.3	523.0		0.0100	0.0085	0.0010
Sum: NewAlta-Redwater Disposal Facility								**0.0000**	**0.0200**	**0.0170**	**0.0020**
Regeration Thermal Oxidizer	353129	5957717	642	12.2	0.6	2.6	567.0	0.0818	0.0034	0.0500	
Sum: Prospec Chemicals-Fort Sask. Plant								**0.0818**	**0.0034**	**0.0500**	**0.0000**
Brine Return Pond Flaring System	359566	5965074	636	2.0	6.0	0.1	300.0		0.0000		0.0000
Ethane/Propane Gas Heater 2	359690	5965193	638	9.5	0.8	3.8	725.0	0.0004	0.0073	0.0060	0.0006
Ethane/Propane Gas Heater 1 Intermittent	359690	5965197	638	9.5	0.8	0.1	725.0	0.0004	0.0073		0.0006
General Plant Operations Flare	359719	5965116	642	54.9	1.8	3.9	1273.0	0.0034	0.0552	0.0460	0.0042
Glycol Regen Heater	359691	5965224	636	14.6	0.5	0.1	725.0	0.0000	0.0020	0.0020	0.0001
Heat Medium Heater - Intermittent	359717	5965223	636	38.0	3.5	3.9	423.0	0.7100	0.1728		0.0130

Company/Facility/Unit	UTM E (m)	UTM N (m)	Elevation (m ASL)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (K)	SO_2 (t/d)	NO_X (t/d)	CO (t/d)	$PM_{2.5}$ (t/d)
Propane Regen Gas Heater	359696	5965206	637	9.4	0.6	3.9	725.0	0.0000	0.0044	0.0040	0.0004
Regen Gas Heater ROF	359717	5965210	637	9.1	0.8	3.0	985.0	0.0000	0.0039		0.0003
Sum: Provident Energy-Redwater Fractionation								**0.7143**	**0.2530**	**0.0580**	**0.0191**
6-26-56-21 W4M	367521	5970791	617	14.0	0.7	1.9	1032.0	0.2680			
Pump Station JACO Amelia7-12-57-21 W4M	369807	5975287	626	9.8	0.2	0.9	1033.0	0.0050			
Pump Station JACO Redwater 8-36-57-21 W4M	360277	5982385	622	9.8	0.2	0.2	869.0	0.0010			
Sum: Redwater Water Disposal Company								**0.2740**	**0.0000**	**0.0000**	**0.0000**
Atmospheric Column Feed Heater	361685	5963365	619	66.0	2.0	20.5	475.0	0.0370	0.5860	0.5600	0.0510
Vacuum Column Feed Heater	361675	5963300	617	68.0	1.5	19.8	475.0	0.0280	0.4350	0.4160	0.0380
RHC Heaters (common stack)	361655	5963120	617	65.0	1.8	15.2	566.0	0.0160	0.1500	0.2410	0.0220
HMU Steam Reformer Stack	361995	5962830	623	50.0	4.0	10.0	428.0	0.0720	1.1300	1.0800	0.0980
SRU Tail Gas Incinerator Stack	361725	5962940	617	90.0	3.0	18.0	673.0	21.8400	0.5100	0.1420	0.0130
Vapour Combustion Unit (VCU)	361162	5962805	620	12.0	2.0	0.3	1253.0		0.0180	0.0250	0.0020
Acid Gas Flare	361559	5962730	620	90.5	6.3	1.0	1273.0	0.8690	0.0400	0.2160	0.0040
Hydrocarbon Flare	361779	5963507	619	85.0	7.9	1.7	1273.0	2.4980	0.1100	0.5960	0.0120
RHC 223 Heaters (common stack)	361655	5963010	614	65.0	1.8	15.2	566.0	0.0160	0.1500	0.2410	0.0220
Train #2 Steam Reformer Stack	362035	5962940	621	50.0	4.0	10.0	428.0	0.0720	1.1300	1.0800	0.0980
Stage 2 Hydrocarbon Flare	361779	5963523	619	77.1	14.6	0.004	1273.0		0.0010	0.0040	
Cogeneration Unit Stack	362043	5963024	623	38.1	4.6	25.3	419.0	0.1310	1.9690	0.9060	0.1780
AHS SDA Vacuum Heater	361575	5963430	620	38.1	2.0	20.6	422.0	0.0110	0.1640	0.1710	0.0150
AHS SDA Hot Oil Heater	361575	5963530	619	40.5	1.6	20.9	422.0	0.0080	0.1110	0.1160	0.0100
Atmospheric Column Feed Heater	361775	5964030	620	66.0	2.0	20.5	473.0	0.0366	0.2651	0.2605	0.0236
Vacuum Column Feed Heater	361825	5964080	620	68.0	1.5	19.8	478.0	0.0106	0.1662	0.1588	0.0144
RHC Heaters (common stack)	361775	5963880	619	65.0	1.8	15.2	688.0	0.0112	0.1052	0.1686	0.0153
HMU Steam Reformer Stack	362025	5963880	618	50.0	4.0	13.8	428.0	0.0990	1.4300	1.4898	0.1348
SRU Tail Gas Incinerator Stack	361675	5963680	620	90.0	2.4	15.2	843.0	2.4720	0.0924	0.0385	0.0035
Vapour Combustion Unit (VCU)	361485	5964030	614	19.8	1.2	0.3	1253.0	0.0001	0.0167	0.0229	0.0021
Package Steam Boiler	361977	5963705	619	45.0	1.8	10.7	423.0	0.0269	0.3881	0.4043	0.0366
Acid Gas Flare	361698	5963664	620	93.3	6.3	0.3	1273.0	0.7830	0.0330	0.1800	0.0040
Hydrocarbon Flare	362045	5964100	618	100.6	12.6	0.3	1273.0	2.2510	0.0990	0.5390	0.0130
SDA Hot Oil Heater	361545	5963710	620	40.5	1.6	20.9	478.0	0.0108	0.1648	0.1376	0.0125
Sum: Shell- Scotford Bitumen Upgrader - Base Plant+SE1								**31.2990**	**9.2645**	**9.1941**	**0.8226**
Boiler HB 301A	362723	5963831	620	30.5	1.9	6.4	378.0	0.0010	0.1850	0.1250	0.0630
Boiler HB-301B	362723	5963799	621	30.5	1.9	6.1	378.0	0.0010	0.0550	0.0920	0.0080
Boiler HB-301C	362723	5963815	621	30.5	1.9	6.4	378.0	0.0010	0.1850	0.1250	0.0630
CO2 Stripper Vent	362690	5963489	628	54.4	0.5	8.2	313.0			0.0001	
Reactor Feed Heater HS-101	362806	5963774	623	62.2	1.6	4.3	463.0		0.1490	0.0990	0.0120
Recovery Column Reboiler HS 103/4/5	362923	5963799	623	76.2	1.7	11.2	413.0	0.0010	0.2110	0.1630	0.0150

Company/Facility/Unit	**UTM E (m)**	**UTM N (m)**	**Elevation (m ASL)**	**Stack Height (m)**	**Stack Diameter (m)**	**Exit Velocity (m/s)**	**Exit Temp (K)**	**SO_2 (t/d)**	**NO_X (t/d)**	**CO (t/d)**	**$PM_{2.5}$ (t/d)**
Regeneration Heater HS-102	362806	5963784	623	30.6	0.5	3.4	823.0		0.0030	0.0050	
Steam Superheaters HS-201 and HS-219	362816	5963734	625	78.0	2.7	5.0	473.0		0.6440	0.4030	0.0360
Sum: Shell- Scotford Chemical Plant								**0.0040**	**1.4320**	**1.0121**	**0.1970**
Boiler House (H-5101A/B)	362165	5962447	622	45.7	1.2	20.8	423.0	0.0143	0.2151	0.1090	0.0135
Continuous Catalytic Reformer (H-3201/02/03/04B/04C)	361735	5962437	627	46.0	1.4	36.9	423.0	0.0349	0.7880	0.5790	0.1331
Continuous Flare	361642	5962862	620	62.4	8.7	0.1	1273.0		0.0018		
Crude Distillation (H-1101)	362000	5962574	623	45.7	1.4	18.5	413.0	0.0172	0.2264	0.1142	0.0143
DHT Heater (H-2001)	361980	5962633	624	45.7	0.8	15.0	678.0	0.0026	0.0128	0.0043	0.0017
Distillate Hydrogeneration (H-2501)	361944	5962632	624	45.7	0.5	15.4	573.0	0.0013	0.0067	0.0015	0.0083
Hot Oil Heater (H-1501)	361907	5962571	625	45.7	1.1	11.2	423.0	0.0060	0.0422	0.0214	0.0027
Hydrocracker 1 (H-2201/02)	361742	5962835	623	45.7	0.9	15.6	423.0	0.0060	0.0499	0.0311	0.0586
Hydrocracker 2 (H-2301/02)	361740	5962755	625	45.7	0.9	15.6	423.0	0.0060	0.0499	0.0311	0.0586
Hydrocracker Fractionation (H-2401/02)	361736	5962686	625	45.7	1.3	16.5	413.0	0.0130	0.2100	0.1548	0.0355
Hydroealylation (H-4201A/B)	362036	5962406	625	45.7	0.9	18.4	423.0	0.0063	0.0365	0.0268	0.0061
Naphtha Hydrotreater (H-3101)	361812	5962408	632	45.7	0.7	20.0	640.0	0.0029	0.0228	0.0057	0.0023
Steam/Methane Reformer Hydrogen Plant (H-2101/02)	362020	5962810	625	45.7	2.8	20.8	433.0	0.0063	1.0714	0.1183	0.0148
Sum: Shell-Scotford Oil Refinery								**0.1168**	**2.7336**	**1.1970**	**0.3496**
Ammonia 1 Unit – Primary Reformer Exhaust Stack	355426	5954754	621	21.0	1.7	10.2	445.0	0.0005	0.1501	0.0847	0.0020
Ammonia Storage Flare	355419	5954935	621	27.4	0.2	0.2	1273.0		1.0800		
Ammonia Unit Clark Natural Gas Compressor Engine #2	355502	5954833	622	11.0	0.5	25.1	673.0	0.0001	0.7873	0.0399	0.0010
Ammonia Unit Clark Natural Gas Compressor Engine #3	355490	5954841	622	11.0	0.5	25.1	673.0	0.0001	0.7873	0.0399	0.0010
Ammonia Unit Clark Natural Gas Compressor Engine #4	355477	5954848	622	11.0	0.5	25.1	673.0	0.0001	0.7873	0.0399	0.0010
Ammonia Unit Clark Natural Gas Compressor Engine #5	355464	5954856	621	11.0	0.5	13.1	673.0	0.0001	0.7873	0.0399	0.0010
Ammonia Unit Clark Natural Gas Compressor Engine #6	355452	5954864	621	13.0	0.6	23.8	673.0	0.0001	0.7873	0.0399	0.0010
Ammonia Unit Flare Stack	355356	5954958	620	18.3	0.4	0.04	1273.0		0.8091		
Ammonium Sulphate Unit – Dryer Scrubber Tank Exhaust	355559	5954625	623	18.2	0.6	19.8	311.0	0.0000	0.0045	0.0009	0.0045
Cobalt Reduction Autoclave Flash Tanks Condenser Vent	355666	5954681	624	25.0	0.3	1.5	353.0				
Cobalt Separation Scrubber Stack	355654	5954712	624	40.0	0.3	30.1	287.0				
Cobalt Sintering Furnaces (former coinage)	355366	5954673	622	11.6	0.4	11.5	444.0	0.0001	0.0184	0.0037	0.0006

Company/Facility/Unit	**UTM E (m)**	**UTM N (m)**	**Elevation (m ASL)**	**Stack Height (m)**	**Stack Diameter (m)**	**Exit Velocity (m/s)**	**Exit Temp (K)**	**SO_2 (t/d)**	**NO_X (t/d)**	**CO (t/d)**	**$PM_{2.5}$ (t/d)**
Leach Unit High Pressure Still Bottoms Evaporator Stack	355766	5954755	624	21.3	0.7	32.5	320.0				
Leach Unit Vent Gas Scrubber Stack	355769	5954728	624	16.8	0.3	20.2	299.0				
Nickel Dryer and Sintering Furncae	355730	5954632	625	7.3	0.4	24.7	444.0	0.0002	0.0300	0.0060	0.0009
Nickel Reduction Autoclave Vent Pots	355709	5954604	626	17.0	0.4	0.9	322.0				
Oxy/Reduction Flash Tank Exhaust Vents (3 sources)	355719	5954593	627	18.3	0.9	7.2	376.0				
Phosphate Granulation Common Stack	355753	5954476	628	30.5	1.9	11.7	322.0	0.0001	0.0180	0.0035	0.0080
Phosphoric Acid Unit – Teller Scrubber Stack	355795	5954534	626	36.9	0.7	8.2	299.0	0.0277			0.0004
Powerhouse Boiler #1	355556	5954741	622	23.0	2.1	2.5	444.0	0.0012	0.6592	0.1454	0.0033
Powerhouse Boiler #2	355550	5954730	622	23.0	2.1	2.5	444.0	0.0012	0.9558	0.1457	0.0033
Powerhouse Boiler #3	355596	5954734	623	19.0	1.2	15.2	432.0	0.0001	0.0011	0.0013	0.0000
Powerhouse Clark Comperssor Engine Exhaust Stack	355570	5954710	623	8.3	0.3	0.4	673.0	0.0004	0.0040	0.0006	0.0000
Proposed Cobalt Reduction #3 Autoclave Condenser Stack	355655	5954660	624	25.0	0.3	1.5	353.0				
Sulphide Precipitation Unit – H2S Scrubber Flare Stack	355616	5954665	624	26.7	0.2	42.4	1273.0	0.0024			
Sulphuric Acid Unit – Tail Gas Stack	355767	5954573	626	61.0	1.5	12.4	350.0	0.8702			
Sum: Sherritt International Corp. - Fort Sask.								**0.9044**	**7.6667**	**0.5913**	**0.0280**
Turbine Exhaust	356690	5956376	626	32.3	4.6	20.2	391.0	0.0300	0.2900	0.2600	0.0200
Sum: TransAlta-Fort Sask. Cogeneration								**0.0300**	**0.2900**	**0.2600**	**0.0200**
Cogeneration unit #1	359928	5965167	635	30.0	3.0	28.0	443.0		0.3451	0.1200	0.0100
Sum: TransCanada-Redwater Power Plant								**0.0000**	**0.3451**	**0.1200**	**0.0100**
Dust Collector (Nickel)	355502	5954813	622	3.7	0.4	6.5	285.0				0.0300
Sum: Umicore Canada Inc-Fort Sask. Production								**0.0000**	**0.0000**	**0.0000**	**0.0300**
Baseline Case Emission								**61.1**	**45.0**	**24.7**	**3.35**
Baseline Case Emission (Short Term)								**65.5**	**45.0**	**24.7**	**3.35**

Table 2A-84 Detailed Stack and Emission Parameters for the Additional Cumulative Case Stack Emissions

Company/Facility/Unit	UTM E (m)	UTM N (m)	Elevation (m ASL)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (K)	SO_2 (t/d)	NO_X (t/d)	CO (t/d)	$PM_{2.5}$ (t/d)
Heater	359430	5960300	630	6.0	0.8	8.3	406.0		0.2800	0.2350	0.0190
Heater	359430	5960305	630	6.0	0.8	8.3	406.0		0.2800	0.2350	0.0190
Heater	359430	5960310	630	6.0	0.8	8.3	406.0		0.2800	0.2350	0.0190
Heater	359430	5960315	630	6.0	0.8	8.3	406.0		0.2800	0.2350	0.0190
Heater	359380	5959900	629	6.0	0.8	8.3	406.0		0.3830	0.3225	0.0260
Heater	359380	5959905	629	6.0	0.8	8.3	406.0		0.3830	0.3225	0.0260
Heater	359370	5959500	635	20.0	1.5	8.3	406.0		0.1505	0.1265	0.0100
Heater	359370	5959505	635	20.0	1.5	8.3	406.0		0.1505	0.1265	0.0100
Sum: Aux Sable Canada Ltd.-Confidential Project No. 3								**0.0000**	**2.1870**	**1.8380**	**0.1480**
ACU Heater	360267	5968444	631	51.0	2.2	10.0	473.0	0.0028	0.1817	0.0866	0.0137
VCU Heater	360330	5968442	630	35.0	1.4	10.0	473.2	0.0011	0.0516	0.0344	0.0054
10-20-HF-0001	360247	5968365	630	44.0	1.5	10.0	443.2	0.0014	0.0910	0.0434	0.0068
10-20-HF-0002	360246	5968316	631	13.4	0.7	10.0	443.2	0.0003	0.0163	0.0108	0.0017
10-20-HF-0004	360243	5968227	631	20.0	1.0	10.0	443.2	0.0006	0.0290	0.0193	0.0030
UOP HCK Heater	360611	5968348	628	22.6	0.9	10.0	420.2	0.0006	0.0264	0.0176	0.0028
UOP HT HTR	360609	5968300	628	22.6	0.9	10.0	420.2	0.0006	0.0280	0.0187	0.0030
Steam Boiler	360239	5968098	631	60.0	2.9	10.0	551.2	0.0042	0.2788	0.1329	0.0210
SRU Incinerator	360296	5968509	631	85.0	1.4	32.0	983.2	5.8884	0.0001	5.4864	0.0016
ACU Heater	360855	5968426	630	51.0	2.2	10.0	473.2	0.0028	0.1817	0.0866	0.0137
VCU Heater	360918	5968424	631	35.0	1.4	10.0	473.2	0.0011	0.0516	0.0344	0.0054
10-20-HF-0001	360706	5968351	628	44.0	1.5	10.0	443.0	0.0014	0.0910	0.0434	0.0068
10-20-HF-0002	360704	5968302	628	13.4	0.7	10.0	443.2	0.0003	0.0163	0.0108	0.0017
10-20-HF-0004	360702	5968213	628	20.0	1.0	10.0	443.2	0.0006	0.0290	0.0193	0.0030
UOP HCK Heater	361070	5968334	631	22.6	0.9	10.0	420.2	0.0006	0.0264	0.0176	0.0028
UOP HT HTR	361068	5968285	630	22.6	0.9	10.0	420.2	0.0006	0.0280	0.0187	0.0030
Steam Boiler	360697	5968075	629	60.0	2.9	10.0	551.2	0.0042	0.2788	0.1329	0.0210
SRU Incinerator	360859	5968492	630	85.0	2.0	32.0	983.2	11.7768	0.0002	10.9729	0.0033
ACU Heater	361250	5968413	630	51.0	2.2	10.0	473.0	0.0028	0.1817	0.0866	0.0137
VCU Heater	361313	5968411	629	35.0	1.4	10.0	473.0	0.0011	0.0516	0.0344	0.0054
10-20-HF-0001	361165	5968336	631	44.0	1.5	10.0	443.0	0.0014	0.0910	0.0434	0.0068
10-20-HF-0002	361163	5968287	630	13.4	0.7	10.0	443.0	0.0003	0.0163	0.0108	0.0017
10-20-HF-0004	361161	5968198	629	20.0	1.0	10.0	443.0	0.0006	0.0290	0.0193	0.0030
UOP HCK Heater	361529	5968320	628	22.6	0.9	10.0	420.0	0.0006	0.0264	0.0176	0.0028
UOP HT HTR	361527	5968271	627	22.6	0.9	10.0	420.0	0.0006	0.0280	0.0187	0.0030
Steam Boiler	361156	5968065	629	60.0	2.9	10.0	551.0	0.0042	0.2788	0.1329	0.0210

Company/Facility/Unit	UTM E (m)	UTM N (m)	Elevation (m ASL)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (K)	SO_2 (t/d)	NO_X (t/d)	CO (t/d)	$PM_{2.5}$ (t/d)
Sum: North West Upgrading								**17.7000**	**2.1090**	**17.5507**	**0.1769**
Sum: North West Upgrading (short term)								**19.5510**	**2.1090**	**17.5507**	**0.1769**
Atmospheric Column Feed Heater	361685	5963365	619	66.0	2.0	20.5	475.0	0.0370	0.5860	0.5600	0.0510
Vacuum Column Feed Heater	361675	5963300	617	68.0	1.5	19.8	475.0	0.0280	0.4350	0.4160	0.0380
RHC Heaters (common stack)	361655	5963120	617	65.0	1.8	15.2	566.0	0.0160	0.1500	0.2410	0.0220
HMU Steam Reformer Stack	361995	5962830	623	50.0	4.0	10.0	428.0	0.0720	2.0910	1.0800	0.0980
SRU Tail Gas Incinerator Stack	361725	5962940	617	90.0	3.0	18.0	673.0	15.8400	0.5100	0.1420	0.0130
Vapour Combustion Unit (VCU)	361162	5962805	620	12.0	2.0	0.3	1253		0.0180	0.0250	0.0020
Acid Gas Flare	361559	5962730	620	90.5	6.3	1.0	1273	0.6970	0.0320	0.1770	0.0040
Hydrocarbon Flare	361779	5963507	619	85.0	7.9	1.7	1273	2.0030	0.0890	0.4830	0.0100
RHC 223 Heaters (common stack)	361655	5963010	614	65.0	1.8	15.2	566.0	0.0160	0.1500	0.2410	0.0220
Train #2 Steam Reformer Stack	362035	5962940	621	50.0	4.0	10.0	428.0	0.0720	2.0910	1.0800	0.0980
Stage 2 Hydrocarbon Flare	361779	5963523	619	77.1	14.6	0.0	1273		0.0010	0.0040	
Cogeneration Unit Stack	362043	5963024	623	38.1	4.6	25.3	419.0	0.1310	1.9690	0.9060	0.1780
AHS SDA Vacuum Heater	361575	5963430	620	38.1	2.0	20.6	422.0	0.0110	0.1640	0.1710	0.0150
AHS SDA Hot Oil Heater	361575	5963530	619	40.5	1.6	20.9	422.0	0.0080	0.1110	0.1160	0.0100
Atmospheric Column Feed Heater	361775	5964030	620	66.0	2.0	20.5	473.0	0.0366	0.2651	0.2605	0.0236
Vacuum Column Feed Heater	361825	5964080	620	68.0	1.5	19.8	478.0	0.0106	0.1662	0.1588	0.0144
RHC Heaters (common stack)	361775	5963880	619	65.0	1.8	15.2	688.0	0.0112	0.1052	0.1686	0.0153
HMU Steam Reformer Stack	362025	5963880	618	50.0	4.0	13.8	428.0	0.0990	2.6458	1.4898	0.1348
SRU Tail Gas Incinerator Stack	361675	5963680	620	90.0	2.4	15.2	843.0	2.4720	0.0924	0.0385	0.0035
Vapour Combustion Unit (VCU)	361485	5964030	614	19.8	1.2	0.3	1253	0.0001	0.0167	0.0229	0.0021
Package Steam Boiler	361977	5963705	619	45.0	1.8	10.7	423.0	0.0269	0.3881	0.4043	0.0366
Acid Gas Flare	361698	5963664	620	93.3	6.3	0.3	1273	0.2510	0.0109	0.0593	0.0014
Hydrocarbon Flare	362045	5964100	618	100.6	12.6	0.3	1273	0.7220	0.0344	0.1872	0.0044
SDA Hot Oil Heater	361545	5963710	620	40.5	1.6	20.9	478.0	0.0108	0.1648	0.1376	0.0125
Shell- Scotford Bitumen Upgrader - Base Plant+SE1								**22.5710**	**12.2866**	**8.5696**	**0.8093**
Cogeneration Unit Stack	363750	5965701	624	30.5	1.2	20.0	419.0	0.0141	0.5645	0.1925	0.0472
Backup Boiler	363802	5965701	624	45.0	2.1	10.7	423.0		0.0122	0.0028	0.0010
SDA Flare	364204	5966050	622	97.1	10.1	0.1	1273		0.0040	0.0060	0.0010
SDA	363734	5965373	619	30.5	2.5	20.9	478.0	0.0094	0.3053	0.1832	0.0166
Cogeneration Unit Stack	363750	5965628	622	30.5	1.2	20.0	419.0	0.0141	0.5645	0.1925	0.0472
Backup Boiler	363802	5965628	622	45.0	2.1	10.7	423.0		0.0122	0.0028	0.0010
SDA Flare	364204	5965936	622	96.0	6.3	0.0	1273	0.0001	0.0008	0.0013	0.0001
SDA	364033	5965373	620	30.5	2.5	20.9	478.0	0.0094	0.3053	0.1832	0.0166
Atmospheric Column Feed Heater	363718	5964635	623	66.0	2.0	20.5	473.0	0.0366	0.2651	0.2605	0.0236
Vacuum Column Feed Heater	363788	5964635	623	68.0	1.9	19.8	478.0	0.0158	0.2493	0.2383	0.0216
RHC Heaters (common stack)	364074	5964691	620	65.0	1.8	15.2	688.0	0.0112	0.1052	0.1686	0.0153

Company/Facility/Unit	UTM E (m)	UTM N (m)	Elevation (m ASL)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (K)	SO$_2$ (t/d)	NO$_X$ (t/d)	CO (t/d)	PM$_{2.5}$ (t/d)
HMU Steam Reformer Stack	364266	5964754	620	50.0	4.0	8.1	428.0	0.0582	1.5567	0.8766	0.0793
SRU Tail Gas Incinerator Stack	364391	5964642	620	90.0	2.1	16.7	843.0	2.4720	0.0715	0.0298	0.0027
Vapour Combustion Unit (VCU)	363716	5964524	623	19.8	1.2	0.3	1253	0.0001	0.0167	0.0229	0.0021
Package Steam Boiler	364038	5964955	624	30.5	2.2	10.7	423.0	0.0403	0.5821	0.6064	0.0549
Acid Gas Flare	364391	5964646	620	93.3	6.3	0.3	1273	0.2512	0.0109	0.0593	0.0014
Hydrocarbon Flare	364601	5964671	623	100.6	12.6	0.3	1273	0.7224	0.0344	0.1872	0.0044
Atmospheric Column Feed Heater	363657	5965256	622	66.0	2.0	20.5	473.0	0.0366	0.2651	0.2605	0.0236
Vacuum Column Feed Heater	363587	5965256	622	68.0	1.9	19.8	478.0	0.0158	0.2493	0.2383	0.0216
RHC Heaters (common stack)	363753	5965200	622	65.0	1.8	15.2	688.0	0.0112	0.1052	0.1686	0.0153
HMU Steam Reformer Stack	364155	5965059	625	50.0	4.0	8.1	428.0	0.0582	1.5567	0.8766	0.0793
SRU Tail Gas Incinerator Stack	364379	5965172	626	90.0	2.1	16.7	843.0	2.4720	0.0715	0.0298	0.0027
Vapour Combustion Unit (VCU)	363711	5964524	623	19.8	1.2	0.3	1253	0.0001	0.0167	0.0229	0.0021
Package Steam Boiler	364026	5964955	624	30.5	2.2	10.7	423.0	0.0403	0.5821	0.6064	0.0549
Acid Gas Flare	364379	5965168	626	93.3	6.3	0.3	1273	0.2512	0.0109	0.0593	0.0014
Hydrocarbon Flare	364601	5964906	622	100.6	12.6	0.3	1273	0.7224	0.0344	0.1872	0.0044
Atmospheric Column Feed Heater	363572	5962624	619	66.0	2.0	20.5	473.0	0.0366	0.2651	0.2605	0.0236
Vacuum Column Feed Heater	363572	5962624	619	68.0	1.9	19.8	478.0	0.0158	0.2493	0.2383	0.0216
RHC Heaters (common stack)	363628	5962268	619	65.0	1.8	15.2	688.0	0.0112	0.1052	0.1686	0.0153
HMU Steam Reformer Stack	363691	5962076	620	50.0	4.0	8.1	428.0	0.0582	1.5567	0.8766	0.0793
SRU Tail Gas Incinerator Stack	363578	5961951	621	90.0	2.1	16.7	843.0	2.4720	0.0715	0.0298	0.0027
Vapour Combustion Unit (VCU)	363461	5962629	620	19.8	1.2	0.3	1253	0.0001	0.0167	0.0229	0.0021
Package Steam Boiler	363891	5962304	620	30.5	2.2	10.7	423.0	0.0403	0.5821	0.6064	0.0549
Acid Gas Flare	363582	5961951	621	93.3	6.3	0.3	1273	0.2512	0.0109	0.0593	0.0014
Hydrocarbon Flare	363558	5961741	619	100.6	12.6	0.3	1273	0.7224	0.0344	0.1872	0.0044
Atmospheric Column Feed Heater	364193	5962685	619	66.0	2.0	20.5	473.0	0.0366	0.2651	0.2605	0.0236
Vacuum Column Feed Heater	364193	5962685	619	68.0	1.9	19.8	478.0	0.0158	0.2493	0.2383	0.0216
RHC Heaters (common stack)	364137	5962589	618	65.0	1.8	15.2	688.0	0.0112	0.1052	0.1686	0.0153
HMU Steam Reformer Stack	364146	5962187	620	50.0	4.0	8.1	428.0	0.0582	1.5567	0.8766	0.0793
SRU Tail Gas Incinerator Stack	364108	5961963	623	90.0	2.1	16.7	843.0	2.4720	0.0715	0.0298	0.0027
Vapour Combustion Unit (VCU)	363461	5962634	620	19.8	1.2	0.3	1253	0.0001	0.0167	0.0229	0.0021
Package Steam Boiler	363891	5962314	620	30.5	2.2	10.7	423.0	0.0403	0.5821	0.6064	0.0549
Acid Gas Flare	364104	5961963	623	93.3	6.3	0.3	1273	0.2512	0.0109	0.0593	0.0014
Hydrocarbon Flare	363843	5961741	621	100.6	12.6	0.3	1273	0.7224	0.0344	0.1872	0.0044
SRU Tail Gas Incinerator Stack	363985	5965516	620	90.0	2.1	18.0	843.0	2.1400	0.0358	0.0149	0.0013
Shell- Scotford Bitumen Upgrader - SU 2								**16.6185**	**13.3728**	**10.5777**	**0.9524**
Sum: Shell- Scotford Bitumen Upgrader - Total								**39.1894**	**25.6593**	**19.1473**	**1.7618**
Atmospheric Tower Heater	362731	5972413	628	45.0	2.7	12.0	422.0	0.0500	0.4190	0.4690	0.0420
Vacuum Furnace	362652	5972416	627	45.0	1.8	12.0	422.0	0.0200	0.1730	0.1940	0.0180

Company/Facility/Unit	UTM E (m)	UTM N (m)	Elevation (m ASL)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (K)	SO_2 (t/d)	NO_X (t/d)	CO (t/d)	$PM_{2.5}$ (t/d)
SDA Heater	362662	5972005	627	45.0	2.9	12.0	422.0	0.0550	0.4680	0.5250	0.0470
DAO Feed Heater #1	362923	5972443	629	45.0	1.1	8.0	533.0	0.0040	0.0210	0.0360	0.0030
AGO Gas Heater #1	362941	5972443	629	45.0	1.2	8.0	644.0	0.0040	0.0210	0.0370	0.0030
VGO Recycle Gas Heater #1	362958	5972442	629	45.0	1.1	8.0	700.0	0.0030	0.0170	0.0290	0.0030
DAO Feed Heater #2	362928	5972012	626	45.0	1.1	8.0	533.0	0.0040	0.0210	0.0360	0.0030
AGO Gas Heater #2	362945	5972011	626	45.0	1.2	8.0	644.0	0.0040	0.0210	0.0370	0.0030
VGO Recycle Gas Heater #2	362963	5972011	626	45.0	1.1	8.0	700.0	0.0030	0.0170	0.0290	0.0030
Sulphur Recovery Unit	362814	5972030	626	85.0	4.0	18.0	810.0	28.4070	0.1500	0.1680	0.0150
Auxiliary Boiler #1	362530	5972450	627	30.0	1.0	53.4	448.0	0.0987	0.5943	1.0000	0.0225
Auxiliary Boiler #2	362530	5972430	627	30.0	1.0	53.4	448.0	0.0987	0.5943	1.0000	0.0225
Auxiliary Boiler #3	362530	5972410	627	30.0	1.0	53.4	448.0	0.0987	0.5943	1.0000	0.0225
Sum: Synenco- Northern Lights Upgrader								**28.8501**	**3.1109**	**4.5600**	**0.2075**
Boiler #1 (150 HP)	376945	5962383	634	14.0	0.4	7.5	501.0		0.0090	0.0110	0.0010
Rotoform Stack #1	377035	5962383	635	14.0	0.4	16.7	309.0				0.0090
Rotoform Stack #2	377101	5962359	635	14.0	0.4	16.7	309.0				0.0090
Sum: HAZCO-Bruderheim Sulphur Forming								**0.0000**	**0.0090**	**0.0110**	**0.0190**
1200# Utility Boiler	358186	5968910	631	40.0	0.9	24.0	448.2	0.0084	0.1020	0.0160	0.0020
1200# Utility Boiler	358194	5968909	631	40.0	0.9	24.0	448.2	0.0084	0.1020	0.0160	0.0020
Turbine/HRSG	357702	5968527	634	30.0	4.1	20.0	448.2	0.2324	2.4667	2.2377	0.0870
Turbine/HRSG	357703	5968550	634	30.0	4.1	20.0	448.2	0.2324	2.4667	2.2377	0.0870
Turbine/HRSG	357700	5968491	633	30.0	4.1	20.0	448.2	0.2324	2.4667	2.2377	0.0870
Fractionator Feed Heater (DRU)	357868	5967482	633	35.0	2.0	15.0	448.2	0.0238	0.2880	0.0440	0.0056
Fractionator Feed Heater (DRU #2)	358009	5968593	632	35.0	2.0	15.0	448.2	0.0253	0.3060	0.0470	0.0059
Feed Furnace (VDU)	358041	5968592	631	35.0	2.2	15.0	448.2	0.0307	0.3720	0.0570	0.0072
Coker heater 1	358210	5967626	629	65.0	2.2	11.3	473.2	0.0211	0.2540	0.0390	0.0049
Coker heater 2	358209	5967601	630	65.0	2.2	11.3	473.2	0.0211	0.2540	0.0390	0.0049
Coker heater 3	358208	5967563	630	65.0	2.2	11.3	473.2	0.0211	0.2540	0.0390	0.0049
SMR Furnace	357916	5968024	630	38.0	4.0	15.0	422.2	0.0436	1.6460	0.2000	0.0785
Main NHT Reactor Feed Furnace	357911	5967651	632	35.0	0.7	14.7	448.2	0.0031	0.0250	0.0060	0.0007
Train 1 Reactor Feed Furnace (MGO)	357861	5967783	631	35.0	0.8	14.8	448.2	0.0045	0.0360	0.0080	0.0011
Train 2 Reactor Feed Furnace (MGO)	357846	5967783	632	35.0	0.8	14.8	448.2	0.0045	0.0360	0.0080	0.0011
MGO Stabilizer Feed Furnace	357849	5967842	632	35.0	1.1	14.8	448.2	0.0069	0.0560	0.0130	0.0016
Train 1 Reactor Feed Furnace (HCU)	357883	5968598	633	35.0	1.1	15.0	448.2	0.0075	0.0600	0.0140	0.0017
Train 2 Reactor Feed Furnace (HCU)	357850	5968599	634	35.0	1.1	15.0	448.2	0.0075	0.0600	0.0140	0.0017
Superheater	358404	5968863	630	35.0	1.6	15.0	448.2	0.0133	0.1620	0.0250	0.0032
Hot Oil Heater	358246	5968718	629	35.0	1.9	15.0	448.2	0.0228	0.2760	0.0420	0.0053
Utility Boiler	357860	5968267	631	40.0	2.1	24.0	448.2	0.0450	0.5440	0.0830	0.0105
Utility Boiler	357873	5968266	631	40.0	2.1	24.0	448.2	0.0450	0.5440	0.0830	0.0105

Company/Facility/Unit	UTM E (m)	UTM N (m)	Elevation (m ASL)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (K)	SO_2 (t/d)	NO_X (t/d)	CO (t/d)	$PM_{2.5}$ (t/d)
Utility Boiler	357885	5968266	631	40.0	2.1	24.0	448.2	0.0450	0.5440	0.0830	0.0105
H2S Flare	358670	5968088	631	91.2	7.9	0.0027	1273	0.0013	0.0015	0.0018	0.0000
HP Flare	358662	5967833	634	66.8	13.3	0.0022	1273	0.0029	0.0034	0.0042	0.0001
Phase 2 Flare	358615	5969054	630	62.4	16.7	0.0026	1273	0.0055	0.0064	0.0077	0.0002
LP Flare	358655	5967606	628	118.0	14.8	0.0022	1273	0.0037	0.0043	0.0052	0.0001
South Tank Farm Flare	357588	5965904	639	20.3	1.9	0.0029	1273	0.0001	0.0001	0.0001	0.0000
Thermal oxidizer	358330	5967947	630	90.0	3.0	25.0	811.2	4.5000	0.5199	0.9497	0.0071
Thermal oxidizer	358339	5968148	634	90.0	3.0	25.0	811.2	4.5000	0.5199	0.9497	0.0071
Sum: Petro-Canada Sturgeon Upgrader								**10.1191**	**14.3766**	**9.5073**	**0.4397**
Sum: Petro-Canada Sturgeon Upgrader (Short Term)								**23.7191**	**14.3766**	**9.5073**	**0.4397**
Cumulative Case Emissions								**95.9**	**47.5**	**52.6**	**2.75**
Cumulative Case Emissions (Short Term)								**111**	**47.5**	**52.6**	**2.75**

2A6 EDMONTON INDUSTRIAL SOURCES (BASELINE AND CUMULATIVE CASES)

The Edmonton emission sources identified in Table 2A-85 were included in this assessment, and the stack parameters that were used are provided in Table 2A-86. This emission information was obtained from Petro-Canada Refinery Conversion Project application.

Table 2A-85 Inclusion List of the Edmonton Industrial Sources

	Facility Included
1	Air Products Ltd. Hydrogen Plants
2	Alberta Envirofuels Inc.
3	Alcan Coke Processing Plant
4	AltaSteel
5	AT Plastics Inc.
6	Celanese Petrochemical Manufacturing Plant
7	Envirofor Preservers CCA Wood Treatment Plant
8	EPCOR Rossdale Thermal Power Plant
9	Georgia-Pacific Gypsum Wallboard Plant
10	Gold Bar Wastewater Treatment Plant
11	Imperial Oil Refinery
12	Owens Corning Canada Insulation Manufacturing Plant
13	Petro-Canada Edmonton Refinery
14	Procor Limited Railcar Washing Facility

Table 2A-86 Summary of the Edmonton Industrial Sources

Emission Source	NAD 83		Base Elevation (m ASL)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (K)	SO_2 (t/d)	NO_X (t/d)	CO (t/d)	$PM_{2.5}$ (t/d)
	UTM E (m)	UTM N (m)									
Stack #1	344264	5936094	684.0	45.7	1.37	15.2	472	0.048	0.073	0.061	0.005
Stack #2	344393	5936098	682.0	45.7	1.98	17.1	505	0.104	0.156	0.13	0.012
Stack #3	344511	5936086	682.1	45.7	1.37	15.2	472	0.048	0.073	0.061	0.005
Stack #4	344349	5935986	683.4	34.4	2.13	7.1	616	0.117	0.175	0.148	0.013
Stack #5	344496	5935974	683.8	41.1	1.22	5	549	0.038	0.057	0.048	0.004
Stack #6	344495	5935964	683.9	41.1	1.22	6	505	0.038	0.057	0.048	0.004
Stack #7	344446	5935924	684.1	22.6	1.6	9.6	872	0.066	0.098	0.083	0.008
Stack #8	344246	5935905	682.3	28.3	1.68	6.2	561	0.072	0.108	0.091	0.008
Stack #9	344246	5935916	682.2	32.9	2.08	6.9	644	0.111	0.167	0.14	0.013
Stack #10	344345	5935914	683.2	28.3	1.62	5.8	711	0.068	0.102	0.086	0.008
Stack #11	344244	5935859	682.7	34.4	0.76	7.6	616	0.015	0.022	0.019	0.007
Stack #12	344245	5935871	682.6	34.9	1.5	8.3	589	0.058	0.086	0.073	0.007
Stack #13	344244	5935841	682.9	76.2	2.29	27.4	589	0.16	1.35	13.205	0.577
Stack #14	344416	5935866	686.0	76.2	2.74	17.7	477	0.001	0.02	0.002	0.13
Stack #15	344116	5935859	680.9	40	2	6.9	661	0.079	0.119	0.1	0.01
Stack #16	344393	5936098	682.0	40	2.62	6.7	661	0.082	0.123	0.103	0.009
Stack #17	344511	5936086	682.1	40	1.49	6.9	661	0.098	0.048	0.014	0.011
Stack #18	344248	5936217	682.7	67.1	1.68	8.5	475	0.004	0.041	0.01	0.005
Stack #19	344496	5935974	683.8	64	2.29	3.6	450	0.006	0.06	0.014	0.074
Stack #20	344248	5936245	682.7	70	1.78	6.1	451	0.006	0.06	0.014	0.074
Stack #21	344248	5936184	683.2	50	2.29	6.7	427	0.006	0.103	0.015	0.008
Stack #22	344256	5936157	683.6	50	2.52	7.3	427	0.008	0.139	0.02	0.011
Stack #23	344279	5936370	680.3	110	1.68	25.6	808	8.113	0.286	0.122	0.023
Sum: Petro-Canada Edmonton Refinery								**9.346**	**3.523**	**14.607**	**1.026**
Boiler Stack	343004	5934914	675.0	9	0.33	1.9	287		0.008		
Dryer Kiln #1	343051	5935011	671.8	7	0.81	2.1	369		0.008		
Dryer Kiln #2	343054	5935011	671.7	7	0.81	2.1	369		0.008		
Dryer Kiln Stack #3	343051	5935006	672.0	7	0.81	2.1	369		0.008		
Dryer Kiln Stack #4	343054	5935006	671.9	7	0.81	2.1	369		0.008		
Dryer Kiln Stack #5	343051	5935000	672.4	7	0.81	2.1	369		0.008		
Dryer Kiln Stack #6	343054	5935000	672.3	7	0.81	2.1	369		0.008		
Dryer Kiln Stack #7	343051	5934995	672.7	7	0.81	2.1	369		0.008		
Dryer Kiln Stack #8	343054	5934995	672.6	7	0.81	2.1	369		0.008		
Sum: Envirofor Preservers CCA Wood Treatment Plant								**0**	**0.072**	**0**	**0**
#1 Kettle Exhaust	344550	5938420	658.3	25	0.88	9	353				0.061
#2 Kettle Exhaust	344565	5938400	658.9	25	0.88	8.2	348				0.008

	NAD 83		Base Elevation	Stack Height	Stack Diameter	Exit Velocity	Exit Temp	SO_2	NO_X	CO	$PM_{2.5}$
Emission Source	**UTM E (m)**	**UTM N (m)**	**(m ASL)**	**(m)**	**(m)**	**(m/s)**	**(K)**	**(t/d)**	**(t/d)**	**(t/d)**	**(t/d)**
#1 Kettle Burner	344575	5938415	658.3	25	0.88	7.7	811		0.008	0.001	
#2 Kettle Burner	344590	5938395	658.9	25	0.88	6.7	711		0.017	0.001	
#1 Board Dryer Exhaust	344600	5938405	658.4	14.3	1.07	7.2	431		0.003	0.024	
#2 Board Dryer Exhaust	344615	5938385	659.3	14.3	1.07	3.8	421		0.003	0.022	
#3 Board Dryer Exhaust	344625	5938395	658.9	14.3	1.07	8.9	384		0.007	0.091	
End Grind Baghouse	344640	5938375	660.0	10.4	0.25	28	293				0.028
Hammer Mill Baghouse	344950	5938435	664.0	10.4	0.48	65.6	298				0.225
Dryer End Seal Exhaust	344965	5938415	664.0	14.3	1.22	15.8	355		0.011	0.18	
Stucco Bin Dust Collection Exhaust Vent	344975	5938425	664.0	11.3	0.25	18.6	298				0.018
Sum: Georgia-Pacific Gypsum Wallboard Plant								**0**	**0.049**	**0.319**	**0.34**
#1 Boiler	341375	5933933	668.8	13.1	0.51	9.2	488		0.004	0.003	
#2 Boiler	341375	5933932	668.8	13.1	0.51	9.2	488		0.005	0.004	
#3 Boiler	341375	5933930	668.9	13.1	0.51	9.2	488		0.006	0.005	
#4 Boiler	341375	5933924	669.0	11.5	0.2	51.1	488		0.005	0.004	
#5 Boiler	341375	5933922	669.1	11.5	0.2	51.1	488		0.005	0.004	
Sum: Procor Limited Railcar Washing Facility								**0**	**0.025**	**0.02**	**0**
Stack for Unit #8	334402	5933825	611.0	58.2	3.2	16.3	404		1.26	0.406	
Stack for Unit #9	334363	5933825	611.7	58.2	3.2	14	409		1.322	0.432	
Stack for Unit #10	334340	5933825	612.2	58.2	3.2	14	409		1.322	0.432	
Sum: EPCOR Rossdale Thermal Power Plant								**0**	**3.904**	**1.27**	**0**
Pyroscrubber	343941	5937250	611.0	45	3.8	15.9	1273	11.37	0.353		1.008
Sum: Alcan Coke Processing Plant								**11.37**	**0.353**	**0**	**1.097**
ULF Forming #B02	344434	5938175	658.8	39.5	1.51	20.7	308		0.003		0.082
W2 Forming #B15	344429	5938196	658.7	39.5	2.12	26.6	334		0.044	0.049	0.593
W2 Ceilcote Exhaust #C31	344382	5938211	658.1	29.8	0.76	12.6	324		0.072	0.167	0.046
W2 Smoke Stripper #C32	344381	5938206	658.0	29.8	0.76	17.6	306				0.034
W2 Cooling LEAF #C34	344359	5938186	657.3	15	0.9	14.5	314				0.011
W2 Furnace West Vent #B18	344434	5938204	658.9	22.3	1.22	4.5	328		0.605		0.041
W2 Furnace East Vent #B19	344443	5938204	659.0	24.7	1.22	4.3	330		0.605		0.041
Exhaust over W2 Riser #B20	344439	5938195	658.9	24.1	0.76	1.6	755				0.054
Furnace Hall Roof Exhaust Stack #B17	344446	5938202	659.1	17.7	2.74	4.4	298		0.004		0.018
Dust Collector Exhaust #A02	344444	5938154	659.1	20.9	0.14	1	293				0.001
Dust Collector Exhaust #A05	344443	5938159	659.1	20.9	0.14	1	293				0.001
Dust Collector Exhaust #A18	344441	5938139	658.9	21.7	0.6	1	293				0.001
Dust Collector Exhaust #A21	344443	5938151	659.1	28.5	0.49	1	293				0.001
Dust Collector Exhaust #B22	344447	5938213	659.1	32.1	0.35	1	293				0.001

Emission Source	NAD 83 UTM E (m)	NAD 83 UTM N (m)	Base Elevation (m ASL)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temp (K)	SO_2 (t/d)	NO_X (t/d)	CO (t/d)	$PM_{2.5}$ (t/d)
Sum: Owens Corning Canada Insulation Manufacturing Plant								**0**	**1.333**	**0.216**	**0.925**
Main Stack	341502	5935486	663.1	109	4	12.6	477	10.602	3.059	2.074	
AF-F-01	341394	5935223	665.1	64.3	1.9	1.6	566		0.121	0.017	
AP-F-01	341374	5935224	665.2	48	3.58	1.6	451		0.484	0.13	
VP-F-01	341409	5935222	665.0	44.3	2.37	1.2	516		0.13	0.058	
NH-F-01	341341	5935227	665.3	52.3	1.68	0.8	516		0.043	0.004	
SL-F-01	341321	5935227	665.3	43	1.6	0.6	505		0.026	0.004	
PF-F-01 and PF-F-04	341265	5935201	663.6	39.1	2.67	1.1	750		0.199	0.001	
PF-F-08	341268	5935176	663.4	25.9	1.22	0.1	446		0.003		
AS-F-01	341249	5935255	663.6	52	1.5	1.1	673		0.043		
AS-F-02	341260	5935257	664.0	32	0.77	0.4	700		0.005		
AS-F-03	341267	5935256	664.2	42	0.5	3.1	644		0.008		
CC-F-01	341426	5935463	663.2	64.6	2.22	0.9	548		0.052		
AL-F-01	341337	5935252	665.6	50.1	2.21	2	523		0.121	0.016	
AL-F-02	341320	5935253	665.6	60.3	2.21	1.5	523		0.06	0.005	
LV-F-01	341694	5935582	662.0	45	1.3	2.4	523		0.043		
HT-F-01	341212	5935691	659.5	53	0.9	1.7	549		0.043	0.002	
HT-F-02	341212	5935680	658.9	41	0.86	1.8	638		0.026	0.001	
Primary Flare	342047	5935114	665.0	98.7	3.73	1.6	1273	0.098	0.059		
Sum: Imperial Oil Refinery								**10.7**	**4.525**	**2.312**	**0**
Boiler #1	343250	5933825	686.3	20	1.83	12.5	423		0.337	0.092	
Boiler #2	343252	5933840	686.4	20	1.83	9	423		0.48	0.022	
Boiler #3	343255	5933855	687.1	20	1.83	11	398		0.086	0.022	
Unit 10 Saltbath Heater	343445	5933840	686.6	20.4	0.75	5	539		0.002	0.001	
Unit 20 Saltbath Heater	343350	5933750	690.2	20.4	0.5	5	539		0.002	0.001	
Unit 40 Saltbath Heater	343510	5933715	690.9	21.7	0.6	4.7	539		0.001	0.001	
Born Heater	343280	5933770	688.4	62.5	2.5	7.7	451	0.006	0.354	0.095	
Sum: Alberta Envirofuels Inc.								**0.006**	**1.262**	**0.234**	**0**
Wheelabrator Baghouse	342069	5933671	674.1	38.2	3.69	16.8	337	0.029	0.123	0.49	0.173
Reheat Furnace	342076	5933790	675.1	30.6	2.14	18.3	1144		0.245	0.206	0.005
Sum: AltaSteel								**0.029**	**0.368**	**0.696**	**0.178**
Compressor - #1 Booster	340430	5934822	668.4	11	0.15	20.8	682		0.103		
Compressor - #1 Primary	340434	5934822	668.4	11	0.15	32	566		0.033		
Compressor - #2 Booster	340430	5934818	668.5	11	0.15	18.9	544		0.089		
Compressor - #2 Primary	340434	5934818	668.4	11	0.15	16.7	562		0.065		
Compressor - #1 Clark	340439	5934822	668.3	11	0.15	33.8	488		0.366		
Compressor - #2 Clark	340439	5934818	668.3	11	0.15	33.8	488		0.366		
Compressor - #3 Primary	340443	5934819	668.3	11	0.15	27.2	558		0.19		

	NAD 83		Base	Stack	Stack	Exit	Exit				
	UTM E	**UTM N**	**Elevation**	**Height**	**Diameter**	**Velocity**	**Temp**	**SO_2**	**NO_X**	**CO**	**$PM_{2.5}$**
Emission Source	**(m)**	**(m)**	**(m ASL)**	**(m)**	**(m)**	**(m/s)**	**(K)**	**(t/d)**	**(t/d)**	**(t/d)**	**(t/d)**
Engine Generator	340497	5934817	667.1	11	0.21	13.9	538		0.042		
Power House Boiler #1	340332	5934750	666.5	18.3	1.37	4.4	501		0.032		
Power House Boiler #2	340338	5934750	666.8	18.3	1.37	5.2	559		0.027		
5R House Boiler #2	340497	5934500	665.7	38.8	1.62	1.6	498		0.035		
Sum: AT Plastics Inc.								**0**	**1.348**	**0**	**0**
Biogas Boiler #1	340150	5937071	637.5	10	1	1.4	477	0.056	0.375	0.315	
Biogas Boiler #2	340150	5937067	637.6	10	1	1.4	477	0.056	0.375	0.315	
Biogas Boiler #3	340150	5937063	637.6	10	1	1.4	477	0.056	0.375	0.315	
Flare	340146	5937067	637.6	21.9	3.84	1.3	1273	0.13	0.035		
Sum: Gold Bar Wastewater Treatment Plant								**0.298**	**1.16**	**0.945**	**0**
pH Boiler #1	343965	5938743	651.8	28.4	2.11	16	397		0.184	0.155	
pH Boiler #2	343964	5938733	651.9	28.4	2.11	10.4	372		0.23	0.193	
pH Boiler #3	343963	5938724	652.1	28.4	2.11	13.4	392		0.558	0.469	
pH Boiler #4	343964	5938712	652.3	28.4	2.11	14.6	396		0.416	0.349	
pH Boiler #5	343963	5938701	652.6	28.4	2.11	18.3	417		1.356	1.14	
Sulzer Incinerator	343962	5938690	652.8	16.8	1.83	13.1	471		0.183	0.154	
Methanol Reformer	344461	5938893	654.0	60	4.57	15.7	420		2.748	2.308	
KA Furnace (F-22)	343897	5939069	650.0	15.2	0.84	6.1	786		0.007	0.006	
Section 39 Furnace	343903	5938725	651.0	12.2	0.91	11.8	672		0.003	0.003	
CA Section 1 Dryer	343832	5938732	650.0	22.6	0.74	31	344				0.093
CA Section 8A Pulp Conveyor	343830	5938629	650.8	29	0.45	16	296				0.003
CA Section 1A Airveyor	343834	5938556	652.4	7.9	0.45	22	303				0.04
Ester Kettle Incinerator	343909	5938875	649.4	30.5	1.22	17	482		0.04	0.034	0.01
Di-PE Wet Dust Scrubber(M-5278)	344035	5938850	650.9	25.9	0.25	5	321				
Sum: Celanese Petrochemical Manufacturing Plant								**0**	**5.725**	**4.811**	**0.146**
Reformer #1	344200	5937200	670.2	30.5	2.99	51.1	422	0.003	0.397	0.264	0.049
Flare #1	344136	5937224	669.4	45.7	2.93	20	1273		1.115	6.065	
Reformer #2	344275	5937197	670.4	30.5	2.99	51.1	422	0.003	0.397	0.264	0.049
Flare #2	344211	5937221	669.7	45.7	2.93	20	1273		1.115	6.065	
Sum: Air Products Ltd. Hydrogen Plants								**0.006**	**3.024**	**12.658**	**0.098**
Total for Edmonton Industrial Sources								**31.755**	**26.671**	**38.088**	**3.721**

2A7 FUGITIVE INDUSTRIAL EMISSIONS

Table 2A-87 provides the fugitive emission parameters that were used for this assessment for the Baseline Case on a facility basis. The Baseline Case includes existing and approved industrial facilities.

For new facilities or for facilities that are proposing an expansion, the fugitive emission parameters for the additional Cumulative Case facilities are provided in Table 2A-88. The parameters in Table 2A-88 replace the parameters in Table 2A-87 for the identified facilities; for all other facilities, the Baseline Case parameters are still applicable.

Table 2A-87 Detailed Fugitive Emission Parameters for the Baseline Case Area Emissions

Operator	**Agrium Products Inc.**		**ARC Resources**	**BA Energy**	**BP Energy**	**Bunge Canada**
Facility	**Fort Sask. Fertilizer Plant**	**Redwater Fertilizer Plant**	**Redwater Gas Conservation Plant**	**Heartland Bitumen Upgrader**	**Fort Sask. Fractionation Plant**	**Fort Sask. Oilseed Processing Plant**
UTM Zone	12	12	12	12	12	12
NE UTM E (m)	355300	362400	363500	365499	357750	352150
NE UTM N (m)	5955200	5968100	5980300	5965483	5959150	5955350
SW UTM E (m)	355200	362300	363400	365183	357650	352050
SW UTM N (m)	5955100	5968000	5980200	5965238	5959050	5955250
Area (m^2)	10,000	10,000	10,000	77,420	10,000	10,000
Base Elevation (m ASL)	617.2	623.9	615.0	625.3	625.3	642.0
Effective Height (m)	10.0	10.0	10.0	10.0	10.0	10.0
Initial Sigma z (m)	10.0	10.0	10.0	10.0	10.0	10.0
VOC (t/d)	3.62E-02	5.86E-01	2.08E-01	8.22E-02	2.38E-01	2.26E-02
PM2.5 (t/d)						3.90E-02
H_2S (t/d)			2.79E-03	6.71E-03		
Benzene (t/d)				1.05E-03	1.97E-03	
C5-C8 aliphatics (t/d)				3.63E-02		
C9-C18 aliphatics (t/d)				1.28E-02		
C9-C16 Aromatics (t/d)				7.13E-04		
Ethylbenzene (t/d)				1.44E-03		
Hexane (t/d)			1.24E-02			1.35E-02
Toluene (t/d)			1.35E-03	5.57E-03	7.21E-04	
Xylenes (t/d)			1.72E-03	2.48E-03		

Operator	**Dow Chemical Inc.**	**Keyera Energy Ltd.**	**Marsulex Inc.**	**Provident Energy Ltd**	**Shell Canada**
Facility	**Fort Sask. Chemical Plant**	**Fort Sask. Fractionation**	**Fort Sask. Chemical Plant**	**Redwater Fractionation**	**Scotford Oil Refinery**
UTM Zone	12	12	12	12	12
NE UTM E (m)	357350	357350	356450	359700	362200
NE UTM N (m)	5956300	5957700	5954550	5965150	5962800
SW UTM E (m)	357150	357250	356350	359600	361100
SW UTM N (m)	5955700	5957600	5954450	5965050	5962300
Area (m^2)	120,000	10,000	10,000	10,000	550,000
Base Elevation (m ASL)	625.2	630.1	622.9	640.9	621.3
Effective Height (m)	10.0	10.0	10.0	10.0	10.0
Initial Sigma z (m)	10.0	10.0	10.0	10.0	10.0
VOC (t/d)	1.58E-01	1.53E+00		7.14E-02	2.62E-01
PM2.5 (t/d)					
H_2S (t/d)	3.26E-04	3.84E-04	3.83E-05		2.66E-03
CS2 (t/d)		2.59E-03			
COS (t/d)		4.50E-03			
Acetaldehyde (t/d)	1.37E-05				
Anthracene (t/d)					5.46E-06
Benzene (t/d)	4.52E-04	5.62E-03			3.66E-03
Benzo(a)anthracene (t/d)					5.21E-08
Benzo(a)pyrene (t/d)					3.03E-08
Benzo (b)fluoranthene (t/d)					2.74E-08
Benzo(g,h,i)perylene (t/d)					4.17E-06
Benzo(k)fluoranthene (t/d)					3.84E-08
C9-C18 aliphatics (t/d)					9.02E-04
C9-C16 Aromatics (t/d)	2.46E-05				5.87E-04
Cyclohexane (t/d)		1.35E-02		7.34E-04	4.54E-04
Dibenz(a,h)anthracene (t/d)					4.11E-08
Ethylbenzene (t/d)		1.37E-04			1.57E-03
Hexane (t/d)	1.86E-04	5.90E-02		4.92E-03	1.42E-02
Indeno(1,2,3-cd)pyrene (t/d)					3.78E-07
Naphthalene (t/d)	3.84E-05				5.87E-04
Phenanthrene (t/d)					1.20E-05
Pyrene (t/d)					1.53E-06
Styrene (t/d)	3.29E-05				
Toluene (t/d)	7.67E-05	3.70E-03		2.52E-04	1.01E-02
Xylenes (t/d)		1.08E-03		7.12E-05	1.46E-02

Operator	**Shell Chemicals**	**Shell Canada**	**Newalta Corporation**
Facility	**Scotford Styrene & MEG**	**Scotford Upgrader (Base+SE1)**	**Redwater**
Unit	Process Area	Process Area	Process Area
NE UTM E (m)	363200	361879	362850
NE UTM N (m)	5963950	5964180	5980150
SW UTM E (m)	362800	361000	362750
SW UTM N (m)	5963700	5962740	5980050
Area (m^2)	100,000	1,265,760	10,000
Base Elevation (m ASL)	620.0	620.7	621.9
Effective Height (m)	6.0	6.0	6.0
Initial Sigma z (m)	10.0	10.0	10.0
VOC (t/d)	7.00E-02		
H_2S (t/d)		1.77E-02	
COS (t/d)		8.59E-04	
Mercaptan Group (t/d)		4.87E-05	
Thiopene Group (t/d)		3.29E-03	
Ammonia (t/d)	3.37E-03	8.54E-04	
Benzene (t/d)	1.81E-02	1.12E-02	
C5-C8 aliphatics (t/d)		1.29E+00	
C9-C18 aliphatics (t/d)		2.85E-02	
C9-C16 Aromatics (t/d)		4.85E-03	
Cyclohexane (t/d)		2.19E-02	
Ethylbenzene (t/d)	1.36E-02	1.62E-03	
Formaldehyde (t/d)	5.87E-04		
Hexane (t/d)		1.45E-01	
Naphthalene (t/d)		3.14E-05	
Styrene (t/d)	2.95E-02		
Toluene (t/d)	9.86E-04	1.30E-02	2.74E-06
Xylenes (t/d)	4.92E-05	8.21E-03	

Table 2A-88 Detailed Fugitive Emission Parameters for the Cumulative Case Area Emissions

Operator	**Access Pipeline Inc.**	**Synenco Energy Inc.**	**Kinder Morgan (Terasen)**	**Shell Canada**	**Shell Canada**	**Shell Canada**
Facility	**Redwater Trim Blending Facility**	**Northern Lights Upgrader Project**	**Heartland Storage Tank Terminal**	**Scotford Upgrader (P1&P2)**	**Scotford Upgrader (P3&P4)**	**Scotford Upgrader (G1&G2)**
NW UTM E (m)	360644	362800	365861	364345	364095	363930
NE UTM N (m)	5967438	5972500	5966529	5965165	5963552	5966170
SW UTM E (m)	360144	362600	365295	362745	363432	363650
NE UTM E (m)	5966938	5972300	5966029	5964496	5961997	5965580
Area (m^2)	250,000	40,000	283,000	1,070,400	1,030,965	165,200
Base Elevation (m ASL)	624.8	626.9	624.4	619.2	619.2	625.0
Effective Height (m)	6.0	6.0	6.0	6.0	6.0	6.0
Initial Sigma z (m)	10.0	10.0	10.0	10.0	10.0	10.0
VOC **(t/d)**	2.39E-02	1.11E+00	1.05E-01			
H_2S **(t/d)**	1.05E-06	7.77E-03	1.08E-04	2.24E-03	2.24E-03	2.14E-04
CS2 **(t/d)**		8.41E-03				
COS **(t/d)**				3.49E-04	3.49E-04	5.16E-05
Mercaptan Group **(t/d)**		5.17E-05		5.58E-06	5.58E-06	5.84E-05
Thiopene Group **(t/d)**		3.38E-02		1.60E-03	1.60E-03	9.78E-04
Aliphatic Alcohols **(t/d)**		6.42E-03				
Aliphatic Aldehydes **(t/d)**		5.99E-03				
Aliphatic Ketones **(t/d)**		9.61E-03				
Ammonia **(t/d)**				3.97E-04	3.97E-04	
1,3-butadiene **(t/d)**	2.43E-04	5.09E-04				
Benzaldehyde **(t/d)**						
Benzene **(t/d)**	2.29E-04	7.01E-03	1.01E-03	5.58E-03	5.58E-03	1.40E-03
C5-C8 aliphatics **(t/d)**		4.05E-01		7.29E-01	7.29E-01	1.41E-01
C9-C18 aliphatics **(t/d)**		1.40E-01		1.42E-02	1.42E-02	3.62E-03
C9-C16 Aromatics **(t/d)**		1.48E-01		2.21E-03	2.21E-03	1.34E-04
Cyclohexane **(t/d)**				1.06E-02	1.06E-02	1.43E-03
Ethylbenzene **(t/d)**	6.38E-04	1.64E-02	2.02E-05	7.63E-04	7.63E-04	4.56E-05
Formaldehyde **(t/d)**				8.15E-02	8.15E-02	1.54E-02
Hexane **(t/d)**	7.19E-04	1.61E-02				
Naphthalene **(t/d)**			6.12E-08	1.18E-05	1.18E-05	
Toluene **(t/d)**	1.95E-03	5.76E-02	5.72E-04	6.01E-03	6.01E-03	1.18E-03
Xylenes **(t/d)**	1.22E-03	2.62E-02	9.10E-05	3.77E-03	3.77E-03	4.36E-04

Operator	**Petro-Canada**		**Enbridge Pipelines (Athabasca) Inc.**	**North West Upgrading Inc.**		
Facility	**North Area**	**South Tank Farm**		**North West Upgrader Project**		
NE UTM E (m)	358427	357613	364900	360203	361783	361578
NE UTM N (m)	5968897	5966746	5964800	5968589	5968617	5967818
SW UTM E (m)	357130	356921	364450	359601	360251	361160
SW UTM N (m)	5967450	5965904	5964350	5968120	5967763	5967618
Area (m^2)	1,876,186	581,881	202,500	282338	1308328	83636
Base Elevation (m ASL)	631.9	640.3	622.4	627.3	628.3	624.1
Effective Height (m)	6.0	6.0	6.0	6.0	6.0	6.0
Initial Sigma z (m)	10.0	10.0	10.0	10.0	10.0	10.0
VOC **(t/d)**	1.07E+00	3.26E-02				
H_2S **(t/d)**	3.61E-02	5.94E-05	3.19E-05	4.01E-04	8.19E-03	-
CS2 **(t/d)**	2.23E-03	2.86E-06		2.88E-03	6.88E-03	-
COS **(t/d)**						
Mercaptan Group **(t/d)**	6.69E-04	7.32E-06	4.85E-05	4.00E-05	2.43E-05	-
Thiopene Group **(t/d)**	8.02E-03	6.17E-05		1.00E-04	3.71E-02	-
Aliphatic Alcohols **(t/d)**	3.62E-05	3.09E-05		4.20E-05	7.10E-03	-
Aliphatic Aldehydes **(t/d)**	9.95E-04			7.90E-05	6.58E-03	-
Aliphatic Ketones **(t/d)**	2.82E-04			1.16E-04	1.06E-02	-
Ammonia **(t/d)**	8.64E-02					
1,3-butadiene **(t/d)**	6.10E-03	4.95E-05		6.82E-04	-	
Benzene **(t/d)**	6.31E-03	3.55E-04	1.03E-02	5.97E-04	7.27E-03	1.82E-04
C5-C8 aliphatics **(t/d)**	7.20E-02	2.00E-02	3.06E-02	2.19E-02	4.32E-01	5.08E-03
C9-C18 aliphatics **(t/d)**			4.39E-05	4.24E-03	1.52E-01	3.43E-06
C9-C16 Aromatics **(t/d)**	5.97E-03	2.57E-03	4.50E-06	3.92E-04	1.65E-02	3.07E-05
C17-C34 Aromatics **(t/d)**	2.94E-06					
Cyclohexane **(t/d)**	6.48E-04	4.32E-04				
Dibenz(a,h)anthracene **(t/d)**						
Dichlorobenzene **(t/d)**				-	-	
Ethylbenzene **(t/d)**	1.02E-03	7.21E-04	1.70E-03	6.49E-04	1.76E-02	3.66E-05
Hexane **(t/d)**	6.39E-03	6.85E-04		1.73E-03	1.63E-02	3.67E-04
Naphthalene **(t/d)**			1.81E-08	-	-	
Propylene Oxide **(t/d)**	5.18E-06					
Toluene **(t/d)**	7.78E-03	2.23E-03	2.31E-02	2.97E-03	6.15E-02	4.14E-04
Xylenes **(t/d)**	2.44E-03	1.65E-03	1.86E-02	1.21E-03	2.82E-02	1.16E-04

2A8 NON-INDUSTRIAL SOURCES

2A8.1 Regional Study Area Emissions

The regional study area also includes non-industrial emission sources that are comprised of commercial emissions, residential heating emissions, and traffic emissions. These non-industrial sources can be and were treated collectively as area sources.

Emission data for Alberta are available on a Census Division Basis, and the regional study area falls within Census Division 11. The Environment Canada emission data for 2000 (the most recently available) for the Census Division were spatially allocated to nominal 4 x 4 km grid cells. Specifically, the emissions that were spatially allocated are as follows:

- Mobile sources include roadway, highway, railroads, off-road vehicles and aircraft. Roadway, highway and railroad emissions were allocated to each grid cell based on the length of the road and rail system with each cell. Off-road use emissions were allocated based on the activity assigned to each cell (e.g. agricultural).

- Non-mobile sources include residential and commercial fuel use. Emissions were allocated to each grid cell based on the level of activities assigned to that cell (e.g. population).

The emission rates for these 4 x 4 km grids vary with time:

- Specifically, the traffic flow will vary primarily with time of day; and the variation that as adopted is provided in Figure 2A-8. This profile was obtained from The City of Edmonton Transportation Department, and primarily reflects a weekday traffic flow rather than a weekend traffic flow that is slightly different.

- The residential and commercial fuel use can also vary with time with higher emission rates occurring during the winter. Specifically, 15% of these emissions were assumed to be constant (i.e., associated with heating water and cooking) and the remaining 85% was assumed to be distributed on a monthly basis according to heating degree days (i.e., for space heating). The Edmonton area experienced 5,189 heating-degree-days (the sum of the daily differences between the average daily temperature and 18°C). The monthly variation is depicted in Figure 2A-9, the monthly heating degree days were obtained from Environment Canada (Canadian Climate Normals 1971-2000).

The emission values are provided in Table 2A-89 and as a series of plots in the following figures:

- SO_2 emissions (Figure 2A-10)

- NO_x emissions (Figure 2A-11)

- CO emissions (Figure 2A-12)

- $PM_{2.5}$ emissions (Figure 2A-13)

- VOC emissions (Figure 2A-14)

For reference purposes, the figures show a 100 by 100 km area centered on the Project. The emission rates provided are based on 2000 emission estimates. These values were assumed to represent the Baseline Case and the Cumulative Case. As the population increases, the levels of activity will increase which will tend to increase emissions, all things being equal. The potential emission increases, however, will be offset by the implementation of more effective technology. The Environment Canada emission projections for Alberta tend to support this premise. For example, NO_x emissions associated with residential fuel combustion are projected to decrease slightly from 6907 t/y in 2000 to 6687 t/y in 2015. NO_x emission associated with light-duty gasoline trucks and vehicles are projected to decrease from 42,753 t/y in 2000 to 21,818 t/y in 2015. On this basis, the 2000 emission values could overstate the future emissions in the region.

Table 2A-18 identified a number of trace substance groups that are of relevance to the Project. The emissions for these substance groups due to non-industrial sources were calculated to allow overlapping effects with the Project to be rigorously evaluated. The emission rates were scaled from the total VOC emission rates according to the scaling values listed in Table 2A-90. The traffic scaling values assume that 85% of the emissions are due to gasoline-fuelled vehicles and 15% are due to diesel-fuelled vehicles.

2A8.1.1 Census Management Division 11 Area Emissions

Cheminfo services completed a forecast of common air contaminant emissions in Alberta for the period 1995 to 2020 (Cheminfo 2002). This study was undertaken for the Alberta Clean Air Strategic Alliance (CASA). A summary of Census Division 11 projections for 2010 is provided in Table 2A-91. Census Division 11 includes the Cities of Edmonton, Fort Saskatchewan, industrial area, and the power plants in the Wabamun area. The following comments can be made relating to the Census Division (CD) emissions:

Most of the SO_2 emissions in the CD are due to the power generation, oil sands and upstream oil & gas industrial sections. The oil sands projection does not reflect the currently approved and Upgrader in the Fort Saskatchewan area.

- Most of the NO_x emissions in the CD are due to the power generation, transportation, and upstream oil & gas sections.
- Most of the $PM_{2.5}$ emissions are due to Power generation and paved dust sources.
- Most of the VOC emissions are due to upstream oil & gas activities.
- Most of the CO emissions are due to Transportation (motor vehicles).
- Most of the NH_3 emissions are due to Agricultural activities associated with livestock.

In comparing the emissions given in Table 2A-85 with the Cheminfo projections for 2010 (Table 2A-86), there are some reasonable close values (e.g., the mobile SO_2 emissions and the heating unit NOx emissions). There are also some considerable differences (e.g., the CO and VOC emissions).

The Cheminfo report indicates that the levels of uncertainty in emission inventory and projection values vary by source category and pollutant. Typically, levels of accuracy are as follows: ±5 percent for SO_x, ±20 percent for NO_x, and ±30 percent for CO. “Large” uncertainties (the values are unstated) are associated with VOC and PM emissions.

Table 2A-89 Urban Mobile and Non-mobile Emission Rates (for 100 km by 100 km area)

	Emission Rate (t/d)		
	Mobile Sources	**Domestic/Commercial Heating Units**	**Both**
SO_2	4.45	0.80	5.25
NO_x	166.8	10.63	177.4
CO	896.6	19.45	916.1
$PM_{2.5}$	8.29	3.81	12.1
VOC	69.5	3.77	73.3

Note: Emission rates are annual average rates provided in a t/d basis.

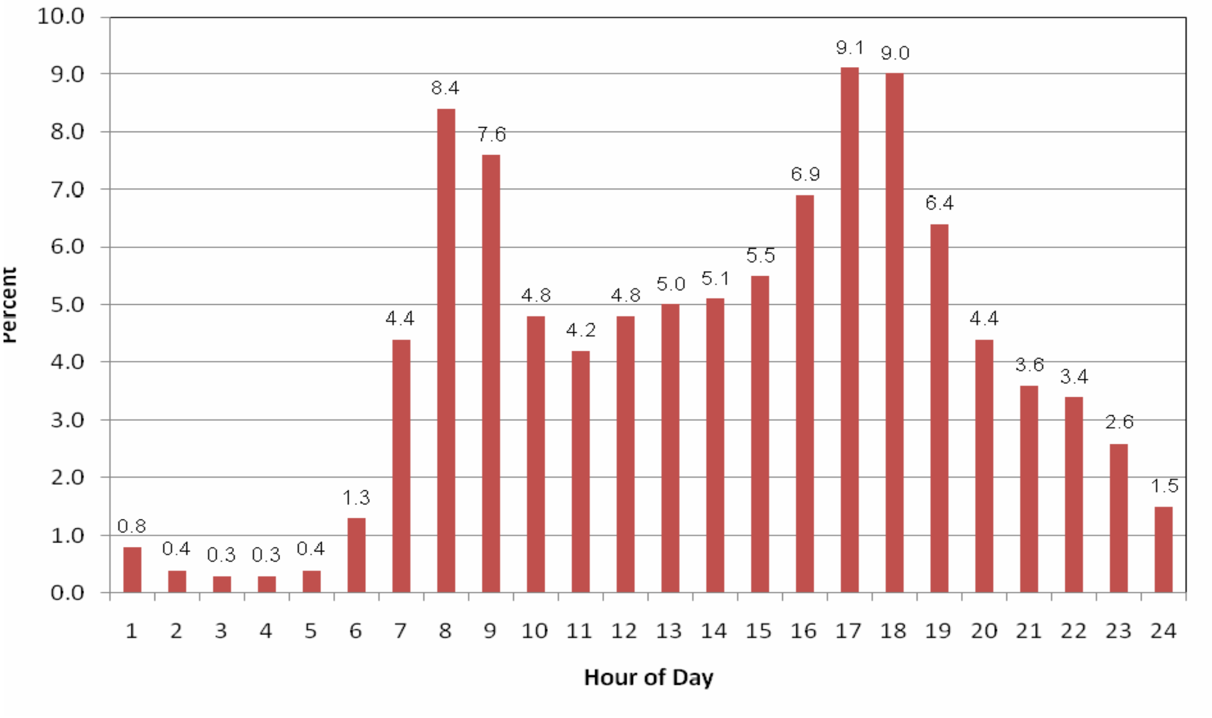


Figure 2A-8 Hourly Distribution of Traffic Emissions (percent values shown)

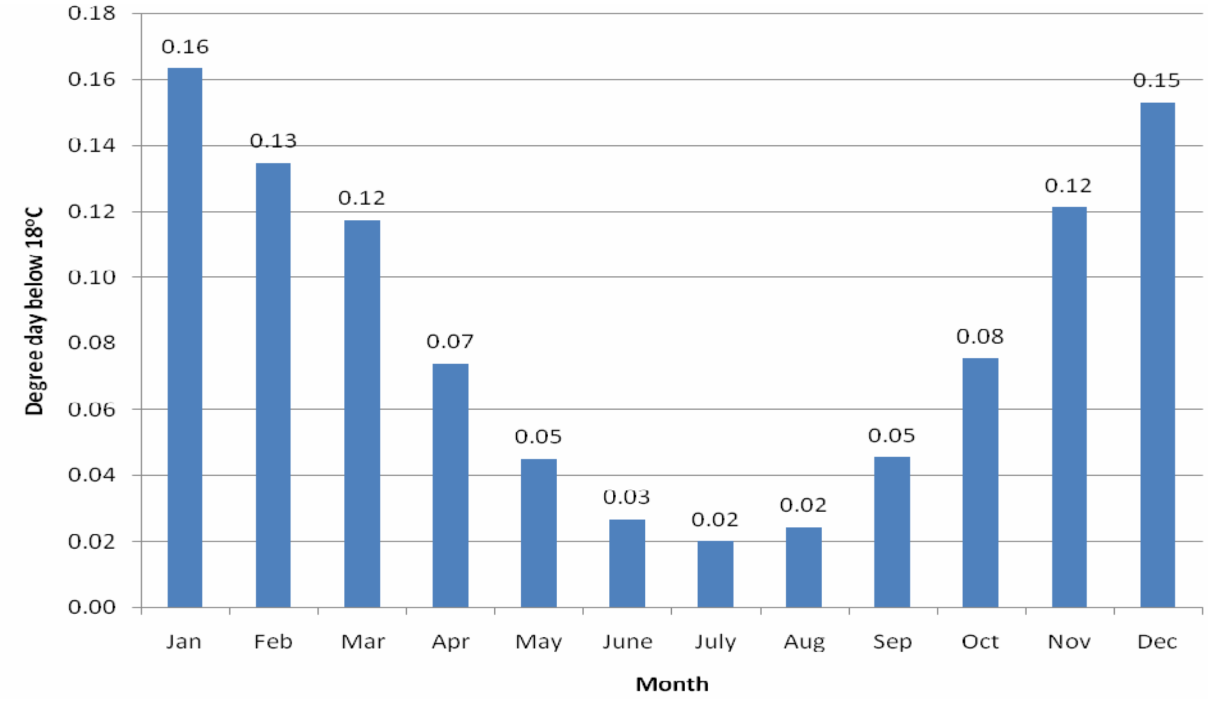
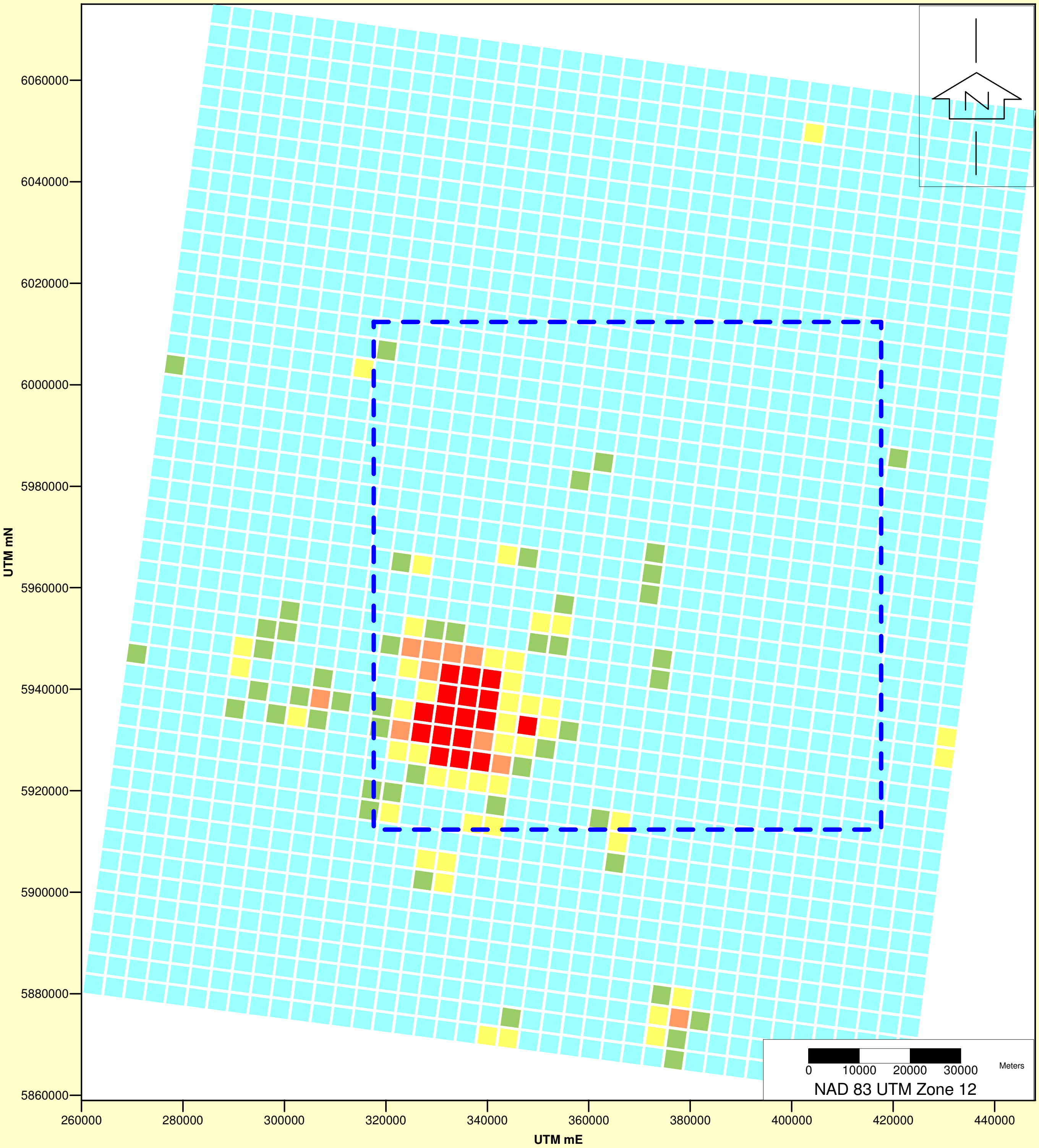


Figure 2A-9 Monthly Distribution of Space-Heating Emissions (fraction values shown)



Legend

SO_2 Emissions (tonne/day)

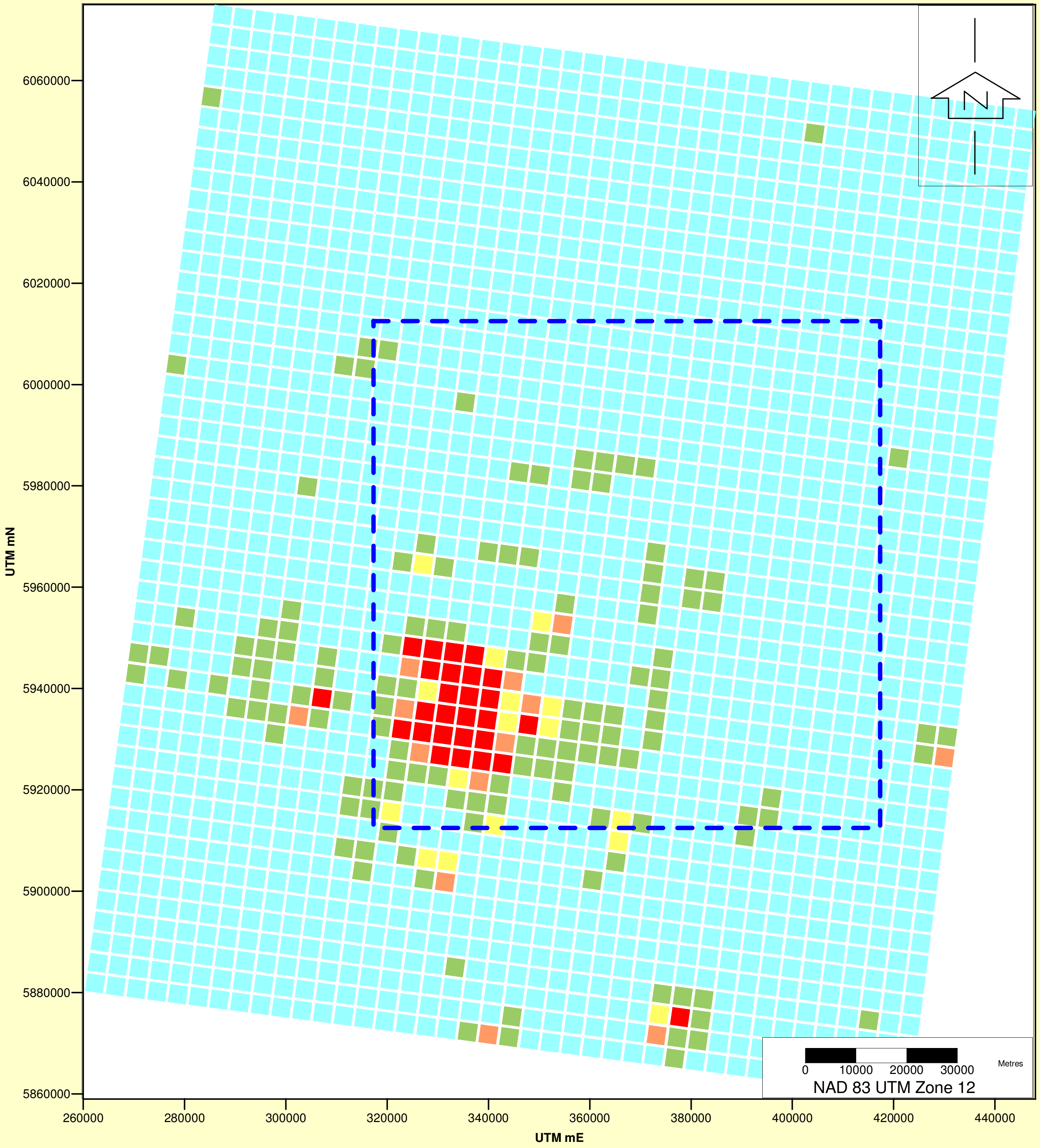
🟦 0 to 0.005
🟩 0.005 to 0.01
🟨 0.01 to 0.05
🟧 0.05 to 0.1
🟥 0.1 to 0.4

Title:

SO_2 EMISSIONS FROM COMMUNITY SOURCES (TONNE/DAY)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:
Revision Date: 17/10/2007
File: H:/AQ/Shared/1018897 NAOSC Matrix/ N8897 NAOSC Emissions/Traffic&Community/Figures/Total
Drawn by: HZ
Checked: MD
Fig. No.: **2A-10**



Legend

NOx Emissions (tonne/day)

🟦	0 to 0.1
🟩	0.1 to 0.5
🟨	0.5 to 1
🟧	1 to 2
🟥	2 to 11

Title:

NOx EMISSIONS FROM COMMUNITY SOURCES (TONNE/DAY)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:

Revision Date: 17/10/2007

File:
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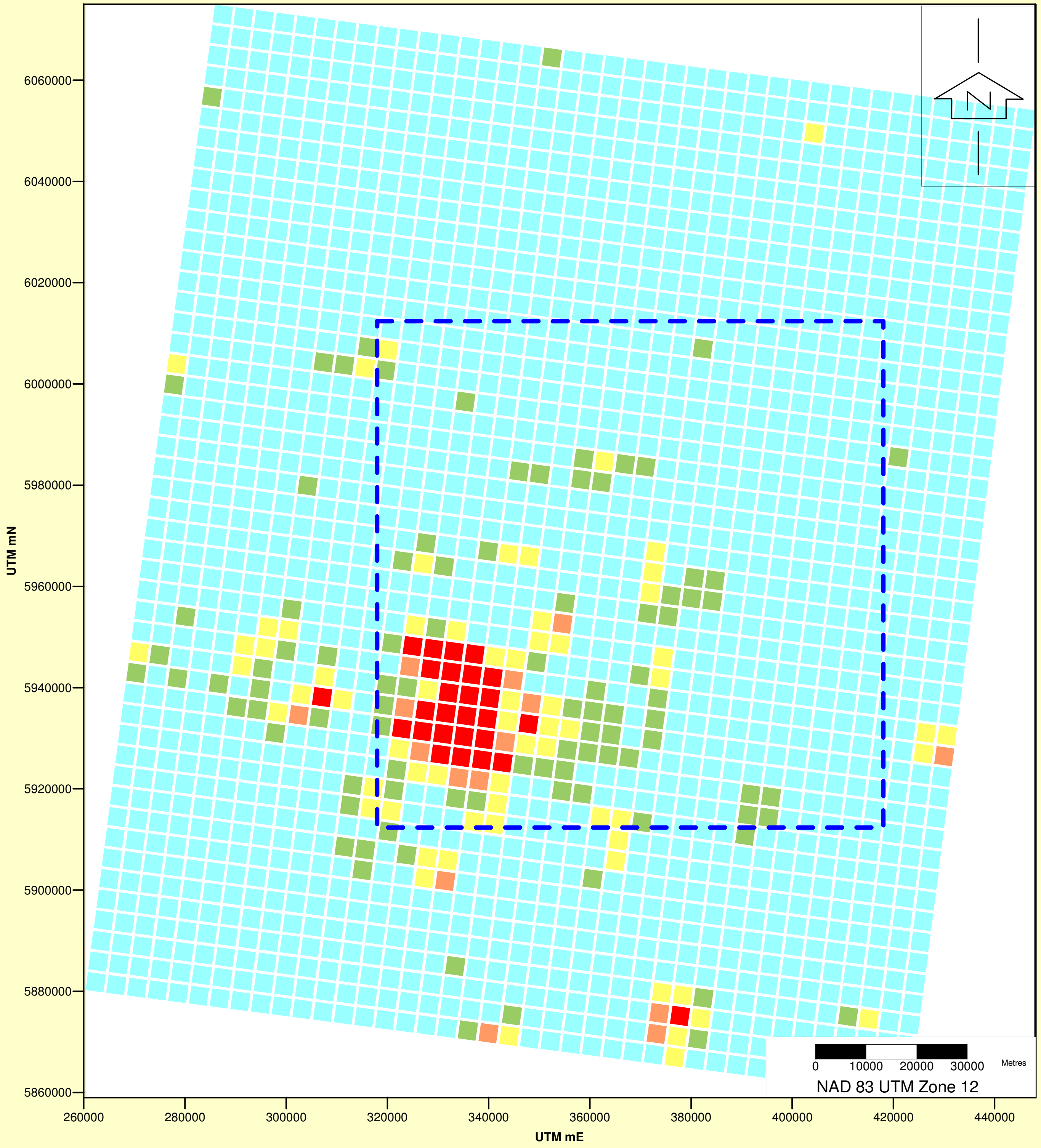
N8897 NAOSC Emissions/Traffic&Community/Figures/Total

Drawn by: HZ

Checked: MD

Fig. No.: **2A-11**



Legend

CO Emissions (tonne/day)

- 🟦 0 to 0.5
- 🟩 0.5 to 1
- 🟨 1 to 5
- 🟧 5 to 10
- 🟥 10 to 53

Title:

CO EMISSIONS FROM COMMUNITY SOURCES (TONNE/DAY)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date: 17/10/2007

File:
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N8897 NAOSC Emissions/Traffic&Community/Figures/Total

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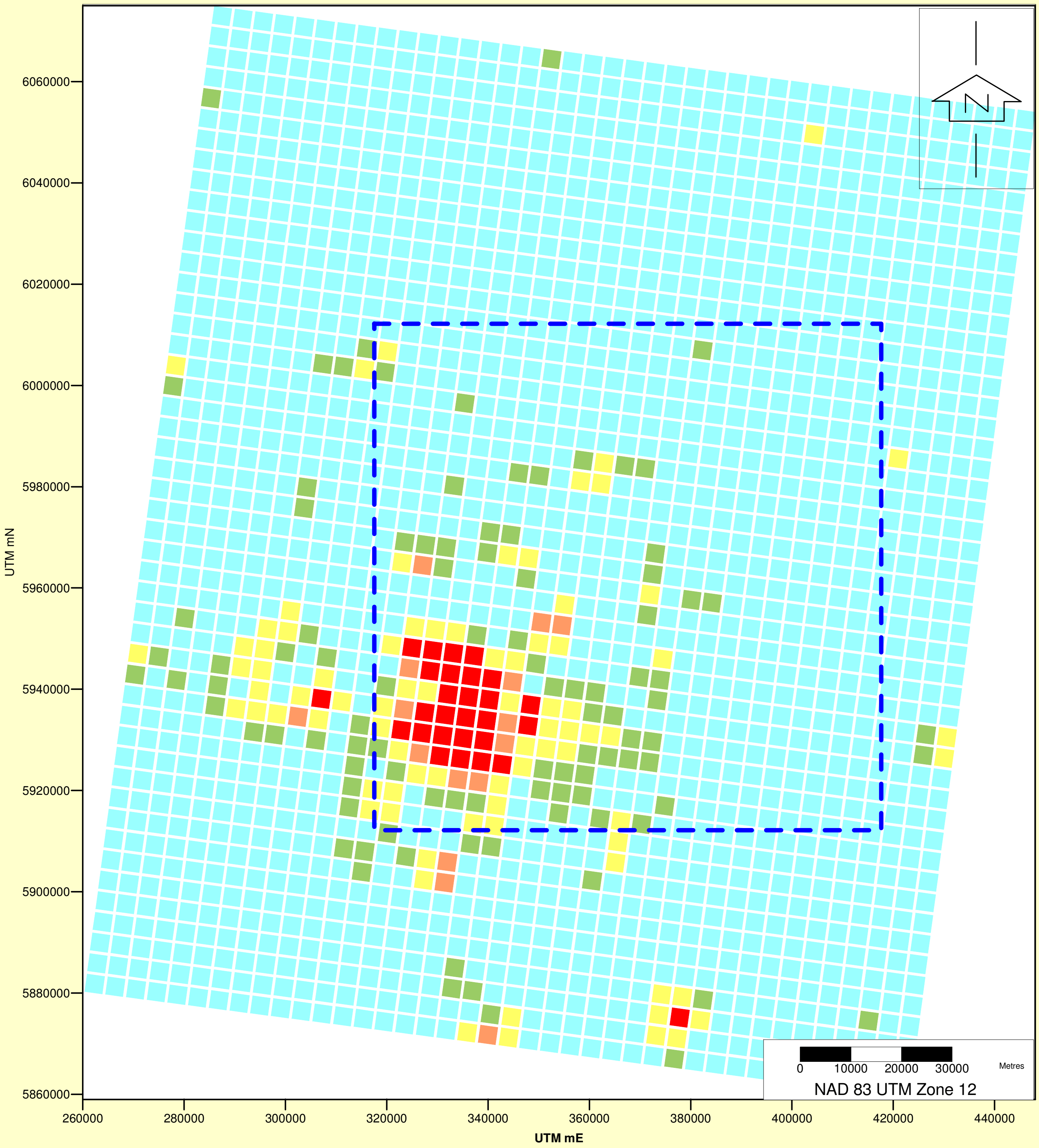

Legend

PM$_{2.5}$ Emissions (tonne/day)

- 🟦 0 to 0.005
- 🟩 0.005 to 0.01
- 🟨 0.01 to 0.05
- 🟧 0.05 to 0.1
- 🟥 0.1 to 0.7

Title:

PM$_{2.5}$ EMISSIONS FROM COMMUNITY SOURCES (TONNE/DAY)

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date: 17/10/2007

File:
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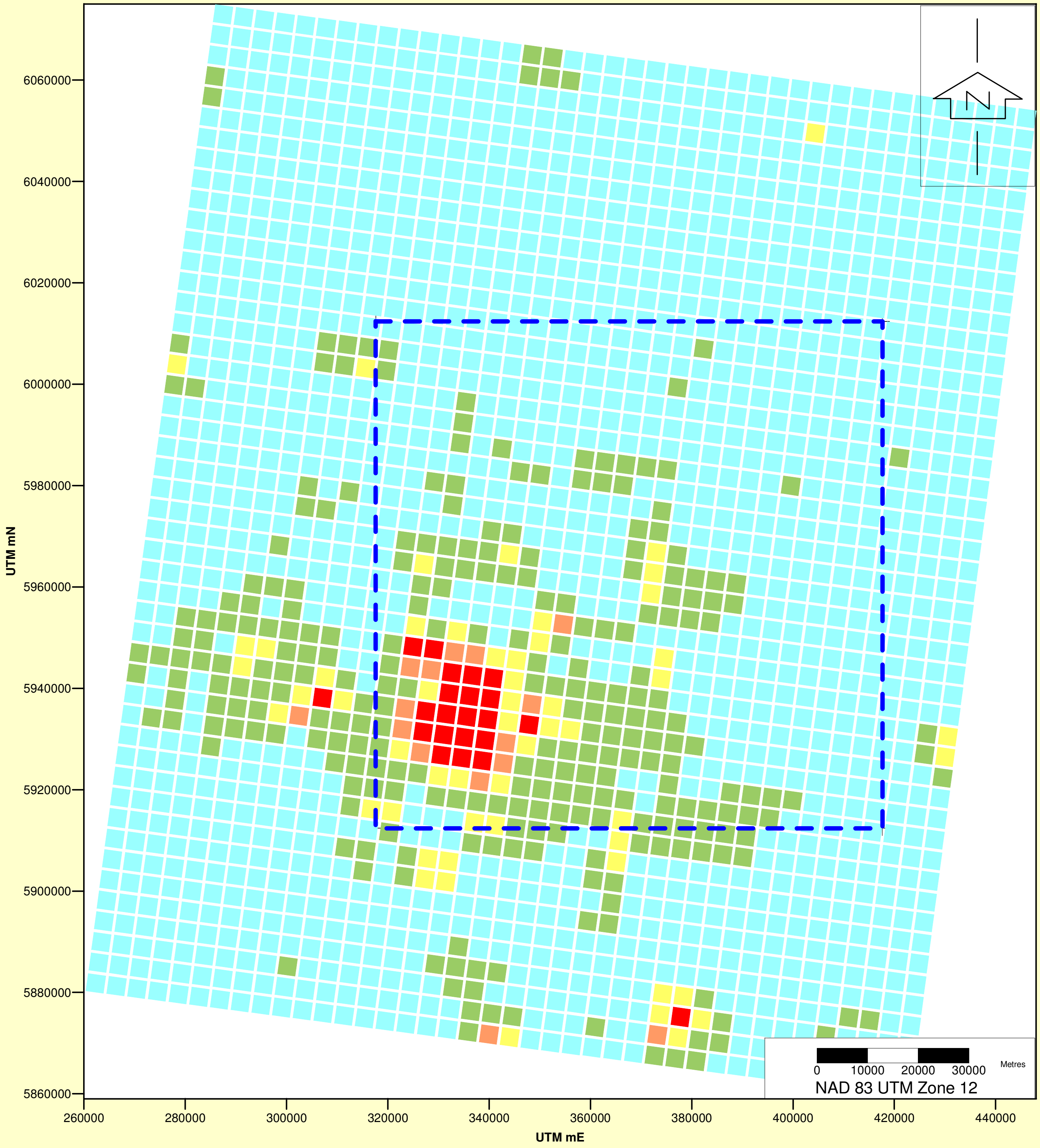

Legend

VOC Emissions (tonne/day)

- 🟦 0 to 0.02
- 🟩 0.02 to 0.1
- 🟨 0.1 to 0.5
- 🟧 0.5 to 1
- 🟥 1 to 4.2

Title:

VOC EMISSIONS FROM COMMUNITY SOURCES (TONNE/DAY)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:

Revision Date: 17/10/2007

File:
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N8897 NAOSC Emissions/Traffic&Community/Figures/Total

Drawn by: HZ

Checked: MD

Fig. No.: **2A-14**

Table 2A-90 Emission Profile for Traffic and Heating Emissions

Substance Group		Portion of Total VOC Due to Traffic[a] (%)	Portion of Total VOC Due to Heating[b] (%)
8	1,3-butadiene	0.45	-
10	2-methylnaphthalene	0.050	0.00044
11	Acenaphthene group	0.007	0.000033
12	Acetaldehyde	4.24	-
13	Acrolein	0.33	-
14	Aliphatic Alcohols	2.38	-
15	Aliphatic Aldehydes	3.90	-
16	Aliphatic Ketones	1.14	-
18	Anthracene	0.0019	0.000044
19	Benzaldehyde	0.40	-
20	Benzene	3.37	0.038
21	Benzo(a)anthracene	0.00024	0.000033
22	Benzo(a)pyrene	-	0.000022
25	Benzo(g,h,i)perylene	-	0.000022
26	Benzo(k)fluoranthene	-	0.000033
28	C17+ aliphatic group	0.10	-
29	C17-C34 Aromatics	0.017	-
30	C5-C8 aliphatics	22.70	47.27
31	C9-C16 Aromatics	8.26	0.000076
32	C9-C18 aliphatics	4.47	-
33	Chrysene	0.00027	0.000033
34	Cyclohexane	0.026	-
36	Dichlorobenzene	-	0.02
38	Ethylbenzene	1.18	-
39	Fluoranthene	0.0043	0.000055
40	Fluorene	0.005	0.000051
41	Formaldehyde	3.08	1.36
43	Hexane	0.59	32.73
44	Indeno(1,2,3-cd)pyrene	-	0.000033
47	Naphthalene	0.21	0.011
48	Phenanthrene	0.008	-
50	Pyrene	-	0.000091
51	Styrene	0.26	-
52	Toluene	8.36	0.062
53	Xylenes	4.79	-
	Total	**70.3**	**81.5**

a Traffic data based on 85% gasoline and 15% diesel fleet mix. Diesel data are from “New upgrades to EPA’s SPECIATE Database” by Hsu, Ying; el at. Gasoline data are from SPECIATE 4.0 Section 1314. 2006.

b From EPA AP-42 (Section 1.4)

Table 2A-91 Summary of Census Division 11 Air Emission for 2010

Source Category	Contaminant (t/d)					
	SO_x	NO_x	CO	$PM_{2.5}$	VOC	NH_3
Cement/Concrete	0.008	4.515	0.290	0.164	0.038	0.000
Chemicals	8.025	47.575	1.819	0.345	27.926	14.164
Mining	0.258	0.175	0.000	1.477	0.090	0.047
Iron and Steel	0.047	0.630	0.036	0.236	0.005	0.005
Non-Ferrous Refinery	11.455	1.274	0.068	0.036	0.005	0.003
Oil Sands	33.301	9.101	1.800	0.200	1.000	0.011
Petroleum Refining	23.318	11.501	2.953	2.858	2.134	0.058
Pulp and Paper	0.000	0.000	0.000	0.000	0.000	0.285
Oil & Gas	30.630	70.378	11.310	0.389	197.277	0.000
Manufacturing	0.148	14.707	145.619	7.915	0.537	0.345
Power Generation	166.852	181.893	17.677	13.885	2.477	0.652
Sum of Industry	274	342	182	27.5	231	15.57
Commercial	0.381	4.816	0.899	0.452	0.230	0.025
Residential	0.468	6.474	73.888	10.126	43.932	0.085
Sum of Heating	0.849	11.3	74.8	10.6	44.2	0.11
Vehicles	6.912	92.208	299.175	3.638	28.893	2.145
Road Dust-Paved	0.000	0.000	0.000	6.773	0.000	0.000
Road Dust-Unpaved	0.000	0.000	0.000	14.962	0.000	0.000
Total Transportation	6.91	92.2	299	25.4	289	2.15
Incineration	0.003	0.000	0.000	0.000	0.047	0.000
Smoking	0.000	0.000	0.301	0.063	0.000	0.000
Structural Fires	0.000	0.000	1.641	0.737	0.795	0.000
Dry Cleaning	0.000	0.000	0.000	0.000	0.167	0.000
Fuel Marketing	0.000	0.000	0.000	0.000	13.159	0.000
General Solvent Use	0.000	0.000	0.000	0.000	37.227	0.000
Printing	0.000	0.000	0.000	0.000	2.260	0.000
Surface Coating	0.000	0.000	0.000	0.000	7.323	0.000
Livestock	0.030	0.000	0.000	0.622	0.000	72.066
Tilling	0.000	0.000	0.000	1.775	0.000	0.000
Pesticide/Fertilizer	0.000	0.000	0.000	0.129	0.000	18.907
Construction	0.000	0.000	0.000	5.290	0.000	0.000
Landfill	0.000	0.000	0.000	0.014	0.403	0.000
Meat Cooking	0.000	0.000	0.000	0.126	0.000	0.000
Mine Tailing	0.000	0.000	0.000	0.022	0.000	0.000
Sum of Other	0.033	0	1.94	8.78	61.4	91.0
Total (t/d)	**282**	**445**	**557**	**72**	**366**	**109**

NOTE: Major contributors indicated by gray shading.

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APPENDIX 2B: AMBIENT AIR QUALITY MONITORING

TABLE OF CONTENTS

TABLES

FIGURES

2B AMBIENT AIR QUALITY MONITORING

2B1 Introduction

Ambient air quality monitoring measurements provide an indication of air quality levels associated with existing sources. This section provides an overview of the magnitude and trends associated with ambient air quality measured in the region.

2B2 Information Sources

2B2.1 Fort Air Partnership (FAP)

The Fort Air Partnership (FAP) is a multi-stakeholder organization that collects representative ambient air quality data in the region. The FAP was formed in 1997; and prior to this date, ambient monitoring was undertaken independently by AENV and selected industries. The integrated operation of these independent monitoring efforts began in the fall of 1997 with the implementation of the FAP.

The FAP operates eight continuous ambient air quality stations in the region; three are located at or near communities (i.e., Fort Saskatchewan and Ross Creek Station in the community of Fort Saskatchewan, and the Lamont Station near Lamont and Bruderheim), four are located near industrial sources (i.e., the Station 401, Range Road 220, Scotford and Redwater Station), and one is located in a remote area (i.e., Elk Island). Figure 2B-1 and Table 2B-1 provide the locations for these stations. The Scotford station moved on December 18, 2006, to a new location (referred to as Scotford 2). The Scotford location depicted in the figures and tables reflects the old location.

Ambient air quality data from these stations for the 48-month period January 1, 2003, to December 31, 2006, were obtained and reviewed to provide an indication of existing air quality in the region. The continuous ambient air quality information includes SO_2, NO_2, $PM_{2.5}$, O_3, H_2S, NH_3, CO and HC measurements. Not all substances are measured at all stations. Only data from the Scotford station up to December 18, 2006 were reviewed.

2B2.2 Environment Canada and FAP

The FAP and Environment Canada (EC) conducted a VOC monitoring study where 24-h air samples were collected once every six days from six locations in the region. The 24-h sampling period once every six days is part of the National Air Pollution Surveillance (NAPS) protocol, and is selected to ensure that sampling is not biased to a specific day of the week. The 19-month study collection period ran from September 12, 2004 to March 6, 2006 and the air samples were analyzed for 150 VOC substances (EC 2006). The locations of these monitoring sites are provided in Table 2B-1 and Figure 2B-1.

2B2.3 Other Sources

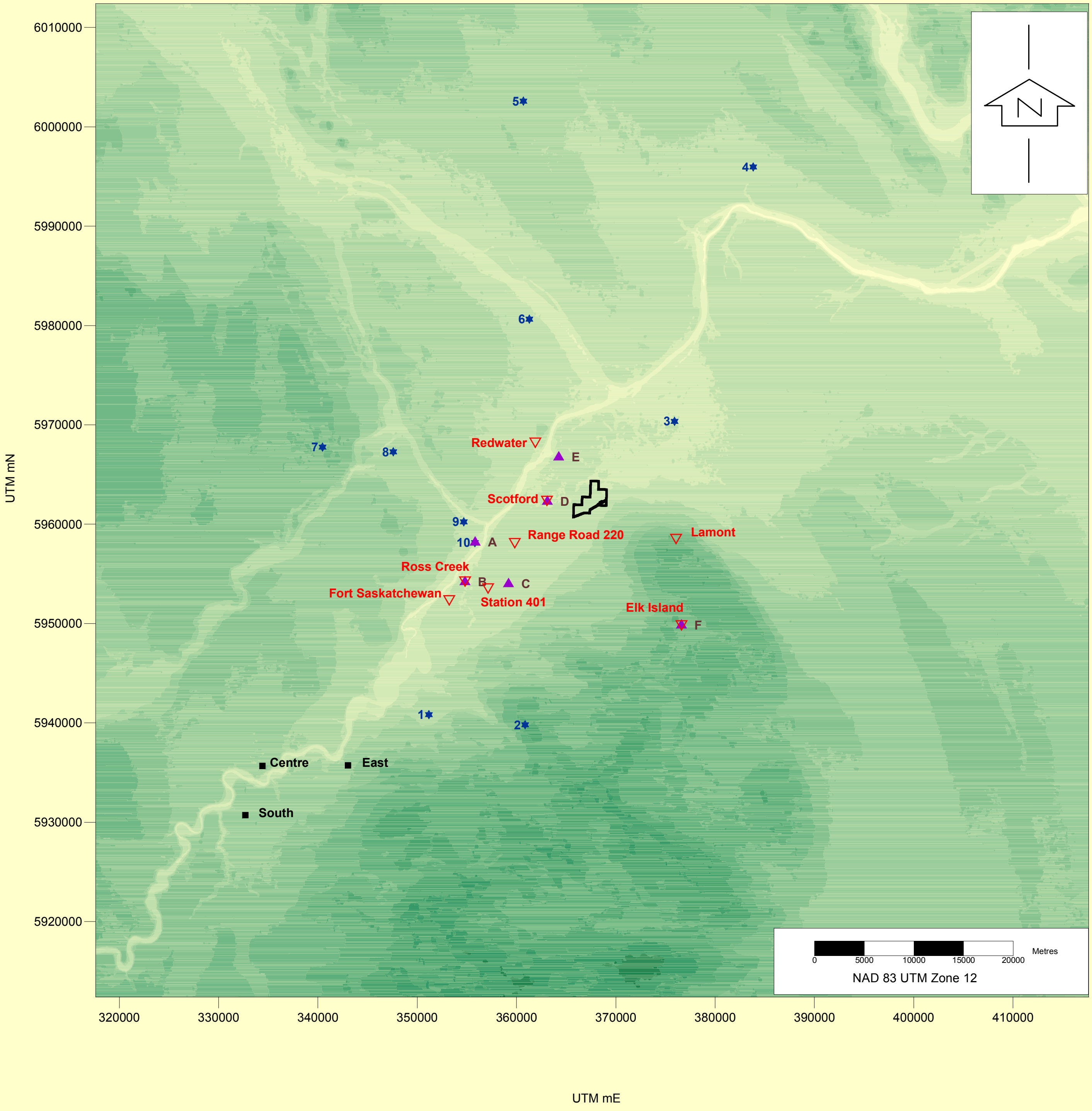
Passive SO_2, NO_2, and O_3 measurements were obtained from FAP for the 18-month period, July 2005 to December 2006. The passive samplers provide monthly average concentrations. Figure2B-1 and Table 2B-1 provide the locations of these monitoring sites. The passive sites are more distant from major industrial emission sources.

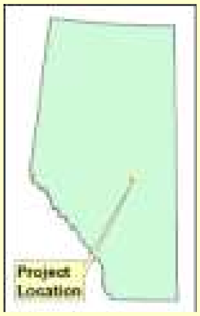
AENV operates three ambient air quality monitoring stations in Edmonton: Edmonton East, Edmonton Central and Edmonton South. Ambient measurements at these three stations were obtained from the CASA data warehouse for the 48-month period January 1, 2003, to December 31, 2006. Figure 2B-1 and Table 2B-1 provide the locations of these monitoring sites.

Potential acid input (PAI) is directly of interest relative to the deposition of acid forming compounds, and indirectly of interest relative to the deposition of nitrogen compounds. PAI and nitrogen deposition is comprised of wet and dry deposition contributions. As measurements are not available for the region, the PAI and nitrogen depositions have to be inferred from other sources (i.e., RELAD acid model modelling and/or measurements outside the region).

Table 2B-1 UTM Coordinates for the Ambient Monitoring Sites in the FAP and Edmonton Region

	UTM NAD 83 Zone 12 Easting	UTM NAD 83 Zone 12 Northing	Elevation ASL
FAP			
Fort Saskatchewan	353232	5952310	627
Lamont	376056	5958500	720
Station 401	357139	5953510	620
Ross Creek	354826	5954196	617
Range Road 220	359833	5958067	628
Scotford	363073	5962319	621
Redwater	361891	5968174	626
Elk Island	376626	5949803	714
FAP/EC			
A (Residence)	355844	5958173	622
B (Ross Creek)	354826	5954196	617
C (Station 401)	357139	5953510	620
D (Scotford)	363073	5962319	621
E (Residence)	364267	5966735	623
F (Elk Island)	376626	5949803	714
Passive			
1 (W of Hwy 21)	351172	5940836	652
2 (N of Ardrossan)	360879	5939796	738
2 (N of Bruderheim)	375926	5970356	622
4 (Waskatenau)	383851	5995967	633
5 (Thorhild)	360697	6002573	646
6 (Redwater)	361296	5980649	631
7 (Bon Accord)	340475	5967758	700
8 (Gibbons)	347591	5967276	661
9 (Hu Haven)	354688	5960244	639
10 (Fort Agustus)	355804	5958150	622
Edmonton			
Edmonton East	343030	5935714	671
Edmonton Central	334403	5935681	671
Edmonton South	332684	5930706	667





Legend

- ✶ FAP Passive Monitoring Station
- ▽ FAP Continuous Monitoring Station
- ▲ FAP VOC Monitoring Station
- ■ Alberta Environment Monitoring Station
- □ Project Fenceline

Title:

AIR QUALITY MONITORING SITES IN THE REGION

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date: 30/11/2007	
File: H:/AQ/Shared/1018897 NAOSC Matrix /N8897 Coordinates		
Drawn by: X.C.	Checked: M.D.	Fig. No.: **2B-1**

2B3 Sulphur Dioxide (SO_2) Concentrations

2B3.1 Hourly Averages

Ambient sulphur dioxide concentrations are routinely measured on a continuous basis at the following FAP stations: Redwater, Scotford, Fort Saskatchewan, Ross Creek, Range Road 220, and Lamont. Ambient SO_2 concentrations are also available at the Edmonton East station. Ambient concentration data are archived as 1-h averages in concentration units of ppb (parts per billion). These units, for the purposes of this assessment, were converted into units of ug/m^3 (micrograms per cubic metre). Note: 1 ppb = 2.6 ug/m^3.

Table 2B-2 provides an overview of the hourly average frequency statistics based on measurements for the 48-month period, January 2003 to December 2006. The hourly AAAQO for SO_2 is 450 ug/m^3, and this was exceeded at the Redwater and Scotford FAP stations:

- Figure 2B-2 shows the SO_2 concentration time series at the Redwater station, and the associated distribution of hourly concentrations with wind direction. High SO_2 concentration events are periodic, and over the period presented, there were 40 exceedances at the Redwater station. Elevated concentration events were associated with winds in the 70º to 95º sector (i.e., winds from the east), which corresponds to the upwind location from the Agrium Redwater facility.

- Figure 2B-3 shows the SO_2 concentration time series at the Scotford station, and the associated distribution of hourly concentrations with wind direction. There was only one exceedance at the Scotford station. Elevated concentration events were associated with winds in the 290º to 310º sector (i.e., winds from the west-northwest), which corresponds to the upwind location from the Scotford Upgrader incinerator stack.

- Figure 2B-4 shows the wind direction dependence for the SO_2 concentrations measured at the Fort Saskatchewan and Lamont monitoring stations.

To provide an indication of SO_2 concentrations associated with air flow from outside the region, the SO_2 concentrations associated with specific wind directions were analyzed:

- When winds are from the northwest sector (270° to 360°), the median and 85th percentile SO_2 concentrations based on the Redwater data are 0.0 and 2.6 ug/m^3, respectively.

- When winds are from the southwest sector (180° to 270°), the median and 75th percentile SO_2 concentrations based on Fort Saskatchewan data are 2.6 ug/m^3 and 5.2 ug/m^3, respectively.

- When winds are from the northeast sector (0° to 90°), the median and 75th percentile SO_2 concentrations based on Lamont data are 0.0 ug/m^3 and 2.6 ug/m^3, respectively.

- When winds are from the southeast sector (90° to 180°), the median and 75th percentile SO_2 based on Lamont data are 2.6 ug/m^3 and 2.6 ug/m^3, respectively.

The Fort Saskatchewan direction specific concentrations show the influence of the Edmonton urban area (2.6 ug/m^3 to 5.2 ug/m^3) relative to the rural contribution values derived from the Redwater and Lamont data (0.0 ug/m^3 to 2.6 ug/m^3). Note these values are in multiples of 2.6 ug/m^3, which reflects the measurement unit of 1 ppb.

For the purpose of comparison, the maximum average hourly ambient SO_2 concentration at the Edmonton East station is 181 ug/m^3 . This is less than the maximum values observed at all the FAP stations (280 ug/m^3 to 1138 ug/m^3) other than the Lamont station (120 ug/m^3).

2B3.2 Daily Averages

Table 2B-3 provides an overview of the daily average frequency statistics based on measurements for the 48-month period, January 2003 to December 2006. The daily AAAQO for SO_2 is 150 ug/m^3, which was exceeded four times at the Redwater FAP station. These days were associated with the days when the hourly average value AAAQO was exceeded. For the purpose of comparison, the maximum daily average ambient SO_2 concentration at the Edmonton East station is 30.7 ug/m^3 . This is similar to the maximum values measured at the Fort Saskachewan, Ross Creek, Range Road 220 and Lamont stations (27.6 ug/m^3 to 38.7 ug/m^3).

2B3.3 Annual Averages

Table 2B-4 provides the annual average SO_2 concentrations for the individual years assessed and for the full 48-month period. The annual AAAQO for SO_2 is 30 ug/m^3, which was not exceeded at any of the FAP stations. The annual averages tend to be the highest for the two sites directly influenced by adjacent industry emissions (i.e., the Redwater and the Scotford stations). For the other sites, the annual averages tend to be in the 1.5 ug/m^3 to 3.7 ug/m^3 range.

Table 2B-5 provides a summary of the monthly maximum and period average SO_2 concentrations measured with the passive samplers. The passive samplers are more accurate for the lower concentration levels, and therefore provide more accurate concentrations for annual averages. The period averages are in the 1.2 ug/m^3 to 2.7 ug/m^3 range, with an average of 1.8 ug/m^3. These values are similar to those measured at Ross Creek and Range Road 220 with the continuous analysers.

For the purpose of comparison, the annual average ambient SO_2 concentration at the Edmonton East station is 3.6 ug/m^3 . This is similar to that measured at the Lamont station (3.7 ug/m^3).

Table 2B-2 Summary of hourly average SO_2 concentrations (ug/m^3) measured at the FAP monitoring and Edmonton stations (AAAQO = 450 ug/m^3)

	Redwater	Scotford	Fort Saskatchewan	Ross Creek	Range Road 220	Lamont	Edmonton
Maximum	1138	463	327	340	280	120	181
99.9th Percentile	465	280	42.4	78.5	52.3	49.7	60.2
99th Percentile	176	115	18.3	26.2	20.9	26.2	28.8
95th Percentile	26.2	31.4	7.9	0.0	7.9	13.1	13.1
90th Percentile	10.5	15.7	5.2	0.0	5.2	10.5	7.9
Median	0.0	2.6	2.6	0.0	2.6	2.6	2.6
Average	8.2	7.7	2.7	1.5	2.5	3.7	3.6

Table 2B-3 Summary of daily average SO_2 concentrations (ug/m^3) measured at the FAP and Edmonton monitoring stations (AAAQO = 150 ug/m^3)

	Redwater	Scotford	Fort Saskatchewan	Ross Creek	Range Road 220	Lamont	Edmonton
Maximum	225	129	35.4	38.7	33.9	27.6	30.7
99.9th Percentile	177	115	15.3	34.9	27.0	22.6	21.1
99th Percentile	101	57.8	9.4	18.2	11.0	16.2	14.4
95th Percentile	36.4	30.6	6.7	8.0	6.8	10.6	9.0
90th Percentile	20.5	18.4	5.3	4.6	5.3	8.2	7.3
Median	2.2	3.8	2.3	0.0	1.8	2.8	2.9
Average	8.2	7.7	2.7	1.5	2.5	3.7	3.6

Table 2B-4 Annual average SO_2 concentrations (ug/m^3) measured at the FAP and Edmonton monitoring stations (AAAQO = 30 ug/m^3)

	Redwater	Scotford	Fort Saskatchewan	Ross Creek	Range Road 220	Lamont	Edmonton
2003	4.0	11.4	2.7	1.9	3.2	4.8	3.5
2004	12.0	7.2	2.8	1.7	2.4	3.5	3.4
2005	9.8	5.1	2.8	1.5	2.1	3.4	4.1
2006	6.9	7.0	2.5	0.9	2.5	3.1	3.5
Full Period	8.2	7.7	2.7	1.5	2.5	3.7	3.6

Table 2B-5 Average SO_2 concentrations (ug/m^3) based on the FAP passive monitoring network (annual AAAQO = 30 ug/m^3)

Site #	FAP Site	18 Month Average	Monthly Maximum
1	W of Hwy 21	2.4	3.9
2	N of Ardrossan	2.7	5.2
3	NE of Bruderheim	1.5	4.2
4	Waskatenau	1.2	2.6
5	Thorhild	1.2	2.6
6	Redwater	1.7	3.5
7	Bon Accord	2.1	4.4
8	Gibbons	1.7	3.8
9	Hu-Haven	1.8	2.9
10	Fort Augustus	1.8	3.4
Average		1.8	3.7

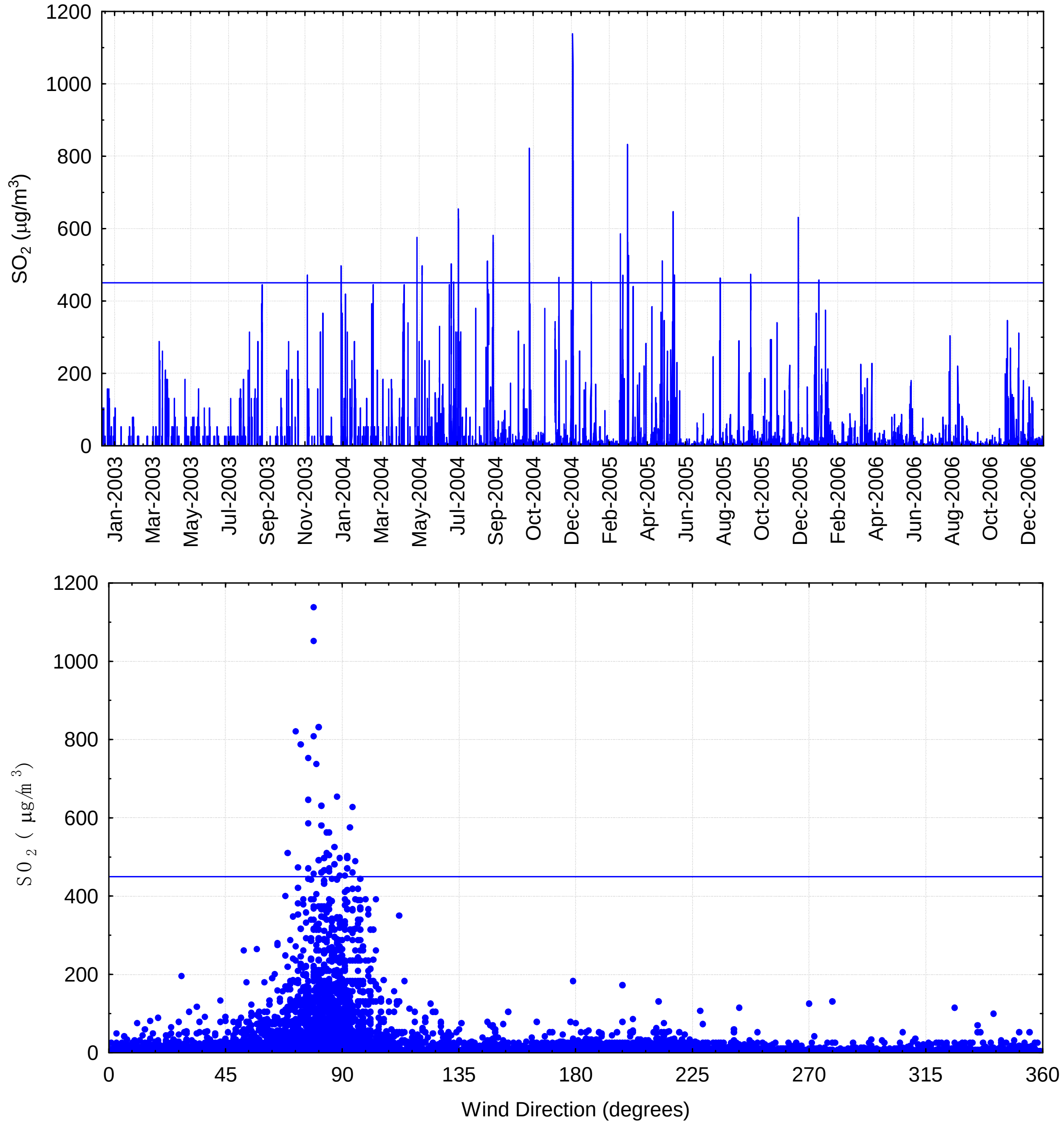
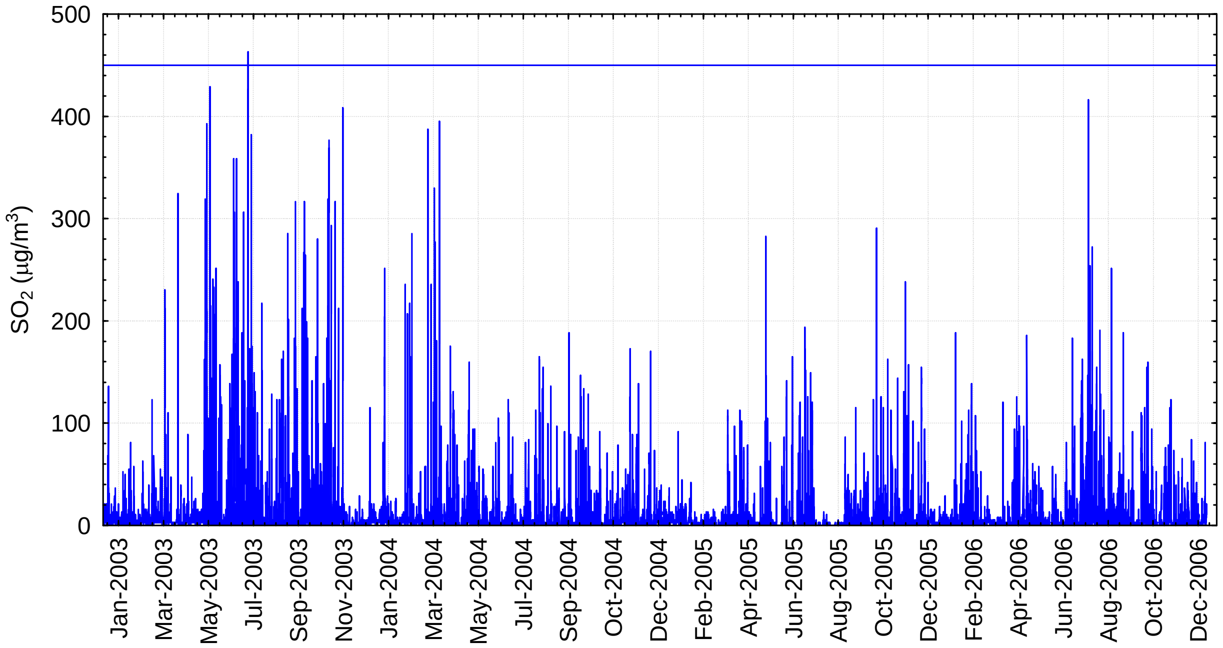


Figure 2B-2 **Ambient hourly SO_2 concentrations measured at the FAP Redwater station. The AAAQO of 450 ug/m^3 is shown by the solid line. The top plot shows the time series and the bottom plot shows the wind direction dependence.**



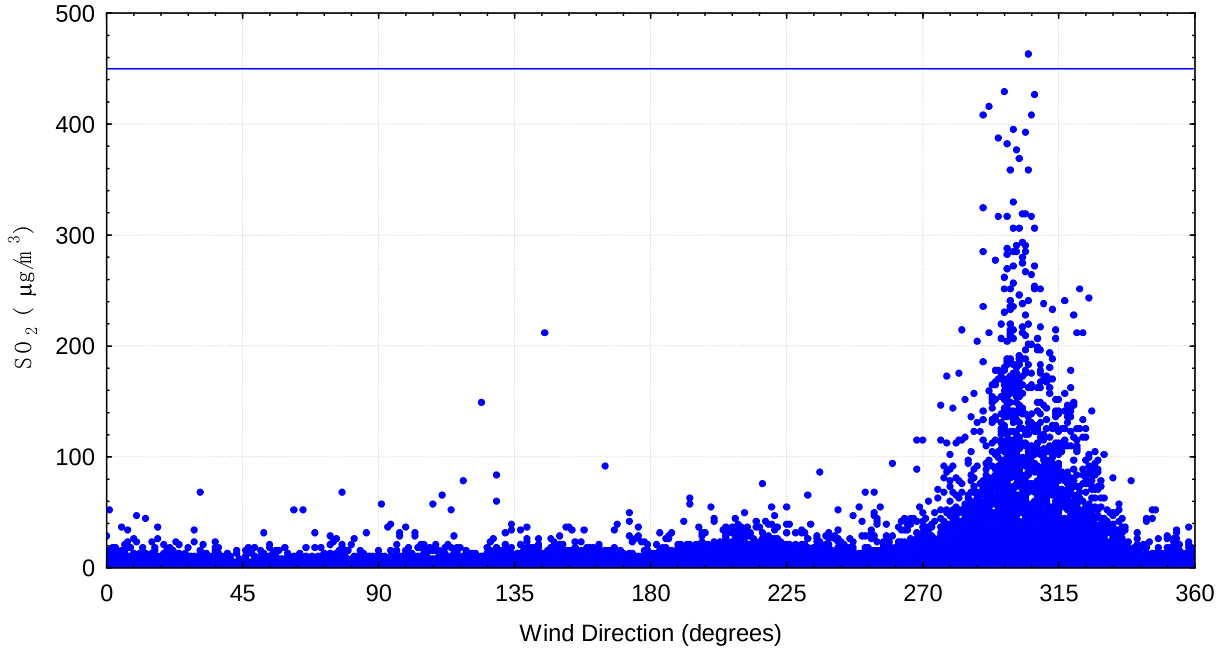
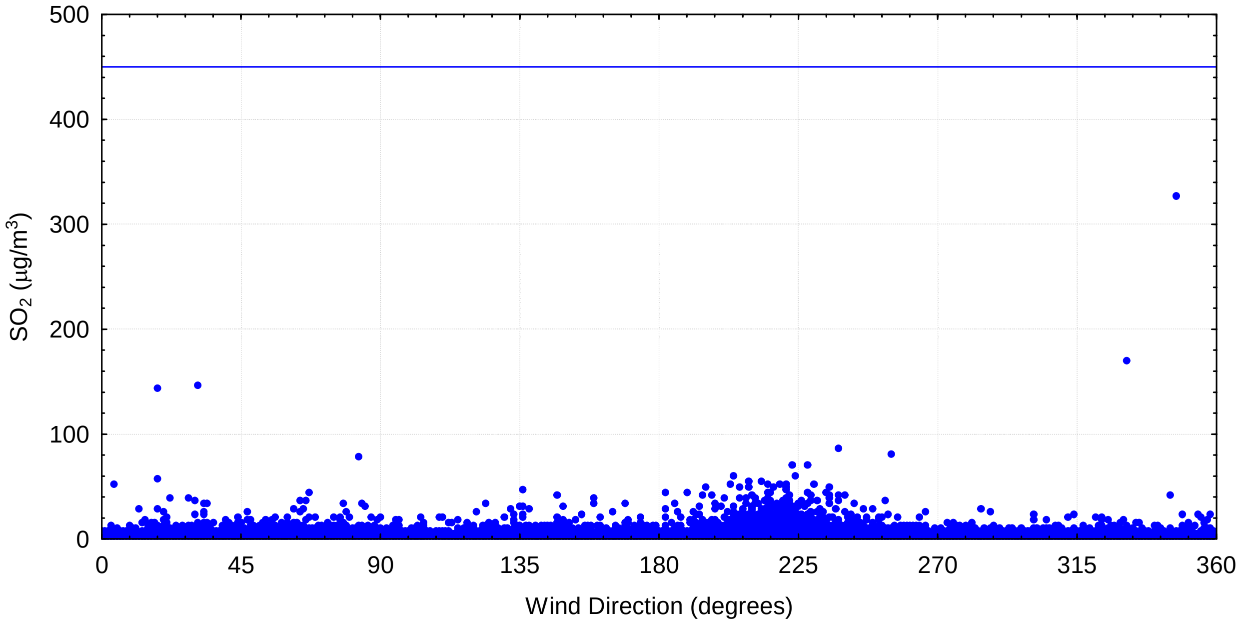
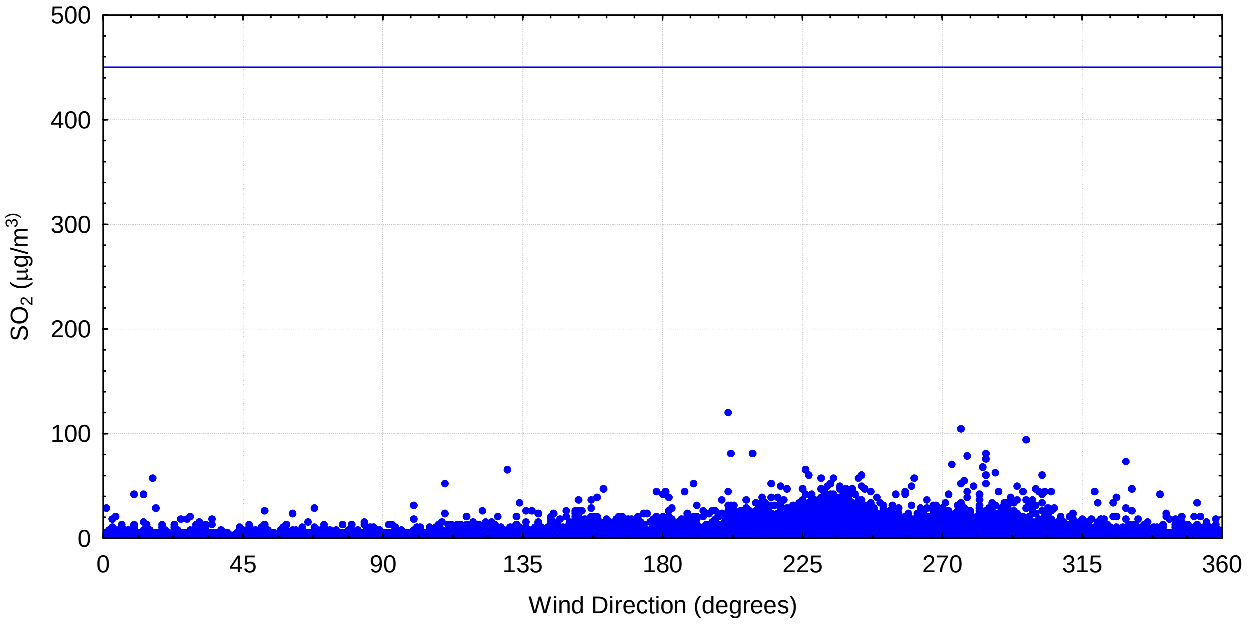


Figure 2B-3 **Ambient hourly SO_2 concentrations measured at the FAP Scotford station. The AAAQO of 450 ug/m^3 is shown by the solid line. The top plot shows the time series and the bottom plot shows the wind direction dependence.**



Fort Saskatchwan



Lamont

Figure 2B-4 Ambient hourly SO_2 concentrations measured at the FAP Fort Saskatchewan and Lamont stations. The AAAQO of 450 ug/m^3 is shown by the solid line. The top plot shows the time series and the bottom plot shows the wind direction dependence.

2B4 Nitrogen Dioxide (NO_2) Concentrations

2B4.1 1-h Averages

Ambient oxides of nitrogen (NO_x) and nitrogen dioxide (NO_2) concentrations are routinely measured on a continuous basis at the following FAP stations: Redwater, Fort Saskatchewan, Ross Creek, Range Road 220, Station 401 and Lamont. Ambient NO_X and NO_2 concentrations are also collected at the Edmonton East, Edmonton Central and Edmonton South stations. Ambient concentration data are archived as 1-h averages in concentration units of ppb (parts per billion). These units, for the purposes of this assessment, were converted into units of ug/m^3 (micrograms per cubic metre). Note: 1 ppb = 1.9 ug/m^3.

Tables 2B-6 and 2B-7, provide an overview of the hourly average NO_x and NO_2 frequency statistics respectively based on measurements for the 48-month period, January 2003 to December 2006. The following are noted:

- The highest FAP values occur at the urban-influenced sites (i.e., traffic) sites of Fort Saskatchewan and Ross Creek. The lowest concentrations are associated with the Lamont site, which is furthest from major NO_X emission sources.

- For high hourly NO_X concentration events, the high NO_2 concentrations are a factor of five lower than the NO_X concentrations. On an average basis, the NO_2 concentrations tend to be a factor of two lower than the NO_X concentrations. The conversion of NO to NO_2 in the atmosphere is limited by the amount of atmospheric ozone (O_3) available.

- The maximum hourly values of NO_2 at the sites range from 102 ug/m^3 to 282 ug/m^3. These are less than the 1-h average AAAQO value of 400 ug/m^3.

The highest concentrations are measured at the Ross Creek station. Figure 2B-5 shows the NO_2 concentration time series at this station, and the associated distribution of hourly concentrations with wind direction. The highest and lowest concentrations are associated with winter and summer periods, respectively. This type of distribution suggests that low level sources, such as traffic is a significant contributor. Elevated concentration events were associated with winds in the 180º to 270º sector (i.e., winds from the southwest), and the lowest concentrations are associated with easterly winds (i.e., 90°). This supports the premise that traffic contributes to high NO_2 concentrations.

To provide an indication of NO_2 concentrations associated with air flow from outside the region, the NO_2 concentrations associated with selected wind directions were analyzed:

- When winds are from the northwest sector (270° to 360°), the median and 75th percentile NO_2 concentrations based on Redwater data are 0.0 ug/m^3 and 18.8 ug/m^3, respectively.

- When winds are from the northeast sector (0° to 90°), the median and 75th percentile NO_2 concentrations based on Lamont data are 0.0 ug/m^3 and 1.9 ug/m^3, respectively.

- When winds are from the west–southwest sector (225° to 270°), the median and 75th percentile NO_2 concentrations based on Lamont data are 13.2 ug/m^3 and 22.6 ug/m^3, respectively.

The Fort Saskatchewan data were not analyzed since the station is located within the community and will be influenced by the community (i.e., Fort Saskatchewan traffic sources) emissions for all wind directions. Direction specific concentrations associated with the west–southwest Lamont data show the influence of the Edmonton urban area (13.2 to 22.6 ug/m^3) relative to the rural contribution derived from the Lamont northeast data (0 to 1.9 ug/m^3).

For the purpose of comparison, the maximum1-h average NO_x concentrations at the Edmonton East, Edmonton Central and Edmonton South stations are 1204, 986 and 850 ug/m^3, respectively. The maximum 1-h average NO_2 concentrations at the Edmonton East, Edmonton Central and Edmonton South stations are 184 ug/m^3, 167 ug/m^3 and 117 ug/m^3, respectively. These sites (especially the Edmonton Central station) would be strongly influenced by traffic emissions.

2B4.2 Daily Averages

Table 2B-8 provides an overview of the daily average frequency statistics based on measurements for the 48-month period, January 2003 to December 2006. The Ross Creek and Lamont stations have the highest and lowest 24-h values, respectively. The Ross Creek station is the only station with an exceedance of the 24-h average AAAQO value of 200 ug/m^3. The exceedance only occurred for one day on the 48-month period.

For the purpose of comparison, the maximum 24-h average NO_2 concentrations at the Edmonton East, Edmonton Central and Edmonton South stations are 103 ug/m^3, 117 ug/m^3 and 83.1 ug/m^3, respectively. These are similar to those measured at the FAP stations (82.6 ug/m^3 to 99.0 ug/m^3) except to Ross Creek (206 ug/m^3) and Lamont (42.4 ug/m^3).

2B4.3 Annual Averages

Table 2B-9 provides the annual average NO_2 concentrations for the individual full years assessed and for the full 48-month period. The annual averages measured at the stations range from 5.9 ug/m^3 at Lamont to 29.4 ug/m^3 at Ross Creek. The annual average values are less than the annual average AAAQO value of 60 ug/m^3.

Table 2B-10 provides a summary of the monthly maximum and period average NO_2 concentrations measured with the passive samplers. The passive samplers are more accurate for the lower concentration levels, and therefore provide more accurate concentrations for annual averages. The period NO_2 averages are in the 5.7 ug/m^3 to 13.8 ug/m^3 range. These values are similar to those measured at the Lamont and Range Road 220 stations.

For the purpose of comparison, the annual average NO_2 concentrations at the Edmonton East, Edmonton Central and Edmonton South stations are 31.0 ug/m^3, 42.2 ug/m^3 and 28.6 ug/m^3, respectively. This is similar to what was measured at the Ross Creek station (29.4 ug/m^3).

Table 2B-6 Summary of hourly average NO_X concentrations (ug/m^3) measured at the FAP and Edmonton monitoring stations (no AAAQO)

	Redwater	Fort Saskatchewan	Ross Creek	Range Road 220	Station 401	Lamont	Edmonton East	Edmonton Central	Edmonton South
Maximum	709	762	1693	376	545	230	1204	986	850
99.9th Percentile	293	501	1129	263	301	138	547	567	580
99th Percentile	186	292	752	169	207	67.7	342	329	295
95th Percentile	105	165	376	94.0	113	35.7	196	194	156
90th Percentile	71.5	109	188	56.4	75.2	22.6	135	147	105
Median	16.9	18.8	0.0	18.8	18.8	1.9	33.9	58.3	26.3
Average	30.0	42.0	56.3	22.9	29.9	7.9	58.1	75.8	45.8

Table 2B-7 Summary of hourly average NO_2 concentrations (ug/m^3) measured at the FAP and Edmonton monitoring stations (AAAQO = 400 ug/m^3)

	Redwater	Fort Saskatchewan	Ross Creek	Range Road 220	Station 401	Lamont	Edmonton East	Edmonton Central	Edmonton South
Maximum	169	154	282	245	113	102	184	167	117
99.9th Percentile	94.0	116	226	113	94.0	71.5	122	126	111
99th Percentile	75.2	90.3	151	75.2	75.2	48.9	97.8	102	82.8
95th Percentile	56.4	67.7	94.0	56.4	56.4	26.3	77.1	82.8	63.9
90th Percentile	37.6	54.5	75.2	37.6	37.6	16.9	65.8	71.5	54.5
Median	18.8	15.0	18.8	0.0	18.8	1.9	24.4	37.6	20.7
Average	16.2	22.6	29.4	13.3	19.5	5.9	31.0	42.2	26.5

Table 2B-8 Summary of daily average NO_2 concentrations (ug/m^3) measured at the FAP and Edmonton monitoring stations (AAAQO = 200 ug/m^3)

	Redwater	Fort Saskatchewan	Ross Creek	Range Road 220	Station 401	Lamont	Edmonton East	Edmonton Central	Edmonton South
Maximum	94.0	99.0	**206**	98.1	82.6	42.4	103	117	83.1
99.9th Percentile	70.4	95.1	185	86.7	80.2	41.5	95.9	97.5	76.5
99th Percentile	61.3	75.4	132	61.7	65.4	32.5	77.9	85.0	65.6
95th Percentile	42.5	57.4	84.2	39.3	47.5	20.4	65.7	73.2	51.7
90th Percentile	31.9	45.4	67.9	31.1	39.3	15.0	55.8	66.4	46.8
Median	13.9	17.4	19.6	9.0	16.4	3.5	27.1	39.5	23.7
Average	16.2	22.6	29.4	13.3	19.6	5.9	31.0	42.2	26.5

Table 2B-9 Annual average NO_2 concentrations (ug/m^3) measured at the FAP and Edmonton monitoring stations (AAAQO = 60 ug/m^3)

	Redwater	Fort Saskatchewan	Ross Creek	Range Road 220	Station 401	Lamont	Edmonton East	Edmonton Central	Edmonton South
2003	19.2	25.0	50.6	12.3	21.3	5.8	33.8	47.2	-
2004	13.8	21.4	18.6	11.6	19.2	5.3	30.4	41.4	-
2005	16.3	22.6	24.1	16.5	19.9	6.6	30.4	40.4	32.5
2006	15.4	21.2	24.3	12.7	17.8	6.1	29.3	40.0	24.8
Full Period	16.2	22.6	29.4	13.3	19.5	5.9	31.0	42.2	28.6

Table 2B-10 Average NO_2 concentrations (ug/m^3) based on the FAP passive monitoring network (AAAQO = 60 ug/m^3)

Site #	FAP Site	18 month Average	Monthly Maximum
1	W of Hwy 21	13.8	28.8
2	N of Ardrossan	7.1	14.1
3	NE of Bruderheim	7.4	34.0
4	Waskatenau	5.7	15.0
5	Thorhild	5.8	15.6
6	Redwater	7.7	22.6
7	Bon Accord	8.7	20.1
8	Gibbons	9.2	23.1
9	Hu-Haven	8.4	22.6
10	Fort Augustus	9.4	24.1
Average		8.0	23.1

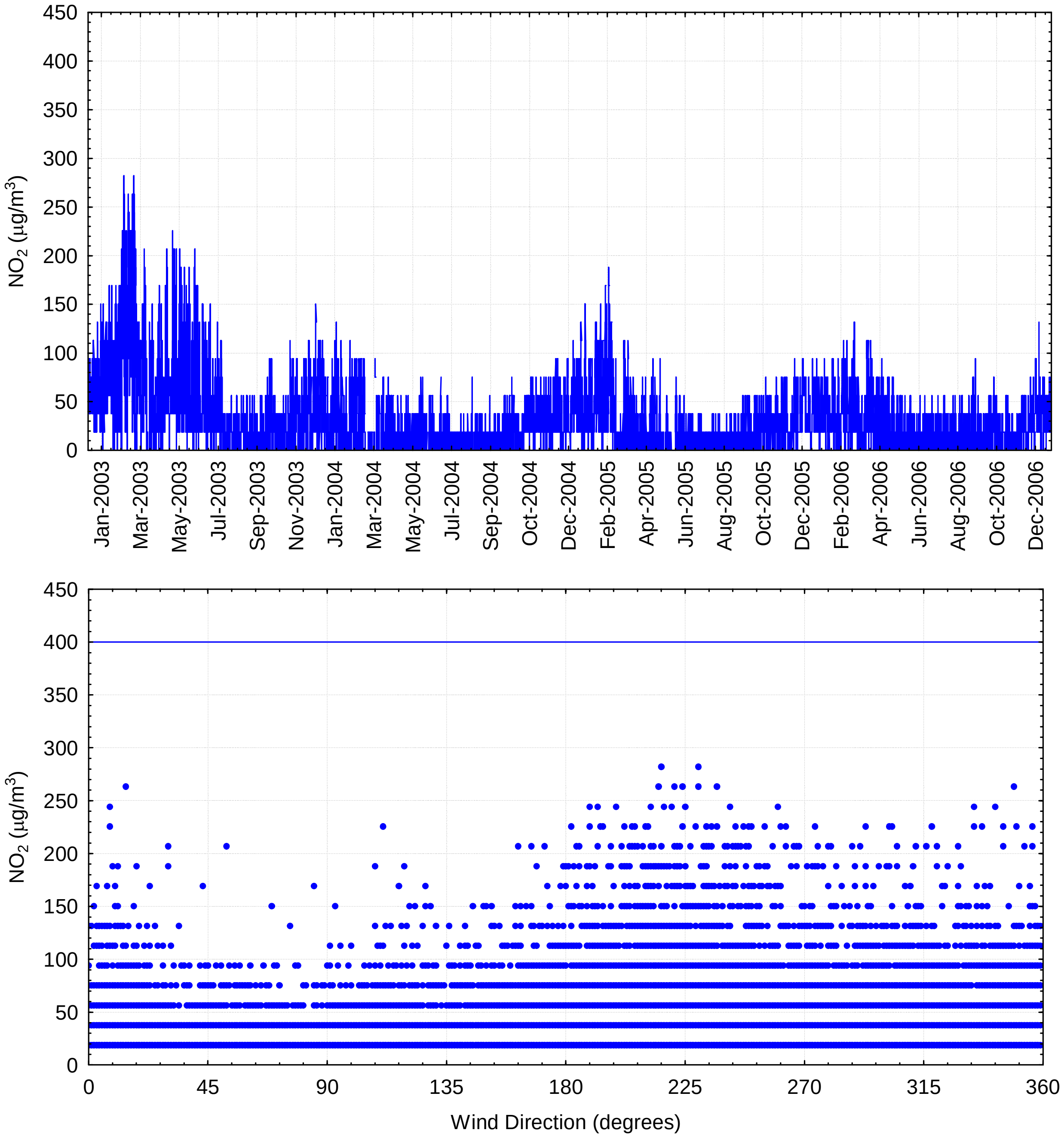


Figure 2B-5 **Ambient hourly NO_2 concentrations measured at the FAP Ross Creek station. The top plot shows the time series and the bottom plot shows the wind direction dependence.**

2B5 Fine Particulate Matter ($PM_{2.5}$) Concentrations, Follow-up and Monitoring

2B5.1 1-h Averages

Ambient fine particulate matter ($PM_{2.5}$) concentrations are routinely measured on a continuous basis at all Edmonton stations and the following FAP stations: Redwater, Fort Saskatchewan, Lamont and Elk Island. Ambient concentration data are archived as 1-h averages in units of micrograms per cubic metre (ug/m^3).

Table 2B-11 provides an overview of the frequency statistics based on hourly measurements for the 48-month period, January 2003 to December 2006. The Redwater station started measuring $PM_{2.5}$ in January 2005. The highest values occur at the Lamont, Elk Island and Edmonton East stations. Environment Canada also noted the high values in Elk Island National Park and attributed these to a combination of proximity to the Edmonton urban area and industrial emissions, and to regional and local wild fires and/or prescribed burns (Bates et al., 2002). There are no AAAQO or CWS for hourly average $PM_{2.5}$ concentrations.

2B5.2 24-h Averages

The maximum and 98th percentile 24-h $PM_{2.5}$ concentrations are listed in Table 2B-12. The highest values are measured at the Lamont station; this may be due to nearby agricultural activities. A review of the 98th percentile values indicates no exceedances of the CWS metric on a yearly basis or for the 3-year based CWS.

The maximum values at each station indicate relatively high concentrations can occur at both urban and rural sites. The long-term average value at Elk Island is 4.5 ug/m^3, and the long-term average values for the other FAP sites are in the 4.9 ug/m^3 to 8.2 ug/m^3 range; and for the Edmonton sites the long-term averages range from 4.8 ug/m^3 to 6.4 ug/m^3. For comparison purposes, Cheng et al (2000) indicate that $PM_{2.5}$ concentrations in the range of 1.7 ug/m^3 to 3.8 ug/m^3 are characteristic of “rural remote” sites; concentrations in the range of 4.5 ug/m^3 to 11.48 ug/m^3 are characteristic of “rural influenced” sites; and concentrations in the 14 ug/m^3 to 24 ug/m^3 range are characteristic of “rural-industrial” sites.

Further comparisons to the Alberta Exceedance, Planning, and Surveillance triggers are provided in Figures 2B-6 and 2B-7 that show the 24-h average $PM_{2.5}$ concentrations measured at the four sites. The values show periodic occurrences when the maximum daily concentrations exceed the CWS metric (i.e., 30 ug/m^3), the planning trigger (i.e., 20 ug/m^3), and the surveillance trigger (i.e., 15 ug/m^3). Minimum $PM_{2.5}$ concentrations at the Redwater station are in the 2 to 4 ug/m^3 range. These minimum values span the full period. At the Lamont and Elk Island stations, for the first part of 2003, and for the end of 2006 at Elk Island, the minimum values are in the 3 to 4 ug/m^3 range. This may be due to a systematic instrument problem rather than a reflection of the actual concentrations.

The planning trigger of 20 ug/m^3 was exceeded one year at the Lamont and Edmonton East sites; and the surveillance trigger of 15 ug/m^3 was exceeded at the Fort Saskatchewan, Lamont, Edmonton East and Edmonton Central sites. Note that the conclusion of exceeding these triggers is based on all measurements, that is natural and/or transboundary contributions have not been factored out.

AENV (2006, 2007) completed two summary reports for the periods 2001 to 2003 and 2002 to 2004 where natural and/or transboundary contributions have been factored out. The review of $PM_{2.5}$ measurements indicated the need for *Surveillance Actions* based on the concentrations measured in the Edmonton Census Metropolitan Area (CMA) and at the FAP Elk Island and Fort Saskatchewan stations. The AENV analysis and the analysis shown in Table 2B-12 both confirm a need for Surveillance Actions, which is currently being undertaken in the region.

2B5.3 Other Measurements

For comparison, Sandhu (1998) summarized $PM_{2.5}$ measurements from Royal Park (located about 70 km to the east-southeast of the study area) for the 1993 to 1995 period. The maximum 24-h $PM_{2.5}$ values measured at this location were 70.8 ug/m^3 (1993), 64.4 ug/m^3 (1994), and 44.5 ug/m^3 (1995). These rural maxima are larger than those shown in Table 2B-12, and may be due to agricultural activities.

Table 2B-11 Summary of hourly average $PM_{2.5}$ concentrations (ug/m^3) measured at the FAP and Edmonton monitoring stations

	Redwater	Fort Saskatchewan	Lamont	Elk Island	Edmonton East	Edmonton Central	Edmonton South
Maximum	147	132	209	326	250	99.6	76.0
99.9th Percentile	65.4	56.9	61.7	51.4	69.1	61.3	62.9
99th Percentile	32.0	26.3	32.0	24.7	32.6	29.3	25.3
95th Percentile	19.0	15.0	19.5	13.4	18.7	17.0	14.3
90th Percentile	15.0	11.1	15.0	9.8	13.7	12.9	10.7
75th Percentile	10.0	6.6	9.2	6.1	8.3	8.0	6.4
Median	7.0	3.4	4.9	3.2	4.5	4.4	3.4
Average	8.2	4.9	6.7	4.5	6.4	6.0	4.8

Table 2B-12 Daily average $PM_{2.5}$ concentrations (ug/m^3) at the FAP monitoring stations

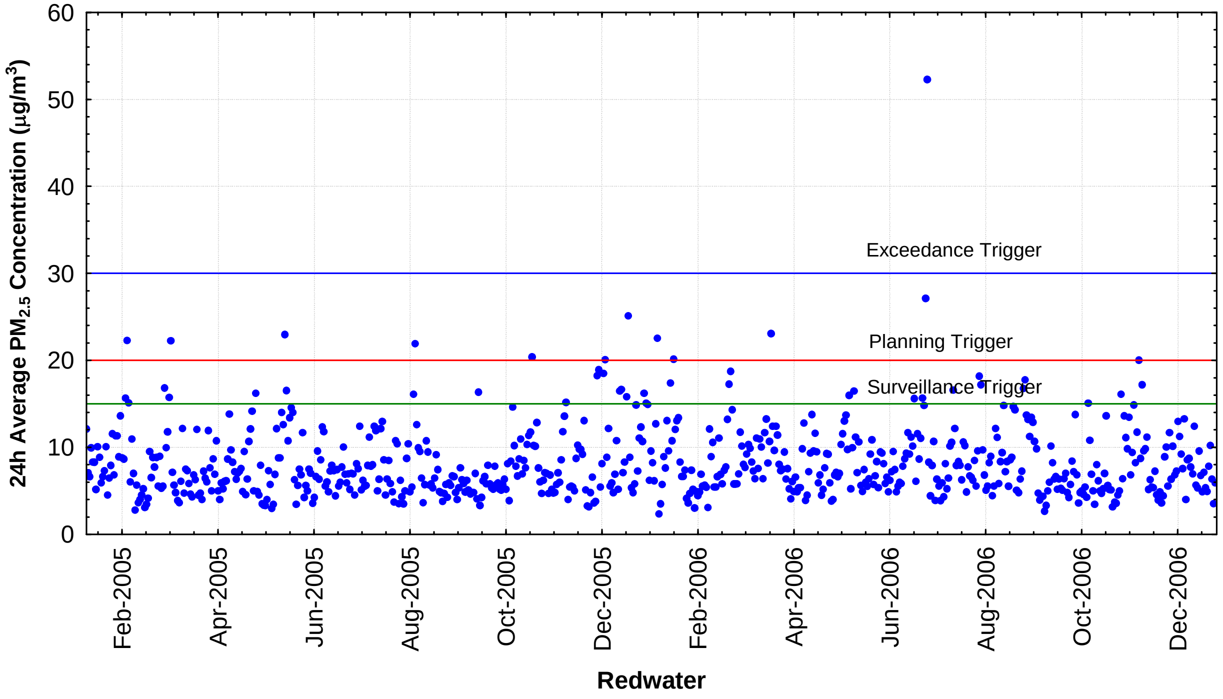
	Period	Redwater		Fort Saskatchewan		Lamont		Elk Island		Edmonton East		Edmonton Central		Edmonton South	
		1-y	3-y	1-y	3-y	1-y	3-y	1-y	3-y	1-y	3-y	1-y	3-y	1-y	3-y
Maximum	2003	-	-	36.3	-	39.4	-	37.1	-	46.6	-	36.1	-	-	-
	2004	-	-	31.6	-	51.2	-	26.9	-	40.6	-	51.5	-	-	-
	2005	23.0	-	19.6	-	29.8	-	17.5	-	23.4	-	15.2	-	18.7	-
	2006	52.3	-	55.1	-	46.2	-	36.8	-	63.5	-	63.4	-	55.1	-
	Average	37.7	-	35.7	-	41.7	-	29.6	-	43.5	-	41.6	-	36.9	-
98th Percentile	2003	-	-	16.8	-	22.4	-	19.1	-	25.6	-	22.5	-	-	-
	2004	-	-	16.8	-	23.5	-	14.2	-	20.7	-	21.5	-	-	-
	2005	18.7	-	14.9	16.2	18.2	21.4	9.5	14.3	15.8	20.7	12.9	19.0	12.0	-
	2006	18.6	-	15.3	15.7	16.7	19.5	11.8	11.8	19.6	18.7	16.8	17.1	16.3	-
	Average	18.7	-	16.0	-	20.2	18.4	13.7	-	20.4	18.6	18.4	-	14.2	-

NOTES:

The “1-y” values are the maximum and 98th percentile 24-h average concentrations measured during the respective year.

The “3-y” values are 3-year rolling averages of the indicated “1-y” values, and provide a direct comparison to CWS of 30 ug/m^3.

A “–” indicates that data are not available.



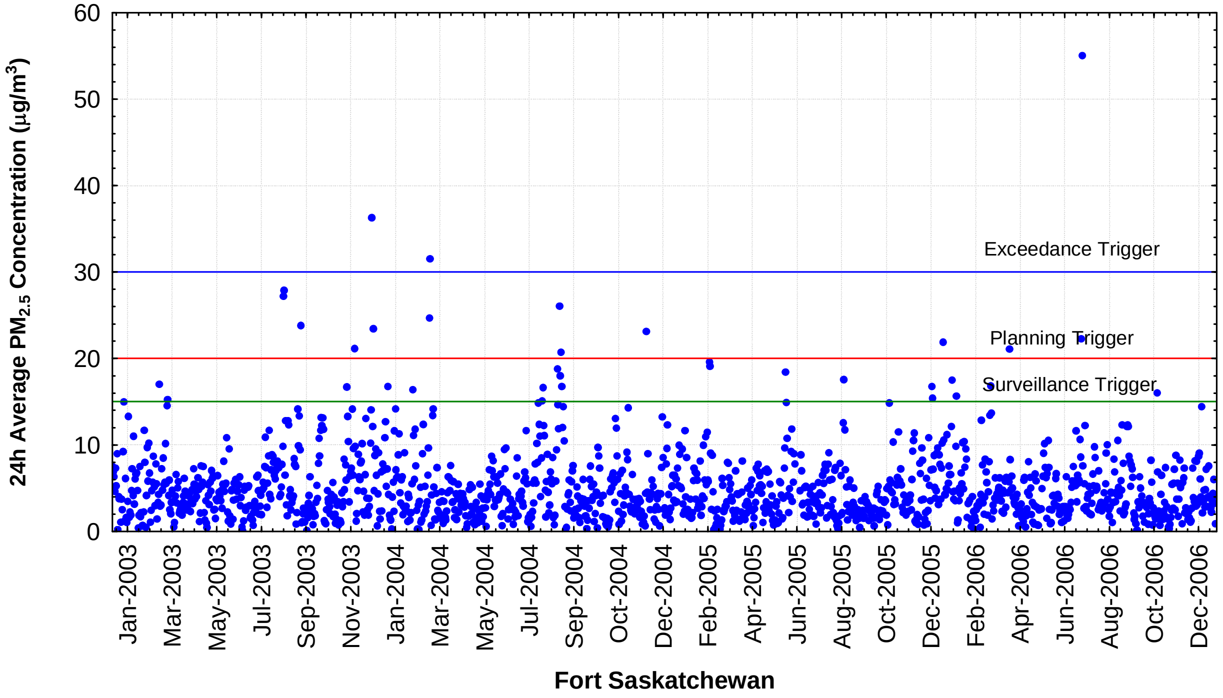


Figure 2B-6 Maximum 24-h average $PM_{2.5}$ concentrations measured at the FAP Redwater and Fort Saskatchewan stations.

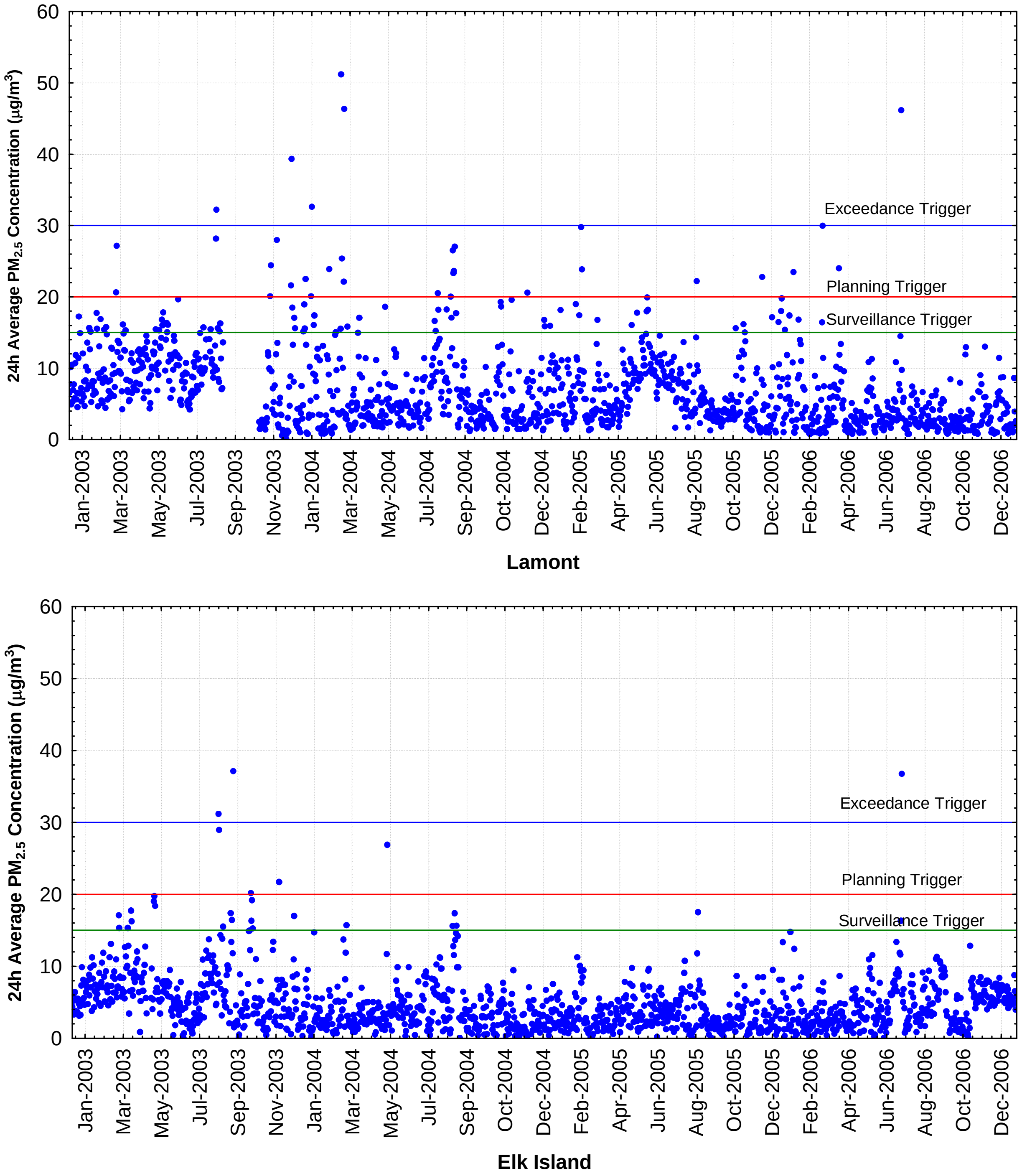


Figure 2B-7 **Maximum 24-h average $PM_{2.5}$ concentrations measured at the Lamont and Elk Island stations.**

2B6 Ozone (O_3) Concentrations

2B6.1 Ozone in the Atmosphere

An Alberta O_3 expert's forum was held in June 1999 to discuss the potential for photochemical formation of O_3 in the Fort McMurray and Fort Saskatchewan areas (Shell 1999). The findings were:

- O_3 in the atmosphere in Alberta can be due to the following sources:
    1. the long-range transport of tropical Pacific air (which has concentrations in the 80 ug/m^3 to 100 ug/m^3 range)
    2. the long-range transport of polar air (which has concentrations in the 160 ug/m^3 to 200 ug/m^3 range)
    3. forest fires (which can produce photochemical enrichments of 20 ug/m^3 to 30 ug/m^3 above background)
    4. short-duration stratospheric intrusions that can lead to sudden increases of ground-level O_3.
- In Alberta, there is a general tendency for greater O_3 concentrations during the spring (March to April) and for greater values during the day.
- In the immediate vicinity of large NO_X emission sources (both industrial and urban), ambient O_3 concentrations are reduced due to O_3 scavenging by high ambient NO concentrations (Leahey and Morrow, 1999). For this reason, downtown urban O_3 concentrations can be much less than those found in the rural upwind air.
- The review of the limited data downwind of NO_X emission sources in Alberta indicates photochemical O_3 production may be limited to a few hours per year during the summer period (Davies and Fellin, 1999). In some cases, these increases resulted in values in excess of the 160 ug/m^3 AAAQO value. In other cases, the AAAQO value was not exceeded.

Environment Canada (EC) conducted a field monitoring program during the summer of 2005 in the Edmonton area; this program is referred to as PrAIRie 2005. EC also conducted photochemical modelling for the Edmonton area to determine the role of precursor emissions and photochemistry in terms of contributing to the natural O_3 in the region. EC is currently analyzing the data and reviewing the information.

2B6.2 1-h Averages

Ambient ozone concentrations are routinely measured on a continuous basis at all Edmonton stations and the following FAP stations: Fort Saskatchewan, Lamont and Elk Island. Ambient concentration data are archived as 1-h averages in concentration units of ppb (parts per billion). These units, for the purposes of this assessment, were converted into units of ug/m^3 (micrograms per cubic metre). Note: 1 ppb = 2.0 ug/m^3.

Table 2B-13 provides an overview of the hourly average frequency statistics based on measurements for the 48-month period, January 2003 to December 2006. Exceedances of the 160 ug/m^3 AAAQO value have been measured at the three FAP sites and at the Edmonton East and Edmonton South sites. The highest concentration was measured at the Lamont site, and the lowest maximum concentration was measured at the Edmonton Central site. The lower

Edmonton Central site values are due to the proximity of the NO_X emissions associated with the traffic sources.

2B6.3 8-h Averages

Mills and Ali (2002) reviewed O_3 data from various rural and urban locations in Alberta to determine compliance with the 8-h CWS. Table 2B-14 provides a summary of their findings up to 2001 based on the Fort Saskatchewan monitoring station. The information from 2002 to 2006 is based on the more recent data. Tables 2B-15 and 2B-16 show the more recent period for the Lamont and Elk Island stations, respectively. While there were a number of exceedances of the 1-h AAAQO value during the period 1990 to 2006, there was only one year (1996) when the 3-year CWS was not met at the Fort Saskatchewan station. The CWS was met at the Lamont and Elk Island stations.

The Planning Trigger 113 ug/m^3 (58 ppb) is exceeded at all three sites. Note that the conclusion of exceeding the Planning Trigger is based on all measurements in that natural and/or transboundary contributions have not been factored out.

AENV (2006, 2007) completed two summary reports for the periods 2001 to 2003 and 2002 to 2004 where natural and/or transboundary contributions have been factored out. The review of O_3 measurements indicated the need for *Management Plan* actions based on the concentrations measured in the Edmonton CMA and at the FAP Fort Saskatchewan station. The measurements also indicated the need for *Surveillance Actions* based on the concentrations measured at the FAP Lamont and Elk Island stations. Exceedances of a Planning Trigger is confirmed by the analysis presented in Tables 2B-14 to 2B-16.

Figures 2B-8 and 2B-9 show the maximum 8-h averages for each day at the Fort Saskatchewan, Lamont and Elk Island stations:

- All stations show the tendency for high concentrations in the spring and summer and low concentrations in the fall and winter.
- At the Fort Saskatchewan station, the high concentrations occurred in March and April for 2005; and in the June to August period for 2003, 2004 and 2006.
- At the Lamont station, the high concentrations occurred in March and April 2005; and in the July to August period for 2003, 2004 and 2006.
- At the Elk Island station, the high concentrations occurred in April and May for 2005 and 2006; and in the June to August period for 2003 and 2004. High concentrations also occurred in March 2005.

The high spring values are characteristic of O_3 values in Alberta. Rural areas in the Rocky Mountain Foothills (e.g., Hightower Ridge and Steeper) routinely exceed the CWS value (Mills and Ali 2002).

For the purpose of comparison, the fourth-highest values at the Edmonton East station for the same period ranged from 99 to 125 ug/m^3; the fourth-highest values at the Edmonton Central station ranged from 99 to 102 ug/m^3; and the fourth-highest values at the Edmonton South station ranged from 72 ug/m^3 to 121 ug/m^3.

2B6.4 Longer Term Averages

Table 2B-17 provides a summary of the monthly maximum and the period-average O_3 concentrations measured with the passive samplers. The period averages range from 40.3 ug/m^3 to 53.3 ug/m^3, this compares to the 43.1 ug/m^3 to 59.7 ug/m^3 range measured at the continuous FAP monitoring stations, and to the 32.9 ug/m^3 to 42.5 ug/m^3 range measured at the Edmonton monitoring stations.

Table 2B-13 Summary of hourly average O_3 concentrations (ug/m^3) measured at the FAP and Edmonton monitoring stations (AAAQO = 160 ug/m^3)

	Fort Saskatchewan	Lamont	Elk Island	Edmonton East	Edmonton Central	Edmonton South
Maximum	171	190	181	181	155	167
99.9th Percentile	128	143	132	133	114	128
99th Percentile	106	118	110	110	94.2	112
95th Percentile	88.3	98.1	96.2	90.3	76.5	92.2
90th Percentile	80.5	90.3	86.4	82.4	66.7	80.5
Median	43.2	58.9	55.0	41.2	29.4	37.3
Average	43.1	59.7	54.8	42.5	32.9	39.5

Table 2B-14 Summary of hourly AAAQO and CWS exceedances for O_3 at the FAP Fort Saskatchewan Station

Year	AAAQO 1-h Value Exceedances (160 ug/m^3, 82 ppb)	O_3 Concentration (ug/m^3)		Meets CWS? (127 ug/m^3, 65 ppb)	Meets Planning Trigger? (113 ug/m^3, 58 ppb)
		1-y	3-y		
1990	5	127.3	–	–	–
1991	5	139.3	–	–	–
1992	0	100.7	**122.4**	Yes	No
1993	1	–	–	–	–
1994	15	142.4	–	–	–
1995	5	140.0	–	–	–
1996	3	124.9	**135.8**	No	No
1997	0	113.9	**126.3**	Yes	No
1998	2	126.6	**121.8**	Yes	No
1999	4	120.0	**120.2**	Yes	No
2000	0	121.5	**122.7**	Yes	No
2001	0	121.9	**121.1**	Yes	No
2002	4	136.9	**127.0**	Yes	No
2003	1	109.4	**123.0**	Yes	No
2004	1	111.1	**119.1**	Yes	No
2005	0	105.0	108.5	Yes	Yes
2006	2	121.4	112.5	Yes	Yes

NOTES:

AAAQO value exceedances = number of hours observed when O_3 exceeded 160 ug/m^3.
The “1-y” value represents the fourth-highest day based on the maximum 8-h average for that day.
The “3-y” value represents the average of the fourth-highest 8-h averages for the three worst days in each of 3 years.

The “–” indicates that data are not available.

Table 2B-15 Summary of hourly AAAQO and CWS exceedances for O_3 at the FAP Lamont Station

Year	AAAQO 1-h Value Exceedances (160 ug/m^3, 82 ppb)	O_3 Concentration (ug/m^3) 1-y	O_3 Concentration (ug/m^3) 3-y	Meets CWS? (127 ug/m^3, 65 ppb)	Meets Planning Trigger? (113 ug/m^3, 58 ppb)
2003	3	126.8	–	–	–
2004	4	132.7	–	–	–
2005	0	110.1	123.2	Yes	No
2006	4	131.2	124.7	Yes	No

NOTES:

AAAQO value exceedances = number of hours observed when O_3 exceeded 160 ug/m^3.
The “1-y” value represents the fourth-highest day based on the maximum 8-h average for that day.
The “3-y” value represents the average of the fourth-highest 8-h averages for the three worst days in each of 3 years.

The “–” indicates that data are not available.

Table 2B-16 Summary of hourly AAAQO and CWS exceedances for O_3 at the FAP Elk Island Station

Year	AAAQO 1-h Value Exceedances (160 ug/m3, 82 ppb)	O_3 Concentration (ug/m^3) 1-y	O_3 Concentration (ug/m^3) 3-y	Meets CWS? (127 ug/m^3, 65 ppb)	Meets Planning Trigger? (113 ug/m^3, 58 ppb)
2003	3	116.0	–	–	–
2004	3	115.8	–	–	–
2005	0	116.4	116.1	Yes	No
2006	3	120.5	117.6	Yes	No

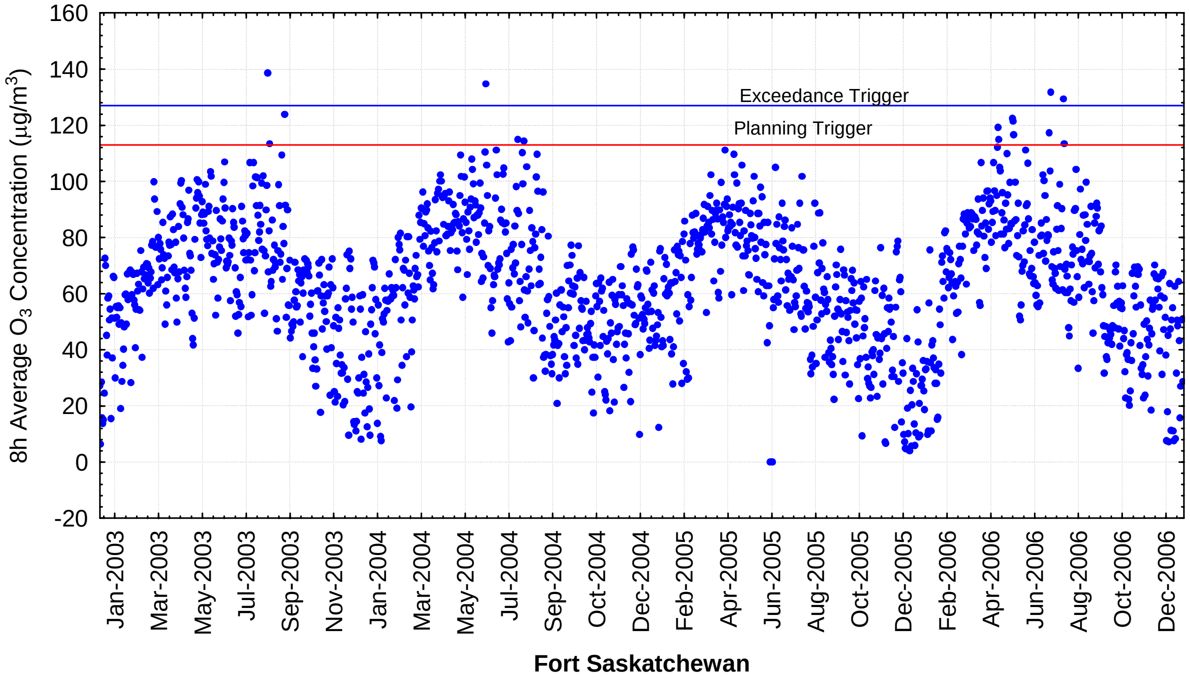
NOTES:

AAAQO value exceedances = number of hours observed when O_3 exceeded 160 ug/m^3.
The “1-y” value represents the fourth-highest day based on the maximum 8-h average for that day.
The “3-y” value represents the average of the fourth-highest 8-h averages for the three worst days in each of 3 years.

The “–” indicates that data are not available.

Table 2B-17 Average O_3 concentrations (ug/m^3) based on the FAP passive monitoring network

Site #	FAP Site	18 Month Average	Monthly Maximum
1	W of Hwy 21	40.3	75.2
2	N of Ardrossan	53.3	86.0
3	NE of Bruderheim	45.4	97.7
4	Waskatenau	49.0	87.9
5	Thorhild	48.4	79.5
6	Redwater	45.7	78.3
7	Bon Accord	47.8	78.9
8	Gibbons	47.2	79.5
9	Hu-Haven	42.7	70.1
10	Fort Augustus	43.9	83.8
Average		46.4	81.7



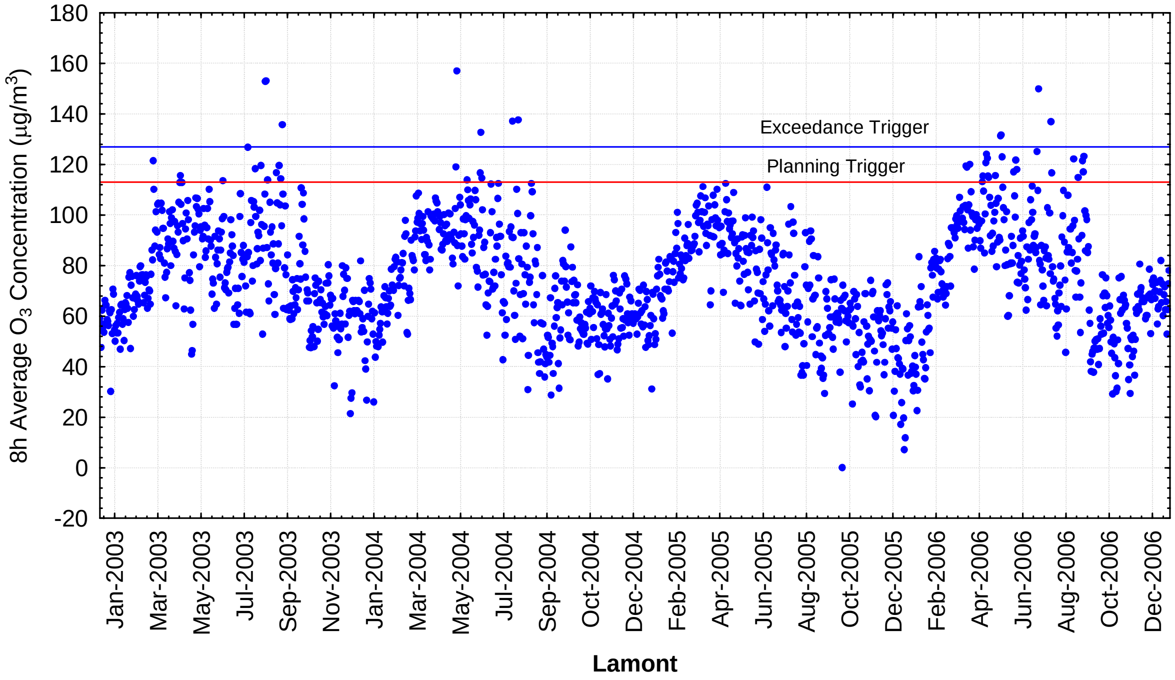


Figure 2B-8 Maximum daily 8-h average O_3 concentrations measured at the FAP Fort Saskatchewan, and Lamont station.

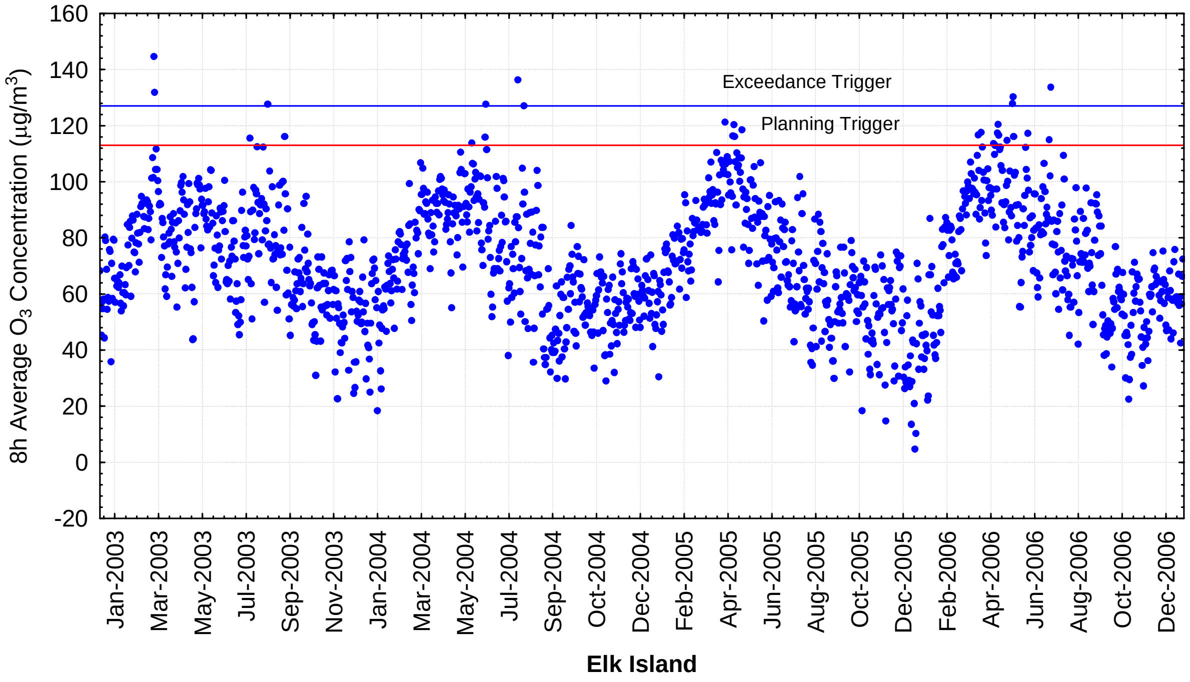


Figure 2B-9 Maximum daily 8-h average O_3 concentrations measured at the Elk Island station.

2B7 Hydrogen Sulphide (H_2S) Concentrations

2B7.1 1-h Averages

Ambient hydrogen sulphide concentrations are routinely measured on a continuous basis at the following FAP stations: Scotford, Fort Saskatchewan, and Lamont. Ambient H_2S concentrations are also collected at the Edmonton East station. Ambient concentration data are archived as 1-h averages in concentration units of ppb (parts per billion). These units, for the purposes of this assessment, were converted into units of ug/m^3 (micrograms per cubic metre). Note: 1 ppb = 1.4 ug/m^3.

Table 2B-18 provides an overview of the hourly average frequency statistics based on measurements for the 48-month period, January 2003 to December 2006. Exceedances of the 14 ug/m^3 AAAQO value have been observed at three stations: Scotford, Lamont and Edmonton East. Figures 2B-10 and 2B-11 show the hourly H_2S concentrations for the period January 2003 to December 2006 and associated wind direction dependencies.

Based on these data, there were five hourly exceedances at the Scotford station (Figure 2B-10) and one at the Lamont station (Figure 2B-11). Four of the Scotford exceedances are likely associated with oil and gas field facilities to the east. One high H_2S concentrat ion was associated with west-northwest winds (approximately 300°) from the direction of the Scotford Complex. The Lamont exceedances are associated with a south-southeast winds (approximately 135 to 180°) and are likely due to field facilities.

2B7.2 24-h Averages

Table 2B-19 provides an overview of the daily average frequency statistics based on measurements for the 48-month period, January 2003 to December 2006. Exceedances of the 4 ug/m^3 AAAQO value have been observed at three stations: Scotford (1 day). Fort Saskatchewan (1 day) and Edmonton East (8 days).

2B7.3 Annual Averages

The annual average H_2S concentrations based on continuous measurements at Fort Saskatchewan, Lamont, Scotford and Edmonton East stations are 0.4 ug/m^3, 0.5 ug/m^3, 0.8 ug/m^3 and 0.8 ug/m^3, respectively. For the purpose of comparison, Shell measured H_2S concentrations at 26 sites near the Scotford complex using passive samplers. The annual average H_2S concentrations based on these samplers range from 0.4 ug/m^3 to 0.7 ug/m^3 (Shell Canada 2005).

Table 2B-18 Summary of hourly average H_2S concentrations (ug/m^3) measured at the FAP and Edmonton monitoring stations (AAAQO = 14 ug/m^3)

	Scotford	Fort Saskatchewan	Lamont	Edmonton East
Maximum	26.4	11.1	18.1	50.0
99.9th Percentile	8.3	5.6	5.6	13.9
99th Percentile	4.2	2.8	4.2	5.6
95th Percentile	2.8	1.4	2.8	2.8
90th Percentile	1.4	1.4	1.4	1.4
Median	0.0	0.0	0.0	0.0
Average	0.8	0.4	0.5	0.8

Table 2B-19 Summary of daily average H_2S concentrations (ug/m^3) measured at the FAP and Edmonton monitoring stations (AAAQO = 4 ug/m^3)

	Scotford	Fort Saskatchewan	Lamont	Edmonton East
Maximum	4.4	5.2	3.9	7.5
99.9th Percentile	3.9	3.4	3.8	5.1
99th Percentile	2.8	2.2	3.1	3.2
95th Percentile	2.1	1.4	2.2	2.1
90th Percentile	1.7	1.0	1.6	1.7
Median	0.7	0.2	0.1	0.7
Average	0.8	0.4	0.5	0.8

Table 2B-20 Annual average H_2S concentrations (ug/m^3) measured at the FAP and Edmonton monitoring stations

	Scotford	Fort Saskatchewan	Lamont	Edmonton East
2003	0.6	0.5	0.2	1.0
2004	0.7	0.3	0.4	0.8
2005	0.8	0.3	1.2	0.7
2006	1.1	0.3	0.1	0.8
Full Period	0.8	0.4	0.5	0.8

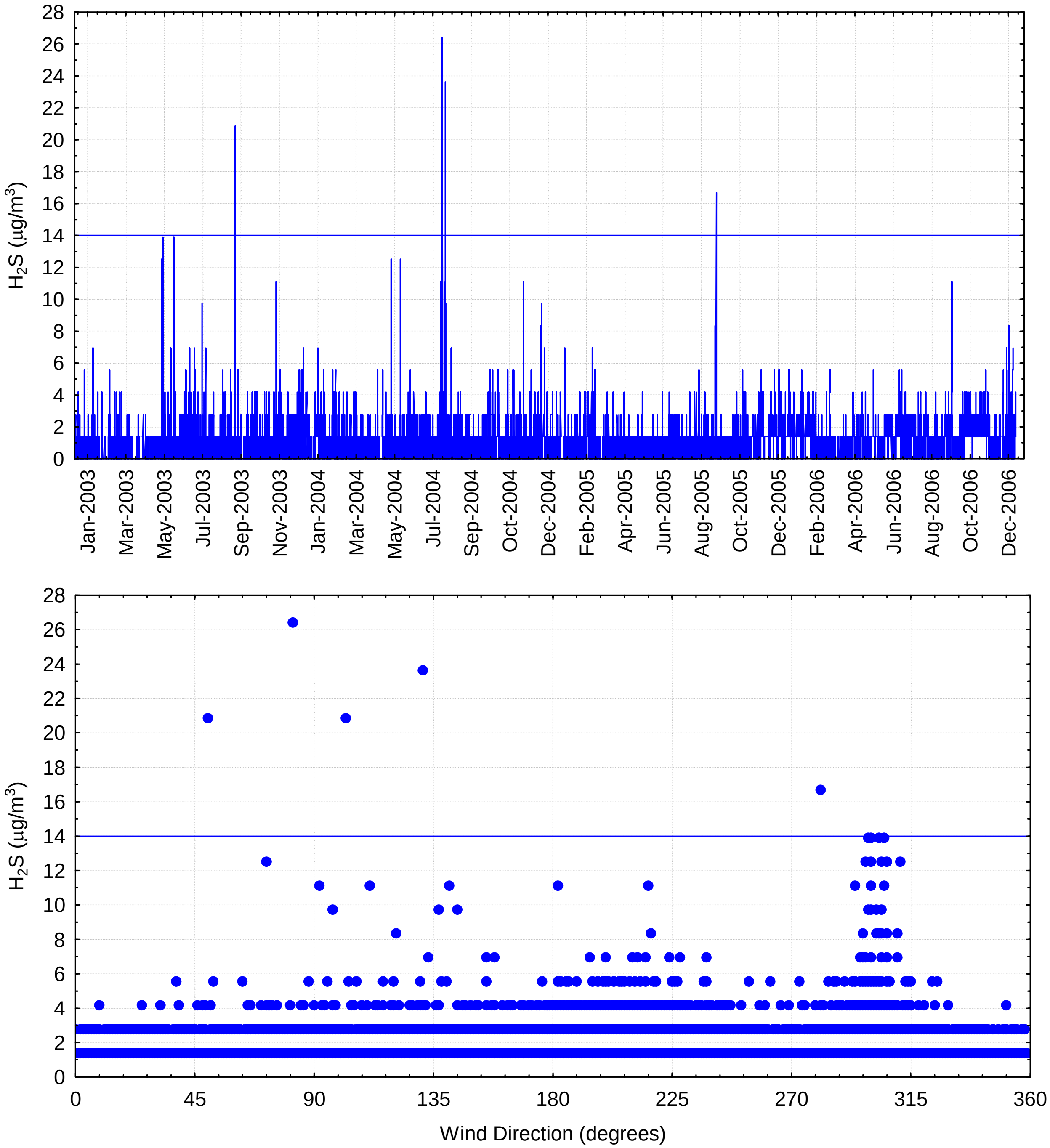


Figure 2B-10 **Ambient hourly H_2S concentrations measured at the FAP Scotford station. The AAAQO of 14 ug/m^3 is shown by the solid line. The top plot shows the time series and the bottom plot shows the wind direction dependence.**

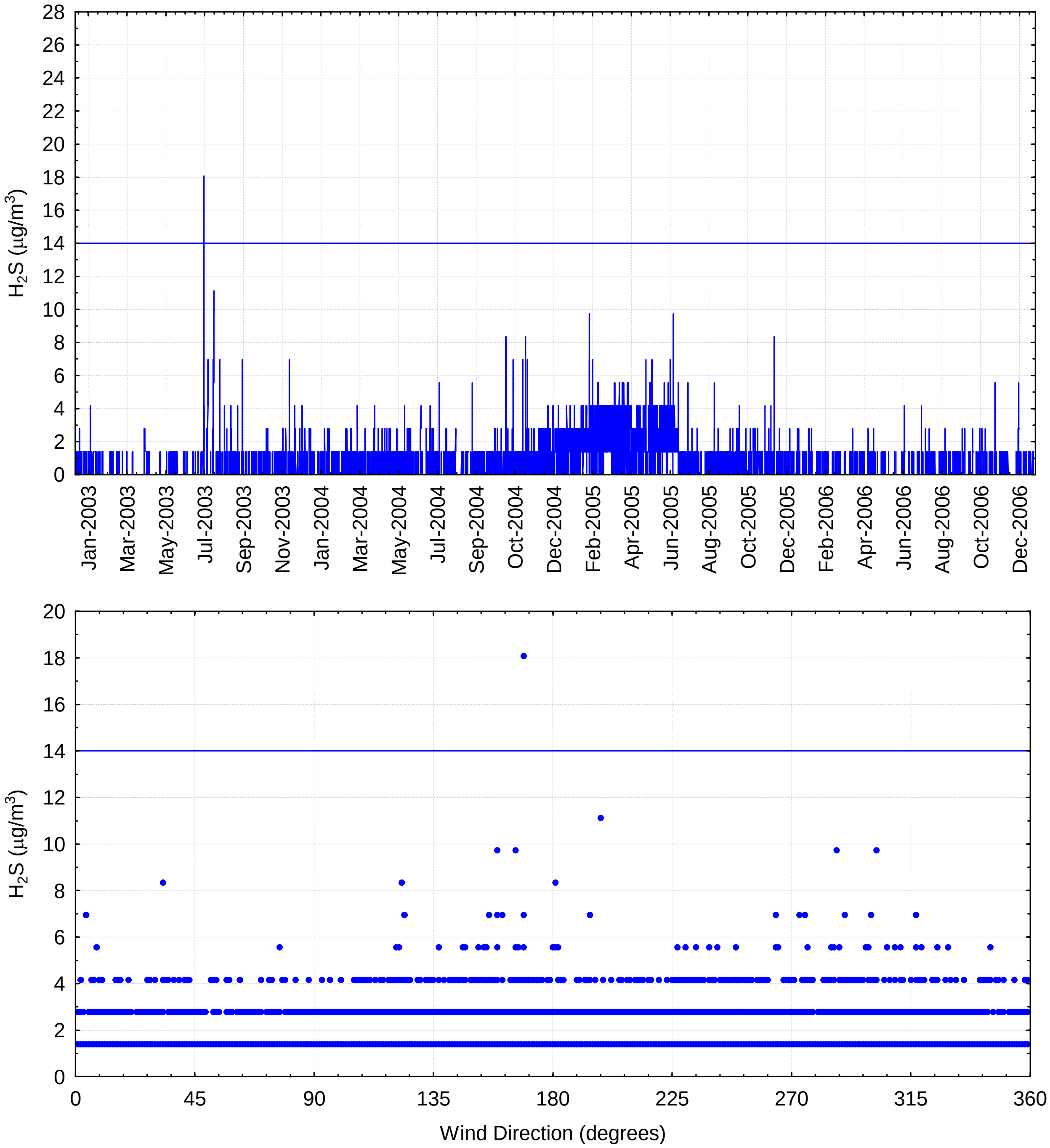


Figure 2B-11 **Ambient hourly H_2S concentrations measured at the FAP Lamont station. The AAAQO of 14 ug/m^3 is shown by the solid line. The top plot shows the time series and the bottom plot shows the wind direction dependence.**

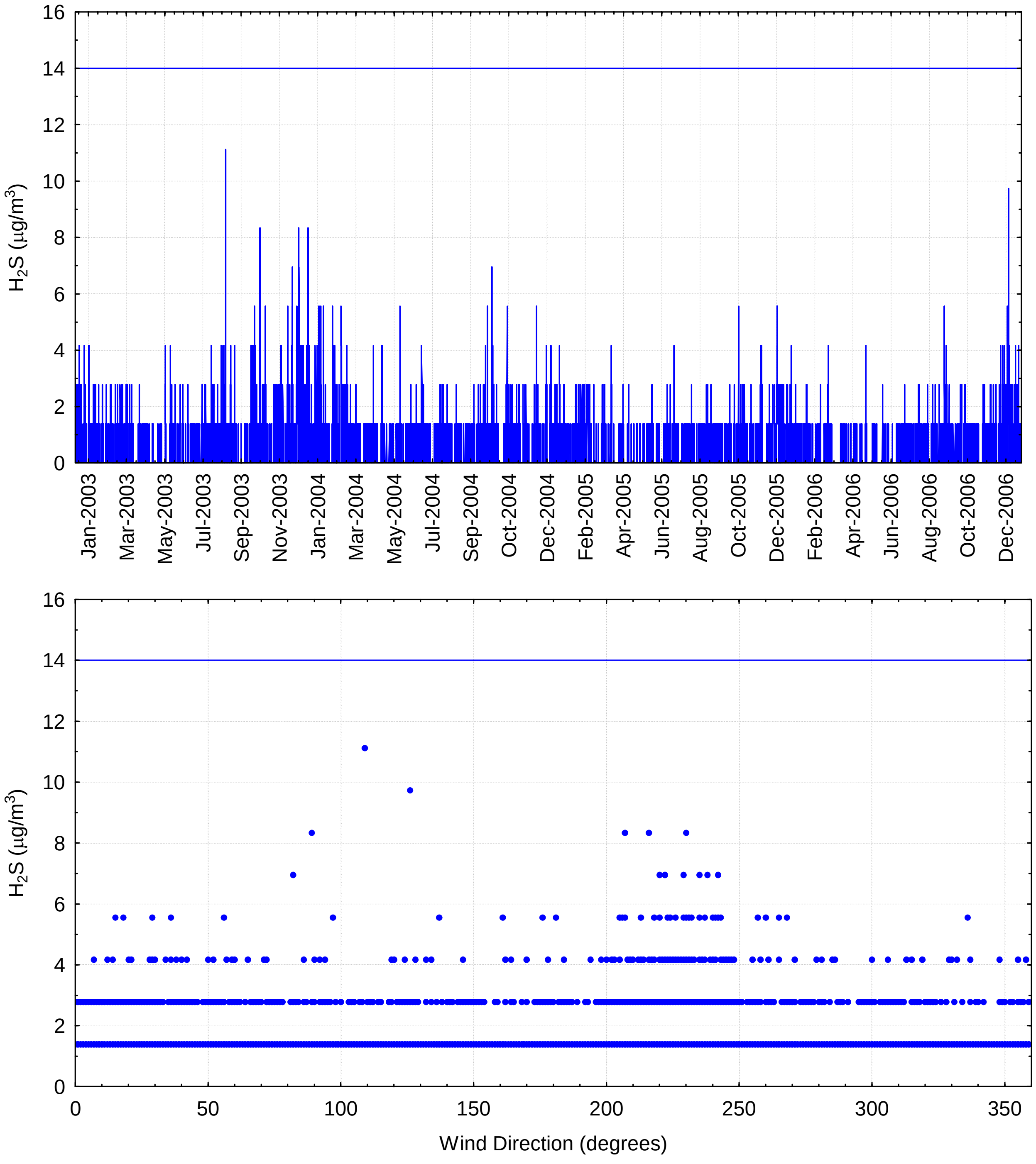


Figure 2B-12 **Ambient hourly H_2S concentrations measured at the FAP Fort Saskatchewan station. The AAAQO of 14 ug/m^3 is shown by the solid line. The top plot shows the time series and the bottom plot shows the wind direction dependence.**

2B8 Ammonia (NH_3) Concentrations

2B8.1 1-h Averages

Ambient ammonia concentrations are routinely measured on a continuous basis at the following FAP stations: Redwater, Fort Saskatchewan, Ross Creek, Range Road 220, and Station 401. Ambient concentration data are archived as 1-h averages in concentration units of ppm (parts per million). These units, for the purposes of this assessment, were converted into units of ug/m^3 (micrograms per cubic metre). Note: 1 ppm = 700 ug/m^3.

Table 2B-21 provides an overview of the hourly average frequency statistics based on measurements for the 48-month period, January 2003 to December 2006. The maximum values measured at these sites range from 279 to 1267 ug/m^3 and are less than the 1,400 ug/m^3 AAAQO value. The largest concentrations are associated with the values that are closest to the fertilizer manufacturing facilities (i.e. the Redwater and Ross Creek stations).

2B8.2 Monthly Averages

Monthly average NH_3 concentrations are required by the CALPUFF model for internal chemistry calculations. Table 2B-22 shows the monthly average NH_3 concentrations for each site and for all sites combined. The monthly averages for all sites combined vary from 2.7 ug/m^3 to 4.9 ug/m^3. The stations located next to the fertilizer manufacturing facilities experience higher monthly values.

The FAP values are also compared to those measured at Royal Park (Bates 1996). Based on ammonia concentrations measured at Royal Park during the October 1992 to June 1994 period (Bates 1996), the monthly average values varied from about 0.35 ug/m^3 to 1.4 ug/m^3

Table 2B-21 Summary of hourly average NH_3 concentrations (ug/m^3) measured at the FAP monitoring stations (AAAQO = 1400 ug/m^3)

	Redwater	Fort Saskatchewan	Ross Creek	Range Road 220	Station 401
Maximum	1267	373	836	348	279
99.9th Percentile	381	40.7	209	69.6	139
99th Percentile	127	12.5	69.6	0.0	69.6
95th Percentile	36.2	5.6	0.0	0.0	0.0
90th Percentile	20.9	4.2	0.0	0.0	0.0
Median	0.7	0.7	0.0	0.0	0.0
Average	9.8	1.8	3.0	0.3	3.4

Table 2B-22 Summary of monthly average NH_3 concentrations (ug/m^3) measured at the FAP monitoring stations (2001-2006)

	Redwater	Fort Saskatchewan	Ross Creek	Range Road 220	Station 401	All FAP	Royal Park
January	4.71	2.32	2.93	0	4.13	2.85	0.36
February	4.72	2.53	0.92	0.66	6.34	3.02	0.35
March	14.54	2.32	1.76	0.07	1.43	3.97	1.01
April	10.58	2.48	3.82	0.15	1.12	3.60	0.94
May	8.27	2.58	5.29	0.22	1.61	3.59	1.14
June	12.86	1.69	4.82	0.26	0.59	4.08	1.03
July	13.02	1.49	1.78	0.65	3.83	4.19	0.97
August	18.35	1.37	2.22	0.25	2.54	4.93	1.35
September	8.94	0.87	4.91	0.08	4.54	3.90	1.04
October	9.17	0.71	2.04	0.42	4.14	3.32	1.46
November	4.76	0.72	2.71	0.31	4.57	2.71	0.99
December	7.04	2.14	2.60	0.10	6.69	3.68	0.81

2B9 Carbon Monoxide (CO) Concentrations

2B9.1 1-h and 8-h Averages

Ambient carbon monoxide concentrations are routinely measured on a continuous basis at the Fort Saskatchewan FAP station and all Edmonton stations. Ambient concentration data are archived as 1-h averages in concentration units of ppm (parts per million). These units, for the purposes of this assessment, were converted into units of ug/m^3 (micrograms per cubic metre). Note: 1 ppm = 1150 ug/m^3.

Table 2B-23 provides an overview of the hourly average frequency statistics based on measurements over the 48-month period January 2003 to December 2006. The maximum 1-h CO value of 10,074 ug/m^3 is well below the AAAQO value (i.e., less than 15,000 ug/m^3). The maximum 8-h CO value of 3,019 ug/m^3 is also below the AAAQO value (i.e., less than 6,000 ug/m^3). The highest values tend to occur during the winter and can be attributed to community (i.e., traffic) sources during poor mixing conditions.

Table 2B-23 Summary of 1-h and 8-h average CO concentrations (ug/m^3) measured at the Fort Saskatchewan and Edmonton monitoring station

	Fort Saskatchewan		Edmonton East		Edmonton Central		Edmonton South	
	1-hour	**8-hour**	**1-hour**	**8-hour**	**1-hour**	**8-hour**	**1-hour**	**8-hour**
Maximum	3663	2432	10074	1689	7441	3019	3778	2633
99.9th Percentile	2289	1717	1946	1445	3434	2414	2633	1929
99th Percentile	1374	1202	1259	1045	1946	1720	1374	987
95th Percentile	801	716	801	730	1145	1058	687	644
90th Percentile	572	544	572	587	916	844	572	511
Median	229	272	229	286	458	472	229	258
Average	319	319	348	348	535	536	307	307
AAAQO	15,000	6,000	15,000	6,000	15,000	6,000	15,000	6,000

2B10 Hydrocarbon Concentrations

Ambient total hydrocarbon (THC) concentrations are routinely measured on a continuous basis at all Edmonton stations and the following FAP stations: Fort Saskatchewan, Range Road 220, and Station 401. Ambient concentration data are archived as 1-h averages in concentration units of ppm (parts per million). Ambient methane and non-methane hydrocarbon (NMHC) concentrations are routinely measured on a continuous basis at the FAP stations of Lamont and Range Road 220. Table 2B-24 provides an overview of the frequency statistics based on THC, methane and NMHC measurements for the 48-month period, January 2003 to December 2006.

2B10.1 Total Hydrocarbon Concentrations

High (relative to the average) concentrations have been measured at all monitoring stations; the highest occurring at the Edmonton East (25.9 ppm) and Range Road 220 (16 ppm) locations. While higher concentrations have been observed primarily during the winter, they tend to be periodic, isolated events. There is no AAAQO value for THC.

2B10.2 Methane Concentrations

Ambient methane (CH_4) concentrations are only measured at the Lamont site. The average value of 1.9 ppm compares to a global background concentration of 1.73 ppm (Deugokencky and Lang,1998). There is no AAAQO value for CH_4.

2B10.3 Non-Methane Hydrocarbon Concentrations

The non-methane hydrocarbon (NMHC value) is the difference between the THC and CH_4 components. Ambient NMHC concentrations are measured at the Lamont and Range Road 220 stations. NMHC concentrations are shown in a time series plot and the dependence on wind direction is shown for the two stations:

- The Lamont data are shown in Figure 2B-13. The intermittent nature of high concentrations is shown in the time series plot, and the high values do not seem to be biased to any specific direction.

- The Range Road 220 data are shown in Figure 2B-14. The intermittent nature of high concentrations is shown in the time series plot, and the high values do not seem to be biased to any specific direction.

Although there are no AAAQO values for NMHC, the presence of elevated values can indicate a potential for odours.

2B10.4 VOC Speciation

Twenty-four hour sampling was conducted on the National Air Pollution Surveillance Network (NAPS) six-day cycle by FAP and Environment Canada (EC) at six locations. The coordinates for these locations are listed in Table 2B-1.

The monitoring program ran for the 19-month period September 2004 to April 2005, and the measurements were obtained from EC and FAP (EC/FAP, 2006). For the purposes of this analysis, the 150 substances were grouped according to two criteria: one was based on the expected emission profile from the proposed Project (Appendix 2A) and the other was based on the expected effects on human health. The grouping scheme is provided in Table 2B-25. The group “Not Evaluated” represents the substances that were measured but are not expected to be released in appreciable quantities from the proposed Upgrader. These are comprised primarily of chlorinated hydrocarbons (which were measured), and are included in this assessment for the purposes of completeness.

Figures 2B-15 to 2B-18 provides a summary of the average and maximum values measured at each site, and at all sites for each group. The results indicate:

- The highest concentrations measured at the Ross Creek site (Site B) are for 1,3-butadiene, C5-C8 aliphatics, dichlorobenzene, hexane, C3-C5, and xylenes. This site is heavily influenced by traffic emissions.
- The highest concentrations measured at the Station 401 site (Site C) are for C9-C16 aliphatics, C9-C16 aromatics, toluene, and xylenes.
- The highest concentrations measured at the Scotford site (Site D) are for benzene, ethylbenzene, and styrene. This site is heavily influenced by a nearby chemicals manufacturing plant.
- Elevated concentrations of some substances were measured at the two residential sites (Sites A and E).
- The remote Elk Island site (Site F) measured the lowest concentrations for a number of substances.

In summary, it appears that some of the selected sites were strongly influenced by local emissions sources as indicated by the high relative concentrations. All sites, whether near or distant from emission sources, indicate measurable VOC concentrations.

The FAP/EC monitoring program collected 24-h average samples. Of the VOC compounds measured, there are 24-h AAAQO for only two substances: toluene and total xylenes. The maximum measured toluene concentration of 33 ug/m^3 is much less than the associated 400 ug/m^3 AAAQO. Similarly, the maximum measured total xylene concentration of 12 ug/m^3 is much less than the associated 700 ug/m^3 AAAQO.

Table 2B-26 provides a summary of the maximum, average and minimum values based on all six stations for each substance group and for the full time period. The table also shows the average for the three lowest stations that can be used to provide an indication of regional background values.

The FAP/EC measurements for selected substances were compared to those collected as part of the Western Interprovincial Scientific Studies (WISSA) program (Davies et al., 2006). This program measured monthly average VOC concentrations over the 21-month period from April 2001 to December 2002 across southern Alberta, central and southern Alberta, and northeastern British Columbia. The comparison is as follows:

- **Benzene**: The average and 90th percentile concentrations across all WISSA regions were 0.29 ug/m^3 and 0.58 ug/m^3, respectively. The FAP/EC program values, based on the averages in Table 2B-26, are larger (i.e., from 0.51 ug/m^3 to 1.03 ug/m^3).
- **Ethylbenzene**: The average and 90th percentile concentrations across all WISSA regions were 0.054 ug/m^3 and 0.10 ug/m^3, respectively. The FAP/EC program values, based on the averages in Table 2B-26, are larger (i.e., from 0.10 ug/m^3 to 0.36 ug/m^3).

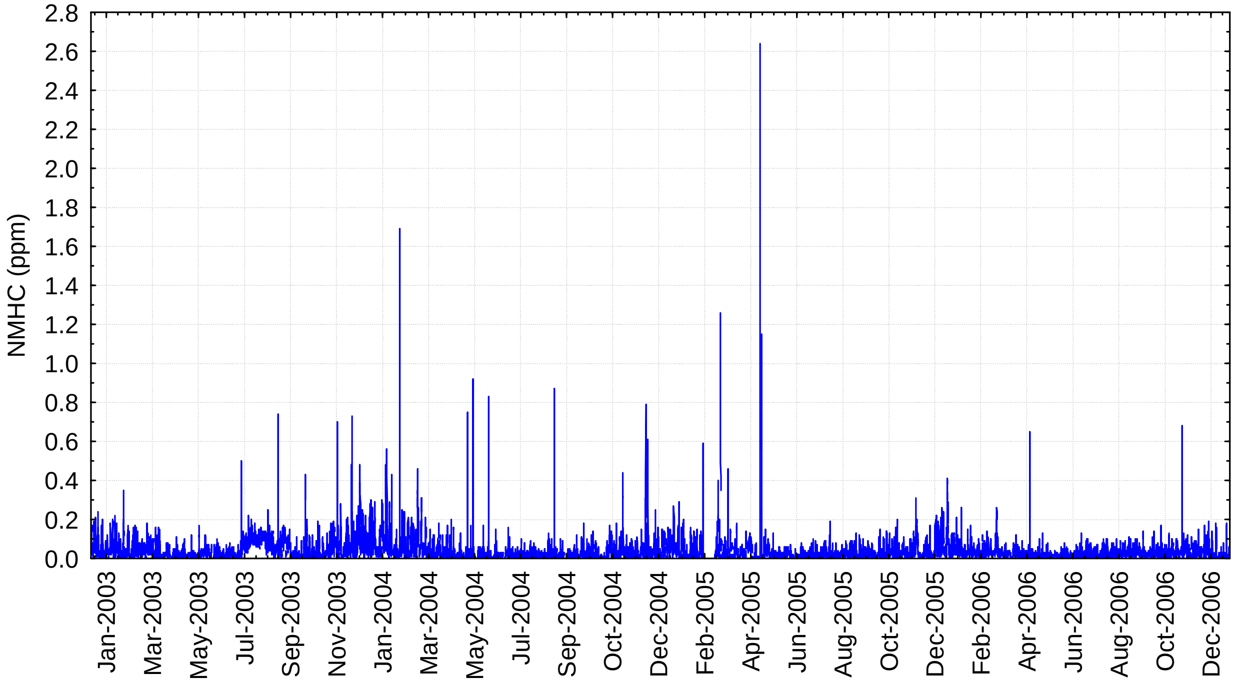
- **Toluene**: The average and 90th percentile concentrations across all WISSA regions were 0.44 ug/m^3 and 0.67 ug/m^3, respectively. The FAP/EC program values, based on the averages in Table 2B-26, are larger (i.e., from 0.62 ug/m^3 to 3.52 ug/m^3).

- **Xylenes**: The average and 90th percentile concentrations across all WISSA regions were 0.16 ug/m^3 and 0.31 ug/m^3, respectively. The FAP/EC program values based on the averages in Table 2B-26, are larger (i.e., from 0.33 ug/m^3 to 1.89 ug/m^3).

In summary, the FAP/EC values are larger than those measured in other rural areas across the Canadian prairie region. This is not surprising considering the proximity bias of FAP/EC sites to the Fort Saskatchewan industrial and Edmonton urban sources.

Table 2B-24 Summary of hourly average hydrocarbon concentrations measured at the FAP monitoring stations (in ppm)

	THC						Methane	NMHC	
	Fort Saskatchewan	**Range Road 220**	**Station 401**	**Edmonton East**	**Edmonton Central**	**Edmonton South**	**Lamont**	**Lamont**	**Range Road 220**
Maximum	7.8	16.0	11.8	25.9	9.5	10.6	5.7	2.64	8.25
99.9th Percentile	4.2	4.9	8.2	10.4	4.1	4.0	2.9	0.48	1.47
99th Percentile	3.2	3.8	4.4	5.5	3.3	3.0	2.4	0.18	0.79
95th Percentile	2.7	3.2	3.1	3.4	2.7	2.6	2.1	0.11	0.28
90th Percentile	2.4	2.7	2.8	2.9	2.5	2.4	2.1	0.08	0.20
Median	1.9	2.0	2.0	2.2	2.1	2.0	1.9	0.02	0.03
Average	2.0	2.1	2.2	2.4	2.2	2.1	1.9	0.03	0.08



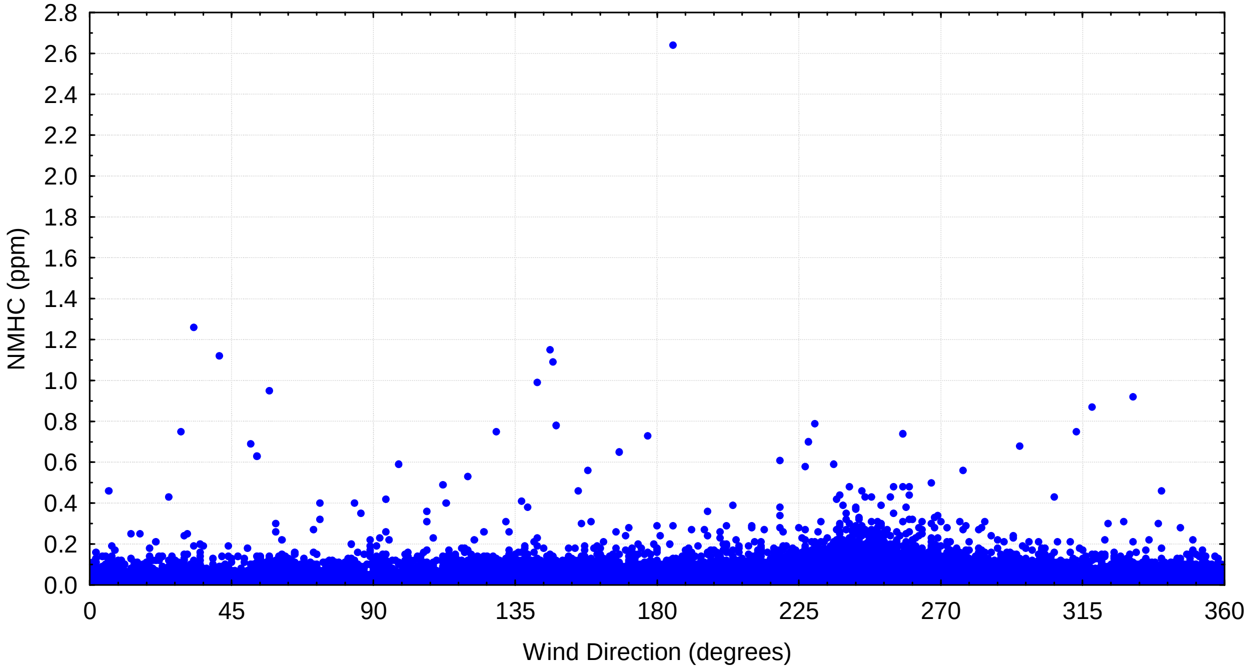


Figure 2B-13 **Ambient hourly NMHC concentrations measured at the FAP Lamont station. The top plot shows the time series and the bottom plot shows the wind direction dependence.**

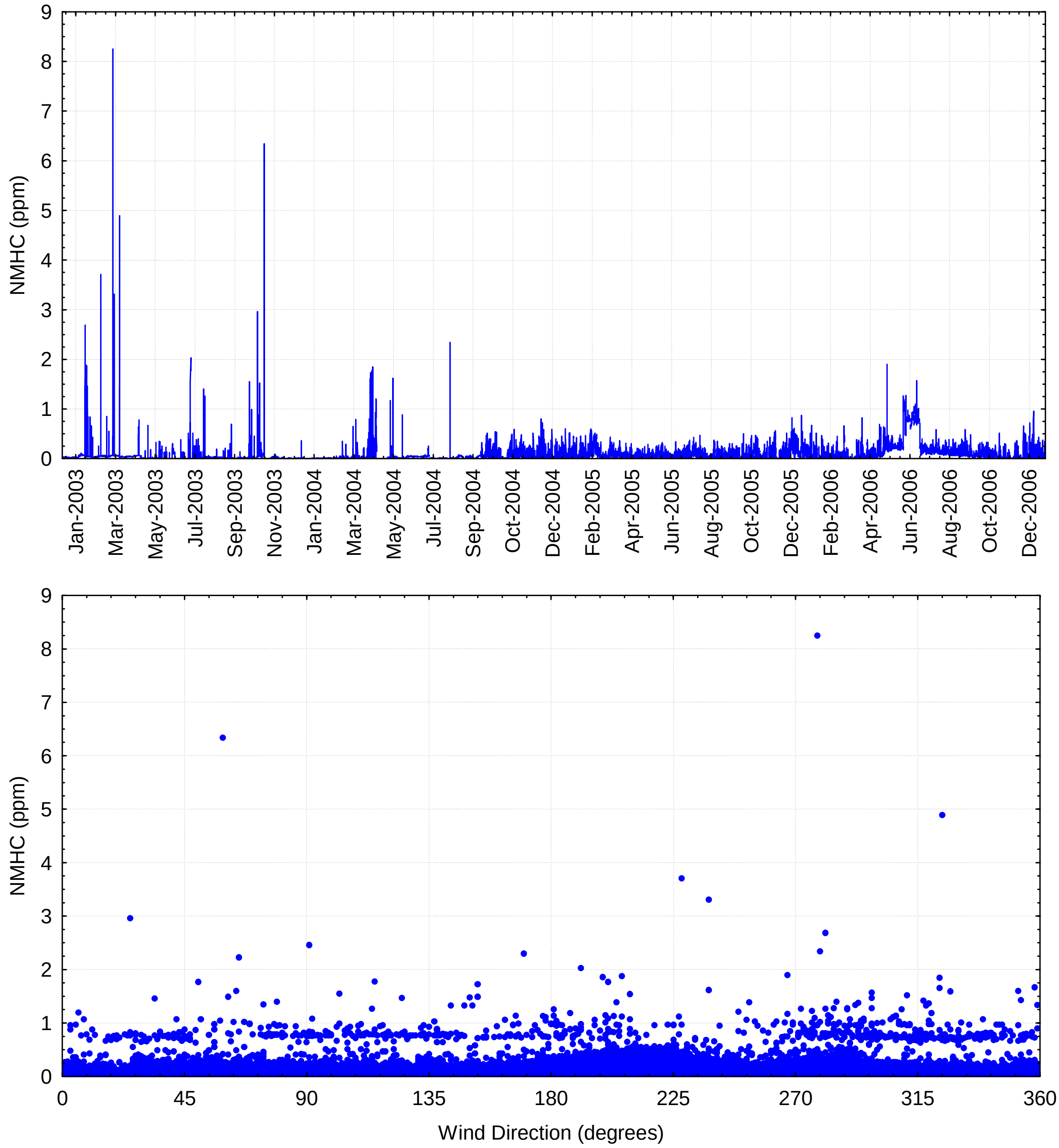


Figure 2B-14 Ambient hourly NMHC concentrations measured at the FAP Range Road 220 station. The top plot shows the time series and the bottom plot shows the wind direction dependence.

Table 2B-25 Adopted grouping for the 150 VOC substances measured by the FAP/EC VOC monitoring program

Grouping	FAP/EC Compound List
1,3-butadiene	1,3-butadiene
Benzene	Benzene
C5-C8 aliphatic group	1-Heptene, 1-Hexene/2-Methyl-1-Pentene, 1-Methylcyclohexene, 1-Methylcyclopentene, 1-Octene, 1-Pentene, 2,2,3-Trimethylbutane, 2,2,4-Trimethylpentane, 2,2-Dimethylbutane, 2,2-Dimethylhexane, 2,2-Dimethylpentane, 2,2-Dimethylpropane, 2,3,4-Trimethylpentane, 2,3-Dimethylbutane, 2,3-Dimethylpentane, 2,4-Dimethylhexane, 2,4-Dimethylpentane, 2,5-Dimethylhexane, 2-Ethyl-1-Butene, 2-Methyl-1-Butene, 2-Methyl-2-Butene, 2-Methylbutane, 2-Methylheptane, 2-Methylhexane, 2-Methylpentane, 3-Methyl-1-Butene, 3-Methyl-1-Pentene, 3-Methylheptane, 3-Methylhexane, 3-Methylpentane, 4-Methyl-1-Pentene, 4-Methylheptane, c-1,2-Dimethylcyclohexane, c-1,3-Dimethylcyclohexane, c-1,4/t-1,3-Dimethylcyclohexane, c-2-Heptene, c-2-Hexene, c-2-Pentene, c-3-Heptene, c-3-Methyl-2-Pentene, c-4-Methyl-2-Pentene, Cyclohexene, Cyclopentane, Cyclopentene, Heptane, Isoprene (2-Methyl-1,3-Butadiene), Methylcyclohexane, Methylcyclopentane, Octane, Pentane, t-1,2-Dimethylcyclohexane, t-1,4-Dimethylcyclohexane, t-2-Heptene, t-2-Hexene, t-2-Octene, t-2-Pentene, t-3-Heptene, t-3-Methyl-2-Pentene, t-4-Methyl-2-Pentene
C9-C16 aliphatic group	1-Decene, 1-Nonene, 1-Undecene, 2,2,5-Trimethylhexane, 3,6-Dimethyloctane, a-Pinene, b-Pinene, Camphene, Decane, Dodecane, Limonene, Nonane, Undecane
C9-C16 aromatic group	1,2,3-Trimethylbenzene, 1,2,4-Trimethylbenzene, 1,2-Diethylbenzene, 1,3,5-Trimethylbenzene, 1,3-Diethylbenzene, 1,4-Diethylbenzene, 2-Ethyltoluene, 3-Ethyltoluene, 4-Ethyltoluene, Hexylbenzene, Indan (2,3-Dihydroindene), iso-Butylbenzene, iso-Propylbenzene, n-Butylbenzene, n-Propylbenzene, p-Cymene (1-Methyl-4-Isopropylbenzene), sec-Butylbenzene, tert-Butylbenzene
Cyclohexane	Cyclohexane
Dichlorobenzene	1,2-Dichlorobenzene, 1,3-Dichlorobenzene, 1,4-Dichlorobenzene
Ethylbenzene	Ethylbenzene
Hexane	Hexane
C3-C5	1-Butene/2-Methylpropene, 1-Butyne, Butane, Isobutane (2-Methylpropane), Methyl-t-Butyl Ether (MTBE), Propane, Propene, Propyne, t-2-Butene
Naphthalene	Naphthalene
Not Evaluated	1,1,1-Trichloroethane, 1,1,2,2-Tetrachloroethane, 1,1,2-Trichloroethane, 1,1-Dichloroethane, 1,1-Dichloroethene, 1,2,4-Trichlorobenzene, 1,2-Dibromoethane (EDB), 1,2-Dichloroethane, 1,2-Dichloropropane, 1,4-Dichlorobutane, Benzyl Chloride, Bromodichloromethane, Bromoform, Bromomethane, Bromotrichloromethane, c-1,2-Dichloroethene, c-1,3-Dichloropropene, c-2-Butene, Carbontetrachloride, Chlorobenzene, Chloroethane, Chloroform, Chloromethane, Dibromochloromethane, Dibromomethane, Dichloromethane, Ethylbromide, Freon 11 (Trichlorofluoromethane), Freon 113 (1,1,2-Trichlorotrifluoroethane, Freon 114 (1,2-Dichlorotetrafluoroethane, Freon 12 (Dichlorodifluoromethane), Freon 22 (Chlorodifluoromethane), Hexachlorobutadiene, t-1,2-Dichloroethene, t-1,3-Dichloropropene, Tetrachloroethene, Trichloroethene, Vinylchloride (Chloroethene)
Styrene	Styrene
Toluene	Toluene
Xylenes	m,p-Xylene, o-Xylene

Table 2B-26 Summary of period average VOC concentrations (ug/m^3) measured by the FAP/EC VOC monitoring program

Grouping	Maximum of 6 Station Averages	Mean of 6 Station Averages	Minimum of 6 Station Averages	Mean of Stations with 3 Lowest Averages
1,3-butadiene	0.083	0.044	0.017	0.029
Benzene	1.03	0.65	0.40	0.51
C5-C8 aliphatic group	19.3	13.2	9.2	9.9
C9-C16 aliphatic group	1.16	0.67	0.28	0.42
C9-C16 aromatic group	1.28	0.57	0.17	0.29
Cyclohexane	0.33	0.21	0.17	0.18
Dichlorobenzene	0.028	0.023	0.016	0.019
Ethylbenzene	0.36	0.24	0.10	0.17
Hexane	2.20	1.30	0.48	0.72
C3-C5	18.90	14.9	10.03	13.0
Naphthalene	0.078	0.042	0.021	0.029
Not Evaluated	11.02	8.7	7.93	8.1
Styrene	0.37	0.19	0.04	0.082
Toluene	3.52	1.69	0.62	1.08
Xylenes	1.89	0.85	0.33	0.53
Total	59.1	43.3	29.9	36.3

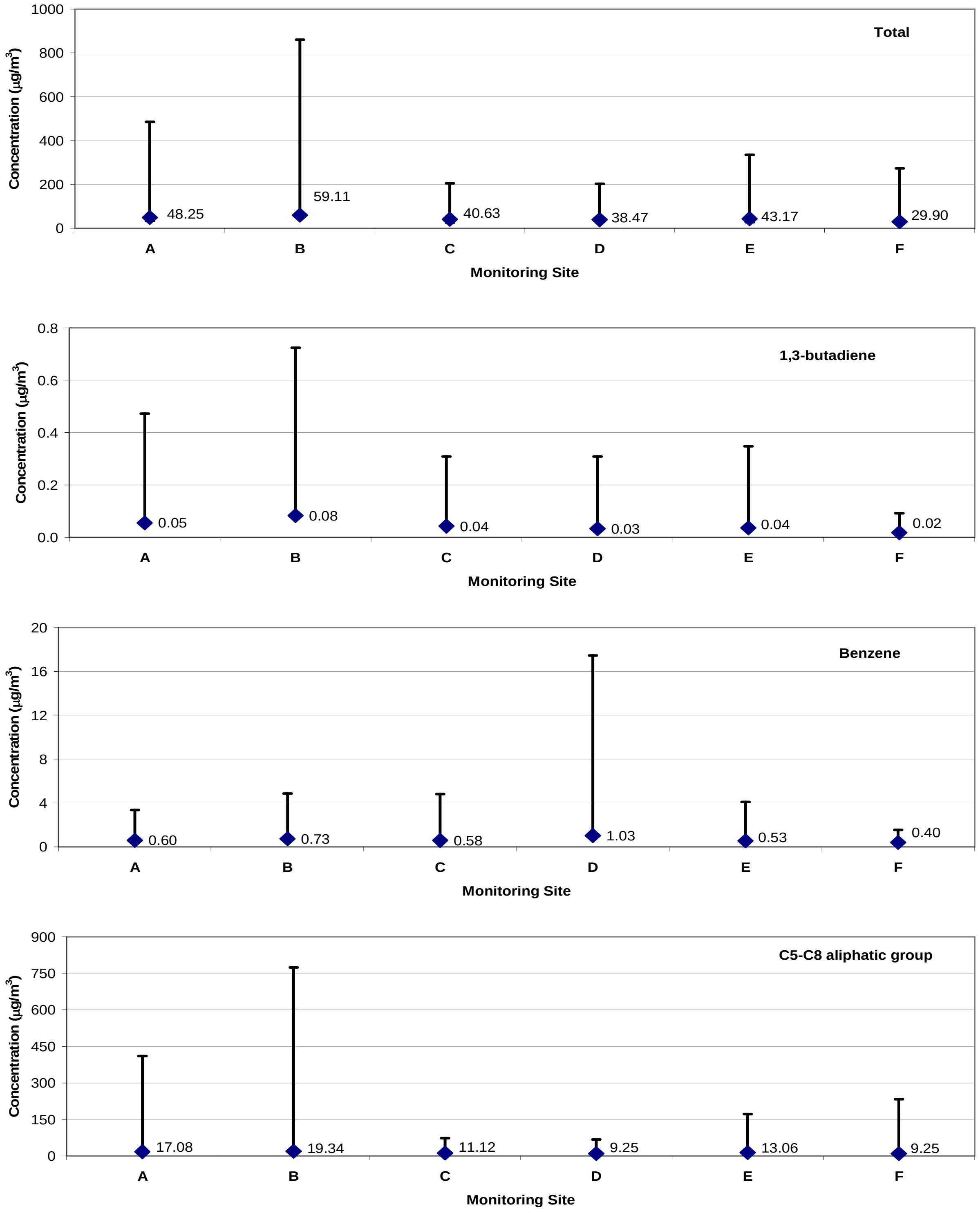


Figure 2B-15 VOC concentrations (ug/m^3) measured as part of the FAP/EC VOC monitoring program. Maximum and average values are shown (September 2004 to April 2005).

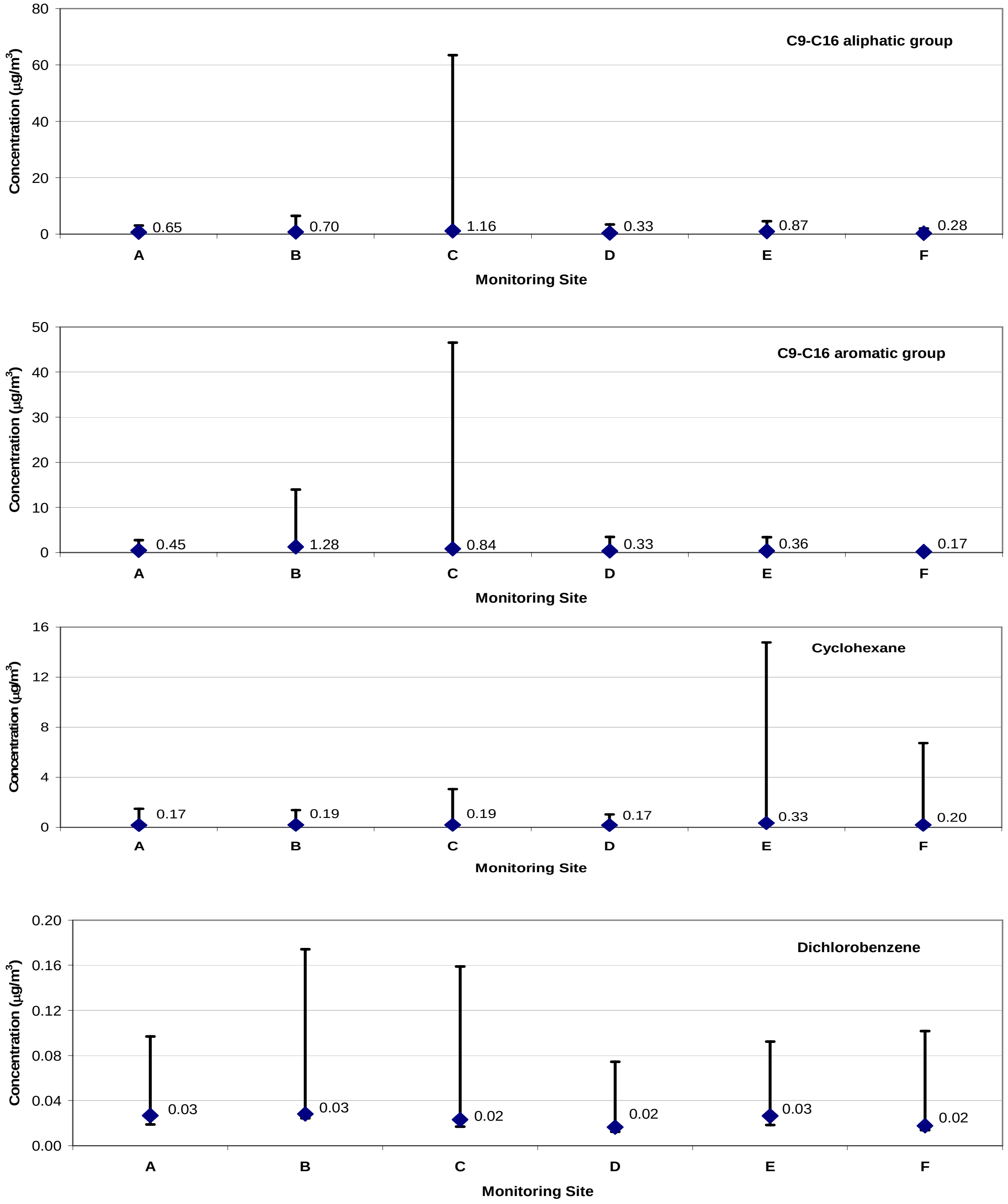


Figure 2B-16 VOC concentrations (ug/m^3) measured as part of the FAP/EC VOC monitoring program. Maximum and average values are shown (September 2004 to April 2005).

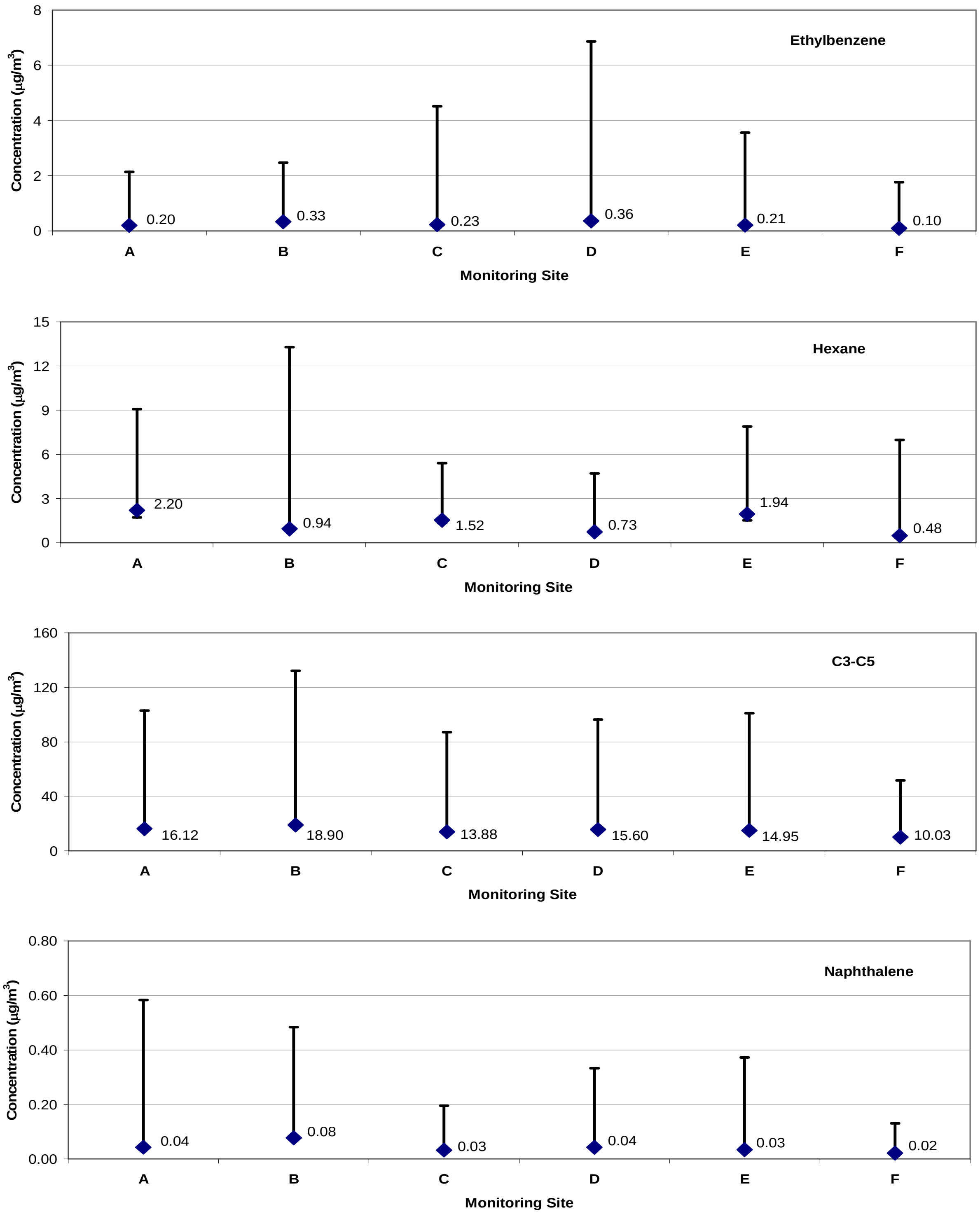


Figure 2B-17 **VOC concentrations (ug/m^3) measured as part of the FAP/EC VOC monitoring program. Maximum and average values are shown (September 2004 to April 2005).**

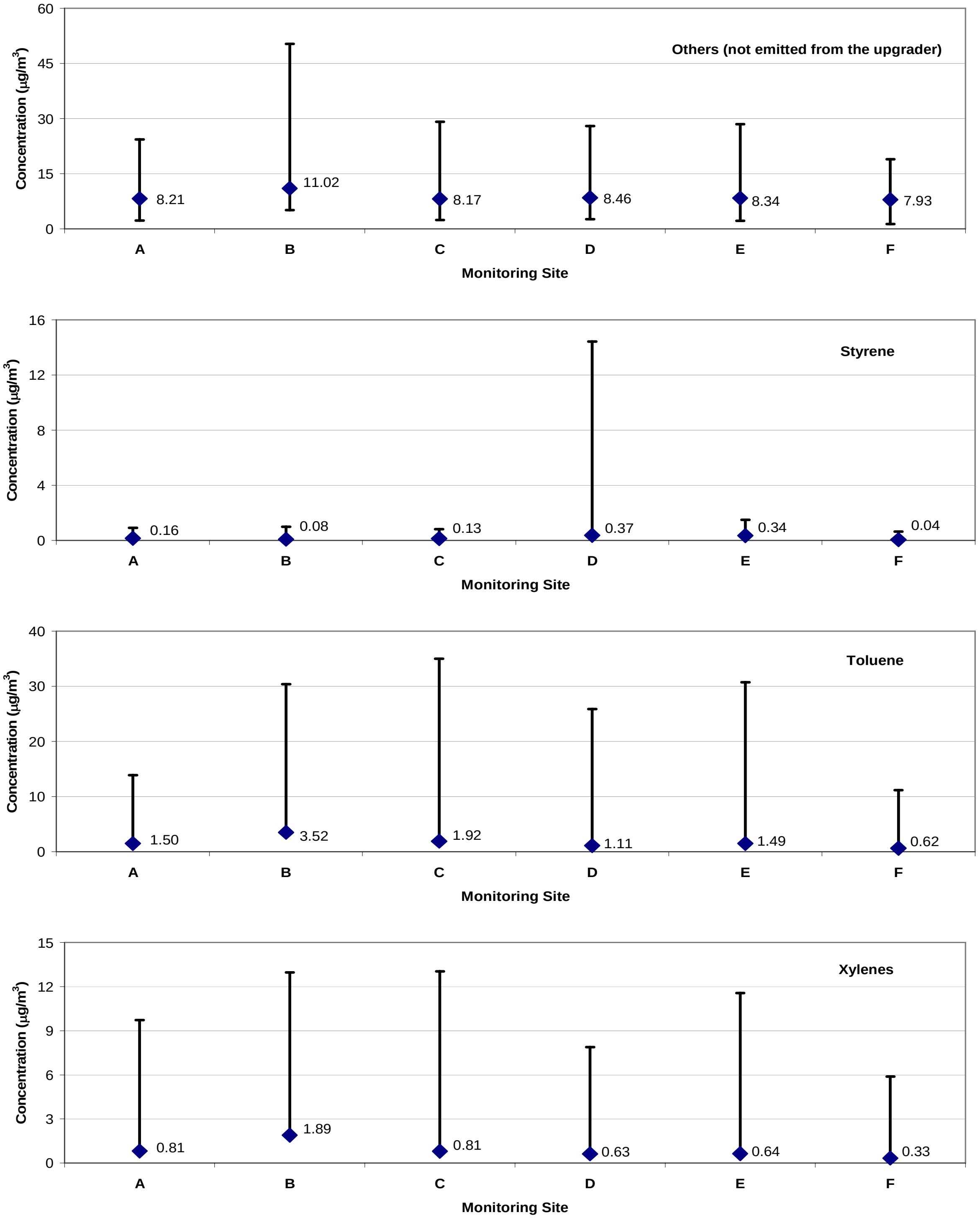


Figure 2B-18 VOC concentrations (ug/m^3) measured as part of the FAP/EC VOC monitoring program. Maximum and average values are shown (September 2004 to April 2005).

2B11 Existing Acidifying Deposition

The deposition of potentially acidifying compounds is the sum of the contribution due to SO_2 and NO_x emissions, minus the neutralizing effects of base cations (e.g., aerosols that are composed of calcium (Ca^{+2}) and magnesium (Mg^{+2}) ions) in the atmosphere. Deposition involves both wet and dry contributions. Because of limitations regarding the measurement of deposition parameters, the estimation of a representative potential acid input (PAI) can be challenging. These limitations can be attributed to a relatively sparse precipitation monitoring network in Alberta, limited monitoring periods for a number of the sampling stations, and no direct measurements of dry deposition components. The existing PAI for the region was estimated from measurements and from provincial scale modelling. PAI deposition is expressed as keq H^+/ha/y, kiloequivalent hydrogen ion per hectare per year.

2B11.1 PAI Deposition Estimation based on Measurements

Total PAI based on measurements can be estimated from the following relationship:

$$\mathrm{PAI}_{\mathrm{total}} = \mathrm{Wet}_{(\mathrm{anion+cation})} + \mathrm{Dry}_{(\mathrm{SOx})} + \mathrm{Dry}_{(\mathrm{NOx})} - \mathrm{Dry}_{(\mathrm{Cation})}$$

For this assessment, the $\mathrm{Wet}_{(\mathrm{anion+cation})}$ term is derived from precipitation measurements, the $\mathrm{Dry}_{(\mathrm{SOx})}$ and $\mathrm{Dry}_{(\mathrm{NOx})}$ terms are derived from annual passive measurements, and the $\mathrm{Dry}_{(\mathrm{Cation})}$ term is derived indirectly from measurements (section 2B.11.1.4). The following describes the parameters that were used.

2B.11.1.1 Wet Deposition ($\mathrm{Wet}_{(\mathrm{anion+cation})}$)

AENV and EC collect precipitation samples, analyses these samples for anions and cations and calculates the wet PAI deposition at various locations across the province. The annual wet PAI values are shown in Table 2B-27 and Figure 2B-19 for the period 1993 to 2006. The PAI values in northern Alberta tend to be low (e.g., Fort McMurray, High Prairie) and the values in southern Alberta tend to be high (e.g., Red Deer, Calgary, Kananaskis). The results indicate a significant year-to-year variability, and this variability is similar to the variability associated with differences between monitoring locations. For the purpose of this assessment, the existing wet PAI (i.e., $\mathrm{Wet}_{(\mathrm{anion+cation})}$) in the Project study area was assumed to be the average of the Beaverlodge representing airflow into the province from the west (0.060 keq H+/ha/y) and Cold Lake representing air flow out of the province to the east (0.074 keq H^+/ha/a) values, this value being <u>0.067 keq $H^{\pm}$/ha/y</u>.

2B.11.1.2 Dry Deposition ($\mathrm{Dry}_{(\mathrm{SOx})}$)

$\mathrm{Dry}_{(\mathrm{SOx})}$ deposition is estimated from the product of sulphur compound concentration measurements and the appropriate deposition velocities. The following assumptions are made:

- A representative annual average SO_2 concentration of 1.2 ug/m^3 (Table 2B-5) was selected for the study area. The values measured at Waskatanau and Thorhild were selected to represent the background value without any regional industrial and urban influences.
- Based on a review of land use and deposition velocities provided by EPMC 2002 for various vegetation canopies; low, average and high deposition velocities of 0.45 cm/s, 0.50 cm/s and 0.55 cm/s were evaluated to calculate dry SO_2 deposition.

- In Alberta, SO_2 typically accounts for 80% of the dry sulphur compound deposition, with the remaining 20% primarily being particulate sulphate (SO_4^{-2}) (Kindzierski, et al., 2006). The calculated SO_2 depositions were therefore multiplied by 1.25 to account for particulate sulphate.

- The total dry sulphur compound contributions were then converted to units of keq H^+/ha/y.

On this basis, the associated $Dry_{(SOx)}$ depositions for the study area are calculated as 0.067 keq $H^{\pm}$/ha/y, 0.074 keq $H^{\pm}$/ha/y and 0.081 keq $H^{\pm}$/ha/y for the low, average and high deposition velocity assumptions.

2B.11.1.3 Dry Deposition ($Dry_{(NOx)}$)

$Dry_{(NOx)}$ deposition is estimated from the product of nitrogen compound concentration measurements with the appropriate deposition velocities. The following assumptions are made:

- A representative annual average NO_2 concentration of 5 ug/m^3 (Table 2B-10) was selected for the study area. The low values based on measurements at Waskatanau and Thorhild were selected to represent the background value without any regional industrial and urban influences.

- Based on a review of land use and deposition velocities provided by EPMC 2002 for various vegetation canopies; low, average and high deposition velocities of 0.10 cm/s, 0.15 cm/s and 0.20 cm/s were evaluated to calculate dry NO_2 deposition.

- Typically, NO_2 accounts for 50% of the dry nitrogen compound deposition, with the remaining 50% being primarily nitric acid (HNO_3), especially near NO_x emission sources (Kindzierski, et al., 2006, Zhang et al., 2005). The calculated NO_2 depositions were therefore multiplied by 2.0 to account for nitric acid.

- The total dry nitrogen compound contributions were converted to units of keq H+/ha/y.

On this basis, the associated $Dry_{(NOx)}$ depositions for the study area are calculated as 0.069 keq $H^{\pm}$/ha/y, 0.103 keq $H^{\pm}$/ha/y and 0.137 keq $H^{\pm}$/ha/y for the low, average and high deposition velocity assumptions.

2B.11.1.4 Dry Deposition ($Dry_{(Cation)}$)

Chaikowsky (2001) estimated dry base cation (BC) deposition in western Canada by inferring air concentrations from precipitation measurements. Two regression approaches were considered, one based on Ontario measurements and the other based on Alberta measurements. Although the Ontario regression did not fit the limited Alberta data, the Alberta regression is based on two sites and cannot be tested as rigorously as the Ontario relationships. The two sites closest to the Project area that are included in Chaikowsky's assessment are Ellerslie and Royal Park. His findings based on these two sites are as follows:

- **Ellerslie:**

o **Wet BC Deposition** = 0.073 keq H^+/ha/y.

  - **Dry BC Deposition** = 0.107 and 0.048 keq H^+/ha/y, based on the Ontario and Alberta regressions, respectively. Priority is given to the Alberta regression based value of 0.048 keq H^+/ha/y.

- **Royal Park:**
  - **Wet BC Deposition** = 0.102 keq H^+/ha/y.
  - **Dry BC Deposition** = 0.154 and 0.053 keq H^+/ha/y, based on the Ontario and Alberta regressions, respectively. Priority is given to the Alberta regression based value of 0.053 keq H^+/ha/y.

Based on the averages of Royal Park and Ellerslie sites, the dry BC deposition in the study area is 0.051 keq $H^{\pm}$/ha/y (the average of 0.048 keq H^+/ha/y and 0.051 keq H^+/ha/y).

2B.11.1.5 Total Deposition

The total existing PAI based on measurements is therefore:

$$PAI_{total} = Wet_{(anion+cation)} + Dry_{(SOx)} + Dry_{(NOx)} - Dry_{(Cation)}$$

$$PAI_{total}\ (Low) = 0.067 + 0.067 + 0.069 - 0.051 = 0.15\ keq\ H^+/ha/y$$

$$PAI_{total}\ (Medium) = 0.067 + 0.074 + 0.103 - 0.051 = 0.19\ keq\ H^+/ha/y$$

$$PAI_{total}\ (High) = 0.067 + 0.081 + 0.137 - 0.051 = 0.23\ keq\ H^+/ha/y$$

The PAI based on the measurement information is therefore calculated to be 0.19 ± 0.04 keq $H^{\pm}$/ha/y. There are a number of subjective assumptions incorporated in this calculation; and the value provided can be viewed as a first order estimate of a regional study area average.

2B11.2 PAI Deposition based on RELAD Model Predictions

AENV uses the RELAD long-range transport, dispersion, transformation and deposition model to predict annual average PAI in western Canada on a 1º latitude by 1º longitude grid basis. (e.g., CASA/AENV 1999, WBK & Associates Inc. 2007). The latter reference provides PAI predictions for the 1995, 1000 and 2010 emission scenarios.

The resulting PAI prediction plots are shown in Figure 2B-20. The DSA is essentially bisected by the 113° meridian and is between 53° and 54° north. The west half of the DSA (between 113° and 114°) includes the City of Fort Saskatchewan and the City of Edmonton. The east half of the DSA (between 112° and 113°) includes Elk Island National Park. A review of the plots indicate:

- For the western grid cell, the predicted PAIs are:
  - 0.10 to 0.17 keq H^+/ha/y for 1995,
  - 0.17 to 0.22 keq H^+/ha/y for 2000, and
  - 0.17 to 0.22 keq H^+/ha/y for 2010.

- For the eastern grid cell, the predicted PAIs are:
  - 0.10 to 0.17 keq H^+/ha/y for 1995,
  - 0.10 to 0.17 keq H^+/ha/y for 2000, and
  - 0.10 to 0.17 keq H^+/ha/y for 2010.

Based on the combined results for both grid cells, a representative PAI for the DSA is viewed as being between 0.15 and 0.22 keq H+/ha/y.

2B11.3 Existing PAI Deposition

There is subjectivity in determining an existing PAI value for the region; the estimation based on measurements indicates a value of 0.19 ± 0.04 keq H^+/ha/y is representative of the study area; and the application of the RELAD model indicates that the existing PAI is in the 0.15 keq H^+/ha/y and 0.22 keq H^+/ha/y range. The regional baseline deposition was therefore assumed to be 0.19 keq $H^\pm$/ha/y.

The CALPUFF model was applied to a Base Case to predict a regional average PAI for the 100 by 100 km study area. The average PAI predicted using CALPUFF was found to be 0.27 keq H^+/ha. The CALPUFF predictions therefore need to be adjusted by subtracting 0.08 keq H^+/ha/y (i.e., 0.08 = 0.27 – 0.19) in order to be consistent with the estimations based on the measurements and the RELAD.

This adjustment can be physically justified in that the CALPUFF predictions do not account for wet or dry base cation deposition. As previously indicated, the dry BC deposition is 0.051 keq H^+/ha/y. The average wet BC deposition based on Ellerslie and Royal Park is 0.088 keq H^+/ha/y, resulting in a total BC deposition of 0.14 keq H^+/ha/y. The 0.08 keq H^+/ha/y adjustment factor appears to represent the neutralizing effects of BC and the contribution of other SO_x and NO_x emissions sources.

Table 2B-27 Summary of annual average wet PAI deposition (keq H^+/ha/y)

Station	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average
Beaverlodge	0.0496	0.0869	0.0747	0.0603	0.0451	0.0778	NA	0.0557	0.0570	0.0618	0.0691	0.043	0.0439	NA	0.0604
Calgary	0.1138	0.0706	0.0663	0.1048	0.0848	0.1966	0.1593	0.1084	0.0673	0.1528	0.0336	0.130	0.0727	NA	0.1046
Cold Lake	0.0575	0.0660	0.0470	0.0883	0.0739	0.0577	0.0594	0.0640	0.0965	0.1130	0.0906	0.089	0.0648	NA	0.0744
Drayton Valley	0.1115	0.1514	0.0907	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.1179
Fort Chipewyan	-0.0008	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-0.0008
Fort McMurray	0.0778	0.0581	0.1041	0.0921	0.0291	0.0244	0.0579	0.0390	0.0724	0.0868	NA	0.037	NA	NA	0.0617
Fort Vermilion	0.0194	0.0276	NA	NA	NA	NA	NA	NA	NA	NA	0.0072	0.025	0.0061	NA	0.0170
High Prairie	0.0287	0.0210	0.0069	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0189
Kananaskis	0.1873	0.0286	0.1196	0.0982	0.0725	0.1578	0.0708	0.0262	0.0419	0.1741	0.0784	0.110	0.0599	NA	0.0942
Red Deer	0.1624	0.1147	0.1431	0.1242	NA	NA	NA	0.1105	0.1063	0.1373	0.1406	0.162	0.1534	NA	0.1355
Royal Park	0.0941	0.0857	0.0494	0.1049	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0835
Suffield	0.0966	0.0439	0.0568	0.0510	0.0340	0.1120	0.0404	0.0489	0.0628	0.0760	0.0319	0.041	NA	NA	0.0579
Average	**0.0832**	**0.0686**	**0.0759**	**0.0905**	**0.0566**	**0.1044**	**0.0776**	**0.0647**	**0.0720**	**0.1145**	**0.0645**	**0.0794**	**0.0668**	**NA**	**0.0688**

NOTE:
NA: Not Available

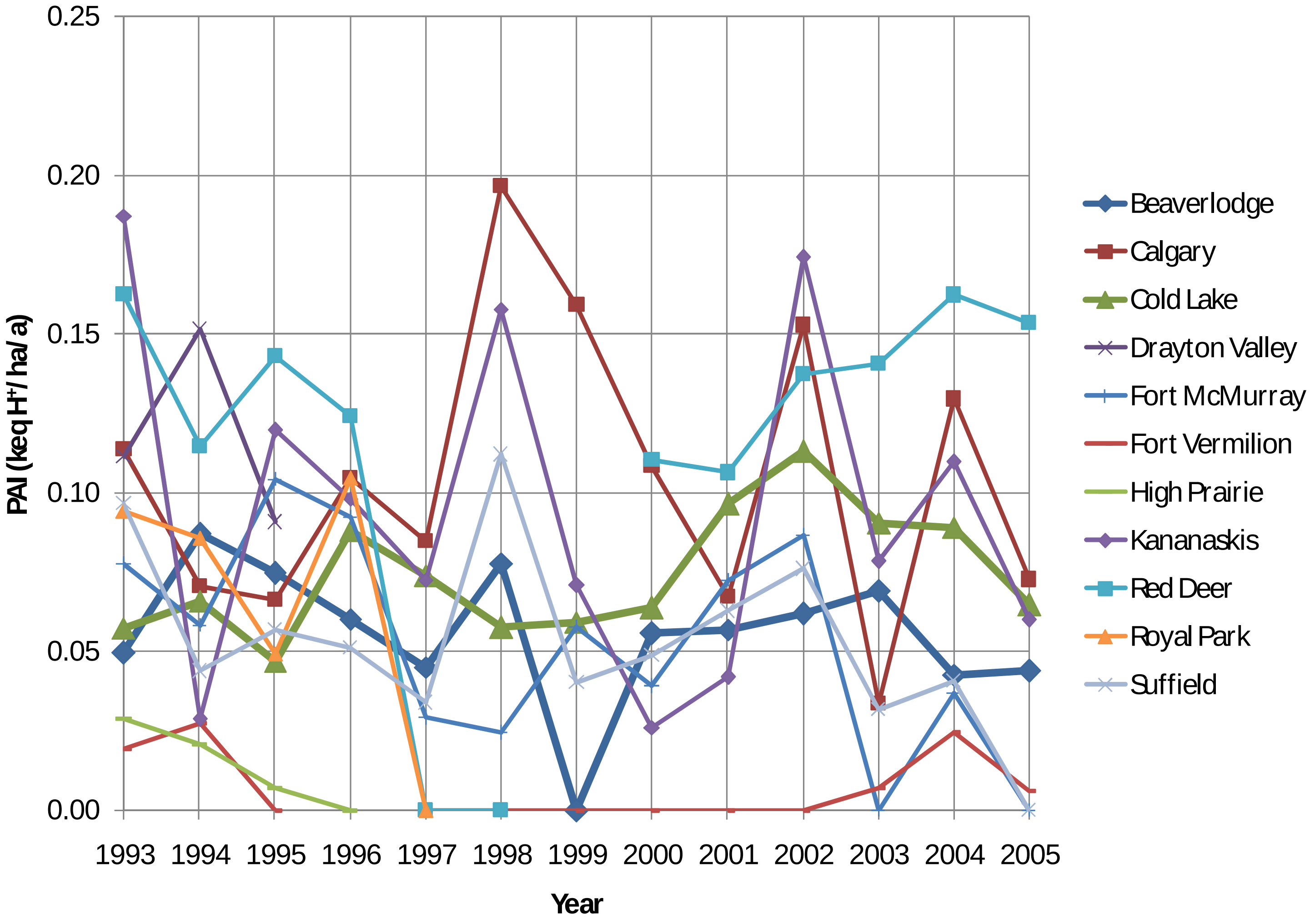
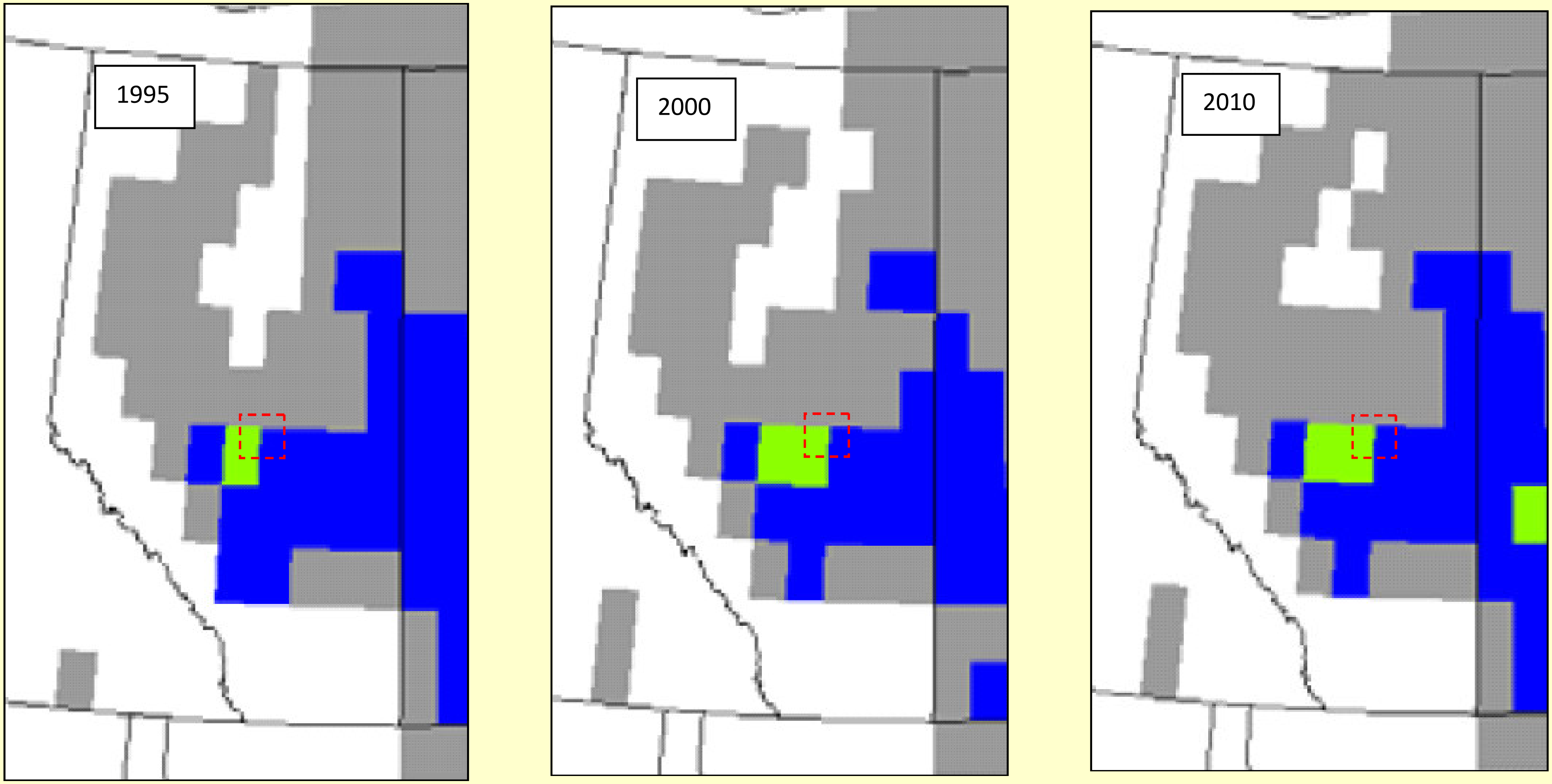
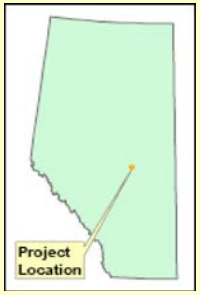


Figure 2B-19 Annual total wet PAI deposition based on AENV precipitation monitoring program





Legend

⬜ 🟫 🟦 🟩 🟧 🟥

0.00 0.10 0.17 0.22 0.25

☐ A grid cell is 1° Latitude by 1° Longitude

⬚ Deposition Study Area (DSA)

Title:

Predicted PAI on a 1° x 1° basis
(RELAD Model)
(keq H^+ /ha/y)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: MD	Revision Date: 03/12/2007

File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897 SURFER/ Case 15 future/05Nov07/Predicted PAI.srf

Drawn by:	Checked:	Fig. No.:
MD	MD	**2B-20**

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APPENDIX 2C: CALMET MODEL

TABLE OF CONTENTS

TABLES

FIGURES

2C1 Introduction

Meteorology determines the transport and dispersion of industrial emissions, and hence plays a significant role in determining air quality downwind of emission sources. For the air quality assessment, meteorological data for the year 2002 were used to define transport and dispersion parameters. The meteorological data from the 2002 period are compared to the longer-term climate information to provide a measure of representativeness for this year.

Meteorological characteristics vary with time (e.g., season and time of day) and location (e.g., height, terrain and land use). The CALMET meteorological pre-processing program was used to provide temporally and spatially varying meteorological parameters for the CALPUFF model. This appendix provides an overview of the meteorology and climate for the region as well as the technical details and options that were used for the application of the CALMET meteorological preprocessor to the Project study area.

2C2 Study Domain

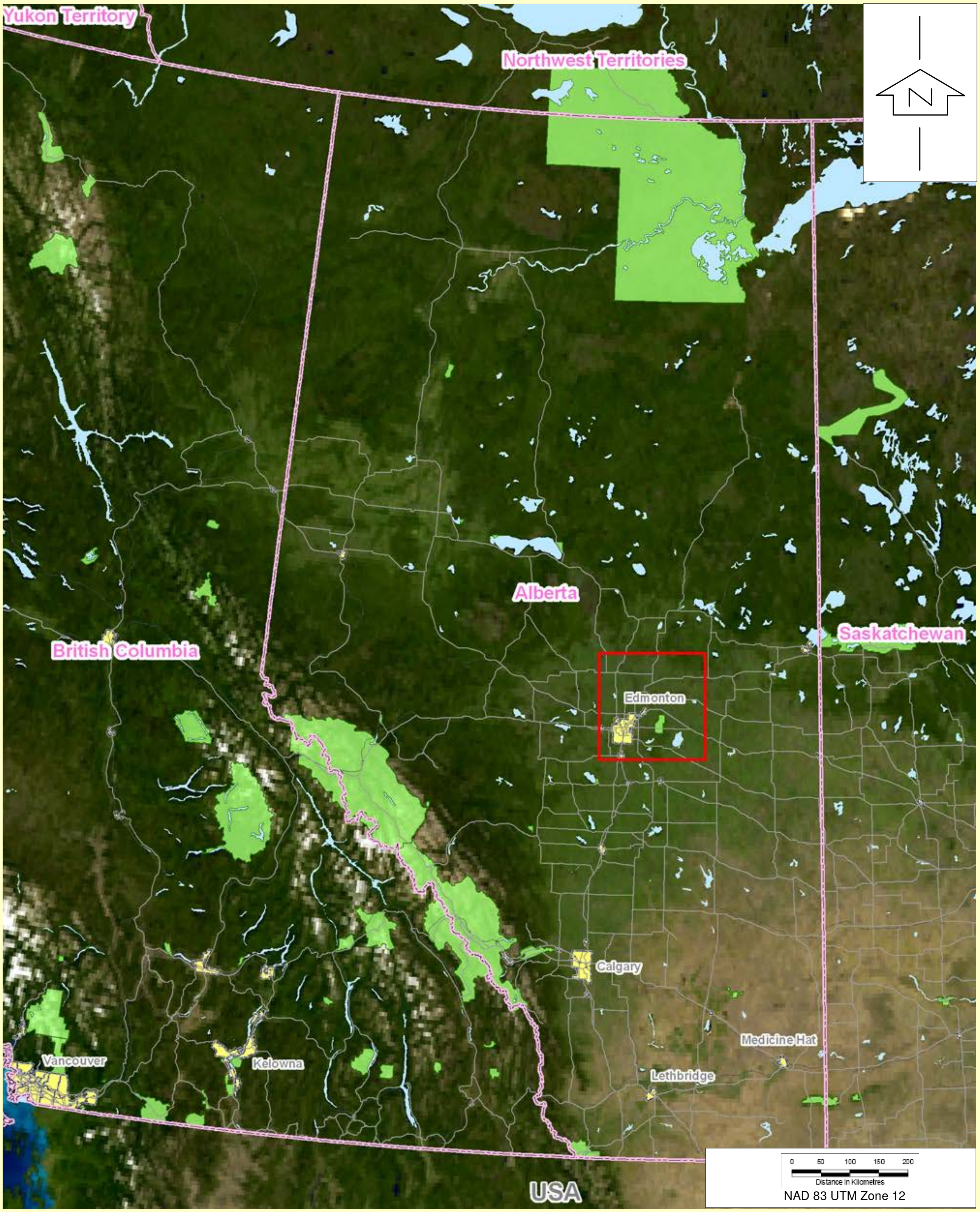
The CALMET study domain adopted for the Project extends from approximately 53.2135 degrees latitude to 54.368 degrees latitude in the north 125 km, and from 113.9204 degrees longitude to 112.0774 degrees longitude in the west 125 km, as shown in Figures 2C-1 and 2C-2. The CALMET study domain includes the communities of Edmonton and Leduc towards the south of the domain, and the community of Redwater in the north. The study domain covers a 15,625-km^2 area, the extents of which are provided in Table 2C-1.

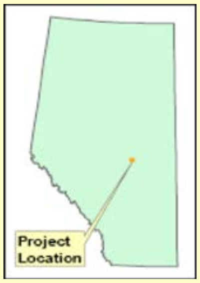
Table 2C-1 CALMET (125 km by 125 km) domain coordinates (UTM Zone 12; NAD 83)

Domain Extent	**Easting** (m)	**Northing** (m)
Southwest	305,000	5,900,000
Northwest	305,000	6,025,000
Southeast	430,000	5,900,000
Northeast	430,000	6,250,000

A horizontal grid spacing of 1 km was selected for the CALMET simulation; the CALMET domain therefore corresponds to 125 rows by 125 columns. With this grid spacing, it was possible to maximize run time and file size efficiencies while still capturing large-scale terrain feature influences on wind flow patterns.

To properly simulate pollution transport and dispersion, it is also important to simulate the representative vertical profiles of wind direction, wind speed, temperature, and turbulence intensity within the atmospheric boundary layer (i.e., the layer within about 2,000 m above the Earth's surface). To capture this vertical structure, eight vertical layers were selected. CALMET defines a vertical layer as the midpoint between two faces (i.e., nine faces corresponds to eight layers, with the lowest layer always being ground level or 10 m). The vertical faces used in this study are 0, 20, 40, 80, 160, 320, 600, 1,400 and 2600 m.





Legend

☐ **CALMET Domain**

🟨 **Urban Area**

🟩 **Parks**

Title:

CALMET Domain

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date: 08/11/2007

File:
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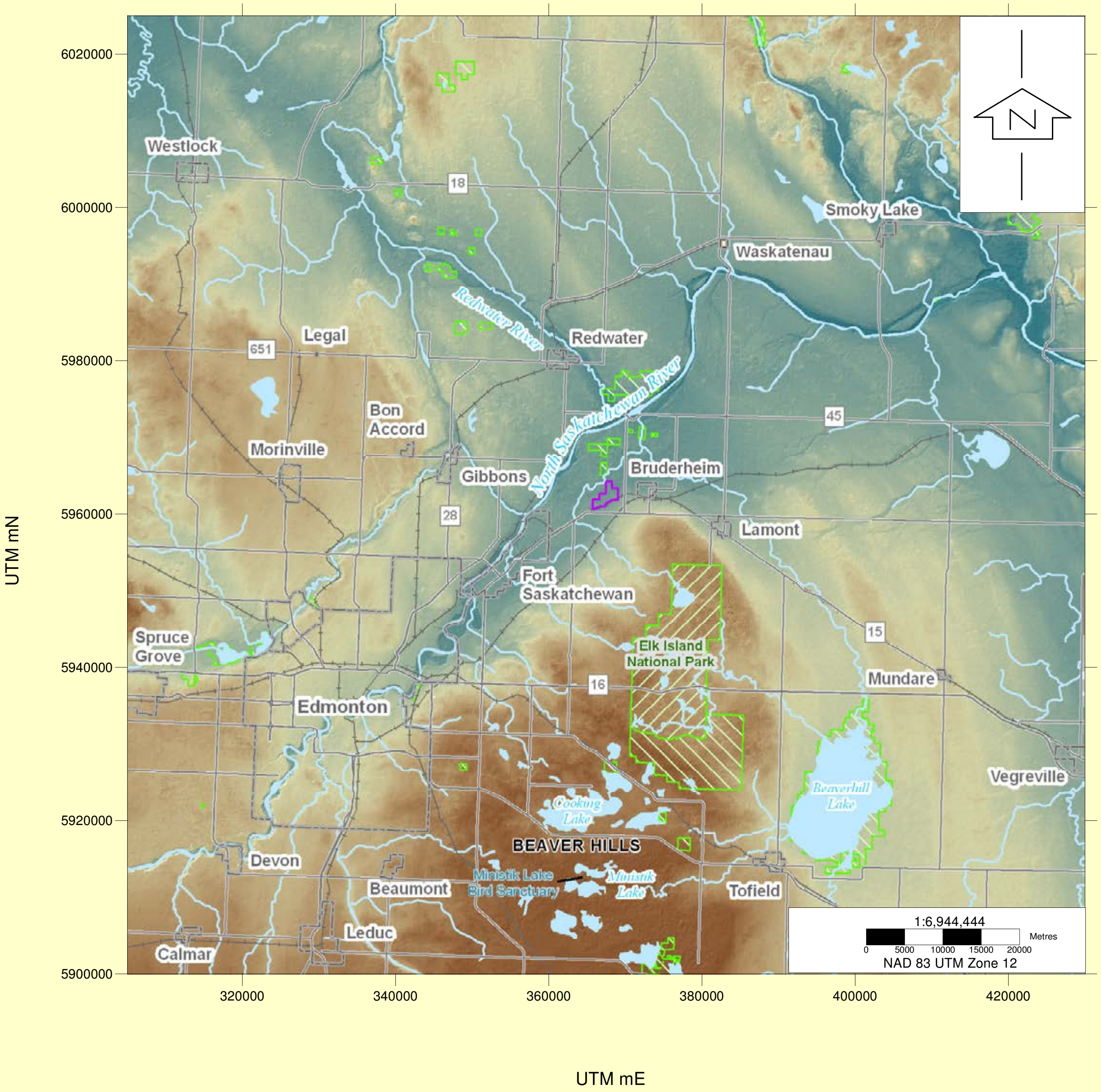
Y.S.	M.D.	2C-1



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		Elevation (m)
▭	Project Area	High : 859
—	Paved Access	
┼┼┼	Railway	Low : 543
▨	Natural Area	
▨	Protected Area	
▭	Urban Area	

Title:

Terrain in the 125 x 125 km CALMET Domain

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date: 08/11/2007

File:
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/N8897 NAOSC Reports/3. CALMET/surfer

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Y.S.	M.D.	2C-2

2C2.1 Regional Topography

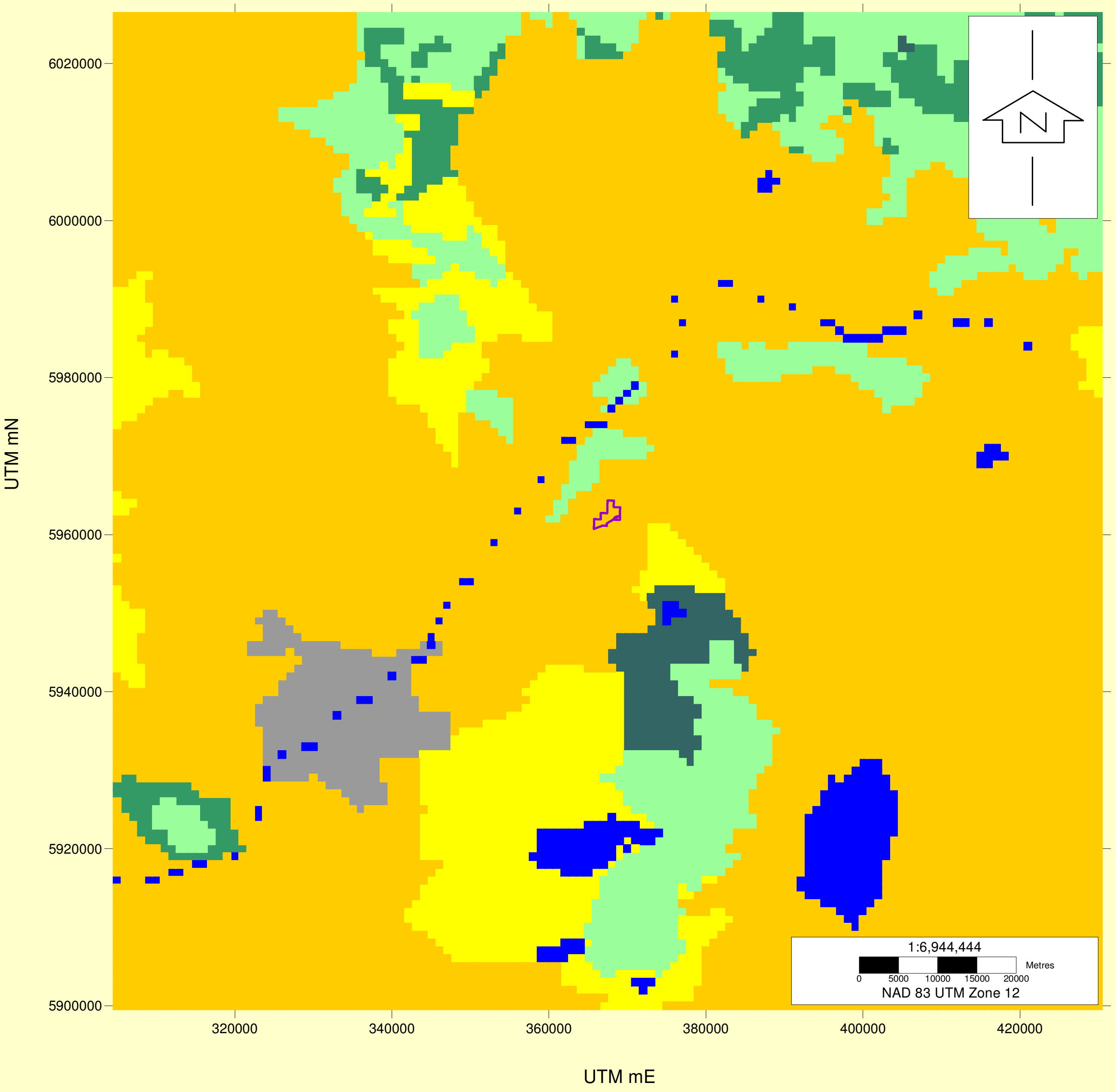
The valleys and elevated terrain features can affect surface wind flow patterns. A general overview of the terrain within the CALMET domain is presented in Figure 2C-2. Terrain features include:

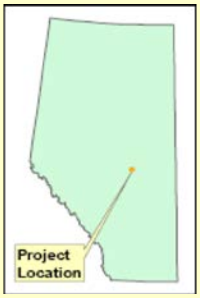
- The North Saskatchewan River valley is an important feature of the domain. The valley is typically about 30 m lower than the surrounding area.
- The Redwater River connects to the North Saskatchewan valley northeast of Fort Saskatchewan.
- Elk Island National Park (~730 m ASL) is in the south-southeast part of the domain.
- Ministik Lake Bird Sanctuary (~762 m ASL) is in the southern part of the domain.
- Beaverhill Lake (~680 m ASL) is in the southeast part of the domain and is the largest body of water in the region.
- Elevated terrain in the Bon Accord area (~720 m ASL) is located in the west-northwest part of the domain and the Beaver Hills region (~760 m ASL) located in the southern part of the domain.
- Lower terrain (~610 m ASL) is in the portion of the domain along the North Saskatchewan River valley.

While valleys and elevated terrain features can affect surface wind flow patterns, the domain is predominantly flat. The selected grid spacing (1 km) is sufficient to resolve broad-scale North Saskatchewan River valley influences, it will not, however resolve detailed local-scale valley influences. As the Project site is above the river valley, this loss of resolution will not affect the assessment.

2C2.2 Land-use Data

Land-use in the CALMET domain is mixed. The domain is characterized by agricultural cropland (80 percent), forestland (6 percent), rangeland (7 percent), urban or built-up land (4 percent), and water (3 percent). Values for surface roughness (z_0), leaf area index (LAI), albedo, Bowen ratio, anthropogenic heat flux, and soil heat flux are given in Table 2C-2. The year was divided into four seasons as follows: winter (November, December, January, February, and March), spring (April and May), summer (June, July, and August) and fall (September and October). Figure 2C-3 shows the land use on a 1 km resolution basis for the CALMET domain.





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▭ Project Area
■ Urban
🟨 Rangeland
🟧 Cropland
■ Coniferous Forest
🟦 Water
🟩 Deciduous Forest
🟩 Mixed Forest

Title:

Land-use classes on a 1 x 1 km grid in the 125 x 125 km CALMET domain

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:
Revision Date: 08/11/2007
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Drawn by: Y.S.
Checked: M.D.
Fig. No.: 2C-3

Table 2C-2 CALMET Domain Land-use Characterization and Associated Geophysical Parameters

Land Use Class	**Surface Roughness (m)**				**Albedo**				**Bowen Ratio**			
	Winter	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**	**Fall**
Cropland	0.15	0.22	0.50	0.32	0.75	0.20	0.20	0.20	2.0	0.4	0.4	0.4
Rangeland	0.15	0.22	0.50	0.32	0.75	0.20	0.20	0.20	2.0	0.4	0.4	0.4
Mixed Forest	1.20	1.2	1.15	1.15	0.17	0.13	0.12	0.12	2.0	1.5	0.9	0.9
Deciduous forest	0.55	0.75	1.05	0.95	0.21	0.15	0.15	0.15	2.0	1.5	0.6	0.6
Coniferous Forest	0.90	0.90	0.80	0.90	0.13	0.11	0.08	0.08	2.0	1.5	1.4	1.4
Urban	1.00	1.00	1.00	1.00	0.18	0.18	0.18	0.18	1.5	1.5	1.5	1.5
Water	.001	.001	.001	.001	0.75	0.1	0.1	0.1	0.0	0.0	0.0	0.0

Land Use Class	**Soil Heat Flux (fraction)**				**Anthropogenic Heat Flux (W/m^2)**				**Leaf Area Index**			
	Winter	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**	**Fall**
Cropland	0.1	0.1	0.1	0.1	0	0	0	0	0.8	2.2	2.8	0.3
Rangeland	0.1	0.1	0.1	0.1	0	0	0	0	0.8	2.2	2.8	0.3
Mixed Forest	0.1	0.1	0.1	0.1	0	0	0	0	2.3	3.3	4.5	2.3
Deciduous Forest	0.1	0.1	0.1	0.1	0	0	0	0	0.1	1.0	3.4	0.1
Coniferous Forest	0.1	0.1	0.1	0.1	0	0	0	0	4.5	5.2	5.2	4.7
Urban	0.25	0.25	0.25	0.25	16	14	8	12	0.2	0.2	0.2	0.2
Water	1.0	1.0	1.0	1.0	0	0	0	0	0.0	0.0	0.0	0.0

2C3 Meteorology and Climate

Meteorological data collected in the area surrounding the Project site have been analyzed to characterize the existing regional and local climate. These data are discussed on a parameter-by-parameter basis and include wind, temperature, mixing heights, precipitation, relative humidity, visibility and solar radiation. As the measurements represent specific locations, the CALMET meteorological model was applied to provide a full three dimensional interpolation of the key meteorological parameters from a plume transport and dispersion perspective. This section describes the existing climate in the region based on the measurements and the CALPUFF predictions.

2C3.1 Sources of Data

A longer period of information is available from the three Environment Canada (EC) airport stations in the region: Edmonton City Centre Airport, Edmonton International Airport, and Edmonton Namao Airport. The Fort Air Partnership (FAP) collects selected meteorological parameters in the Fort Saskatchewan area as part of their ambient air quality monitoring program. These data are only available for the period since the FAP was formed (i.e., since the fall of 1997). In addition, data from two Alberta Environment (AENV) air quality monitoring stations in the region are available: Edmonton Northwest and Edmonton East. The locations of the meteorological stations used in this climate analysis are summarized in Table 2C-3 and presented graphically in Figure 2C-4.

Information relating to wind was obtained from five years of continuous hourly monitoring data for the Fort Saskatchewan station and for three years of data for the Ross Creek, Redwater, Scotford and Lamont stations. Wind data from these stations were obtained from the Alberta Clean Air Strategic Alliance (CASA) database (CASA, 2006).

Regional scale climate data were obtained from the EC climate normals (1971-2000) for Fort Saskatchewan and for the three airports (EC, 2006). Solar radiation data were obtained from the Agriculture and Agri-Food Canada (AAFC) (1961-1990) Canadian Ecodistrict Climate Normals (CECN) for the Edmonton area (AAFC, 1997).

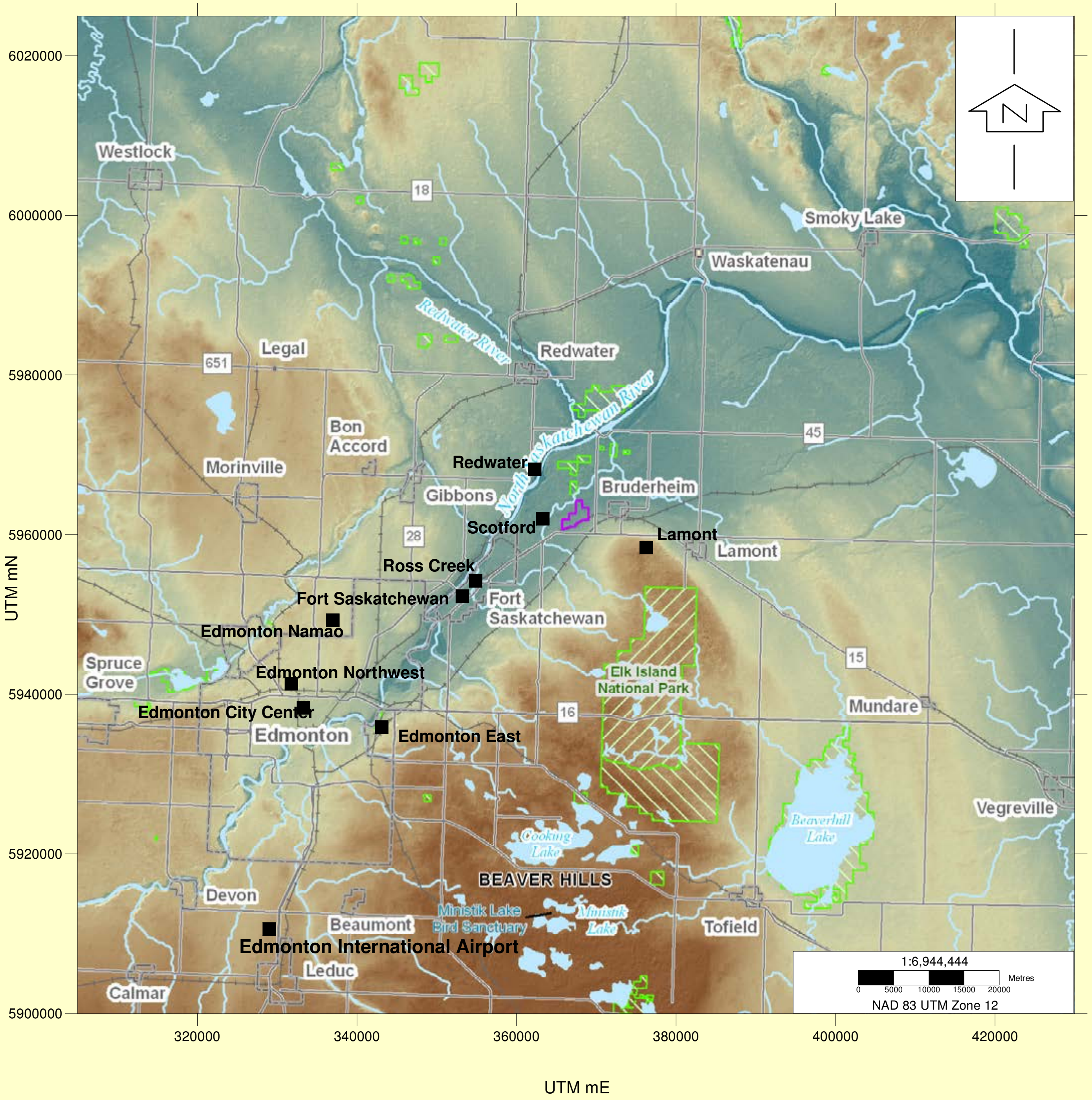
2C3.2 CALMET

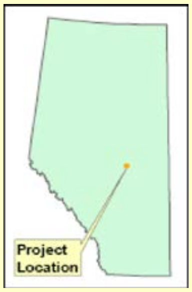
The CALMET model was applied for 2002 (i.e., for 8760 hours). The model requires surface and upper air information. The following 10 surface stations were used: Edmonton International Airport (EC), Edmonton City Centre Airport (EC), Edmonton Namao Airport (EC), Edmonton Northwest (AENV), Edmonton East (AENV), Fort Saskatchewan (FAP), Lamont (FAP), Ross Creek (FAP), Redwater (FAP), and Scotford (FAP).

The upper air meteorological data produced by the MM5 model (a mesoscale meteorological model assimilation produced by Penn State/National Center Atmospheric Research) were used as an initial guess field (Scire et al., 2000). The CALMET model adjusted the initial guess field for the kinematic effects of terrain, slope flows, and terrain blocking effects using the finer scaled CALMET terrain data to produce a modified wind field. The MM5 mesoscale information was supplied by EC and was used to generate vertical wind and temperature profiles across western Canada on a 12 km grid resolution for the 2002 model year. Figure 2C-5 shows the MM5 grids used in the CALMET modelling.

Table 2C-3 Geographic Coordinates of Meteorological Stations Included in the Climate Analysis

Source	Station Name	Latitude	Longitude	Elevation (m ASL)	UTM NAD83		
					Easting	Northing	Zone
Environment Canada (EC)	Edmonton Namao Airport	53^{o} 40’ N	113^{o} 28’ W	688	337037	5949263	12
	Edmonton City Centre Airport	53° 34' N	113° 31' W	671	333341	5938256	12
	Edmonton International Airport	53°19' N	113°35' W	723	327919	5910610	12
Alberta Environment (AENV)	Edmonton Northwest	53^{o} 36 ’ N	113^{o} 33’ W	676	331830	5941300	12
	Edmonton East	53^{o} 33’ N	113^{o} 22’ W	670	343100	5935900	12
Fort Air Partnership (FAP)	Fort Saskatchewan	53^{o} 42’ N	113^{o} 13’ W	627	353223	5952316	12
	Lamont	53^{o} 46’ N	112^{o} 53’ W	724	376285	5958423	12
	Ross Creek	53^{o} 43’ N	113^{o} 12’ W	618	354895	5954151	12
	Redwater	53^{o} 51’ N	113^{o} 06’ W	624	362260	5968154	12
	Scotford	53^{o} 47’ N	113^{o} 04’ W	618	363306	5962031	12





Legend

■ Meteorological Station

▭ Project Area

Title:

Locations of Meteorological Stations in the 125 x 125 km CALMET Domain

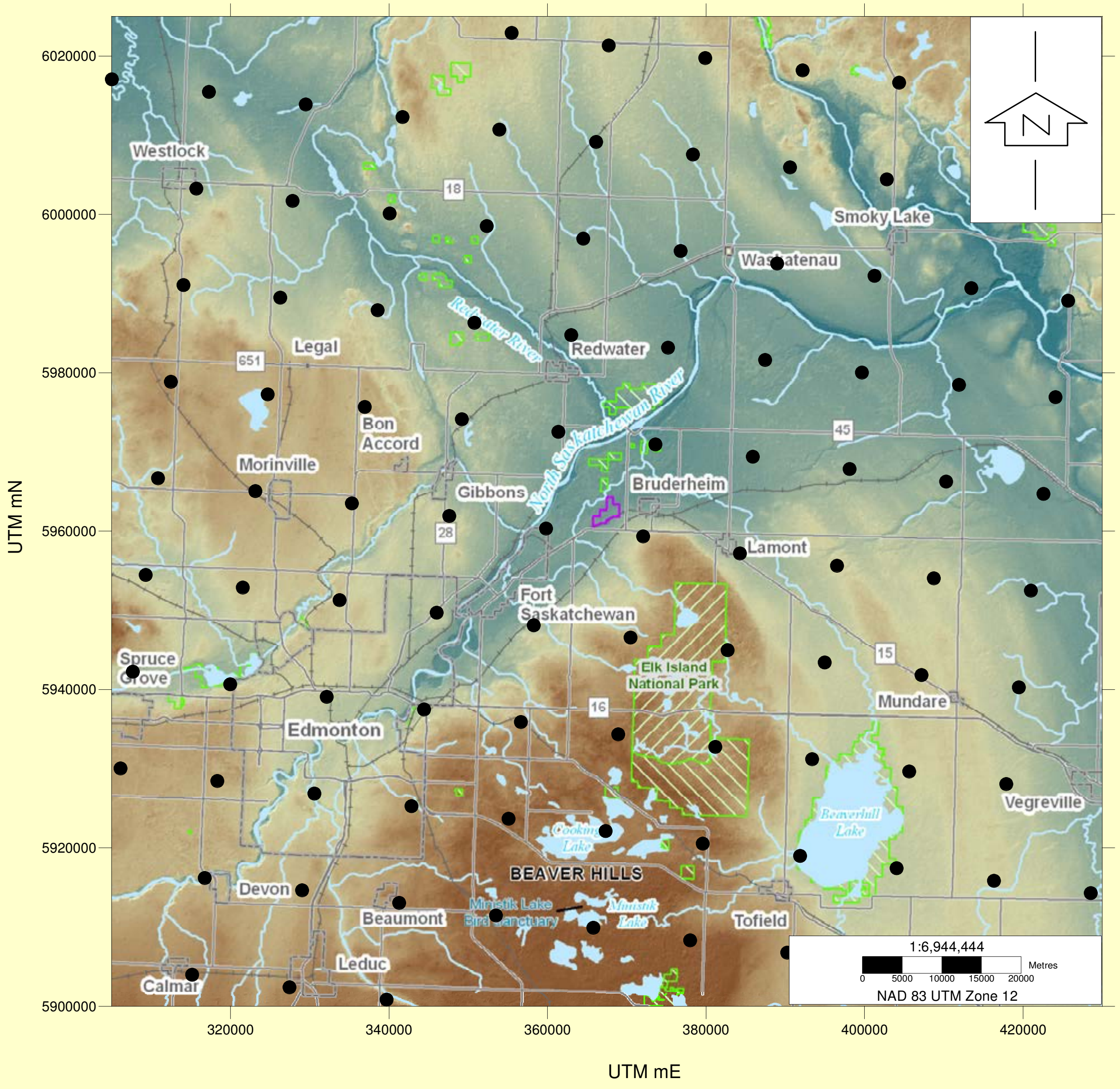
NORTH AMERICAN OIL SANDS CORPORATION

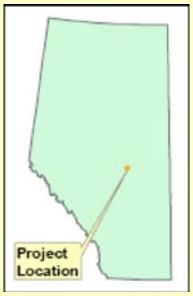
Approved:

Revision Date: 08/11/2007

File: H:/AQ/Shared/1018897 NAOSC Matrix /N8897 NAOSC Reports/3. CALMET/surfer

Drawn by:	Checked:	Fig. No.:
Y.S.	M.D.	2C-4





Legend

▭ Project Area
— Paved Access
+—+ Railway
▨ Natural Area
▨ Protected Area
▭ Urban Area

Elevation (m)
High : 859
Low : 543

● MM5 grid points

Title:

MM5 Grid Points in the 125 x 125 km CALMET Domain

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:
	08/11/2007

File:
H:/AQ/Shared/1018897 NAOSC Matrix /N8897 NAOSC Reports/3. CALMET/surfer

Drawn by:	Checked:	Fig. No.:
Y.S.	M.D.	2C-5

2C4 Wind

2C4.1 Measured Surface Winds

At the Fort Saskatchewan station, wind data were analyzed for a five-year period from January 1, 2001 to December 31, 2005. The wind data collected at other stations were analyzed for the period January 1, 2003 to December 31, 2005. Wind data for the other stations were also reviewed and used in the CALMET model even though data for the full 2002 year were not available.

The wind data are presented in a wind rose format, which is a joint frequency distribution of wind speed and direction plotted as a histogram in a polar format. The direction of the bar indicates the direction the wind is blowing from on a 16-point compass basis. The length of the radial bars gives the total percent frequency of winds from the indicated direction, while portions of the bars of different widths indicate the frequency of associated wind speed categories.

Figure 2C-6 compares the wind roses for a longer period with the 2002 data. The following are noted with respect to each station:

- The **Fort Saskatchewan** station has mean and maximum wind speeds of 2.0 and 11.0 m/s respectively. The predominant winds are from the southwest and northwest quadrants, and calms occur 5.6 percent of the time. Approximately 63 percent of winds are less than 2 m/s and 1.2 percent of winds are greater than 6 m/s. The 2002 data are similar to the longer-term data.

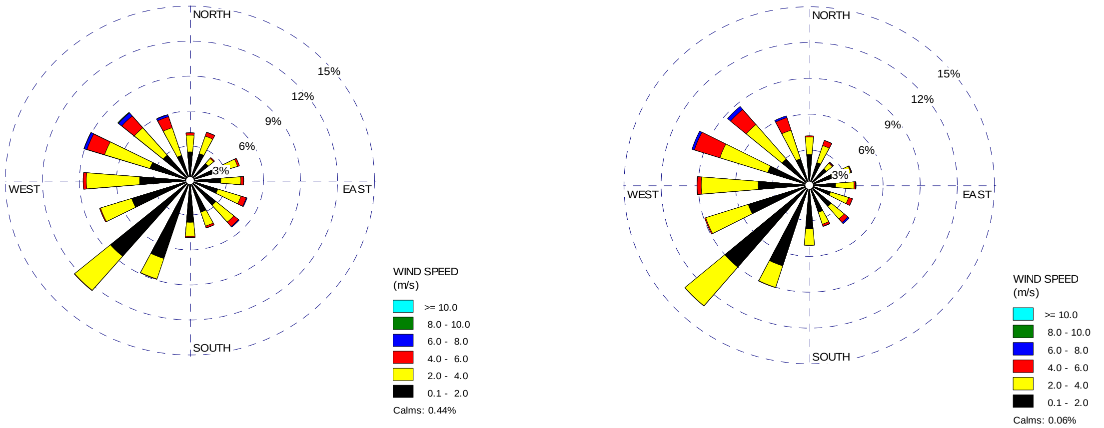
- For the **Ross Creek** station, the winds originate most often from the west. The strongest recorded wind speed is 9.9 m/s and the mean wind speed is 2.7 m/s. Calms occur 3.0 percent of the time. Approximately 36 percent of winds are less than 2 m/s while 4.1 percent are greater than 6 m/s. The 2002 data are different from the longer-term period; this may be due to the partial 2002 year.

- The **Redwater** station has mean and maximum wind speeds of 3.6 and 17.8 m/s. The predominant winds are from the southwest and northwest quadrants. Calms occur 2.0 percent of the time. Approximately 21 percent of winds are less than 2 m/s and 13 percent of winds are greater than 6 m/s. The 2002 data are similar to the longer-term period despite the partial 2002 year.

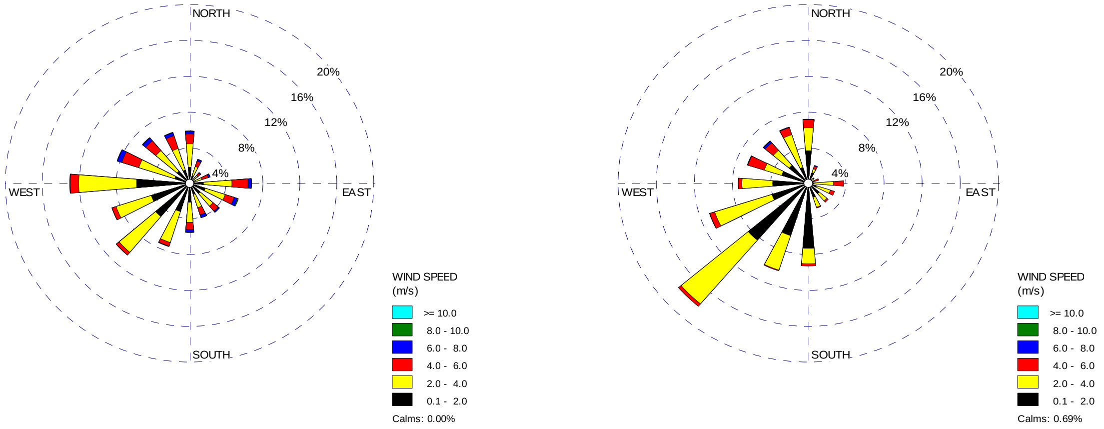
- At the **Scotford** monitoring station, the predominant winds are from the south-southwest. The strongest recorded wind speed is 12.7 m/s and the mean speed is 3.5 m/s. Calms occur 3.3 percent of the time. Approximately 24 percent of winds are less than 2 m/s and 13 percent of winds exceed 6 m/s. The 2002 data are different from the longer-term period; this may be due to the partial 2002 year.

- For the **Lamont** station, the winds originate from the southwest and northeast quadrants; they also appears to be significant southerly component. The strongest recorded wind speed is 15.8 m/s and the mean wind speed is 3.8 m/s. Calms occur 0.9 percent of the time. Approximately 17.5 percent of winds are less than 2 m/s while 13.9 percent are greater than 6 m/s. The 2002 data are similar to the longer-term period despite the partial 2002 year.

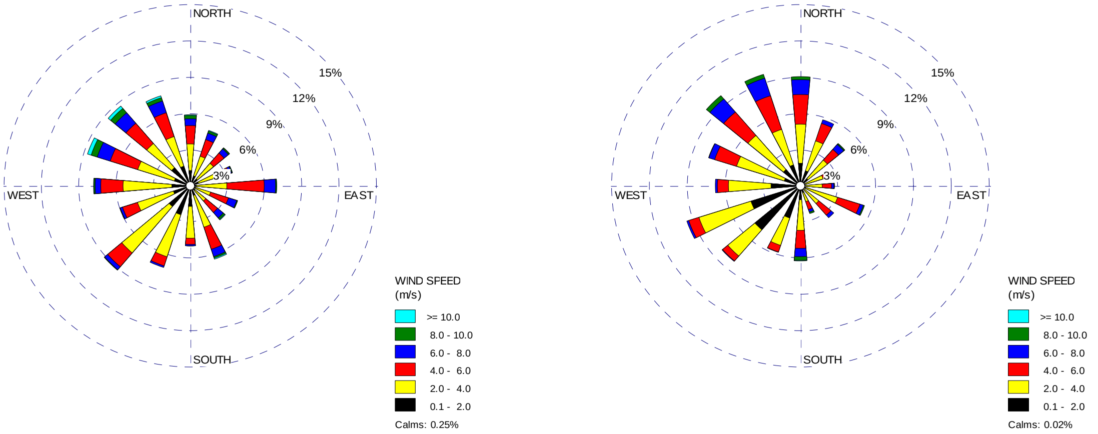
A comparison of the longer-term wind roses indicates some variability across the region. To some extent, this may be more due to local influences associated with each monitoring station, than to large-scale regional variations. The Lamont station is the closest to the Project site, and the data from this site indicate strong winds from the northwest to southwest sectors. There appears to be a tendency for all stations to show a southwest component; this is likely due to channelling effects associated with the Fort Saskatchewan River valley. Lighter winds are associated with the monitoring sites that are in the Fort Saskatchewan community area (i.e., North Saskatchewan and Ross Creek); this is likely due to the increased roughness associated with buildings and trees.


Fort Saskatchewan (2001 to 2005)

Fort Saskatchewan (2002)

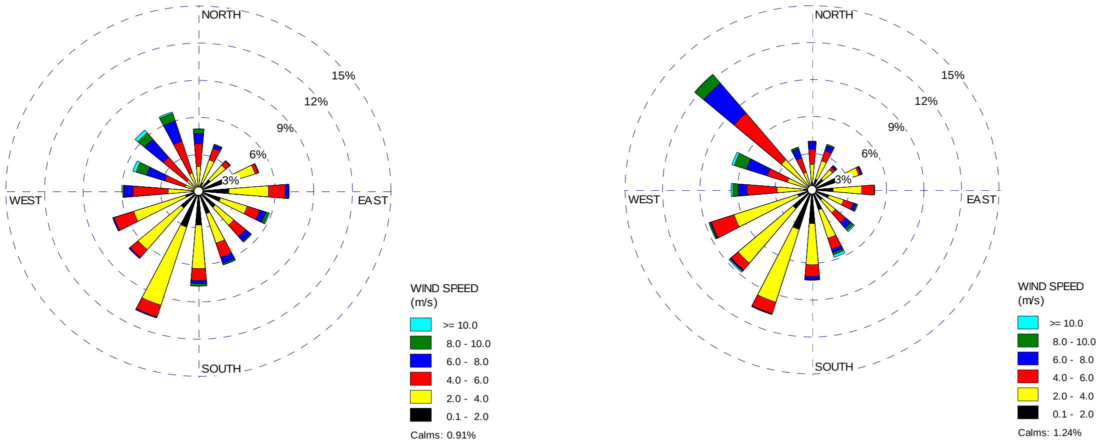

Ross Creek (2003 to 2005)

Ross Creek (Aug 12 to Dec 31, 2002)


Redwater (2003 to 2005)

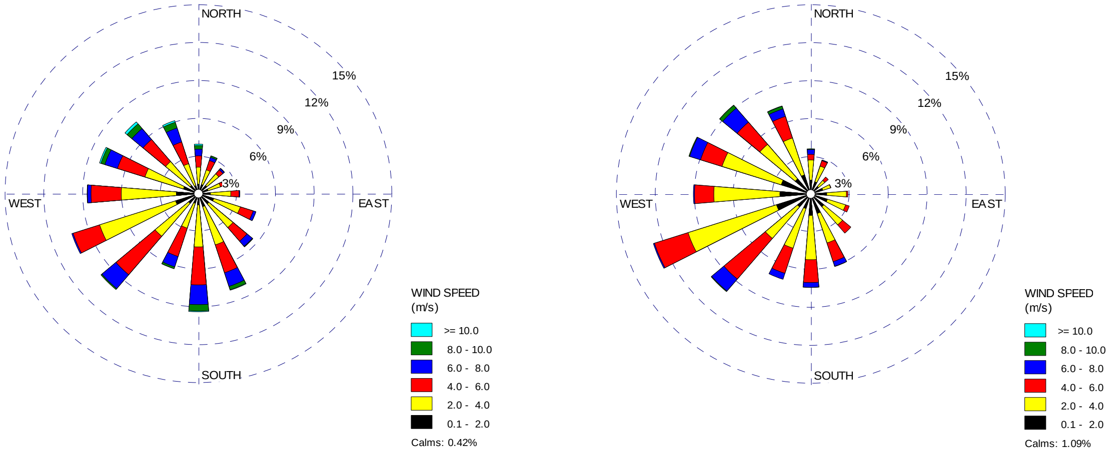
Redwater (Apr 26 to Dec 31, 2002)

Figure 2C-6 Comparison of Long-Term and 2002 Measured Surface Winds



Scotford (2003 to 2005)

Scotford (May 14 to Dec 31, 2002)



Lamont (2003 to 2005)

Lamont (May 18 to Dec 31, 2002)

Figure 2C-6 Comparison of Long-Term and 2002 Measured Surface Winds (cont'd)

2C4.2 Predicted Surface Winds (2002)

Figure 2C-7 compares the predicted (full year) and measured (partial year) wind roses. The following are noted with respect to each station:

- The Edmonton International Airport and Edmonton Namao Airport predicted and measured wind roses are similar.
- The Edmonton City Centre Airport station shows some differences between predicted (full year) and measured (full year); the measured indicates more westerly winds.
- The Edmonton Northwest, Edmonton East, Scotford and Lamont station predicted and measured wind roses are similar.
- The Ross Creek and Redwater stations show some differences between predicted (full year) and measured (partial year) wind roses

The wind roses show some differences between measured and the predicted wind directions and frequencies. The differences may be attributed to the use of a partial 2002 year to represent the measured data, and to the CALMET model not accounting for local influences. The CALMET model surface feature resolution is on a 1 x 1 km grid basis.

2C4.3 Surface Wind Vector Plots

Figure 2C-8 shows the wind field as a vector plot at 1300 LST on July 15 under convective conditions (Pasquill-Gifford (PG) class B). The general airflow appears to be from the west-southwest to southwesterly direction. Winds at the site are from the west-southwest. Low wind speeds are predicted in the southwest of the domain, with higher wind speeds occurring in the northwest part of the domain. The measured data for this hour at the Lamont monitoring station shows winds from the west-northwest with a wind speed of 1.9 m/s.

Figure 2C-9 shows the wind field as a vector plot at 0500 LST on January 19 under very stable conditions (PG class F). A northeasterly flow dominates the domain for this hour. The measured data for this hour at the Lamont monitoring station shows winds from the northeast with a wind speed of 1.8 m/s.

Figure 2C-10 shows the wind field as a vector plot at 1900 LST on November 15 under neutral conditions (PG class D). A south flow dominates the domain for this hour. The predicted wind at the Project site for this hour has a high wind speed of 11.12 m/s. The measured data for this hour at the Lamont monitoring station shows winds from the southwest with a wind speed of 5.2 m/s.

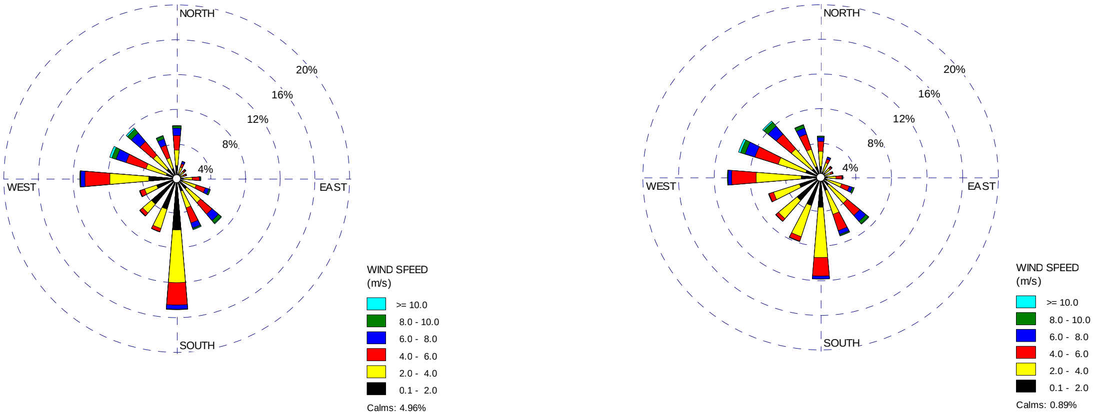
The vector plots presented in Figures 2C-8 to 2C-10 were not selected to be representative of any select meteorological condition. The vector plots are shown as examples of the variability of the airflow that can occur over the 125 by 125 km model domain in any given hour.

2C4.4 Predicted Upper Wind Plots

Figure 2C–11 shows the wind roses predicted by CALMET for the Project site for varying elevations above ground level. The results indicate a tendency for more west-northwest/northwest winds and an increase in wind speed with increasing height above the ground.

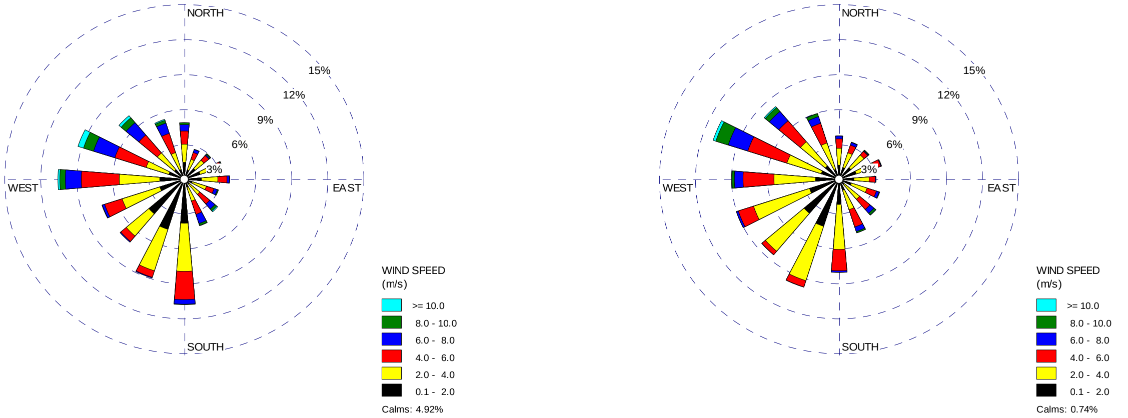
Edmonton International Airport (Measured)

Edmonton International Airport (Predicted)



Edmonton City Center Airport (Measured)

Edmonton City Center Airport (Predicted)



Edmonton Namao Airport (Measured)

Edmonton Namao Airport (Predicted)

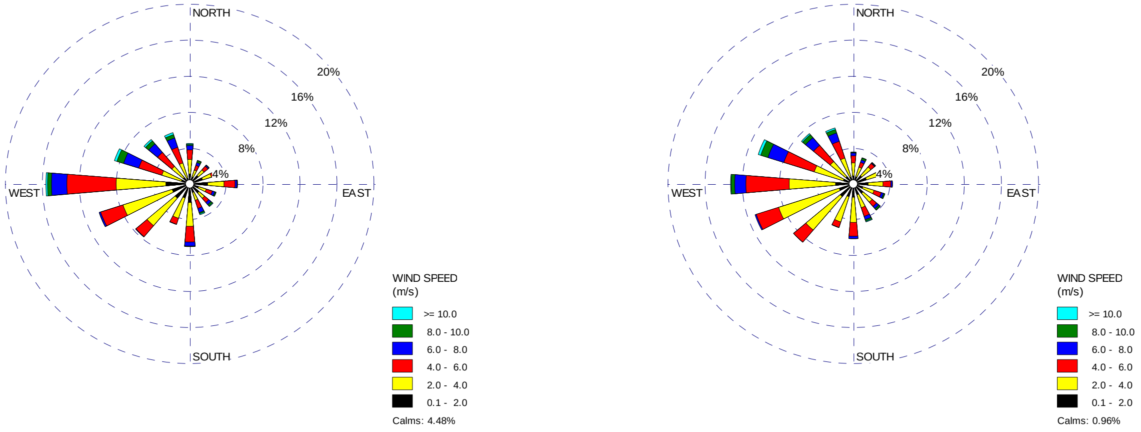
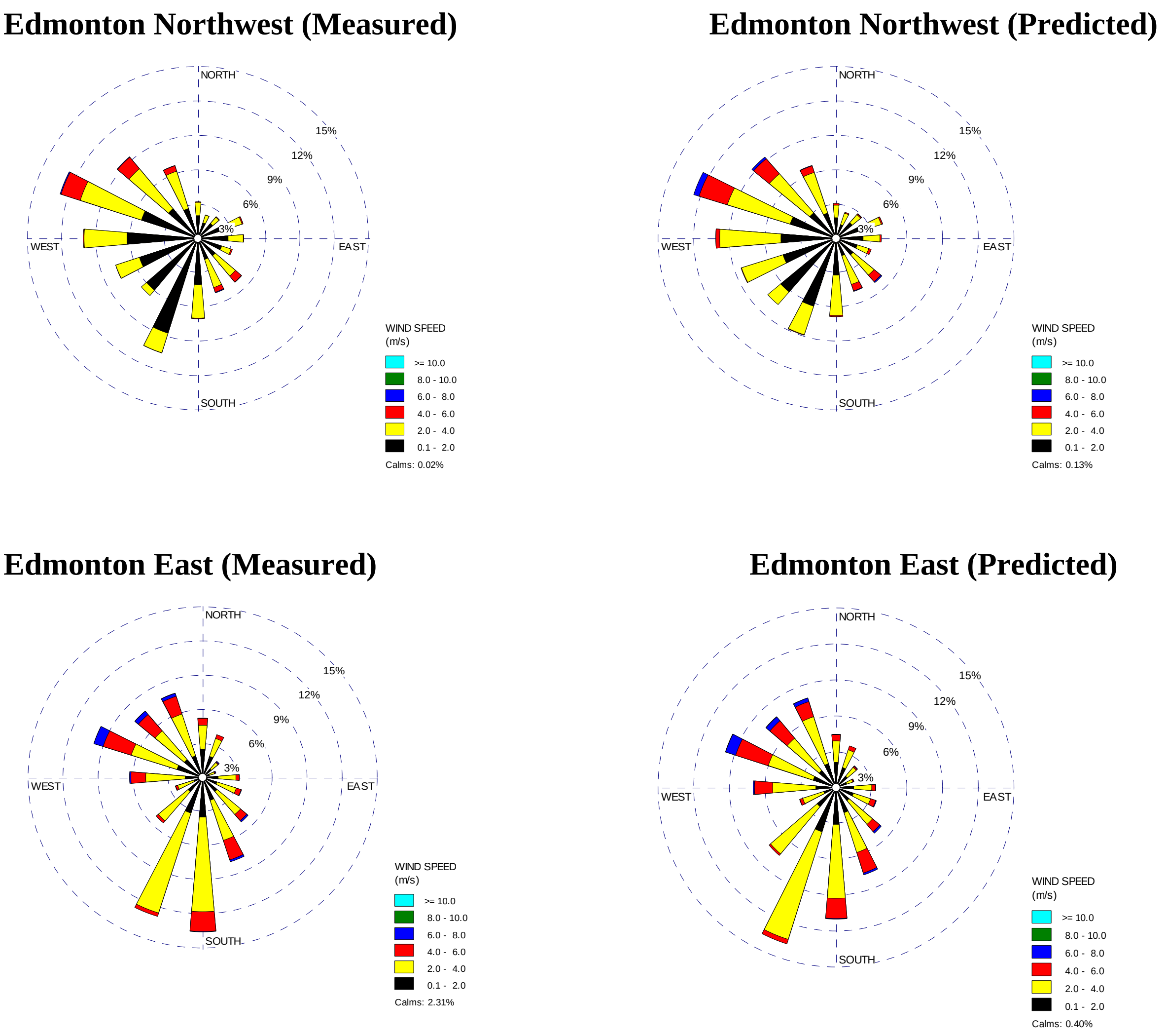


Figure 2C-7 Comparison of Measured and Predicted Surface Winds (2002)



Edmonton Northwest (Measured)

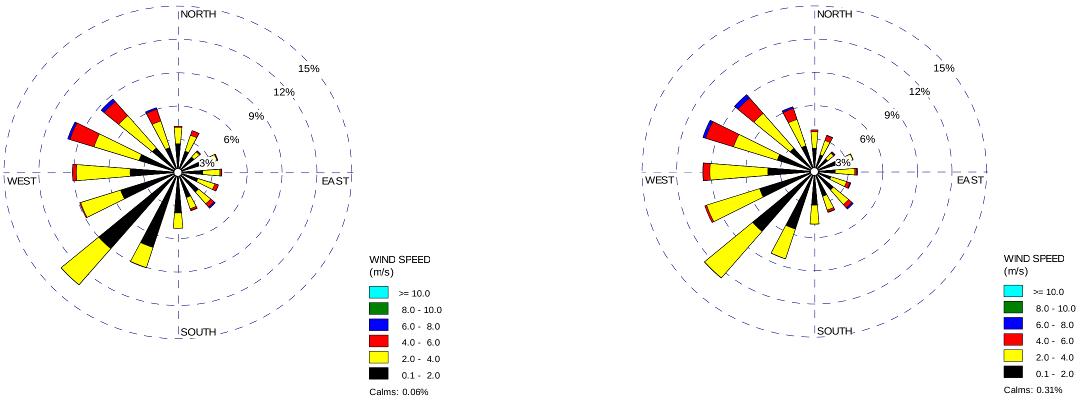
Edmonton Northwest (Predicted)

Edmonton East (Measured)

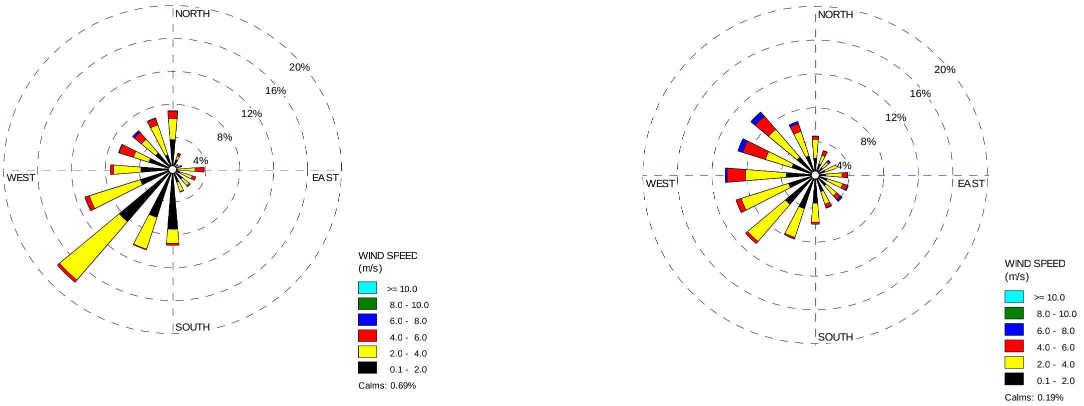
Edmonton East (Predicted)

Figure 2C-7 Comparison of Measured and Predicted Surface Winds (2002) (cont'd)

Fort Saskatchewan (Measured) Fort Saskatchewan (Predicted)



Ross Creek (Measured) Ross Creek (Predicted)



Redwater (Measured) Redwater (Predicted)

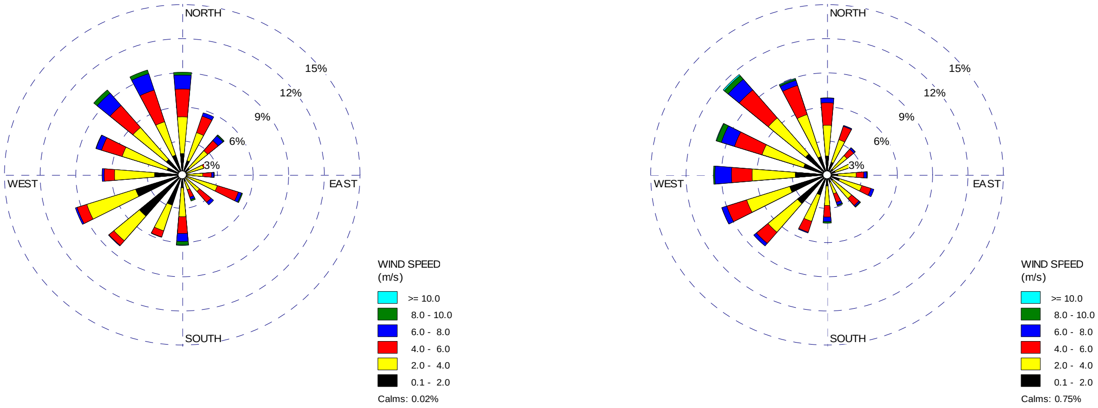
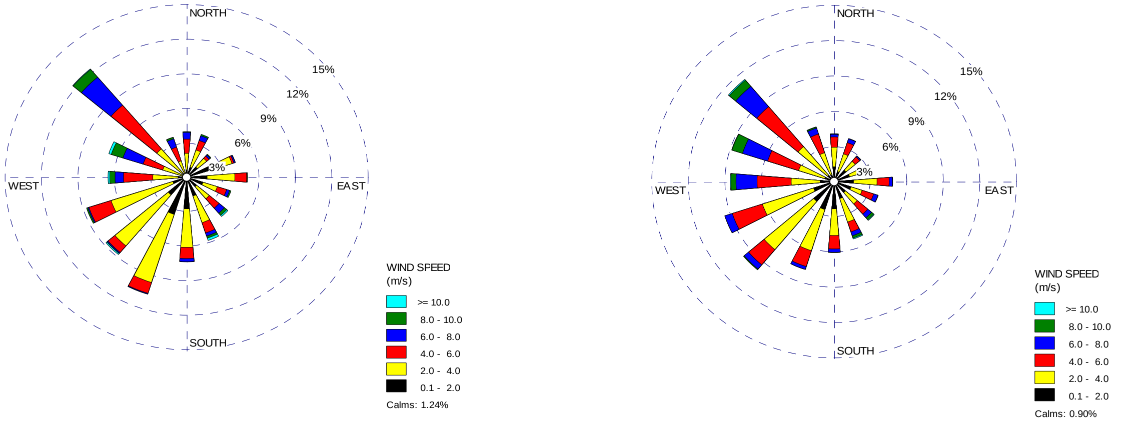


Figure 2C-7 Comparison of Measured and Predicted Surface Winds (2002) (cont'd)

Scotford (Measured) **Scotford (Predicted)**



Lamont (Measured) **Lamont (Predicted)**

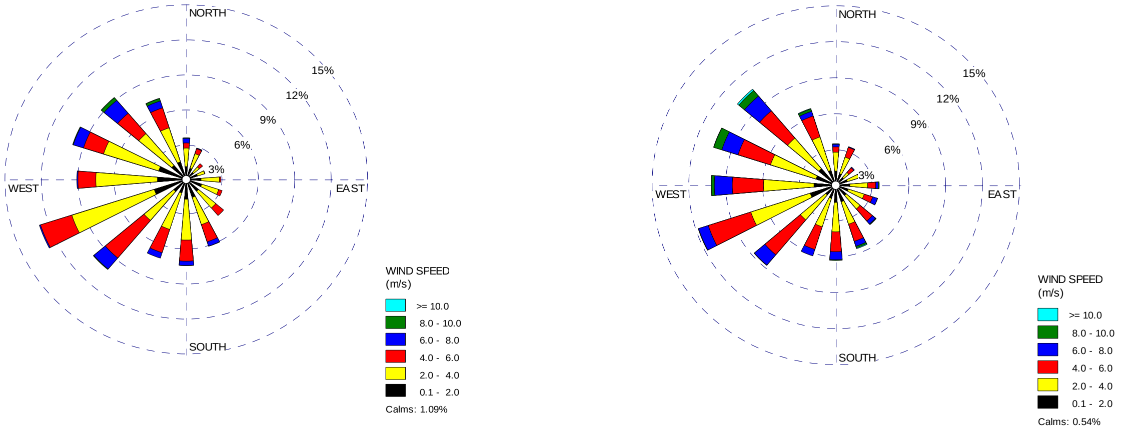
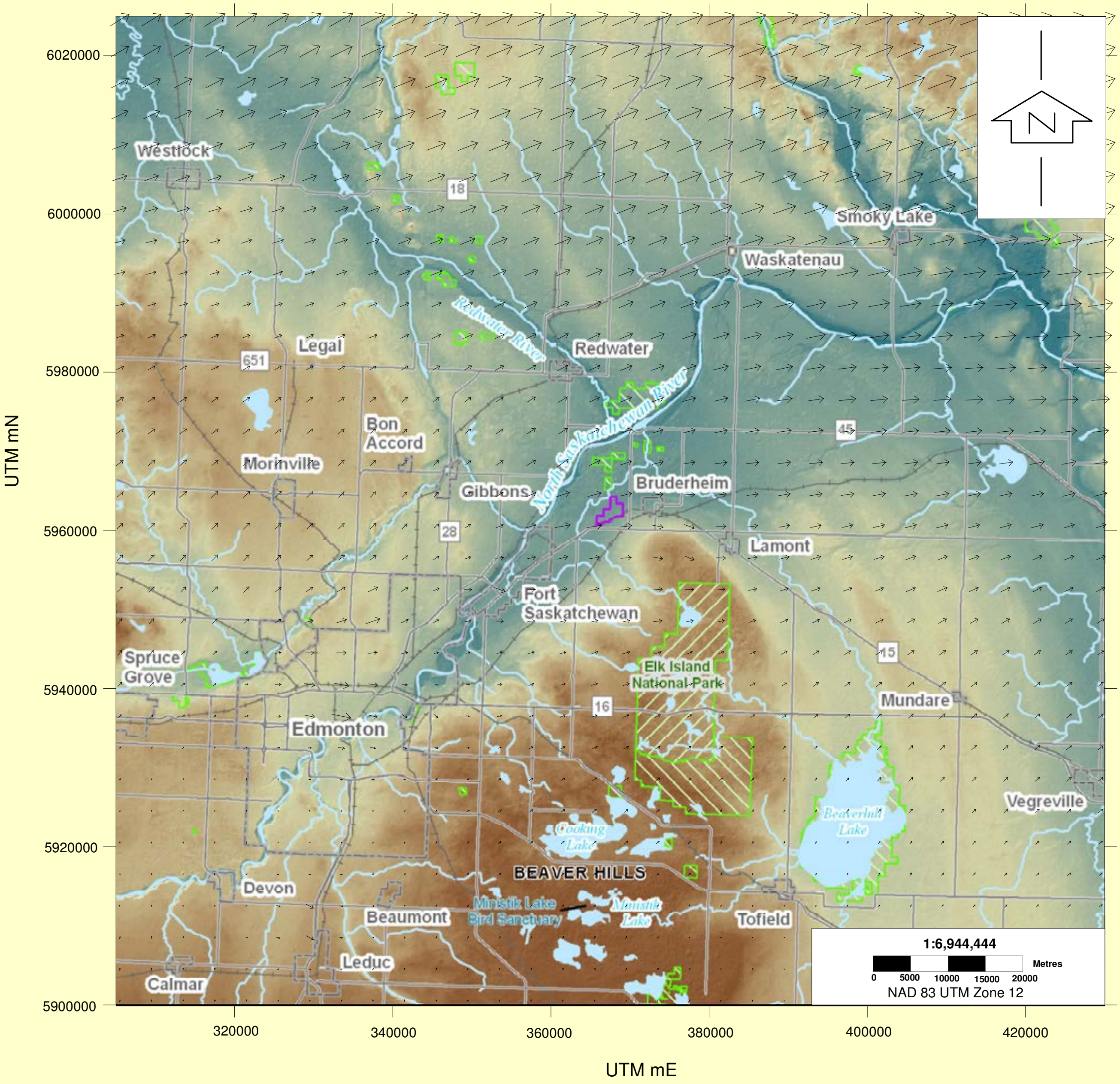
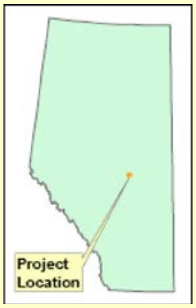


Figure 2C-7 Comparison of Measured and Predicted Surface Winds (2002) (cont'd)





Legend

↑ Wind Vector

Title:

Predicted surface wind field for unstable conditions (1300 LST July 15, 2002)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:

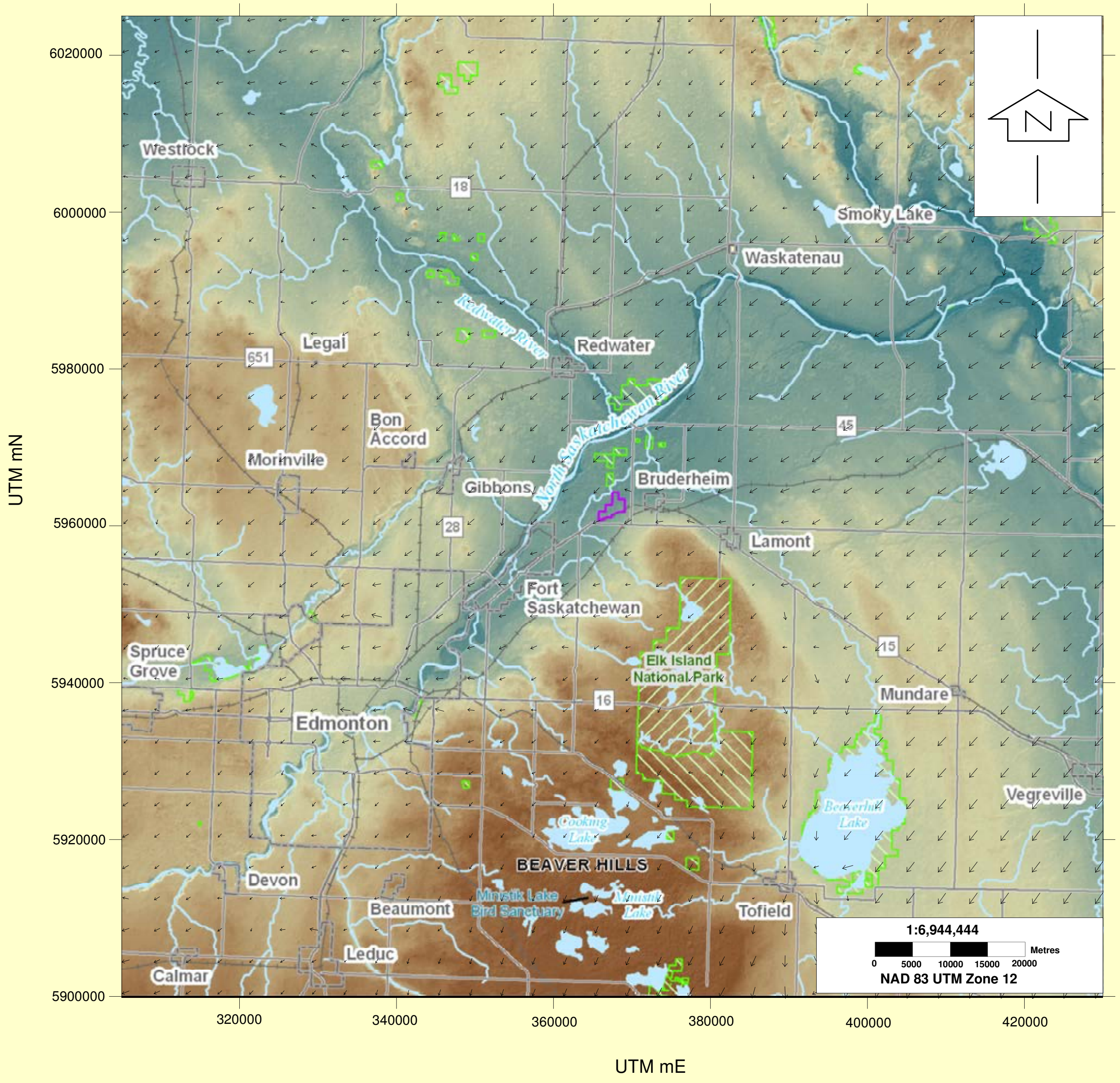
Revision Date: 08/11/2007

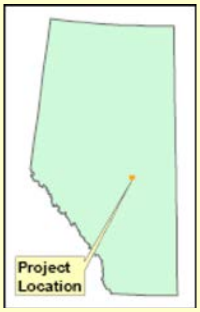
File: H:/AQ/Shared/1018897 NAOSC Matrix /N8897 NAOSC Reports/3. CALMET/surfer

Drawn by: Y.S.

Checked: M.D.

Fig. No.: 2C-8





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↑ **Wind Vector**

Title:

Predicted surface wind field for stable conditions (0500 LST January 19, 2002)

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date: 08/11/2007

File: H:/AQ/Shared/1018897 NAOSC Matrix /N8897 NAOSC Reports/3. CALMET/surfer

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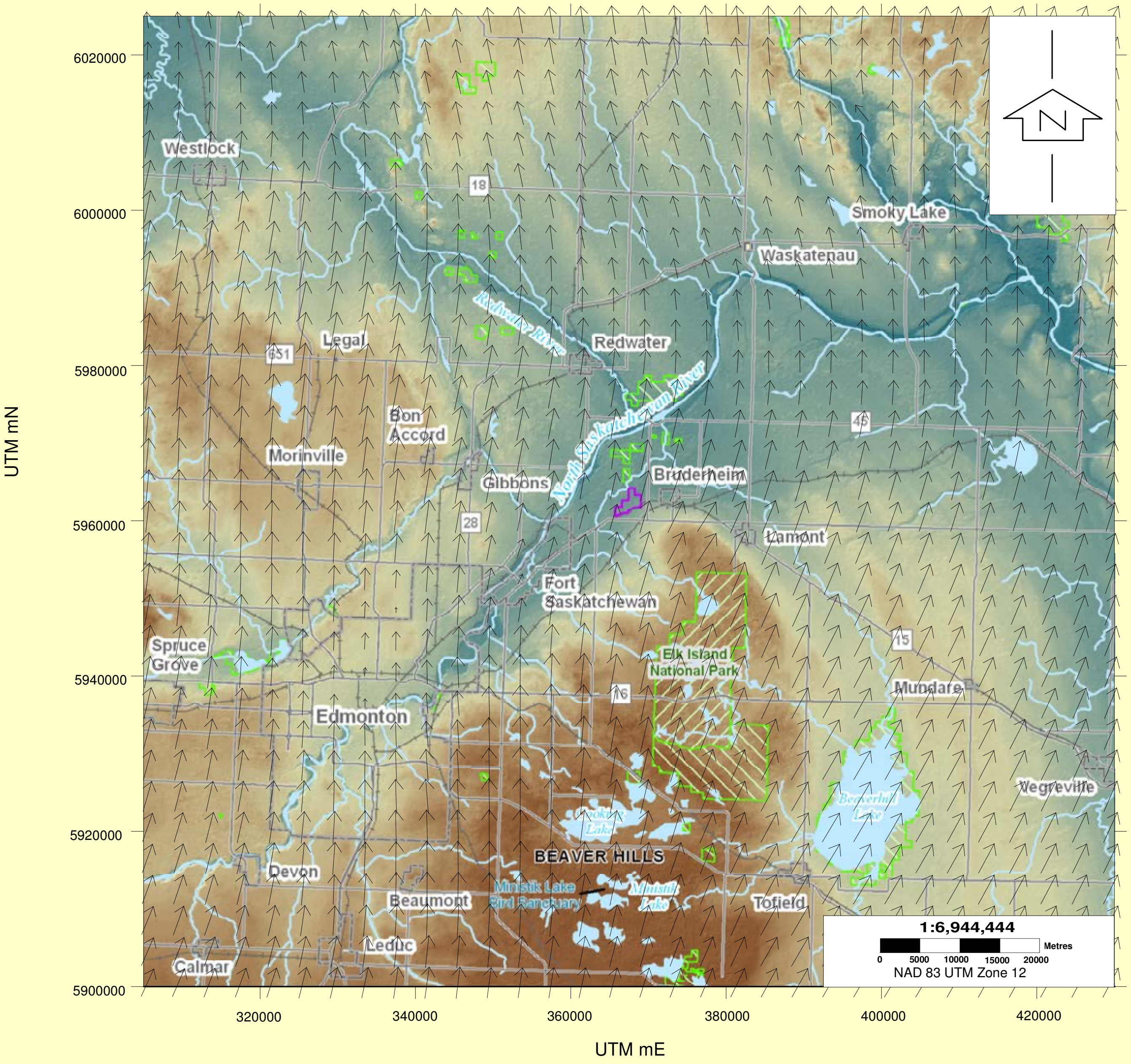
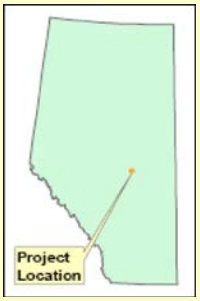
Y.S.	M.D.	2C-9





Legend

↑ Wind Vector

Title:

Predicted surface wind field for high wind speed conditions (1900 LST November 15, 2002)

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date: 08/11/2007

File: H:/AQ/Shared/1018897 NAOSC Matrix /N8897 NAOSC Reports/3. CALMET/surfer

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Y.S.	M.D.	2C-10

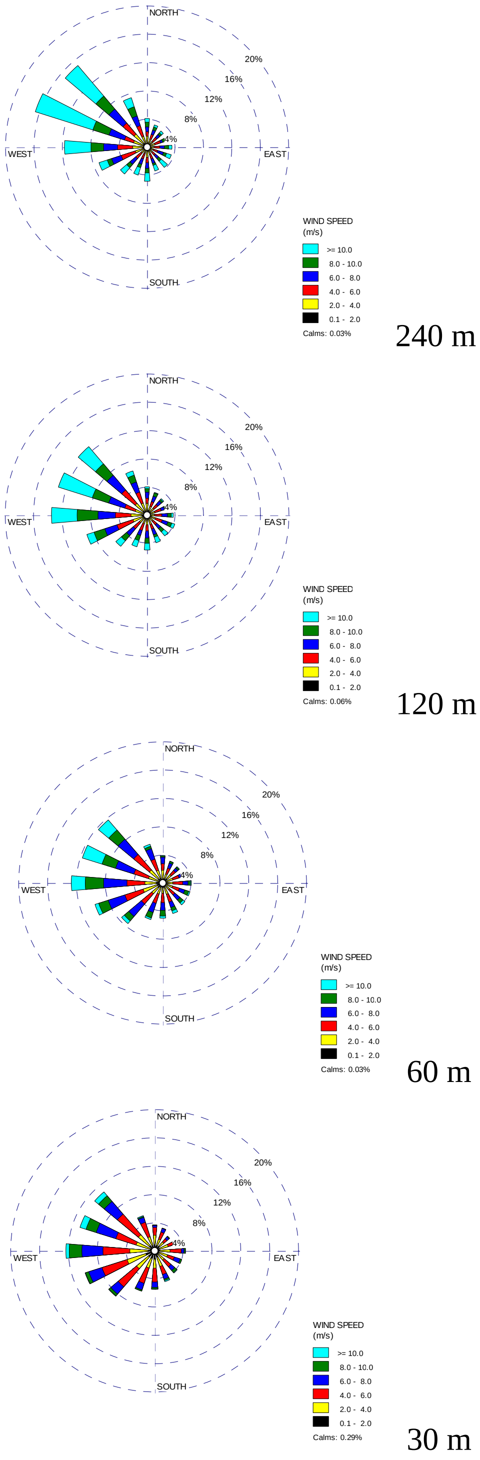


Figure 2C-11 Predicted Winds at various Elevations above the Project Site

2C5 Temperature

2C5.1 Ambient Air Temperature

Table 2C-4 summarizes the historical seasonal and annual mean air temperatures in the study area. Annual average ambient temperatures range from 2.4 and 3.9°C. Historical mean daily temperatures are presented in Figure 2C-12 for the four long-term stations in the area. Edmonton City Centre Airport experiences slightly warmer temperatures due to its urban location. Mean daily high temperatures are in the 15.0 to 16.5°C range in the summer; and the mean daily lows are in the -7.3 to -9.1 °C range in the winter.

Figure 2C-13 also compares the 2002 mean daily temperatures with the long-term Fort Saskatchewan values. While the summer of 2002 was similar to the long-term, the 2002 winter period was warmer than normal, and the 2002 spring period was cooler than normal.

2C5.2 Mixing Heights

The presence of an elevated inversion can trap effluents discharged into the atmosphere in the layer between the surface and the base of the inversion layer, which can increase ground-level ambient concentrations relative to the absence of an inversion layer. Mixing heights are usually the highest (i.e., in the 1,000 m to 2,000 m range) during daytime periods that are characterized by strong solar heating, and the lowest (i.e., about 100 m) during the night. High wind speeds can also produce well-mixed layers.

Mixing heights are typically determined by analyzing vertical temperature profiles, which are not directly measured on a routine basis. A number of studies that have measured mixing heights have been conducted in the Edmonton region:

- Portelli (1977) reviewed temperature profiles from Stony Plain (which is about 35 km east of Edmonton) to calculate the mean maximum afternoon mixing heights. These were found to range from low (i.e., 200 m to 300 m) for the December to February period, to high (i.e., 2,000 m to 2,400 m) for the May to August period.
- AENV (Sakiyama et al., 1991) collected and analyzed temperature profiles collected at Ellerslie from the fall of 1977 to the fall of 1983. The data indicated similar mean maximum afternoon mixing heights (i.e., around 200 m) in the winter, but lower (i.e., 600 to 800 m) values in the spring/summer period.
- AENV (Concord Environmental, 1993) collected and analyzed temperature profiles collected near the Scotford Refinery from the spring of 1989 to the summer of 1992. The data also indicated similar mean maximum afternoon mixing heights (i.e., around 200 m) in the winter, and lower (i.e., 600 m to 800 m) values in the spring/summer period.

  For this assessment, the CALMET post-processor was used to extract the mixing heights from CALMET output files, and the mixing height predictions for the Project site are provided in Figure 2C-14. The results show:

- Winter: The mean maximum values are in the 200 m to 300 m range, which is consistent with the measurment studies.
- Spring: The mean maximum afternoon values are about 1,100 m, which is between the Portelli and the AENV values.

- Summer: The mean maximum afternoon values are about 1400 m, which is less than the Portelli values and larger than the AENV values. The summer AENV measurements, however, may have not fully captured the time in the afternoon when the highest depth would be expected.

- Fall: The mean maximum afternoon values are about 900 m, which is similar the Portelli values (i.e., about 900 m) and more than the AENV measurements (i.e., 500 m).

The minimum values for each season are predicted to occur during the night. The CALMET model predicts minimum values in the 50 to 100 m range. This compares to the early morning values measured by AENV, which tend to be in the 200 to 300 m range.

Table 2C-4 Historical Seasonal and Annual Mean Daily Temperatures at Meteorological Stations in the Study Area

Season	Mean Daily Temperature (°C)				
	Fort Saskatchewan	**Edmonton International Airport**	**Edmonton City Centre Airport**	**Edmonton Namao Airport**	**Average**
Winter [1]	-8.9	-9.1	-7.3	-8.2	-8.4
Spring [2]	8.0	7.4	8.6	8.0	8.0
Summer [3]	15.8	15.0	16.5	15.6	15.7
Fall [4]	7.7	7.2	8.5	7.7	7.8
ANNUAL	2.9	2.4	3.9	3.1	3.1

SOURCE: Environment Canada Climate Data

NOTEs:
1 Winter: November, December, January, February, March.
2 Spring: April, May.
3 Summer: June, July, August.
4 Fall: September, October.

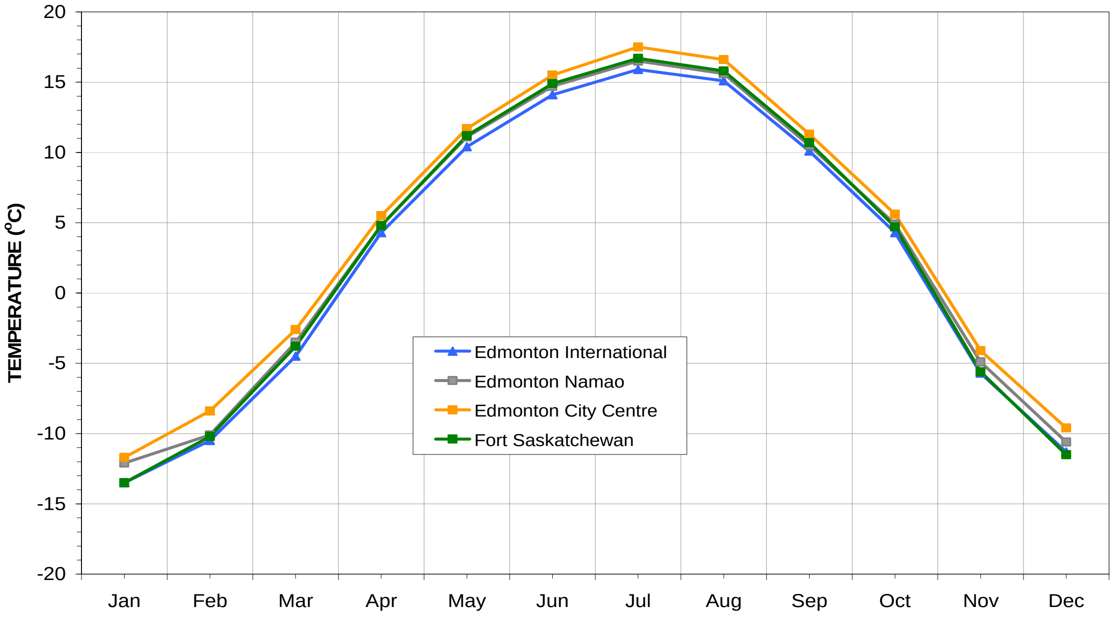


Figure 2C-12 Mean Monthly Average Temperatures at Fort Saskatchewan (1971-2000) and Edmonton Airports (1971-2000)

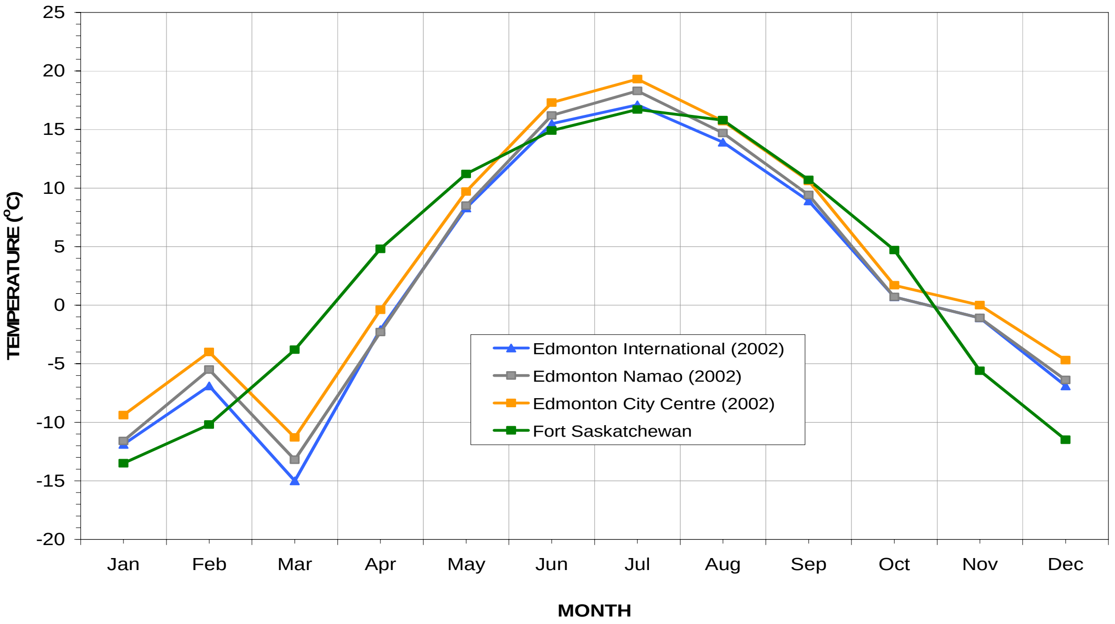
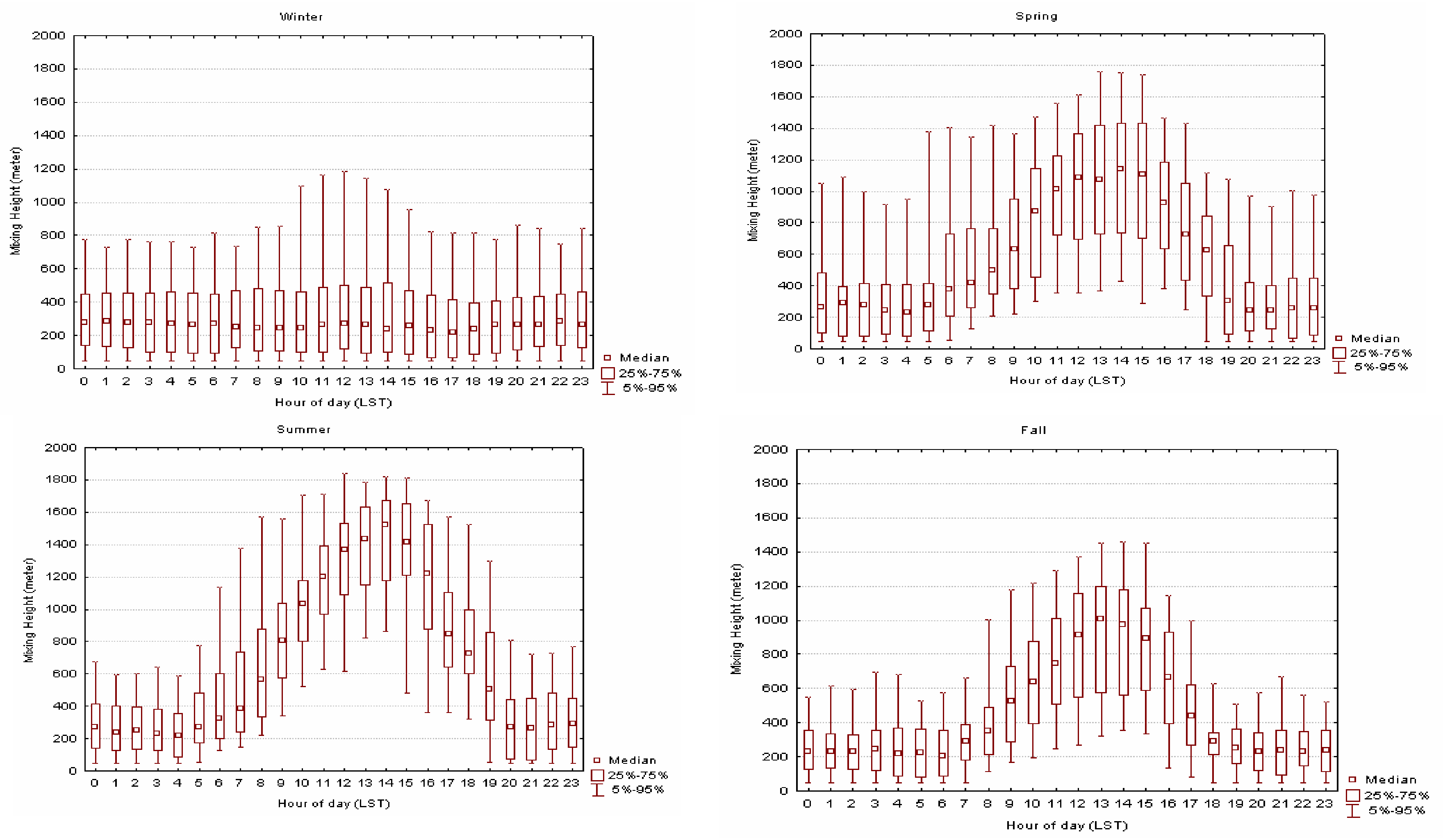


Figure 2C-13 Mean Monthly Average Temperatures at Fort Saskatchewan (1971-2000) and Edmonton Airports (2002)



NOTE: **Winter:** November, December, January, February and March. **Spring**: April and May.

Summer: June, July and August. **Fall**: September and October

Figure 2C-14 Predicted Mixing Heights for Different Seasons and Times of Day

2C6 Precipitation

The annual average precipitation (rainfall plus snowfall) rates based on data from 1971 to 2000 from Fort Saskatchewan and the regional airports are:

Fort Saskatchewan	460 mm (355 mm rainfall)
Edmonton International	483 mm (375 mm rainfall)
Edmonton Namao	466 mm (362 mm rainfall)
Edmonton City Centre	477 mm (366 mm rainfall)
Average	472 mm (365 mm rainfall)

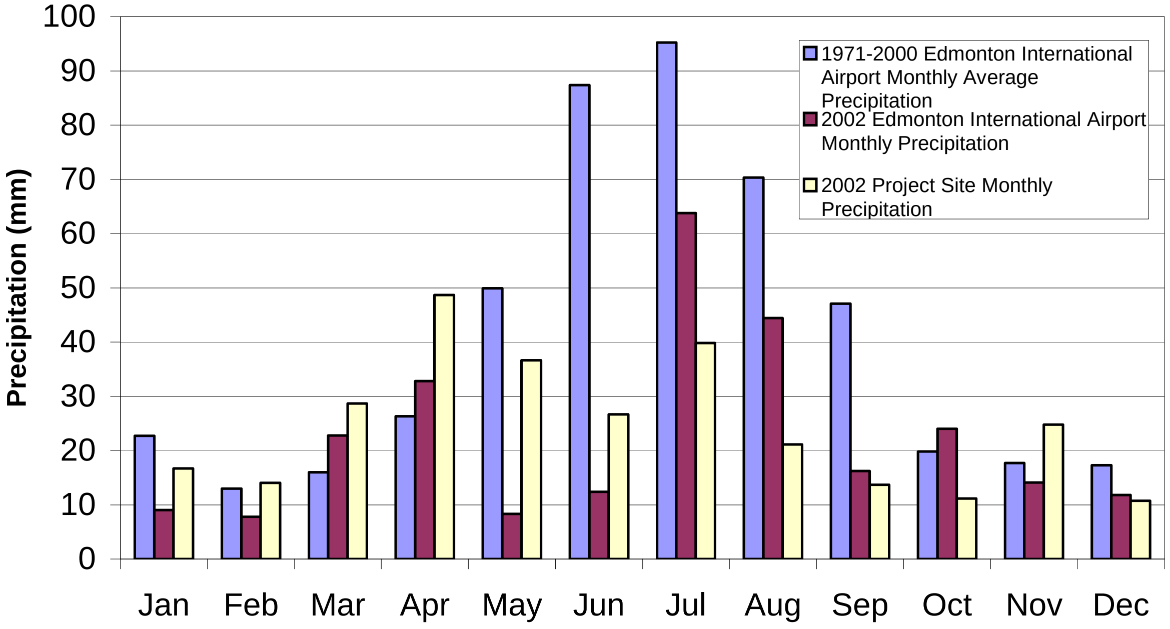
The amounts are similar for all four locations.

Figure 2C-15 (top) compares the long-term and 2002 monthly mean total precipitation values measured at the Edmonton International Airport. The 2002 precipitation was about 55 percent of the normal rate. Specifically, the May and June periods were very dry when compared to the longer term averages. For the purpose of comparison, the precipitation at the Project site as interpolated from the MM5/CALMET data are also shown, and it is consistent with 2002 being a drier than normal year.

Figure 2C-15 (bottom) compares the 2002 monthly mean total precipitation values measured at the three airports with the values interpolated for the Project site. The total 2002 precipitation (rainfall plus snowfall) rates based on observation data at the Edmonton stations and interpolated values at Project site are:

Edmonton International	267 mm
Edmonton Namao	226 mm
Edmonton City Centre	247 mm
Project site	293 mm

While all three airports indicate drier than normal conditions for the year, Edmonton Namao experienced a wetter June than the other airports, and Edmonton International Airport experienced a wetter July than the other airports. The interpolated values at the Project site indicated more precipitation for a number of months and a drier August when compared to the airport locations. While the Project site values are larger than the corresponding 2002 values from the airports, they are still less than the expected long-term average.



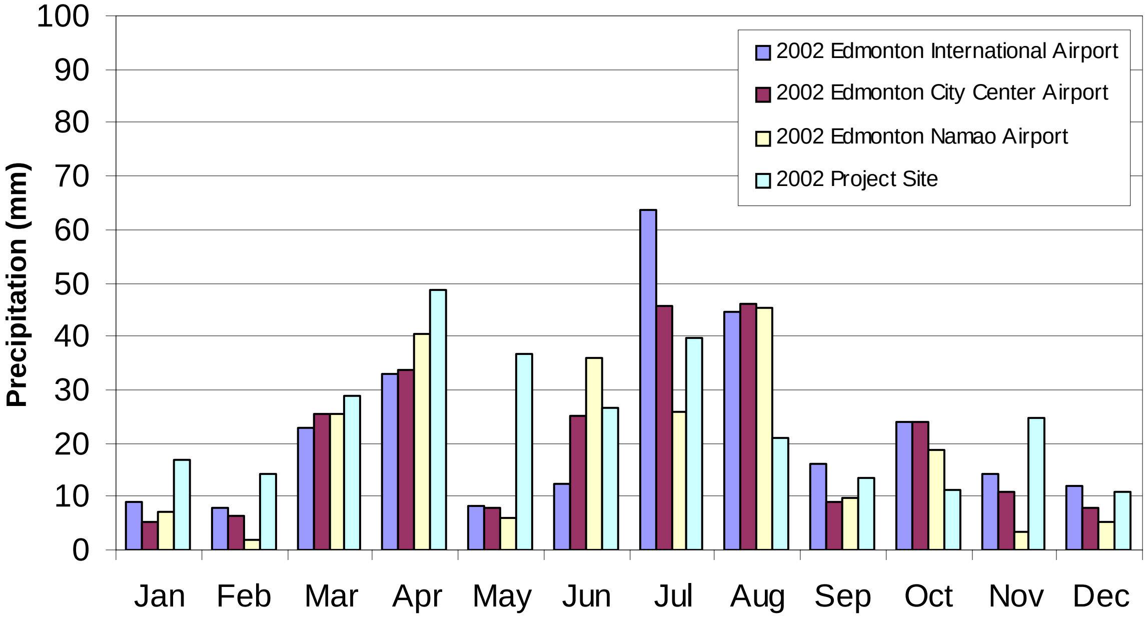


Figure 2C-15 Comparison of Total Precipitation Measured at the Edmonton Airports and that Predicted at the Project Site

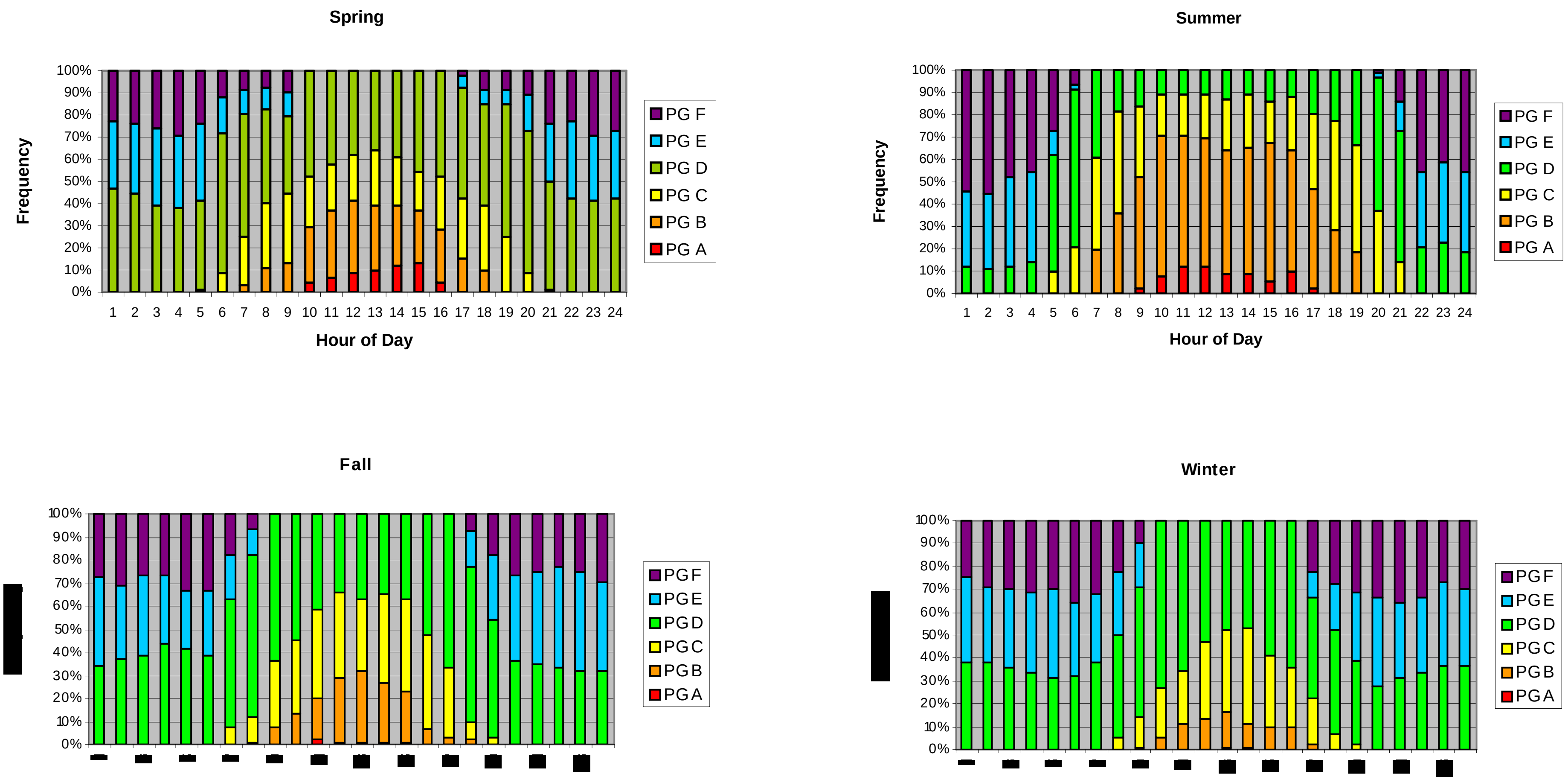
2C7 Atmospheric Stability

Atmospheric dispersion results from atmospheric turbulence, which can be related to atmospheric stability. Meteorologists define six stability classes (referred to as the Pasquill-Gifford [PG] classes):

- Stability classes A, B and C occur during the day, when the earth is heated by solar radiation. The air next to the earth is heated and tends to rise, enhancing vertical motions. This is referred to as an unstable atmosphere.
- Stability class D is associated with completely overcast conditions (day or night) when there is no net heating or cooling of the earth, transitional periods between stable and unstable conditions, or during high wind speed periods (winds greater than 6 m/s [or 22 km/h]). This is referred to as a neutral atmosphere.
- Stability classes E and F occur during the night, when the earth cools due to long-wave radiation losses. The air next to the earth cools, suppressing vertical motions. This is referred to as a stable atmosphere.

Stability classes undergo a significant daily variation, and they have a seasonal dependence. Stability classes can be determined from routine airport observations using the method devised by Turner (1963). A stability classification calculation algorithm is also included in the CALMET model. Figure 2C-16 shows the frequency of predicted seasonal PG stability classes at the Project site on a seasonal and diurnal basis. Unstable conditions are more frequent during the summer, and during daytime periods. Stable conditions are more frequent during nighttime periods. Table 2C-5 compares the stability class frequency distributions based on the airport/Turner approach with those estimated the CALMET model for the Project site.

At the Project site, the CALMET pre-processor indicates more frequent unstable periods (28 percent versus 19 percent for the other sites), less frequent neutral periods (39.4 percent versus 45 percent for the other sites) and less frequent stable conditions (32.6 percent versus 36 percent). The differences are more likely due to the two different methods used to estimate stability rather than actual differences between the sites. For example, Sedefian and Bennett (1980) indicate that the method that uses airport data can overestimate neutral conditions. Skaggs and Robinson (1976), who found that the airport approach tends to overestimate neutral conditions and underestimate unstable conditions, reinforce this finding.



NOTE: **Winter:** November, December, January, February and March.
Summer: June, July and August.
Spring: April and May.
Fall: September and October

Figure 2C-16 Frequency of Predicted PG Stability Class at the Project Site

Table 2C-5 Stability Class Frequency Distributions at Various Locations

PG Class	Edmonton International Airport	Edmonton City Centre Airport	Edmonton Namao Airport	Project Site
A	0.1	0.0	0.2	1.7
B	6.4	5.7	5.9	11.3
C	14.5	14.2	12.4	15.0
D	44.5	45.1	44.4	39.4
E	15.1	14.6	16.7	17.1
F	19.5	20.3	20.3	15.5
Total	100.0	100.0	100.0	100.0

NOTE:
PG – Pasquill-Gifford

2C8 Relative Humidity

Relative humidity is the ratio of the amount of water vapour in the air compared to the maximum amount of water vapour the air can hold before becoming saturated. Relative humidity depends on the water content of the air and the ambient air temperature. It is therefore the ratio expressed as percent of the air's water vapour content to its capacity, as shown below:

Relative Humidity (%) = 100 x (Water Vapour Content) / (Water Vapour Capacity)

Figure 2C-17 shows the mean relative humidity for each month at 0600 and 1500 LST, as recorded at the three airports from 1971 to 2000. Relative humidity is not recorded at the Fort Saskatchewan monitoring station. The mean 0600 LST relative humidity fluctuates to its lowest point in late spring and its highest in late summer and early fall. The mean 1500 LST annual relative humidity fluctuates to its lowest point in late spring and its highest in late fall and early winter. The higher morning (6:00 LST) values are due to the colder air temperatures, as colder air cannot hold as much water.

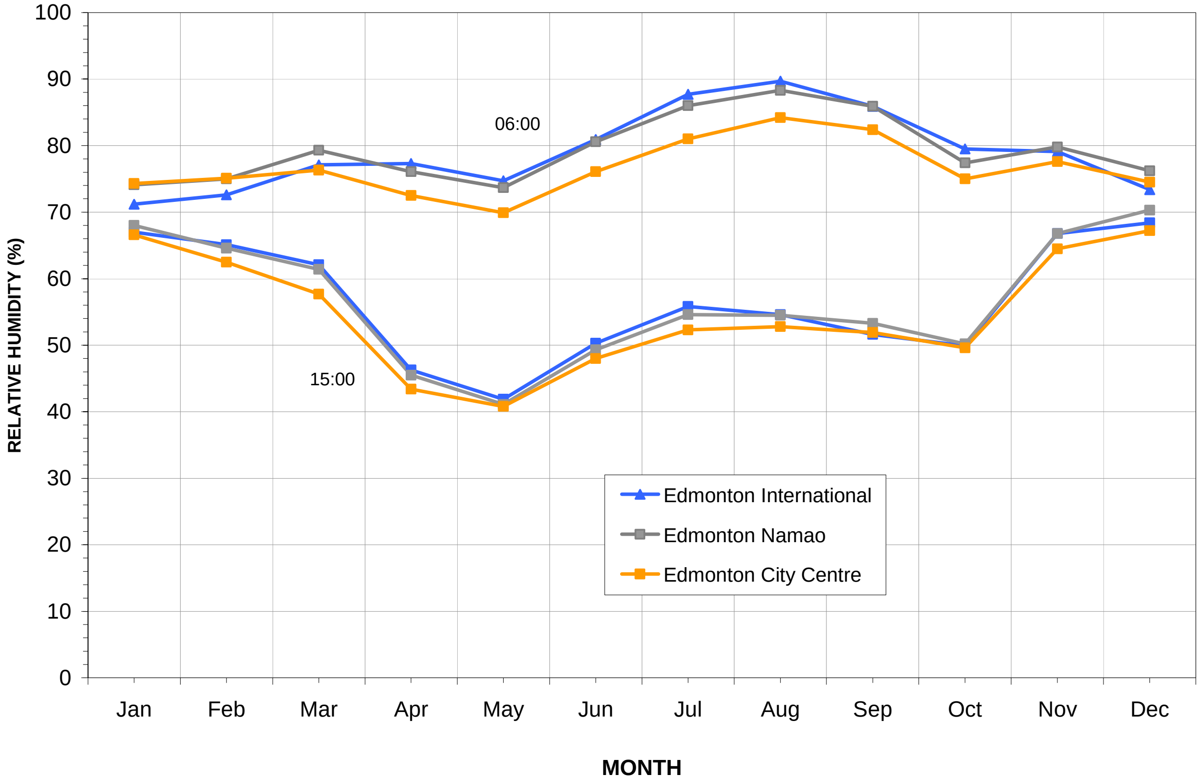


Figure 2C-17 Monthly Mean Relative Humidity at the Edmonton Airports (1971 – 2000)

2C.9 Visibility

Figure 2C-18 presents the mean number of hours in each month from 1971 to 2000 when reported visibilities were less than 1 km, and when the visibilities were between 1 and 9 km. Visibility is not recorded at the Fort Saskatchewan monitoring station. Visibilities less than 1 km tends to be more frequent in late fall, early winter (November to December) and least frequent during the summer (June and July). Visibilities between 1 and 9 km tend to be more frequent in late fall to spring period (November to March) and least frequent during the late spring to fall period (April to October).

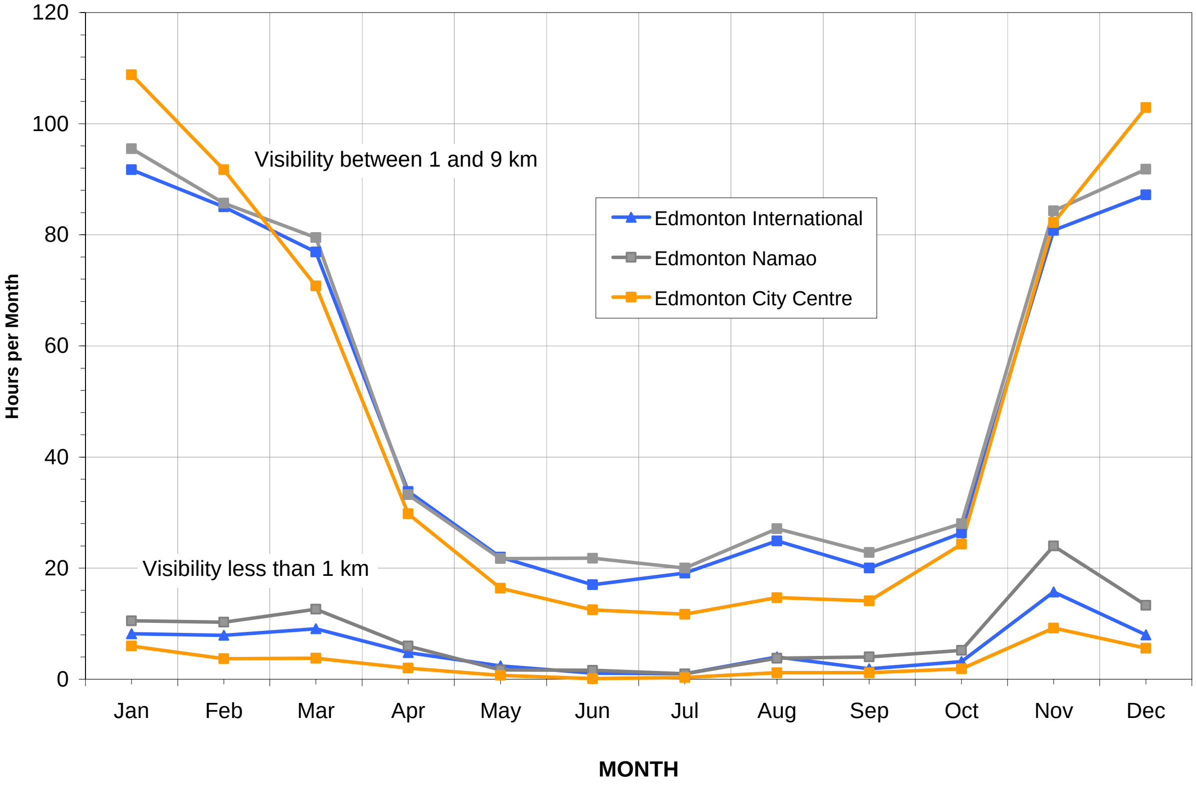


Figure 2C-18 Monthly Mean Visibilities at the Edmonton Airports (1971 – 2000)

2C10 Solar Radiation

Figure 2C-19 presents the mean daily global solar radiation values measured in the Edmonton. The highest global solar radiation values are recorded in the months of May through July while the lowest values are recorded in the months of December and January. Alberta has some of the sunniest skies in Canada. Summer is the sunniest season, partly because the northern parts of Alberta can experience up to 18 hours of daylight in the summer months. The amount of annual bright sunshine is in excess of 2000 hours in almost all areas of the province (EC, 1990).

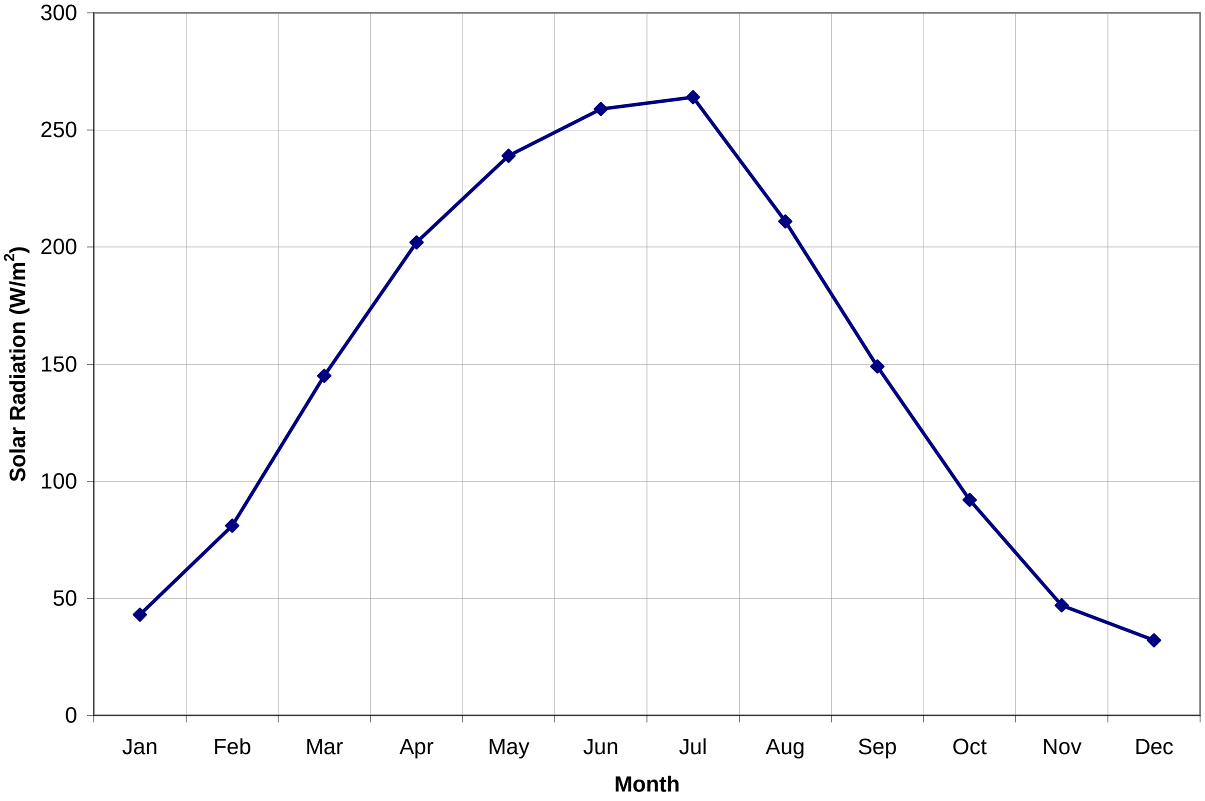


Figure 2C-19 Mean Daily Global Solar Radiation at Various Monitoring Stations in the Study Area

2C11 CALMET Technical Options

The technical options used in running CALMET are entered through a CALMET control file. Previously determined sensitivity parameters were adopted for the Project. The input parameters for the CALMET control file used in the Project modelling assessment are provided in Tables 2C-6 to 2C-13.

Table 2C-6 Input Groups in the CALMET Control File

Input Group	Description	Applicable to Project
0	Input and output file names	Yes
1	General run control parameters	Yes
2	Grid control parameters	Yes
3	Output Options	Yes
4	Meteorological data options	Yes
5	Wind Field Options and Parameters	Yes
6	Mixing Height, Temperature and Precipitation Parameters	Yes
7	Surface meteorological station parameters	Yes
8	Upper air meteorological station parameters	No
9	Precipitation parameters	No

Table 2C-7 CALMET Model Options Groups 0 and 1

Input Group 0: Input and Output File Names

Parameter	Default	Project	Comment
NUSTA	-	0	Number of upper air stations
NOWSTA	-	0	Number of overwater met stations
MM3D	-	10	Number of MM4/MM5/3D.DAT files
NIGF	-	0	Number of IGF-CALMET.DAT files

Input Group 1: General run control parameters

Parameter	Default	Project	Comment
IBYR	-	2002	Starting year
IBMO	-	1	Starting month
IBDY	-	1	Starting day
IBHR	-	0	Starting hour
IBSEC	-	0	Starting second
IEYR	-	2003	Ending year
IEMO	-	1	Ending month
IEDY	-	1	Ending day
IEHR	-	0	Ending hour
IESEC	-	0	Ending second
ABTZ	-	UTC-0700	UTC time zone
NSECDT	3600	3600	Length of modeling time-step (seconds)
IRTYPE	1	1	Run type
LCALGRD	T	T	Special data fields
ITEST	2	2	Flag to stop run after SETUP phase

Table 2C-8 CALMET Model Options Group 2: Grid control parameters

Parameter	Default	Project	Comment
PMAP	UTM	UTM	Map projection
IUTMZN	-	12	UTM Zone
UTMHEM	N	N	Hemisphere for UTM projection
DATUM	WGS-84	NAR-C	Datum-region for output coordinate
NX	-	125	No. X grid cells
NY	-	125	No. Y grid cells
DGRIDKM	-	1.	Grid spacing (km)
XORIGKM	-	305.0	Reference coordinate of SW corner of grid cell (1,1) -X coordinate (km)
YORIGKM	-	5900.0	Reference coordinate of SW corner of grid cell (1,1) -Y coordinate (km)
NZ	-	8	Vertical grid definition: Number of vertical layers
ZFACE	-	0,20,40,80, 160,320,600, 1400,2600	Vertical grid definition: Cell face heights in arbitrary vertical grid (m)

Table 2C-9 CALMET Model Options Group 3: Output Options

Parameter	Default	Project	Comment
Disk Output:			
LSAVE	T	T	Save met. Fields in the unformatted output files
IFORMO	1	1	Type of unformatted output file
Line Printer Output:			
LPRINT	F	T	Print meteorological fields
IPRINF	1	12	Print intervals (hrs)
IUVOUT (NZ)	0	1,0,0,0,0, 0,0,0	Specify which layers of U,V wind component to print
IWOUT (NZ)	0	0,0,0,0,0, 0,0,0	Specify which level of the w wind component to print
ITOUT (NZ)	0	1,0,0,0,0, 0,0,0	Specify which levels of the 3-D temperature field to print
Meteorological fields to print:			
Variable		**Print? 0 = no print 1 = print**	**Comment**
STABILITY		1	PGT stability
USTAR		0	Friction velocity
MONIN		0	Monin-Obukhov length
MIXHT		1	Mixing height
WSTAR		0	Convective velocity scale
PRECIP		1	Precipitation rate
SENSHEAT		0	Sensible heat flux
CONVZI		0	Convective mixing height

Table 2C-9 CALMET Model Options Group 3: Output Options (cont'd)

Parameter	Default	Project	Comment
Testing and debug print options for micrometeorological module:			
LDB	F	F	Print input meteorological data and internal variables
NN1	1	1	First time step for which debug data are printed
NN2	1	1	Last time step for which debug data are printed
LDBCST	F	F	Print distance to land internal variables
Testing and debug print options for wind field module:			
IOUTD	0	0	Control variable for writing the test/debug wind fields to disk files
NZPRN2	1	0	Number of levels, starting at surface, to print
IPR0	0	0	Print the interpolated wind components
IPR1	0	0	Print the terrain adjusted surface wind components
IPR2	0	0	Print the smoothed wind components and the initial divergence fields
IPR3	0	0	Print the final wind speed and direction
IPR4	0	0	Print the final divergence fields
IPR5	0	0	Print the winds after kinematic effects are added
IPR6	0	0	Print the winds after the Froude number adjustment is made
IPR7	0	0	Print the winds after slope flows are added
IPR8	0	0	Print the final wind field components

Table 2C-10 CALMET Model Options Group 4: Meteorological Data Options

Parameter	Default	Project	Comment
NOOBS	0	1	No observation mode
Number of Surface & Precipitation Meteorological Stations:			
NSSTA	-	6	Number of surface stations
NPSTA	-	-1	Number of precipitation stations
Cloud Data Options:			
ICLOUD	0	3	Gridded cloud fields
File Formats:			
IFORMS	2	2	Surface meteorological data file format
IFORMP	2	2	Precipitation data file format
IFORMC	2	2	Cloud data file format

Table 2C-11 CALMET Model Option Group 5: Wind Field Options and Parameters

Parameter	Default	Project	Comment
Wind Field Model Options:			
IWFCOD	1	1	Model selection variables
IFRADJ	1	1	Compute Froude number adjustment
IKINE	0	0	Compute kinematic effects
IOBR	0	0	Use O'Brien procedure for adjustment of the vertical velocity
ISLOPE	1	1	Compute slope flow effects
IEXTRP	-4	-4	Extrapolate surface wind observations to upper layers (similarity theory used with layer 1 data at upper air stations ignored)
ICALM	0	0	Extrapolate surface winds even if calm
BIAS	0	0,0,0,0,0,0, 0,0	Layer-dependent biases modifying the weights of surface and upper air stations
RMIN2	4	-1.0	Minimum distance from nearest upper air station to surface station for which extrapolation of surface winds at surface station will be allowed
IPROG	0	14	Use gridded prognostic wind field model output fields as input to the diagnostic wind field model (from MM5.DAT)
ISTEPPG	1	1	Timestep (hours) of the prognostic model input data
IGFMET	0	0	Use coarse CALMET fields as initial guess fields
Radius of Influence Parameters:			
LVARY	F	F	Use varying radius of influence
RMAX1	-	12	Maximum radius of influence over land in the surface layer (km)
RMAX2	-	12	Maximum radius of influence over land aloft (km)
RMAX3	-	5	Maximum radius of influence over water
Other Wind Field Input Parameters:			
RMIN	0.1	0.1	Minimum radius of influence used in the wind field interpolation (km)
TERRAD	-	15	Radius of influence of terrain features (km)
R1	-	3	Relative weighting of the first guess field and observations in the surface layer (km)
R2	-	3	Relative weighting of the first guess field and observations in the layers aloft (km)
RPROG	-	0	Relative weighting parameter of the prognostic wind field data (km)
DIVLIM	5.0E-6	5.0E-6	Maximum acceptable divergence in the divergence minimization procedure

Table 2C-11 CALMET Model Option Group 5: Wind Field Options and Parameters (cont'd)

Parameter	Default	Project	Comment
NITER	50	50	Maximum number of iterations in the divergence minimization procedure
NSMTH (NZ)	2, (mxnz-1) *4	2,7,7,14,14, 28,28,28	Number of passes in the smoothing procedure
NINTR2	99	99,99,99,99, 99,99,99,0	Maximum number of stations used in each layer for the interpolation of data to a grid point
CRITFN	1.0	1.0	Critical Froude number
ALPHA	0.1	0.1	Empirical factor controlling the influence of kinematic effects
FEXTR2(NZ)	0.0	0.,0.,0.,0., 0.,0.,0.,0.	Multiplicative scaling factor for extrapolation of surface observations to upper layers
Barrier Information:			
NBAR	0	0	Number of barriers to interpolation of the wind fields
KBAR	NZ	12	Level (1 to NZ) up to which barriers apply
XBBAR	-	0	X coordinate of beginning of each barrier
YBBAR	-	0	Y coordinate of beginning of each barrier
XEBAR	-	0	X coordinate of ending of each barrier
YEBAR	-	0	Y coordinate of ending of each barrier
Diagnostic Module Data Input Options:			
IDIOPT1	0	0	Surface temperature (0 = compute internally from hourly surface observation)
ISURFT	-	2	Surface meteorological station to use for the surface temperature
IDIOPT2	0	0	Domain-averaged temperature lapse (0 = compute internally from hourly surface observation)
IUPT	-	0	Upper air station to use for the domain-scale lapse rate
ZUPT	200	200	Depth through which the domain-scale lapse rate is computed (m)
IDIOPT3	0	0	Domain-averaged wind components
IUPWND	-1	-1	Upper air station to use for the domain-scale winds
ZUPWND	1., 1000	1., 2200	Bottom and top of layer through which domain-scale winds are computed (m)
IDIOPT4	0	0	Observed surface wind components for wind field module
IDIOPT5	0	0	Observed upper air wind components for wind field module
Lake Breeze Information:			
LLBREZE	F	F	Use lake breeze module
NBOX	-	0	Number of lake breeze regions
XG1	-	0	X Grid line 1 defining the region of interest

Table 2C-11 CALMET Model Option Group 5: Wind Field Options and Parameters (cont'd)

Parameter	Default	Project	Comment
XG2	-	0	X Grid line 2 defining the region of interest
YG1	-	0	Y Grid line 1 defining the region of interest
YG2	-	0	Y Grid line 2 defining the region of interest
XBCST	-	0	X Point defining the coastline in kilometres (Straight line)
YBCST	-	0	Y Point defining the coastline in kilometres (Straight line)
XECST	-	0	X Point defining the coastline in kilometres (Straight line)
YECST	-	0	Y Point defining the coastline in kilometres (Straight line)
NLB	-	0	Number of stations in the region
METBXID	-	0	Station ID's in the region

Table 2C-12 CALMET Model Option Group 6: Mixing Height, Temperature and Precipitation Parameters

Parameter	Default	Project	Comment
Empirical Mixing Height Constants:			
CONSTB	1.41	1.41	Neutral, mechanical equation
CONSTE	0.15	0.15	Convective mixing height equation
CONSTN	2400	2400	Stable mixing height equation
CONSTW	0.16	0.16	Over water mixing height equation
FCORIO	1.0E-4	1.2E-04	Absolute value of Coriolis (l/s)
Spatial Averaging of Mixing Heights:			
IAVEZI	1	1	Conduct spatial averaging
MNMDAV	1	3	Maximum search radius in averaging (grid cells)
HAFANG	30	30	Half-angle of upwind looking cone for averaging
ILEVZI	1	1	Layer of winds used in upwind averaging
Convective Mixing Heights Options:			
IMIXH	1	1	Method to compute the convective mixing height (Maul-Carson)
THRESHL	0.05	0.05	Threshold buoyancy flux required to sustain convective mixing height growth overland (W/m^3)
THRESHW	0.05	0.05	Threshold buoyancy flux required to sustain convective mixing height growth overwater (W/m^3)
ITWPROG	0	0	Option for overwater lapse rates used in convective mixing height growth (1=use prognostic lapse rates)
ILUOC3D	16	16	Land use category ocean in 3D.DAT datasets

Table 2C-12 CALMET Model Option Group 6: Mixing Height, Temperature and Precipitation Parameters (cont'd)

Parameter	Default	Project	Comment
Other Mixing Height Variables:			
DPTMIN	0.001	0.001	Minimum potential temperature lapse rate in the stable layer above the current convective mixing height (K/m)
DZZI	200	200	Depth of layer above current convective mixing height through which lapse rate is computed (m)
ZIMIN	50	50	Minimum overland mixing height (m)
ZIMAX	3000	3200	Maximum overland mixing height (m)
ZIMINW	50	100	Minimum overwater mixing height (m)
ZIMAXW	3000	3200	Maximum overwater mixing height (m)
Overwater Surface Fluxes Method and Parameters:			
ICOARE	10	10	COARE with no wave parameterization
DSHELF	0	0	Coastal/Shallow water length scale (km)
IWARM	0	0	COARE warm layer computation
ICOOL	0	0	COARE cool skin layer computation
Relative Humidity Parameters:			
IRHPROG	0	1	3D relative humidity from observations or from prognostic data
Temperature Parameters:			
ITPROG	0	1	3D temperature from observations or from prognostic data
IRAD	1	1	Interpolation type
TRADKM	500	500	Radius of influence for temperature interpolation (km)
NUMTS	5	6	Maximum number of stations to include in temperature interpolation
IAVET	1	1	Conduct spatial averaging of temperatures (1 = yes)
TGDEFB	-0.0098	-0.0098	Default temperature gradient below the mixing height over water (K/m)
TGDEFA	-0.0045	-0.0045	Default temperature gradient above the mixing height over water (K/m)
JWAT1	-	55	Beginning land use categories for temperature interpolation over water
JWAT2	-	55	Ending land use categories for temperature interpolation over water
Precipitation Interpolation Parameters:			
NFLAGP	2	2	Method of interpolation
SIGMAP	100	500	Radius of Influence (km)
CUTP	0.01	0.01	Minimum Precipitation rate cut-off (mm/h)

Table 2C-13 CALMET Model Option Group 7: Surface Meteorological Station Parameters

Name	ID	X coordinate (km)	Y coordinate (km)	Time zone	Anemometer Height
EDIA	12205	329.027	5910.563	7	10
EDCC	12208	333.345	5938.260	7	10
EDNA	12210	337.035	5949.266	7	10
EDNW	99991	331.830	5941.341	7	10
EDE	99992	343.094	5935.880	7	10
RDWT	14001	362.260	5968.154	7	10
FTSK	14002	353.223	5952.316	7	10
RCRK	14003	354.895	5954.151	7	10
LMT	14004	376.285	5958.423	7	10
SCTF	14005	363.306	5962.031	7	10

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APPENDIX 2D: CALPUFF DISPERSION MODEL

TABLE OF CONTENTS

TABLES

FIGURES

2D1 Introduction

Ambient air quality models are used to predict air quality changes (i.e., changes to ambient concentrations or deposition) associated with current and future emission scenarios. This section discusses the selection and application of the dispersion model that was used to evaluate the proposed Project.

2D1.1 Model Types

Air quality simulation (or dispersion) models provide a scientific means of relating industrial and community emissions to air quality changes by using mathematical equations to simulate transport, dispersion, transformation, and deposition processes in the atmosphere. Dispersion models can address a wide range of distance scales (hundreds of m to thousands of km) and time scales (minutes to years). There are two levels of modelling levels of effort:

- **Screening models** estimate maximum short-term (~1 hour) average concentrations for a wide range of pre-selected meteorological conditions. These models are typically limited to single sources and downwind distances less than 10 km (e.g., the U.S. EPA SCREEN3 model)

- **Refined models** use sequential hourly meteorological data for a 1 to 5 year period (8760 to 47,800 h, respectively). These models can address multiple sources, and predicted hourly average concentrations for all source, meteorology, and receptor combinations. The hourly concentrations can be used to predict concentrations for averaging periods that are factors of 24 (i.e. 2, 3, 4, 6, 8 or 12 h), or for longer periods (i.e., seasonal or annual) (e.g., the U.S. EPA ISC-PRIME and AERMOD models). Some refined models can also account chemical transformation, and deposition processes (e.g., the CALPUFF model).

Regulatory agencies have relied on dispersion models as part of the approval process. Numerous models are available for air quality predictions and the appropriate selection depends on project-specific circumstances. In response to the regulatory use of these models, formal guidelines regarding the selection and application of these models have been developed (e.g., AENV, 2003a; U.S. EPA, 2005).

2D1.2 Model Application

The application of a dispersion model requires the preparation of input files and the analysis of output files. The input files include the following:

- Control/Option information to identify the model run, and to select the available technical and output features specific to the selected model.

- Source data that identifies the location, the emissions characteristics (e.g., stack height), and the emission amounts (e.g., SO_2 emission rate).

- Terrain elevations and surface characteristics to account for terrain influences on airflow and turbulence.

- Surface characteristics to provide the deposition properties for the vegetation canopy.

- Meteorological data to characterize airflow and turbulence in the region on an hourly basis.

The output files include:

- A summary file to identify the model run and provide an overview of the run.
- Hourly concentration files for each receptor and meteorological combination.
- Hourly deposition files for each receptor and meteorological combination.

Presentation software is used to re-format the model predictions and to provide concentrations and deposition contour plots that can be superimposed over base maps.

2D2 Model Selection

2D2.1 Model Requirements

For the Project assessment, the models must have the ability to account for:

- Multiple point and area sources;
- Flat and elevated terrain features;
- Secondary $PM_{2.5}$ formation;
- SO_2 to sulphate (SO_4^{2-}), and NO_x to nitrate (NO_3^-) conversion; and
- Wet, dry, gaseous, and particulate deposition processes.

These features are required to predict ambient concentrations and potential acid input (PAI); and according to Alberta Environment's (2003a) definition, a refined model is required.

2D2.2 Candidate Models

Table 2D-1 describes the refined dispersion models outlined in the Alberta Air Quality Model Guideline (AENV, 2003a). Of these models, only the CALPUFF model can be used to predict secondary $PM_{2.5}$ formation and the deposition of acidifying compounds. If deposition was not a requirement, then the ISC3-PRIME or AERMOD models could be used. AERMOD provides a more refined treatment of dispersion relative to ISC3-PRIME. The RTDM and CTDM-PLUS models are primarily single source models designed for complex terrain applications such as the Alberta Foothills.

The CALPUFF model was therefore selected as the preferred model for this assessment. CALPUFF has two major options with respect to meteorological data:

- The ISC mode assumes a uniform meteorological field over the modelling domain during a given hour. While this is consistent with the ISC-PRIME and AERMOD models, CALPUFF has the advantage of allowing the effluent trajectory to vary from hour-to-hour in a systematic manner as the wind direction varies from hour-to-hour.

- The CALMET mode allows for three-dimensionally varying meteorological field over the modelling domain during a given hour.

For this assessment, the CALPUFF model with the three dimensional CALMET wind field was selected (see Appendix 2C). The CALPUFF model performance was tested by comparing model predictions to selected observations.

The SCREEN3, ISCST3, ISC3-PRIME, ISC-OLM, AERMOD, RTDM, and CTDM models and corresponding documentation are available from the U.S. Support Centre for Regulatory Air Models (SCRAM) web site (http://www.epa.gov/ttn/scram/). The CALPUFF and CALMET models and documentations are available from the http://www.src.com/calpuff/calpuff1.htm website.

Table 2D-1 Dispersion Models identified in the Alberta Air Model Guideline

The **SCREEN3** (U.S. EPA, 1995) model is a simple Gaussian plume model that uses Pasquill-Gifford dispersion coefficients to characterize atmospheric turbulence and Briggs relationships to determine plume rise. The model calculates the maximum ground-level concentration that occurs below the plume centreline. The model examines a wide range of atmospheric stability class and wind speed combinations (54) to identify the combination that results in the maximum ground-level concentration. Limited mixing conditions are assumed for selected meteorological events. A pre-selected array of 50 distances, ranging from 100 m to 50 km, can be used. An iteration routine is used to determine the maximum concentration and the associated distance to the nearest metre.
The **Industrial Source Complex (ISC3-PRIME** (Schulman et al., 1998) **and ISC-OLM** (Tikvart, 1996) models with refined meteorological data are U.S. EPA multi-source Gaussian models capable of predicting both long-term (annual) and short-term (down to 1-h mean) concentrations arising from point, area, and volume sources. Gravitational settling of particles can be accounted for using a dry deposition algorithm; wet deposition and depletion due to rainfall can also be treated. Effects of building wakes can be incorporated. The model has options for both urban and rural dispersion coefficients.
AERMOD (U.S. EPA, 2004) is a new-generation U.S. air quality modelling system. It contains updated algorithms for convective boundary layers; for computing vertical profiles of wind, turbulence, and temperature; and for the treatment of all types of terrain. It was developed by the U.S EPA, in collaboration with the American Meteorological Society.
The **Rough Terrain Diffusion Model (RTDM)** (Paine and Egan, 1987) is a U.S. EPA Gaussian model capable of predicting short-term concentrations arising from point sources in complex terrain. The model cannot address building wake effects. RTDM can be used with routinely available meteorological data relating to wind and stability categories.
The **Complex Terrain Diffusion Model (CTDMPLUS)** (U.S. EPA, 1989) is a refined air quality model that is preferred for use in all stability conditions in complex terrain applications. CTDMPLUS is applicable to all receptors on terrain elevations greater than stack top height. However, the model contains no algorithms for simulating building downwash, or the mixing and recirculation found in cavity zones in the lee of a hill.
The **CALPUFF** (Scire et al., 1999) model is a multi-layer, multi-species, non-steady state puff dispersion model that can simulate the effects of time and space-varying meteorological conditions on substance transport, transformation, and removal. CALPUFF can use the three-dimensional meteorological fields developed by the CALMET model or simple, single station winds in a format consistent with the meteorological files used to derive ISCST3 steady-state Gaussian models.

2D2.3 CALPUFF Model

CALPUFF is a multi-layer, multi-species, non-steady-state puff dispersion model, which can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation, and deposition. CALPUFF can use the three-dimensional meteorological fields developed by CALMET model, or simple, single station winds in a format consistent with the meteorological files used to drive the ISCST3 steady-state Gaussian model. However, single-station ISCST3 winds do not allow CALPUFF to take advantage of its capabilities to treat spatially varying meteorological fields.

CALPUFF contains algorithms for near-source effects such as building downwash, transitional plume rise, partial plume penetration, as well as longer-range effects such as chemical transformation, and pollutant removal (wet scavenging and dry deposition). It can accommodate arbitrarily varying point source and area source emissions. Most of the algorithms contain options to treat the physical processes at differing levels of detail depending on the requirements for the particular model application.

The major features and options include the following.

- **Dispersion Coefficients**: Several options are provided in CALPUFF for the computation of dispersion coefficients:

  - Based on direct turbulence measurements (σ_v and σ_w),
  - Based on similarity theory to estimate σ_v and σ_w from surface heat and momentum fluxes provided by CALMET,
  - Based on the Pasquill-Gifford (PG) or McElroy-Pooler (MP) dispersion coefficients, or
  - Based on dispersion equations based on the Complex Terrain Dispersion Model (CDTM).

Options are also provided to apply averaging time or surface roughness length adjustments to the PG coefficients.

- **Chemical Transformation**: CALPUFF includes options to parameterize chemical transformation effects using the five species scheme (SO_2, SO_4^{2-}, NO_x, HNO_3, and NO_3^-) employed in the MESOPUFF II model, a modified six-species scheme (SO_2, SO_4^{2-}, NO, NO_2, HNO_3, and NO_3^-) adapted from the RIVAD/ARM3 method, or a set of user-specified, diurnally-varying transformation rates.

- **Dry Deposition**: A full resistance model is provided to calculate dry deposition rates of gases and particulate matter as a function of geophysical parameters, meteorological conditions, and pollutant species. Options are provided to allow user-specified, diurnally varying deposition velocities to be used for one or more pollutants instead of the resistance model (e.g., for sensitivity testing) or to bypass the dry deposition model completely.

- **Wet Deposition**: An empirical scavenging coefficient approach is used in CALPUFF to compute the depletion and wet deposition fluxes due to precipitation scavenging. The scavenging coefficients are specified as a function of the pollutant and precipitation type (i.e., frozen vs. liquid precipitation).

The following section describes the application of the CALPUFF model specific to the assessment.

2D3 Model Application

2D3.1 Model Doman

The CALPUFF model requires the user to define locations where concentrations are to be calculated, these locations are referred to as “receptors”. The CALPUFF computational domain was selected to represent a 100 km by 100 km centered on the Project. Deposition predictions are displayed for an 80 km by 80 km domain, and concentration predictions are displayed for a smaller 50 km by 50 km area, Table 2D-2 also provides the corners of the smaller 50 by 50 km area and the coordinates for the corners of these regions. Two types of receptors within the modelling domain were defined: nested Cartesian grid points, and discrete locations.

Table 2D-2 CALPUFF Modelling Domain Coordinates (UTM Zone 12; NAD 83)

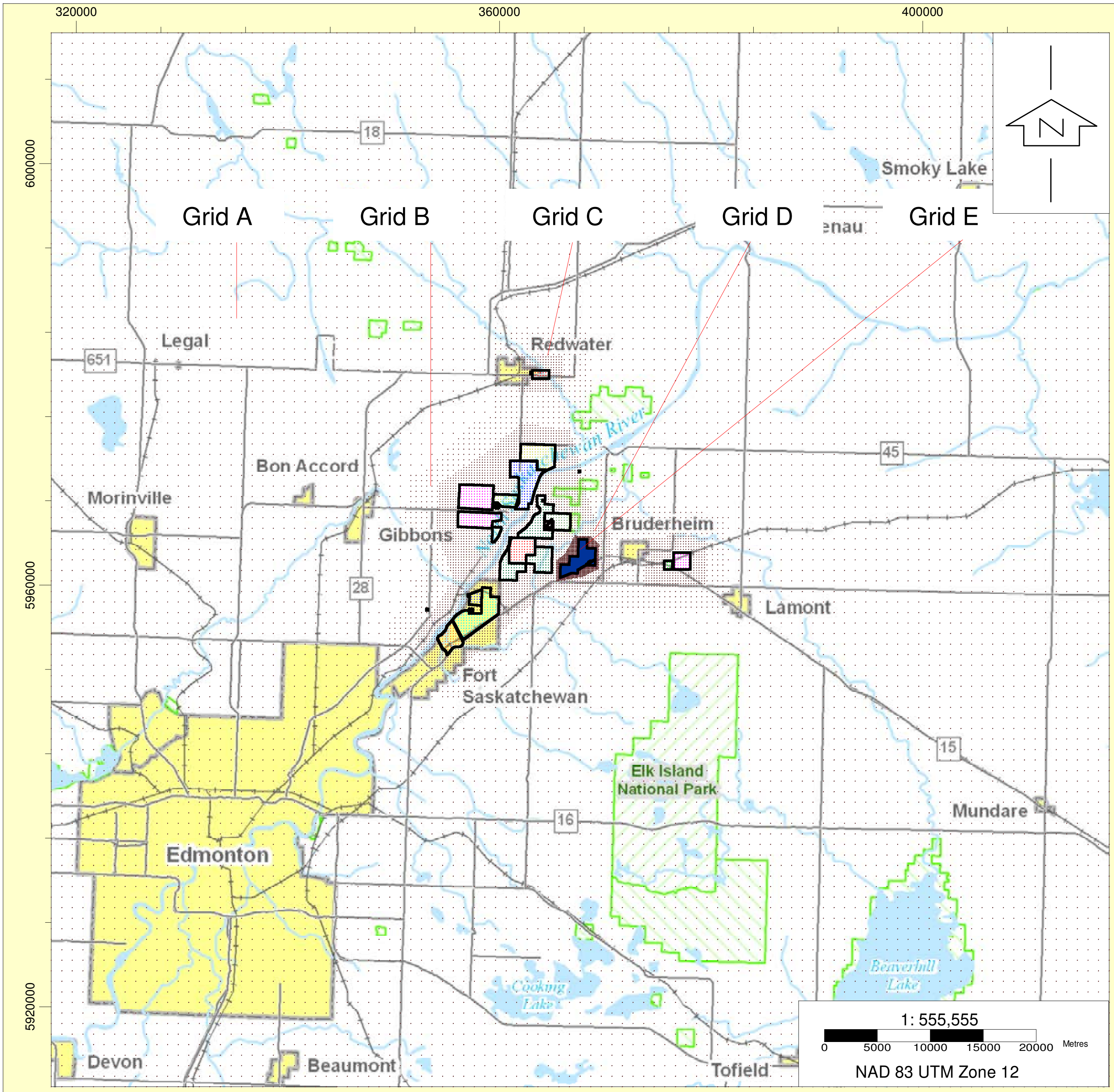
CALPUFF 100 km by 100 km Area	**Easting (m)**	**Northing (m)**
Southwest Corner	317625	5912405
Northwest Corner	317625	6012405
Southeast Corner	417625	5912405
Northeast Corner	417625	6012405
CALPUFF 50 km by 50 km Area	**Easting (m)**	**Northing (m)**
Southwest Corner	342625	5937405
Northwest Corner	342625	5987405
Southeast Corner	392625	5937405
Northeast Corner	392625	5987405

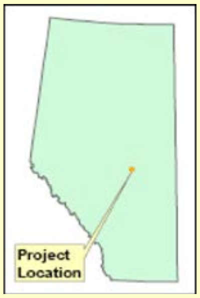
Figure 2D-1 shows the receptor points used to provide an understanding of the spatial concentration and deposition patterns. The receptors are based on:

- 20 m spacing along all the study facilities’ fence lines;
- 50 m spacing inside the North American Upgrader fence line (Grid E);
- 100 m spacing within 0.5 km from the plant fence line (Grid D);
- 250 m spacing within 2 km from the sources of interest (Grid C);
- 500 m spacing within 5 km from the sources of interest (Grid B), and;
- 1,000 m spacing for the 100 km by 100 km area centred on the North American Upgrader area (Grid A).

The described grid results in 27,024 receptor points. The density is greater near the Project to provide a greater resolution and facilitate the determination of the maximum concentrations due to the Project emissions. The indicated discrete receptor grid deviates from the guidance provided by AENV (2003a). The receptor spacing guidance was developed for a wide spectrum of facilities ranging from a single compressor station to facilities as large as the existing and proposed upgraders in the region. The spacing is viewed as being sufficient to provide an indication of maximum values due to Project emissions and the contribution of the Project to high values near other facilities.

In addition, 197 discrete locations corresponding to specific sites of interest were included. Figure 2D-2 shows the locations of these residential/agricultural (AGR), public use area (PUA), community (COM) and industrial (IND) receptors. These receptors are also identified in Table 2D-3. Agricultural receptors typically include residences. Public use areas can include recreation areas and areas where the public has access. Commercial areas include other industrial facility locations. Most of the discrete receptors are located within a nominal 4 km radius of the Project site. These receptors are numbered from 1 to 197 based on an original numbering scheme. During the assessment, a number of receptor locations were removed as they were located within a proposed industrial site.





Legend

🟪 Project Property Line

🟨 Community/Town

🟩 Natural Area

Grid A 1000m spacing in 100 x 100 km
Grid B 500m spacing within 5 x 5 km
Grid C 250 m spacing within 2 x 2 km
Grid D 100 m spacing within 500 m
Grid E 50m spacing within the Property Line

Title:

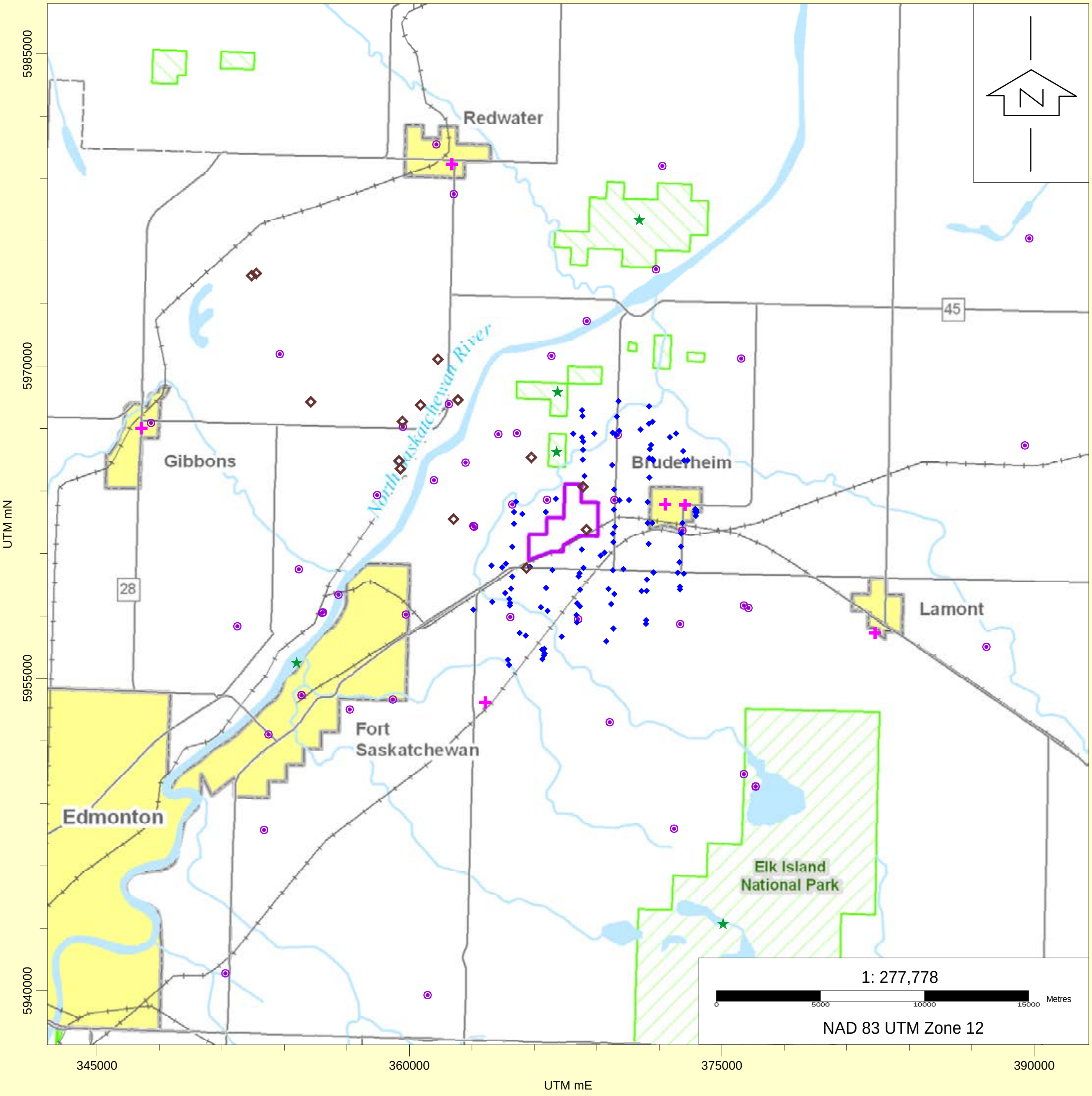
CALPUFF Dispersion Model Receptor Grid in the 100 x 100 km Area.

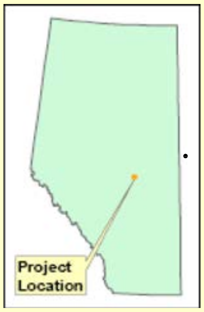
NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 11/16/07

File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897 Coordinates/receptors/receptors-final.srf

Drawn by: XC	Checked: MD	Fig. No.: 2D-1





Legend

- ◆ Agriculture/Residential
- ✚ Residential/Community
- ◇ Commercial/Industrial Area
- ★ Public Access Area
- ◎ FAP Monitoring Stations

Title:

LOCATION OF DISCRETE RECEPTORS

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: MD	Revision Date: 09/10/2007
File: H:/AQ/Shared/1018897 NAOSC Matrix/ N8897 Coordinates/receptors/ Figure 2.7-30.srf	

Drawn by:	Checked:	Fig. No.:
XC	MD	**2D-2**

Table 2D-3 Locations of the Discrete Receptors

AIR QUALITY MODELID	Receptor Group	Receptor Name (Individual residents are not identified)	UTM Easting (m)	UTM Northing (m)	Elevation (m)
1-327	f7	North American Property line			
425	MON	MON-Elk Island	376626	5949803	714
426	MON	MON-Fort Saskatchewan	353232	5952310	627
427	MON	MON-Lamont	376056	5958500	719
428	MON	MON-Range Road 220	359833	5958067	627
429	MON	MON-Redwater	361891	5968174	625
430	MON	MON-Ross Creek	354826	5954196	617
431	MON	MON-Scotford	363073	5962319	620
432	MON	MON-Scotford 2	364935	5963352	621
433	MON	MON-Station 401	357139	5953510	620
434	MON	MON-Bon Accord	340475	5967758	700
435	MON	MON-Fort Augustus	355804.3	5958149	621
436	MON	MON-Gibbons	347591.2	5967276	660
437	MON	MON-Hu-Haven	354688.1	5960244	638
438	MON	MON-N of Ardrossan	360878.8	5939796	738
439	MON	MON-NE of Bruderheim	375925.6	5970356	619
440	MON	MON-RedwaterP	361295.7	5980649	630
441	MON	MON-Thorhild	360697.3	6002572	645
442	MON	MON-W of Hwy 21	351171.8	5940836	652
443	MON	MON-Waskatenau	383851.1	5995967	632
444	MON	MON-Passive 11	365162.6	5966771	624
445	MON	MON-Passive 12	366816.4	5970490	620
446	MON	MON-Passive 13	370007.3	5966697	619
447	MON	MON-Passive 14	366611.9	5963581	626
448	MON	MON-Passive 15	369842.4	5963565	621
449	MON	MON-Passive 16	373105.3	5962105	645
450	MON	MON-Passive 17	364845.2	5957949	627
451	MON	MON-Passive 18	368102.3	5957846	649
452	MON	MON-Passive 19	373003.3	5957615	717
453	MON	MON-Passive 20	376282.8	5958384	723
454	MON	MON-Passive 21	369619.5	5952902	673
455	MON	MON-Passive 22	376055.4	5950401	723
456	MON	MON-Passive 23	372711.2	5947789	715
457	MON	MON-Passive 24	362696.6	5965372	622
458	MON	MON-Passive 25	356590.3	5959016	612
459	MON	MON-Passive 26	358451.9	5963805	635
460	MON	MON-Passive 27	368513.2	5972164	599
461	MON	MON-Passive 28	371842.8	5974654	620
462	MON	MON-Passive 29	372141.6	5979614	637
463	MON	MON-Passive 30	362130.9	5978255	630
464	MON	MON-Passive 31	361179.8	5964520	617

AIR QUALITY MODELID	Receptor Group	Receptor Name	UTM Easting (m)	UTM Northing (m)	Elevation (m)
		(Individual residents are not identified)			
465	MON	MON-Passive 32	359687.2	5967081	625
466	MON	MON-Passive 33	351746.7	5957506	646
467	MON	MON-Passive 34	336223.4	5958056	675
468	MON	MON-Passive 35	336842.4	5966913	698
469	MON	MON-Passive 36	353021.2	5947726	627
470	MON	MON-Passive 37	353779.9	5970579	654
471	MON	MON-Passive 38	389763.4	5976129	631
472	MON	MON-Passive 39	389551	5966186	633
473	MON	MON-Passive 40	387702.1	5956521	650
474	MON	MON-VOC A	355844	5958173	621
475	MON	MON-VOC B	354822.3	5954184	617
476	MON	MON-VOC C	359200.8	5953989	626
477	MON	MON-VOC D	363112.4	5962284	621
478	MON	MON-VOC E	364267.2	5966735	622
479	MON	MON-VOC F	376626.5	5949818	714
484	RES	COM-Gibbons	347140	5967010	658
485	RES	COM-Redwater	362040	5979690	630
486	RES	COM-Bruderheim	372290	5963360	624
487	RES	COM-Josephberg	363650	5953851	645
488	RES	COM-Bon Accord	340889	5967709	700
489	RES	COM-Lamont	382356	5957181	656
490	IND	IND-DeGussa Canada Inc.	359660	5967340	633
491	IND	IND-Northwest Upgrading	360538	5968123	629
492	IND	IND-Providence Energy	359505	5965444	633
493	IND	IND-Nikiforuk Construction Ltd.	355265	5968284	643
494	IND	IND-Provident Energy Ltd	359570	5965070	636
495	IND	IND-Agrium Products Inc.	361366	5970322	637
496	IND	IND-Agrium Products Ltd.	362330	5968371	626
497	IND	IND-Shell Canada Ltd	362120	5962650	624
498	IND	IND-Value Creation Inc. (BA Energy)	365860	5965610	623
499	IND	IND-Ag-Oil Alberta Ltd.	352645	5974457	653
500	IND	IND-Ag-Oil Alberta Ltd.	352421	5974349	651
501	PUA	PUA-Bruderheim Natural Area	367121	5968750	626
502	PUA	PUA-Astotin Natural Area	367069	5965875	623
503	PUA	PUA-Fort Sask. Natural Area	354582	5955741	603
504	PUA	PUA-Redwater Natural Area	371039	5977003	630
505	PUA	PUA-Elk Island National Park	375062	5943202	715
506	AGR		370275	5960257	663
507	AGR		369871	5962288	636

AIR QUALITY MODELID	Receptor Group	Receptor Name (Individual residents are not identified)	UTM Easting (m)	UTM Northing (m)	Elevation (m)
508	AGR		370552	5963564	624
509	AGR		370087	5963561	624
510	AGR		366867	5960212	631
511	AGR		368360	5960315	641
512	AGR		369188	5960895	647
513	AGR		369791	5961541	646
514	IND	R9-Grain	368507	5962145	630
515	AGR		365790	5960355	629
516	AGR		364939	5961328	631
517	AGR		364632	5960507	631
518	AGR		365024	5962425	623
519	AGR		366546	5962995	623
520	AGR		365417	5962893	625
521	AGR		365025	5962997	621
522	AGR		365116	5963482	625
523	AGR		369773	5961956	642
524	AGR		369824	5963113	629
525	AGR		369832	5964079	622
526	IND	R21-Energy	368343	5964208	622
527	AGR		369731	5965243	619
528	AGR		368408	5964719	623
529	AGR		367030	5963624	626
530	AGR		368326	5965508	620
531	AGR		364457	5960341	631
532	AGR		364883	5959319	628
533	AGR		364943	5959893	628
534	AGR		366566	5959343	632
535	AGR		368124	5959901	639
536	AGR		368169	5960050	640
537	AGR		369773	5960194	658
538	AGR		368274	5961193	634
539	AGR		369842	5959053	667
540	AGR		371151	5959194	675
541	AGR		371402	5959750	669
542	AGR		371396	5959205	674
543	AGR		371728	5960095	667
544	AGR		371728	5960095	667
545	AGR		372887	5960078	679
546	AGR		372967	5960587	669
547	AGR		373037	5961334	659
548	AGR		371482	5961462	659
549	AGR		371440	5962468	646
550	AGR		373055	5961967	650

AIR QUALITY MODELID	Receptor Group	Receptor Name (Individual residents are not identified)	UTM Easting (m)	UTM Northing (m)	Elevation (m)
551	AGR		371660	5962466	645
552	AGR		373113	5962465	636
553	RES		373233	5963335	627
554	AGR		365585	5957062	632
555	AGR		368179	5958462	649
556	AGR		369689	5958576	667
557	AGR		368039	5957693	649
558	AGR		368020	5958047	649
559	AGR		366630	5958239	635
560	AGR		368057	5958605	644
561	AGR		366314	5958425	632
562	AGR		365291	5957189	629
563	AGR		363072	5958305	630
564	AGR		369554	5959301	666
565	AGR		363936	5960424	628
566	AGR		371705	5965471	618
567	AGR		371440	5963472	625
568	AGR		371517	5964655	616
569	AGR		371505	5965582	617
570	AGR		371543	5966013	619
571	AGR		371705	5965471	618
572	AGR		371672	5965528	618
573	AGR		371604	5966213	618
574	AGR		369963	5967577	618
575	AGR		370078	5966896	620
576	AGR		370041	5968315	618
577	AGR		368338	5965982	623
578	AGR		367868	5966756	622
579	AGR		368291	5966578	627
580	AGR		368345	5966376	624
581	AGR		369919	5966711	621
582	AGR		369764	5966800	618
583	AGR		368311	5967597	624
584	AGR		368289	5967882	619
585	AGR		369376	5961036	647
586	AGR		369794	5957398	673
587	AGR		369459	5956792	671
588	AGR		371361	5957617	688
589	AGR		371364	5957793	686
590	AGR		364602	5959099	627
591	AGR		368197	5959266	644
592	AGR		367310	5957015	644
593	AGR		371094	5966951	619

AIR QUALITY MODELID	Receptor Group	Receptor Name (Individual residents are not identified)	UTM Easting (m)	UTM Northing (m)	Elevation (m)
594	AGR		368884	5966764	619
595	IND	R94-Country Boyz Restaurant	365627	5960298	628
596	AGR		364822	5958500	627
597	AGR		364834	5958621	627
598	AGR		364794	5958821	628
599	AGR		363977	5958680	628
600	AGR		373186	5965469	618
601	AGR		373178	5960033	686
602	AGR		371494	5967230	618
603	AGR		364790	5955647	637
604	AGR		372986	5959273	700
605	AGR		366478	5956424	648
606	AGR		366378	5956387	647
607	AGR		366489	5956203	648
608	AGR		366457	5956105	648
609	AGR		366385	5955931	648
610	AGR		364726	5955895	637
611	AGR		372996	5959403	698
612	AGR		373360	5965477	618
613	AGR		373147	5965921	620
614	AGR		371516	5968066	616
615	AGR		371681	5967326	620
616	AGR		372809	5966762	615
617	AGR		373774	5963090	632
618	AGR		373724	5963133	630
619	AGR		373733	5963001	631
620	AGR		373767	5963010	632
621	AGR		373776	5962963	632
622	AGR		373755	5962802	634
623	AGR		372507	5966589	614

2D3.2 Meteorology

The CALMET diagnostic wind field module was used to provide representative wind, temperature and turbulence fields (Appendix 2C).

2D3.3 Building Downwash

Building downwash was not viewed as being applicable given the stack heights associated with the Project (see Appendix 2A). As the larger process structures tend to be open, they will not result in downwash influences that would be associated with a solid structure of similar size.

2D3.4 Terrain Coefficients

Terrain in the study area was described in the CALMET description (Appendix 2C). While the terrain near the Project is relatively flat (~625 m ASL), there are locations where higher terrain occurs (e.g., Bon Accord area at 700 m ASL, Elk Island National Park at 715 m ASL, and Beaver Hills at 740 m ASL). As a plume/puff passes over complex terrain, it has the potential to move closer to the ground. The plume path coefficient (PPC) method can be used to account for this potential decrease in height above the ground. A PPC of 1.0 assumes that the plume trajectory is parallel to the terrain features.

The default CALPUFF values are 0.5, 0.5, 0.5, 0.5, 0.35, and 0.35 for PG stability categories A, B, C, D, E and F, respectively. The selection of these values is not justified in the user guide. Lott (1984) compared a number of alternate terrain schemes and recommended PPC values of 0.8, 0.7, 0.6, 0.5, 0.4, and 0.3 for Pasquill-Gifford (PG) stability categories A, B, C, D, E and F, respectively. For this assessment, PPC values based on Lott's evaluation have been adopted.

2D3.5 Chemical Transformation

CALPUFF employs two alternate chemical reaction schemes: the MESOPUFF II and the RIVAD/ARM3 schemes. The RIVAD/ARM3 chemical scheme was selected since the MESOPUFF II scheme is viewed as being outdated (Morris et al 2003). This chemistry scheme treats the NO and NO_2 conversion process in addition to the NO_2 to NO_3^- and SO_2 to SO_4^{2-} conversions, with equilibrium between gaseous HNO_3 and particulate NH_4NO_3 (Scire et al., 1999). The selected chemical transformation scheme was applied relative to the prediction of sulphate and nitrate compounds and the associated deposition.

2D3.6 NO to NO_2 Chemistry

While the CALPUFF model can predict ambient NO and NO_2 concentrations, the calculation has been shown to overestimate ambient NO_2 concentrations. For this assessment, the ozone limiting method (OLM) was applied to account for this overestimation. The OLM assumes that the conversion of NO to NO_2 in the atmosphere is limited by the ambient ozone (O_3) concentration in the atmosphere. The approach assumes that 10% (on a volume basis) of the NO is converted to NO_2 prior to discharge into the atmosphere. For the remaining NO, the following is adopted:

- If 0.9 (NO) is greater than the ambient O_3 concentration then NO_2 = 0.1 (NO) + 0.9 (O_3). For this case, the conversion is not complete.

- If 0.9 (NO) is less than the ambient O_3 concentration then NO_2 = 0.1 (NO) + 0.9 (NO) = NO. This is equivalent to the total conversion approach, since there is sufficient ozone to effect the complete conversion.

In the application of the OLM, the above relationships assume the concentrations are expressed on a ppb basis.

Alberta Environment (2003a) recommends ambient ozone concentrations for 1-h, 24-h and annual averaging periods (i.e., 50, 40 and 35 ppb for rural areas, and 50, 35 and 20 ppb for urban areas). Alternately, hourly ambient ozone data can be used to calculate the NO to NO_2 conversion on an hourly basis. For consistency, the hourly ozone data should coincide with the meteorological data used in the modelling. For the application of the OLM approach in this assessment, hourly ozone data from Lamont for 2002 were used to estimate hourly NO_2 concentrations. The Lamont ozone data are discussed in Appendix 2B.

2D3.7 Particulate Formation

The CALPUFF model was used to predict secondary $PM_{2.5}$ formation due to precursor SO_2 and NO_x emissions. The model predicts particulate nitrate NO_3^-, which can exist as an aerosol (i.e., dissolved in a water droplet) or as a particle (e.g., NH_4NO_3). Similarly, sulphate SO_4^{2-} can also exist as an aerosol (i.e., dissolved in a water droplet) or as a particle (e.g., $(NH_4)_2SO_4$). As the predicted NO_3^- and SO_4^{2-} concentrations have been assumed to react with ambient ammonia (NH_3) to produce ammonium nitrate and ammonium sulphate, respectively; the predicted sulphate and nitrate are multiplied by the factors indicated in Table 2D-4.

Table 2D-4 $PM_{2.5}$ Multipliers for SO_4^{2-} and NO_3^-

Predicted Parameter	**SO_4^{2-}**	**NO_3^-**
Molecular Mass	96	62
End Product	**$(NH_4)_2SO_4$**	**NH_4NO_3**
Molecular Mass	132	80
Multiplier	1.375	1.290

NOTE:
Multiplier = (Molecular Mass of End Product)/(Molecular Mass of Predicted Parameter)

2D3.8 Intermittent Sources

The CALPUFF model was also used to evaluate air quality changes associated with short-term events (e.g., flaring) that are typically 1 hour or less in duration. When evaluating these sources, each upset flaring event was addressed as an isolated event by adjusting the model input so puffs associated with a given hour did not overlap with puffs from preceding or following hours. Specifically, the event was assumed to occur once every 4 hours, and the model was run four times with staggered emission releases to include all hours in the meteorological data. In this manner, the highest one-hour SO_2 concentration due to each intermittent event could be determined. If for some reason, a calm condition was to persist for 4 hours and the predicted puffs were to overlap, the model would overstate the air quality effect by overpredicting the expected concentrations.

2D3.9 Deposition

The CALPUFF model was used to predict SO_2, SO_4^{2-}, NO, NO_2, HNO_3, and NO_3^- deposition as annual averages. The Potential Acid Input (PAI) due to these individual substances was calculated as follows:

$$\mathrm{PAI} = \frac{2}{64}\left[\mathrm{SO_2}\right] + \frac{2}{96}\left[\mathrm{SO_4}^{2-}\right] + \frac{1}{30}\left[\mathrm{NO}\right] + \frac{1}{46}\left[\mathrm{NO_2}\right] + \frac{1}{63}\left[\mathrm{HNO_3}\right] + \frac{1}{62}\left[\mathrm{NO_3}^{-}\right]$$

where the PAI is expressed in keq H^+/ha/y and the values in the brackets [ ] represent the sum of the predicted wet and dry deposition in kg/ha/y. The multiplication coefficients account for valance and molecular mass differences for the individual species. The neutralizing effect of base cation contribution was addressed by subtracting 0.14 keq H^+ /ha/y (Appendix 2B).

The total nitrogen deposition (N) was calculated as follows:

$$\mathrm{N} = \frac{14}{30}\left[\mathrm{NO}\right] + \frac{14}{46}\left[\mathrm{NO_2}\right] + \frac{14}{63}\left[\mathrm{HNO_3}\right] + \frac{14}{62}\left[\mathrm{NO_3}^{-}\right]$$

where the N is expressed in kg N/ha/y and the values in the brackets [ ] represent the sum of the predicted wet and dry deposition in kg/ha/y. The multiplication coefficients account for molecular mass differences for the individual species. No background term was added as the model area is sufficiently large that the contribution from the main sources is accounted for explicitly in the model.

2D3.10 Interpretation of Predictions

Alberta Environment (2003a) recommends discarding the eight highest 1-h predictions at each receptor location during any given year, as these values “are considered outliers and should not be used as the basis for selecting stack height”. This means that the hourly AAAQO values should be compared to the 9th highest prediction, not to the highest prediction. For a one-year period, the 9th highest value corresponds to the 99.9th percentile predicted concentration.

For $PM_{2.5}$, the CWS is applicable to the 98th percentile. The 98th percentile was taken as the 8th highest daily average at each receptor location based on the 365-day simulation period.

2D4 CALPUFF Performance

2D4.1 Model Prediction Confidence

Uncertainty associated with dispersion model predictions stems from two main areas (U.S. EPA 2005):

- Reducible uncertainty results from uncertainties associated with the input values and with the limitations of the model physics and formulations. Reducible uncertainty can be minimized by better (i.e., more accurate and representative) measurements and improved model physics.

- Inherent uncertainty is associated with the stochastic nature of the atmosphere and its representation. Models predict concentrations that represent an ensemble average of numerous repetitions for the same nominal event. An individual observed value can deviate significantly from the ensemble value. This uncertainty may be responsible for a ±50 percent deviation from the measured values.

Generally, models are quoted as having a factor-of-two accuracy. Comparison studies have indicated that models can predict the magnitude of highest concentration occurring sometime and somewhere within an area to within ±10 to ±40 percent. Predictions for a specific site and time are often poorly correlated with observed values. This poor correlation can be related to reducible errors in wind direction. For example, an uncertainty of 5º to 10º in the wind direction can produce a concentration error in the 20 to 70 percent range. (U.S. EPA, 2005).

The confidence associated with CALPUFF/CALMET dispersion model predictions was determined by comparing the ambient air quality data measured at the FAP sites with model predictions. Any comparison should note:

- The Base Case scenario described in Appendix 2A does not represent existing emissions since the Base Case includes approved facilities that are not yet operating. The model predictions also assume emissions are constant with time, and that no upset or abnormal conditions occur. The comparison provided in this section focuses on existing sources (i.e., the approved but not yet constructed BA Energy Heartland Upgrader is not included) and is referred to as the Existing Case.

- The ambient monitoring data represent contributions from existing facilities in the study area and smaller contributions from sources outside the study area. The model, as applied for this comparison assessment, does not include the contribution from sources outside the study area.

- The existing sources are subject to hour-to-hour and day-to-day variability associated with normal and abnormal emissions. The model, as applied for this comparison assessment, does not explicitly account for abnormal emissions.

The CALPUFF model comparison was undertaken for existing sources and the comparison focuses on SO_2, NO_x, NO_2 and $PM_{2.5}$ concentration comparisons.

2D4.2 Sulphur Dioxide Comparisons

The comparison of measured and predicted SO_2 concentrations provides the best indication of model performance because: the emissions originate from a few, well documented sources; chemical reactions that affect SO_2 concentrations are not significant for the associated transport times; are significantly large that they can be measured in the ambient air; and there are a number of locations where ambient measurements are taken. **The modelling, however, does not account for upset and abnormal events and hence may underpredict**. Measured and predicted 1-h, 24-h and annual average values were compared.

2D4.3 1-h SO_2 Comparison

Table 2D-5 compares the measured 1-h average values at the FAP and Edmonton stations with the predicted maximum (i.e., the 100th percentile) and 99.9th percentile values at the same locations. The table shows the prediction bias and provides a scatter plot. The comparison indicates that:

- There is an average bias to underpredict by 44 percent, based on comparing maximum values.

- There is an average bias to overpredict by 13 percent, based on comparing 99.9th percentile values.
- The respective overprediction biases for the East Edmonton station are 82 percent and 182 percent, respectively.
- The model is generally predicting high concentrations where high concentrations are measured, and is predicting low concentrations where low concentrations are measured.

Hourly average SO_2 exceedances have only been measured at the Scotford and Redwater stations. The model predictions only indicate a potential for exceedances at the Redwater stations.

This comparison only focuses on high values, which is one measure of model performance. On average, the model is predicting within a factor of two. On average, there is reasonable agreement between predicted and measured 1-h average SO_2 concentrations.

2D4.4 24-h SO_2 Comparison

Table 2D-6 compares the measured 24-h average values at the FAP and Edmonton stations with the predicted maximum (i.e., the 100th percentile) and 99.9th percentile values at the same locations. The table shows the prediction bias and provides a scatter plot. The comparison indicates that:

- There is an average bias to underpredict by 27 percent, based on comparing maximum values.
- There is an average bias to underpredict by 49 percent, based on comparing 99.9th percentile values.
- The respective overprediction biases for the East Edmonton station are 89 percent and 14 percent, respectively.
- The model is generally predicting high concentrations where high concentrations are measured, and predicting low concentrations where low concentrations are measured.

This comparison only focuses on high values, which is one measure of model performance. On average, the model is predicting within a factor of two at most locations. The highest underpredictions are at the Scotford and Redwater stations. This may be due to underestimation of emissions from the nearby facilities.

2D4.5 Annual SO_2 Comparison

Table 2D-7 compares the measured annual average values at the FAP and Edmonton stations with the predicted values at the same locations. The table shows the prediction bias and provides a scatter plot. The comparison indicates that:

- There is an average bias to overpredict by 9 percent.
- The model is predicting high concentrations where high concentrations are measured, and predicting low concentrations where low concentrations are measured.

The model is predicting within a factor of two at most locations. The highest underpredictions are at the Redwater, Thorhild and Waskateneu. On average, there is reasonable agreement between predicted and measured annual average SO_2 concentrations.

Table 2D-5 Comparison of 1-h SO_2 Concentrations with those Predicted for Existing Sources.

Monitoring Station	Maximum Predicted (100th Percentile)			99.9th Percentile		
	Measured	Predicted (Existing Case)		Measured	Predicted (Existing Case)	
	SO_2 Concentration (ug/m³)	SO_2 Concentration (ug/m³)	Prediction Bias (%)	SO_2 Concentration (ug/m³)	SO_2 Concentration (ug/m³)	Prediction Bias (%)
Lamont	120	80.5	-33	49.7	61.0	23
Range Road 220	280	143	-49	52.3	97.6	87
Ross Creek	340	109	-68	78.5	68.3	-13
Redwater	1138	787	-31	465	393	-16
Fort Saskatchewan	327	91.0	-72	42.4	47.8	13
Scotford	463	415	-10	280	230	-18
Average prediction bias for FAP stations			-44			+13
Edmonton East	181	329	82	60.2	170	182
Average prediction bias for Edmonton stations			+82			+182

NOTES:

A "+" prediction bias indicates a tendency to overpredict.

A "-" prediction bias indicates a tendency to underpredict.

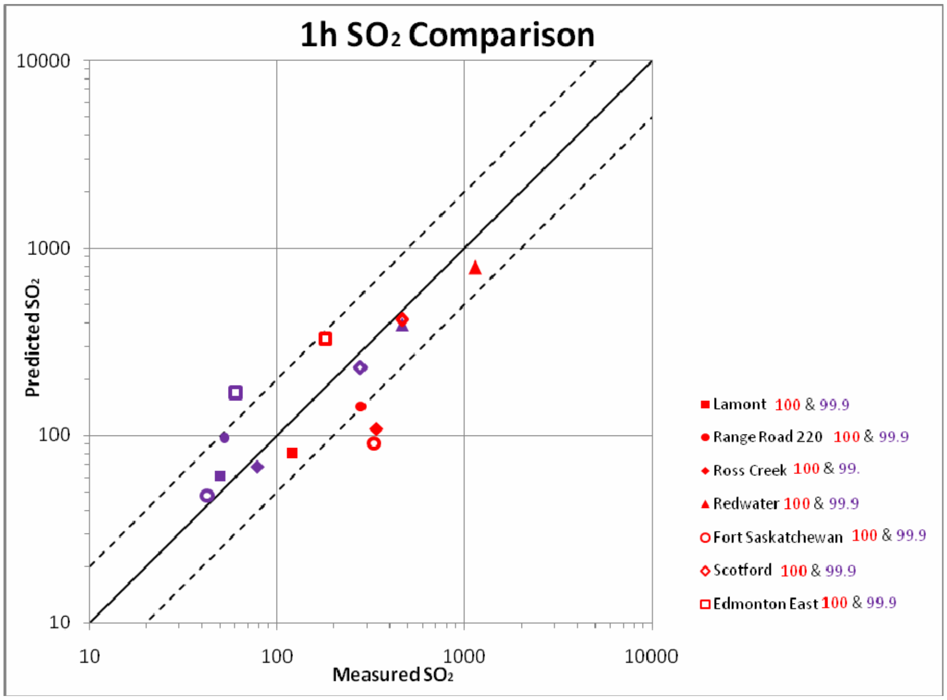


Table 2D-6 Comparison of 24-h SO2 Concentrations with those Predicted for Existing Sources

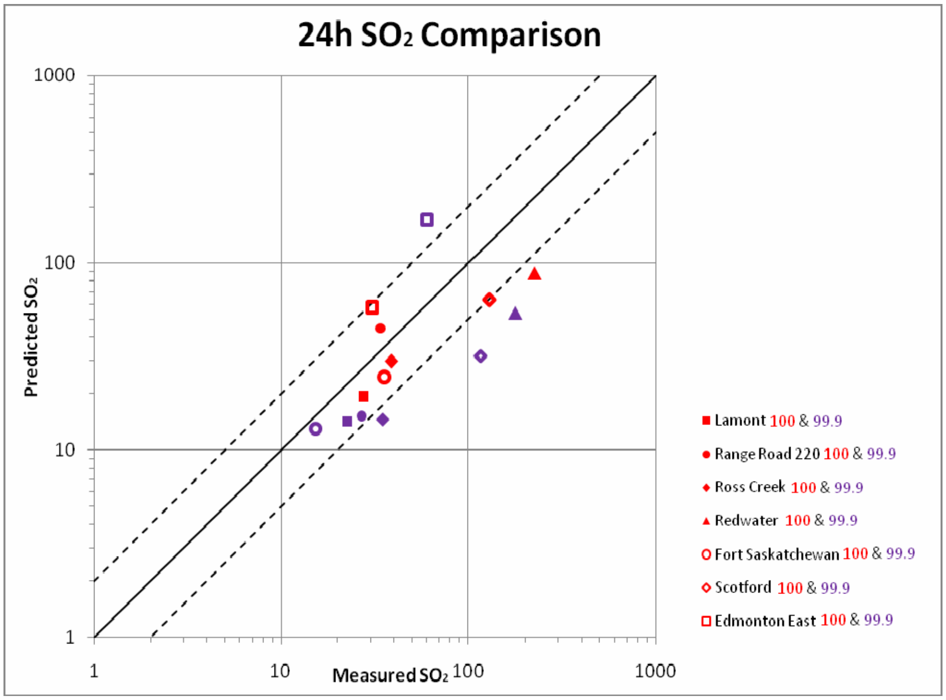
Monitoring Station	Maximum Predicted (100th Percentile)			99.9th Percentile		
	Measured	Predicted (Existing Case)		Measured	Predicted (Existing Case)	
	SO_2 Concentration (ug/m³)	SO_2 Concentration (ug/m³)	Prediction Bias (%)	SO_2 Concentration (ug/m³)	SO_2 Concentration (ug/m³)	Prediction Bias (%)
Lamont	27.6	19.4	-30	22.6	14.3	-37
Range Road 220	33.9	45	33	27.0	15.3	-43
Ross Creek	38.7	30	-23	34.9	14.6	-58
Redwater	225	89	-61	177	54	-69
Fort Saskatchewan	35.4	24.6	-30	15.3	13.1	-14
Scotford	129	63	-51	115	32	-72
Average prediction bias for FAP stations			-27			-49
Edmonton East	30.7	58	89	21.1	24	14
Average prediction bias for Edmonton stations			+89			+14
NOTES: A “+” prediction bias indicates a tendency to overpredict. A “-” prediction bias indicates a tendency to underpredict.						

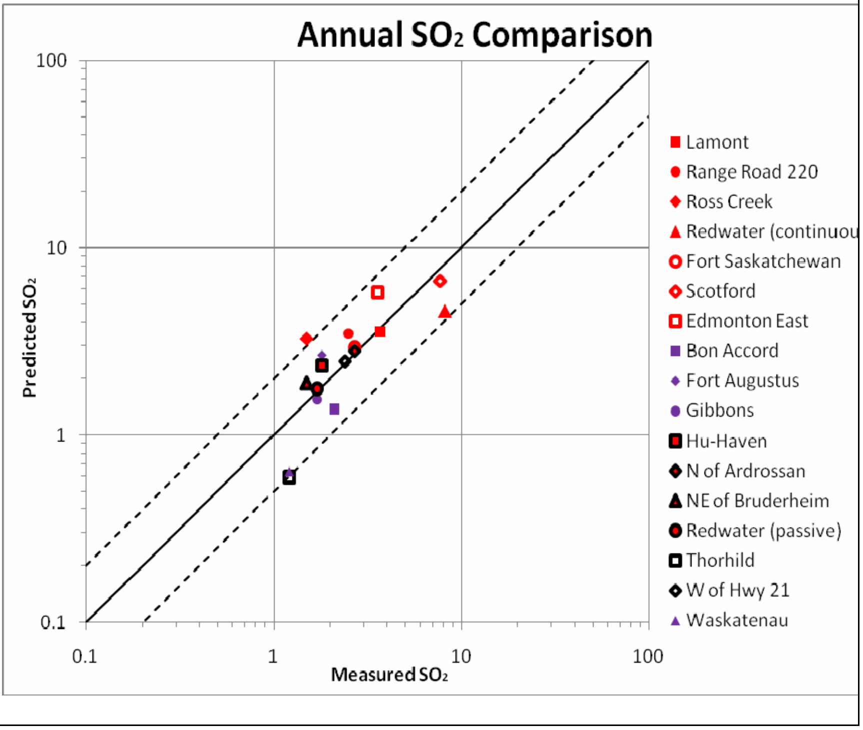
Table 2D-7 Comparison of Annual SO_2 Concentrations with those Predicted for Existing Sources

Monitoring Station	**Average Measured SO_2 Concentration** (ug/m³)	**Average Predicted (Existing Case)**	
		SO_2 Concentration (ug/m³)	**Prediction Bias** (%)
Lamont	3.70	3.59	-3
Range Road 220	2.50	3.50	40
Ross Creek	1.50	3.28	119
Redwater (continuous)	8.2	4.62	-44
Fort Saskatchewan	2.70	2.94	9
Scotford	7.7	6.64	-14
Edmonton East	3.60	5.80	61
Bon Accord	2.10	1.38	-34
Fort Augustus	1.80	2.68	49
Gibbons	1.70	1.56	-8
Hu-Haven	1.80	2.36	31
N of Ardrossan	2.70	2.82	5
NE of Bruderheim	1.50	1.89	26
Redwater (passive)	1.70	1.78	5
Thorhild	1.20	0.60	-50
W of Hwy 21	2.40	2.49	4
Waskatenau	1.20	0.64	-46
Average prediction bias			+9

NOTES:

A "+" prediction bias indicates a tendency to overpredict.

A "-" prediction bias indicates a tendency to underpredict.



2D4.6 Nitrogen Dioxide Comparison

The predicted NO_2 concentrations are based on contributions from industrial and non-industrial sources, and NO_x emissions are not as well documented as the SO_2 emissions. The non-industrial emissions undergo more daily and seasonal variations than the industrial sources, which were incorporated into the modelling. While the SO_2 predictions have to account for emission, transport and dispersion processes, the NO_2 predictions have to account for emission, transport, dispersion, and chemical transformation processes. The ability for the model to predict NO_2 concentrations can therefore be more demanding than that for SO_2. Measured and predicted 1-h NO_x and NO_2 concentrations were compared, and measured and predicted 24-h and annual average NO_2 values were compared.

2D4.7 1-h NO_x Comparison

Table 2D-8 compares the measured 1-h average values at the FAP and Edmonton monitoring stations with the predicted maximum (i.e., the 100th percentile) and 99.9th percentile values at the same locations. The table shows the prediction bias and provides a scatter plot. The comparison indicates that:

For FAP monitoring stations:

- There is an average bias to overpredict by 55 percent, based on comparing maximum values.
- There is an average bias to overpredict by 79 percent, based on comparing 99.9th percentile values.
- The model is predicting high concentrations where high concentrations are measured, and is predicting low concentrations where low concentrations are measured.

For Edmonton monitoring stations:

- There is an average bias to overpredict by 189 percent, based on comparing maximum values.
- There is an average bias to overpredict by 275 percent, based on comparing 99.9th percentile values.

The comparison indicates that, on average, the model is overpredicting NO_x concentrations by about a factor of two.

2D4.8 1-h NO_2 Comparison

Table 2D-9 compares the measured 1-h average values at the FAP and Edmonton stations with the predicted maximum (i.e., the 100th percentile) and 99.9th percentile values at the same locations. The table shows the prediction bias and provides a scatter plot. The comparison indicates that:

For FAP monitoring stations:

- There is an average bias to underpredict by 7 percent, based on comparing maximum values.
- There is an average bias to overpredict by 12 percent, based on comparing 99.9th percentile values.

For Edmonton monitoring stations:

- There is an average bias to overpredict by 119 percent, based on comparing maximum values.
- There is an average bias to overpredict by 123 percent, based on comparing 99.9th percentile values.

The comparison indicates that, on average, the model is predicting within a factor of two. Higher overpredictions are noted for the Edmonton area.

2D4.9 24-h NO_2 Comparison

Table 2D-10 compares the measured 24-h average values at the FAP and Edmonton stations with the predicted maximum (i.e., the 100th percentile) and 99.9th percentile values at the same locations. The table shows the prediction bias and provides a scatter plot. The comparison indicates that:

For FAP monitoring stations:

- There is an average bias to underpredict by 17 percent, based on comparing maximum values.
- There is an average bias to underpredict by 31 percent, based on comparing 99.9th percentile values.

For Edmonton monitoring stations:

- There is an average bias to overpredict by 44 percent, based on comparing maximum values.
- There is an average bias to overpredict by 11 percent, based on comparing 99.9th percentile values.

This comparison only focuses on the maximum values, which is one measure of model performance. On average, the model is predicting within a factor of two at most locations. On average, there is reasonable agreement between predicted and measured 24-h average NO_2 concentrations.

2D4.10 Annual NO_2 Comparison

Table 2D-11 compares the measured annual average values at the FAP and Edmonton stations with the predicted values at the same locations. The table shows the prediction bias and provides a scatter plot. The comparison indicates that:

- There is an average bias to overpredict by 51 percent.
- The model is generally predicting high concentrations where high concentrations are measured, and the model is predicting low concentrations where low concentrations are measured.

The model is predicting within a factor of two at most locations. On average, there is reasonable agreement between predicted and measured annual average NO_2 concentrations.

Table 2D-8 Comparison of 1-h NO$_x$ Concentrations with those Predicted for Existing Sources

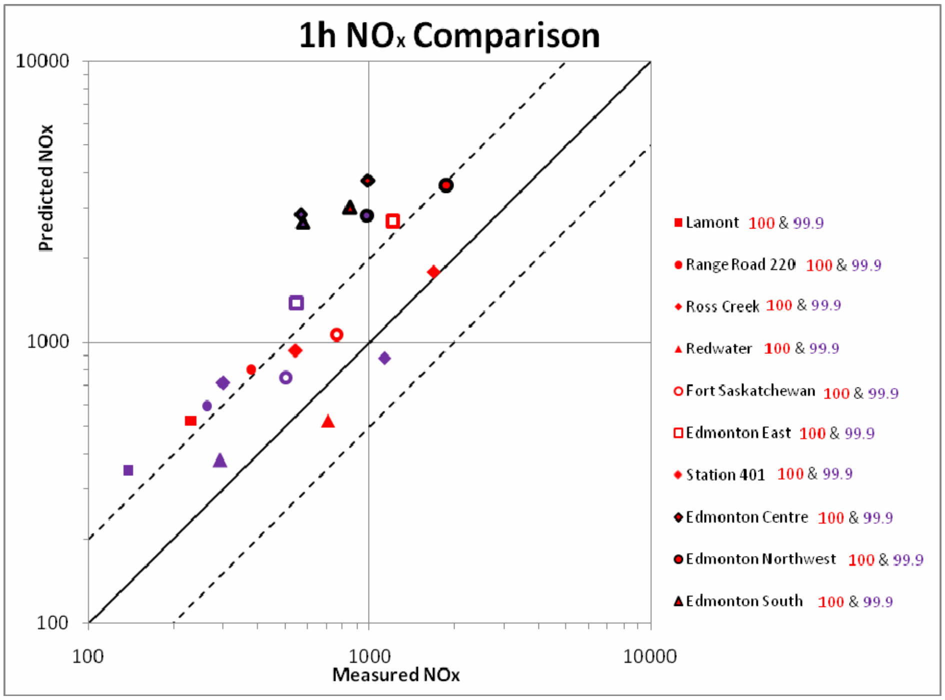
Monitoring Station	Maximum (100th Percentile)			99.9th Percentile		
	Measured	Predicted (Existing Case)		Measured	Predicted (Existing Case)	
	NOx Concentration (ug/m^3)	NOx Concentration (ug/m^3)	Prediction Bias (%)	NOx Concentration (ug/m^3)	NOx Concentration (ug/m^3)	Prediction Bias (%)
Lamont	229	525	128	138	351	155
Range Road 220	376	801	113	263	594	126
Station 401	545	928	70	301	714	137
Ross Creek	1693	1782	5	1129	878	-22
Redwater	709	527	-26	293	381	30
Fort Saskatchewan	762	1067	40	501	747	49
Average prediction bias for FAP stations			+55			+79
Edmonton East	1204	2702	124	547	1377	152
Edmonton Centre	986	3762	282	567	2840	401
Edmonton Northwest	1869	3617	93	974	2821	190
Edmonton South	850	3013	254	580	2667	360
Average prediction bias for Edmonton stations			+189			+275
NOTES: A "+" prediction bias indicates a tendency to overpredict. A "-" prediction bias indicates a tendency to underpredict.						

Table 2D-9 Comparison of 1-h NO_2 Concentrations with those Predicted for Existing Sources

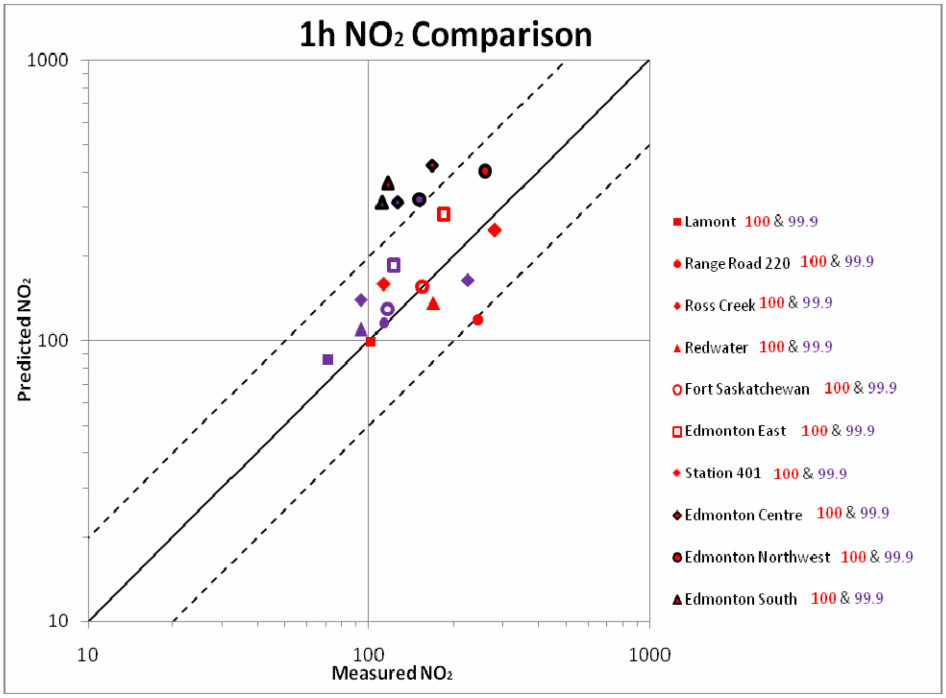
Monitoring Station	**Maximum (100th Percentile)**			**99.9th Percentile**		
	Measured	**Predicted (Existing Case)**		**Measured**	**Predicted (Existing Case)**	
	NO_2 Concentration (ug/m³)	**NO_2 Concentration** (ug/m³)	**Prediction Bias** (%)	**NO_2 Concentration** (ug/m³)	**NO_2 Concentration** (ug/m³)	**Prediction Bias** (%)
Lamont	102	99.4	-2	71.5	86.0	20
Range Road 220	244	119	-51	113	116	3
Station 401	113	159	41	94.0	140	49
Ross Creek	282	248	-12	226	165	-27
Redwater	169	136	-19	94.0	110	17
Fort Saskatchewan	154	156	1	116	130	12
Average prediction bias for FAP stations			-7			+12
Edmonton East	184	283	54	122	185	52
Edmonton Centre	167	423	153	126	313	148
Edmonton Northwest	260	403	55	150	320	112
Edmonton South	117	364	212	111	310	180
Average prediction bias for Edmonton stations			+119			+123
NOTES: A “+” prediction bias indicates a tendency to overpredict. A “-” prediction bias indicates a tendency to underpredict.						

Table 2D-10 Comparison of 24-h NO_2 Concentrations with those Predicted for Existing Sources

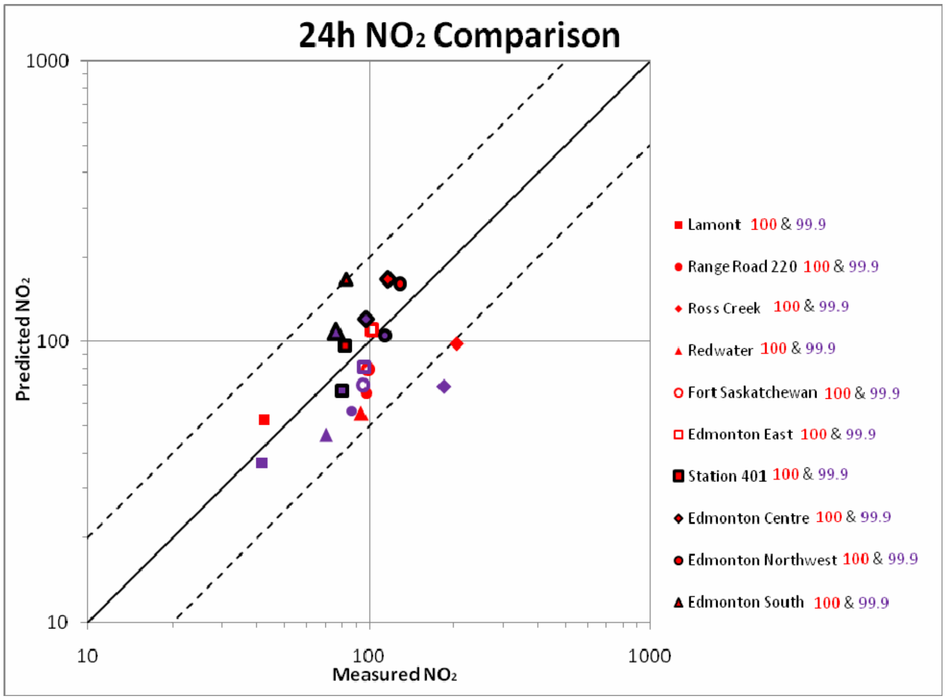
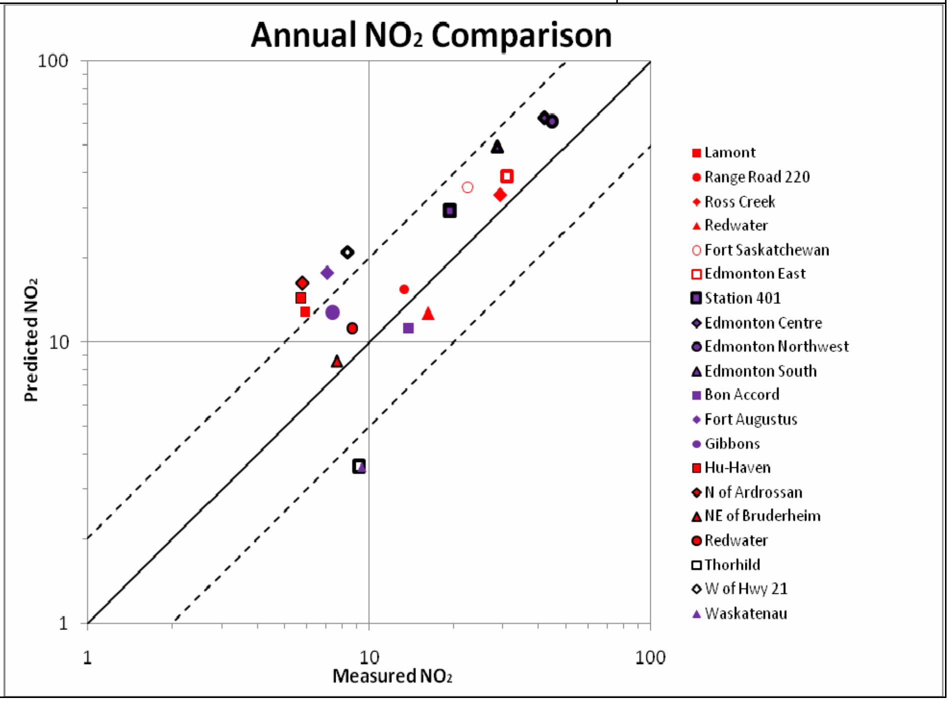
Monitoring Station	Maximum (100th Percentile)			99.9th Percentile Predicted		
	Measured	Predicted (Existing Case)		Measured	Predicted (Existing Case)	
	NO_2 Concentration (ug/m³)	NO_2 Concentration (ug/m³)	Prediction Bias (%)	NO_2 Concentration (ug/m³)	NO_2 Concentration (ug/m³)	Prediction Bias (%)
Lamont	42.4	53.0	25	41.5	37.1	-11
Range Road 220	98.1	65.8	-33	86.7	56.9	-34
Station 401	82.6	96.7	17	80.2	67.2	-16
Ross Creek	206	98.4	-52	185	69.1	-63
Redwater	94.0	55.8	-41	70.4	46.6	-34
Fort Saskatchewan	99.0	79.9	-19	95.1	70.3	-26
Average prediction bias for FAP stations			-17			-31
Edmonton East	103	111	8	95.9	81.4	-15
Edmonton Centre	117	167	43	97.5	121	24
Edmonton Northwest	129	161	25	114	106	-7
Edmonton South	83.1	167	101	76.5	109	42
Average prediction bias for Edmonton stations			+44			+11
NOTES: A "+" prediction bias indicates a tendency to overpredict. A "-" prediction bias indicates a tendency to underpredict.						

Table 2D-11 Comparison of Annual NO_2 Concentrations with those Predicted for Existing Sources

Monitoring Station	Average Measured NO_2 Concentration (ug/m³)	Average Predicted (Existing Case)	
		NO_2 Concentration (ug/m³)	Prediction Bias (%)
Lamont	5.90	12.9	118
Range Road 220	13.3	15.5	17
Station 401	19.5	29.3	50
Ross Creek	29.4	33.4	14
Redwater (continuous)	16.2	12.8	-21
Fort Saskatchewan	22.6	35.6	58
Edmonton East	31.0	39.0	26
Edmonton Centre	42.2	62.6	48
Edmonton Northwest	44.8	61.2	37
Edmonton South	28.6	49.8	74
Bon Accord	13.8	11.3	-18
Fort Augustus	7.10	17.6	148
Gibbons	7.40	12.8	74
Hu-Haven	5.70	14.4	153
N of Ardrossan	5.80	16.2	179
NE of Bruderheim	7.70	8.57	11
Redwater (passive)	8.70	11.2	29
Thorhild	9.20	3.63	-61
W of Hwy 21	8.40	20.9	149
Waskatenau	9.40	3.62	-61
Average prediction bias			+51
NOTES: A "+" prediction bias indicates a tendency to overpredict. A "-" prediction bias indicates a tendency to underpredict.			

2D4.11 $PM_{2.5}$ Comparison

The measured $PM_{2.5}$ concentrations include contributions from industrial, traffic and community sources, as well as contributions from other sources. The latter includes forest fires, agricultural operations and windborne dust. These latter emission sources are not included in the modelling. The ability for the model to predict $PM_{2.5}$ concentrations can therefore be more demanding. Measured and predicted 1-h, 24-h and annual average values were compared. The predicted values included primary $PM_{2.5}$ (i.e., directly emitted) and secondary $PM_{2.5}$ (i.e., sulphate formed from SO_2 emissions and nitrate formed from NO_x emissions).

Table 2D-12 provides the comparison for the FAP sites, which indicates that:

- The predicted maximum and 99.9th percentile 1-h predictions are similar to the 99.9th percentile measured values at all monitoring stations except the Fort Saskatchewan Station. At this station, the maximum predicted values are similar to the maximum measured value.

- The predicted maximum and 98th percentile 24-h values are slightly less than the corresponding measured values for the Lamont and Redwater stations. For the Fort Saskatchewan and Elk Island stations, there is good agreement.

- The annual average predicted and measured values at the Elk Island station are 2.29 and 4.5 $\mu g/m^3$, respectively. For the other FAP stations, the predictions are in the 2.7 to 7.6 $\mu g/m^3$ range, and the measured values are in the 4.9 to 8.2 $\mu g/m^3$ range.

The predicted FAP measurements and predictions indicate a reasonable agreement. There is, however, a significant degree of overprediction for $PM_{2.5}$ in the Edmonton area. It is not clear if this overprediction results from an overestimation of $PM_{2.5}$ emissions or from an underestimation of dispersion in the urban core.

Table 2D-12 Comparison of $PM_{2.5}$ Concentrations with those Predicted for Existing Sources

Monitoring Station	Measured $PM_{2.5}$ Concentration		Predicted $PM_{2.5}$ Concentration (Existing Case) (µg/m^3)	Comment
	Averaging Period	(µg/m^3)		
Fort Saskatchewan	1-h maximum	132	162	Predicted is larger than measured
	1-h 99.9th percentile	56.9	123	Predicted is between measured maximum and 99.9th percentile
	24-h maximum	55.1	53.6	Measured and predicted are similar
	24-h 98th percentile	16.0	27.9	Predicted is larger than measured
	Annual	4.9	7.57	Predicted is larger than measured
Lamont	1-h maximum	209	85.9	Predicted is between measured maximum and 99.9th percentile
	1-h 99.9th percentile	61.7	57.2	Predicted and measured are similar
	24-h maximum	51.2	30.2	Predicted is smaller than measured
	24-h 98th percentile	20.5	10.0	Predicted is smaller than measured
	Annual	6.7	2.74	Predicted is smaller than measured
Redwater	1-h maximum	147	89.1	Predicted is between measured maximum and 99.9th percentile
	1-h 99.9th percentile	65.4	63.5	Measured and predicted are similar
	24-h maximum	52.3	28.0	Predicted is smaller than measured
	24-h 98th percentile	18.7	12.1	Predicted is smaller than measured
	Annual	8.2	3.05	Predicted is smaller than measured
Elk Island	1-h maximum	326	81.5	Predicted is between measured maximum and 99.9th percentiles
	1-h 99.9th percentile	51.4	47.3	Measured and predicted are similar
	24-h maximum	37.1	29.1	Measured and predicted are similar
	24-h 98th percentile	13.1	13.0	Measured and predicted are similar
	Annual	4.5	2.29	Measured and predicted are similar
Edmonton East	1-h maximum	250	373	Over predictions
	1-h 99.9th percentile	69.1	232	Over Predictions
	24-h maximum	63.5	103	Over predictions
	24-h 98th percentile	20.4	50.7	Over predictions
	Annual	6.4	10.5	Over predictions
Edmonton Central	1-h maximum	99.6	555	Over predictions
	1-h 99.9th percentile	61.3	454	Over predictions
	24-h maximum	63.4	164	Over predictions
	24-h 98th percentile	18.4	93.7	Over predictions
	Annual	6.0	21.7	Over predictions
Edmonton South	1-h maximum	76.0	503	Over predictions
	1-h 99.9th percentile	62.9	406	Over predictions
	24-h maximum	55.1	175	Over predictions
	24-h 98th percentile	14.2	74.4	Over predictions
	Annual	4.8	15.0	Over predictions

2D4.12 CO Comparison

Table 2D-13 compares the predicted and measured CO 1-h concentrations for the Fort Saskatchewan monitoring station. The predicted 99.9th percentile value is slightly higher that the maximum measurements. The predicted values show a reasonable agreement with the available measurements.

Table 2D-13 Comparison of 1-h CO Concentrations (ug/m³) with those Predicted for Existing Sources

FAP Station	Maximum (100th Percentile)			99.9th Percentile		
	Measured	Predicted (Existing Case)		Measured	Predicted (Existing Case)	
	CO Concentration	CO Concentration	Prediction Bias (%)	CO Concentration	CO Concentration	Prediction Bias (%)
Fort Saskatchewan	3663	5355	+46	2289	3729	+63
Average prediction bias			+46			+63

2D4.13 H2S Comparison

Table 2D-14 compares the predicted and measured H_2S 1-h and 24-h concentrations for the FAP monitoring stations. While the closest agreement is for the Scotford station, there is a tendency to underpredict H_2S concentrations. This underprediction may be attributable to basing H_2S emissions on annual average emissions when fugitive H_2S sources can be intermittent, short-term events.

Table 2D-14 Comparison of 1-h and 24-h H_2S Concentrations (ug/m³) with those Predicted for the Existing Sources

FAP Sites	Measured H_2S Concentration		Predicted H_2S Concentration (Existing Case) (µg/m³)
	Averaging Period	(µg/m³)	
Fort Saskatchewan	1-h maximum	11.1	0.334
	1-h 99.9th percentile	5.6	0.216
	24-h maximum	5.2	0.072
	24-h 99.9th percentile	3.4	0.041
Lamont	1-h maximum	18.1	0.379
	1-h 99.9th percentile	5.6	0.303
	24-h maximum	3.9	0.100
	24-h 99.9th percentile	3.8	0.057
Scotford	1-h maximum	26.4	5.08
	1-h 99.9th percentile	8.3	3.49
	24-h maximum	4.4	1.13
	24-h 99.9th percentile	3.9	0.52
Edmonton East	1-h maximum	50.0	0.140
	1-h 99.9th percentile	13.9	0.100
	24-h maximum	7.53	0.040
	24-h 99.9th percentile	5.12	0.018

2D4.14 Benzene Comparison

Table 2D-15 compares the predicted and measured benzene 24-h and annual concentrations for the EC/FAP VOC monitoring sites. The maximum and 99.9th percentile predicted 24-h concentrations are similar to the maximum and 99.9th percentile measured values. The good general agreement is based on including benzene from transportation emissions in the modelling. There is an underprediction at the Scotford site which may be attributable to basing Scotford Complex emissions on annual average emissions when fugitive benzene sources can be intermittent events.

Table 2D-15 Comparison of 24-h and Annual Benzene Concentrations with those Predicted for Existing Sources

EC/ FAP VOC Sites	Measured Benzene Concentration		Predicted Benzene Concentration (Existing Case) (µg/m^3)
	Averaging Period	(µg/m^3)	
A	24-h maximum	2.8	3.37
	24-h 99.9th percentile	2.7	2.07
	Annual	0.60	0.35
B (FAP Ross Creek monitoring site)	24-h maximum	4.1	4.26
	24-h 99.9th percentile	4.0	3.10
	Annual	0.73	0.69
C (FAP Station 401 monitoring site)	24-h maximum	4.3	3.34
	24-h 99.9th percentile	4.1	1.92
	Annual	0.58	0.33
D (FAP Scotford monitoring site)	24-h maximum	16.4	5.48
	24-h 99.9th percentile	15.5	1.96
	Annual	1.03	0.41
E	24-h maximum	3.6	2.72
	24-h 99.9th percentile	3.4	1.31
	Annual	0.53	0.21
F (FAP Elk Island monitoring site)	24-h maximum	1.1	1.42
	24-h 99.9th percentile	1.1	0.59
	Annual	0.40	0.120

2D5 Summary and Conclusions

The CALPUFF dispersion model (Version 6.112, Level 060412) was selected as the primary air quality assessment tool to predict ambient concentrations and deposition. The following were adopted for the application of the model:

- 27,173 receptor grid points were selected for a 100 km by 100 km CALPUFF receptor area. The receptor spacing varied from 50 m nearest to the Project to 1 km at the furthest reaches of the modelling domain. This total includes the 178 community and monitoring site receptors, most of which are within a 5 km radius of the North American Upgrader Project.

- One year of meteorological data for the period January 2002 to December 2002 was selected. The CALMET model (Appendix 2C) was used to provide the meteorological data for the CALPUFF model.

- Hourly ozone concentrations from Lamont were used. The ozone limiting method was selected to estimate ambient NO_2 concentrations from the predicted NO_x values.

A comparison between model 99.9th percentile predictions and measurements in the FAP area indicates that on average, the CALPUFF/CALMET model system is predicting:

- **1-h average SO2** concentrations that are in the range of -18 to +87 percent of the measurements, with an **average overprediction of 5 percent**. **The average overprediction at the one Edmonton monitoring station is 182 percent.**

- **24-h average SO2** concentrations that are in the range of -72 to -14 percent of the measurements, with an **average underprediction of 49 percent. The average overprediction at the one Edmonton monitoring stations is 14 percent.**

- **Annual average SO2** concentrations that are in the range of -50 to 119 percent of the measurements, with an **average overprediction of 9 percent**. **The Edmonton monitoring station estimations are included in the average overprediction of 51 percent.**

- **1-h average NO2** concentrations that are in the range of -27 to 49 percent of the measurements, with an **average overprediction of 12 percent. The average overprediction at the four Edmonton monitoring stations is 123 percent.**

- **24-h average NO2** concentrations that are in the range of -11 to -63 percent of the measurements, with an **average underprediction of 31 percent. The average overprediction at the four Edmonton monitoring stations is 11 percent.**

- **Annual average NO2** concentrations that are in the range of -61 to 179 percent of the measurements, with an **average overprediction of 51 percent. The Edmonton monitoring station estimations are included in the average overprediction of 51 percent.**

- $PM_{2.5}$, CO and benzene concentrations that are reasonable in the FAP area. There is a significant degree of overprediction for $PM_{2.5}$ in the Edmonton area. It is not clear if this results from an overestimation of $PM_{2.5}$ emissions, or from an underestimation of dispersion in the urban core.

- H_2S concentrations that are generally underestimated. This may be due to the intermittent, short-term nature of fugitive H_2S emissions.

These are general conclusions and there are site-to-site variations. Overpredicting annual average SO_2 and NO_2 concentrations may lead to an overestimate of the dry deposition contribution to the PAI. This is because dry deposition is directly related to the ambient concentrations.

2D6 CALPUFF Model Options

For the purposes of organization, the CALPUFF control file defines 18 input groups as identified in Table 2D-16. For many of the options, default values used in the absence of site/project specific data. Tables 2D-17 to 2D-24 identify the input parameters, the default options, and the values used for the Project assessment.

Table 2D-16 Input Groups in the CALPUFF Control File

Input Group	Description	Applicable to PROJECT?
0	Input and output file names	Yes
1	General run control parameters	Yes
2	Technical options	Yes
3	Species list	Yes
4	Grid control parameters	Yes
5	Output options	Yes
6	Sub grid scale complex terrain inputs	No
7	Dry deposition parameters for gases	Yes
8	Dry deposition parameters for particles	Yes
9	Miscellaneous dry deposition for parameters	Yes
10	Wet deposition parameters	Yes
11	Chemistry parameters	Yes
12	Diffusion and computational parameters	Yes
13	Point source parameters	Yes
14	Area source parameters	Yes
15	Line source parameters	No
16	Volume source parameters	No
17	Discrete receptor information	Yes

Table 2D-17 CALPUFF Model Options Groups 1 and 2

Input Group 1: General Run Control Parameters

Parameter	Default	PROJECT	Comments
METRUN	0	0	All model periods in met file(s) will be run
IBYR	-	2002	Starting year
IBMO	-	1	Starting month
IBDY	-	1	Starting day
IBHR	-	0	Starting hour
XBTZ		7	Base time zone (7 = MST)
NSPEC	5	10	Number of chemical species
NSE	3	7	Number of chemical species to be emitted
ITEST	2	2	Program is executed after SETUP phase
MRESTART	0	0	Do not read or write a restart file during run
NRESPD	0	24	File updated every 24 periods
METFM	1	1	CALMET binary file (CALMET.MET)
AVET	60	60	Averaging time in minutes
PGTIME	60	60	PG Averaging time in minutes

Input Group 2: Technical Options

Parameter	Default	PROJECT	Comments
MGAUSS	1	1	Gaussian distribution used in near field
MCTADJ	3	3	Partial plume path terrain adjustment
MCTSG	0	0	Scale-scale complex terrain not modelled
MSLUG	0	0	Near-field puffs not modelled as elongated
MTRANS	1	1	Transitional plume rise modelled
MTIP	1	1	Stack tip downwash used
MBDW	1	2	PRIME Method is used to simulate building downwash
MSHEAR	0	1	(0,1) Vertical wind shear (not modelled, modelled)
MSPLIT	0	0	Puffs are not split
MCHEM	1	3	Transformation rates computed internally using (RIVID/ARM3) scheme
MAQCHEM	0	0	Aqueous phase transformation not modelled
MWET	1	1	Wet removal modelled
MDRY	1	1	Dry deposition modelled
MTILT	0	0	Gravitational settling (plume tilt) is not modeled

Table 2D-17 CALPUFF Model Options Groups 1 and 2 (cont'd)

Input Group 2: Technical Options (cont'd)

Parameter	Default	PROJECT	Comments
MDISP	3	2	Dispersion coefficients from internally calculated sigma v, sigma w using micrometeorological variables (u*, w*, L, etc.)
MTURBVW	3	3	Use both σ_v and σ_w from PROFILE.DAT to compute σ_y and σ_z (n/a)
MDISP2	3	3	PG dispersion coefficients for rural areas (computed using ISCST3 approximation) and MP coefficients in urban areas when measured turbulence data is missing
MTAULY	0	0	Draxler default 617.284 (s)
MTAUADV	0	0	No turbulence advection
MCTURB	1	1	Standard CALPUFF subroutines
MROUGH	0	1	PG σ_y and σ_z is adjusted for roughness
MPARTL	1	1	Partial plume penetration of elevated inversion
MTINV	0	0	Strength of temperature inversion computed from default gradients
MPDF	0	0	PDF not used for dispersion under convective conditions
MSGTIBL	0	0	Sub-grid TIBL module not used for shoreline
MBCON	0	0	Boundary concentration conditions not modelled
MSOURCE	0	0	Individual source contributions not saved
MFOG	0	0	Do not configure for FOG model output
MREG	1	0	Do not test options specified to see if they conform to regulatory values

Table 2D-18 CALPUFF Model Options Groups 3 and 4

Input Group 3: Species List-Chemistry Options

CSPEC	Modelled[1]	Emitted[2]	Dry Deposition[3]	Output Group Number
SO_2	1	1	1	0
SO_4^{2-}	1	0	2	0
NO	1	1	1	0
NO_2	1	1	1	0
HNO_3	1	0	1	0
NO_3^-	1	0	2	0
NOx	1	1	0	0
PM	1	1	0	0
VOC	1	1	0	0
CO	1	1	0	0

NOTES:
[1] 0=no, 1=yes
[2] 0=no, 1=yes
[3] 0=none, 1=computed-gas, 2=computed particle, 3=user-specified

Input Group 4: Map Projection and Grid Control Parameters

Parameter	Default	PROJECT	Comments
PMAP	UTM	UTM	Universal Transverse Mercator
FEAST	0	0	False Easting (km) at the projection origin
FNORTH	0	0	False Northing (km) at the projection origin
IUTMZN	-	12	UTM zone
UTMHEM	N	N	Northern Hemisphere for UTM projection
DATUM	WGS-84	WGS-84	NAR-C used for output coordinates
NX	-	125	Number of X grid cells in meteorological grid
NY		125	Number of Y grid cells in meteorological grid
NZ	-	8	Number of vertical layers in meteorological grid
DGRIDKM	-	1	Grid spacing (km) to match CALMET (see `Appendix 5C)
ZFACE	-	0,20,40,80,160,320, 600,1400,2600	Cell face heights in meteorological grid (m)
XORIGKM	-	305	Reference X coordinate for SW corner of grid cell (1,1) of meteorological grid (km)
YORIGKM	-	5900	Reference Y coordinate for SW corner of grid cell (1,1) of meteorological grid (km)

Table 2D-18 CALPUFF Model Options Groups 3 and 4 (cont'd)

Input Group 4: Map Projection and Grid Control Parameters (cont'd)

Parameter	Default	PROJECT	Comments
IBCOMP	-	1	X index of lower left corner of the computational grid
JBCOMP	-	1	Y index of lower left corner of the computational grids
IECOMP	-	125	X index of the upper right corner of the computational grid
JECOMP	-	125	Y index of the upper right corner of the computational grid
LSAMP	T	F	Sampling grid is not used
IBSAMP	-	1	X index of lower left corner of the sampling grid
JBSAMP	-	1	Y index of lower left corner of the sampling grid
IESAMP	-	125	X index of upper right corner of the sampling grid
JESAMP	-	125	Y index of upper right corner of the sampling grid
MESHDN	1	1	Nesting factor of the sampling grid

Table 2D-19 CALPUFF Model Option Group 5

Input Group 5: Output Option

Parameter	Default	PROJECT	Comments
ICON	1	1	Output file CONC.DAT containing concentrations is created
IDRY	1	1	Output file DFLX.DAT containing dry fluxes is created
IWET	1	1	Output file WFLX.DAT containing wet fluxes is created
IT2D	0	0	2D Temperature
IRHO	0	0	Density
IVIS	1	0	Output file containing relative humidity data is not created
LCOMPRS	T	F	Do not perform data compression in output file
IQAPLOT	1	1	Create a standard series of output files (e.g. locations of sources, receptors, grids ...) suitable for plotting
IMFLX	0	0	Do not calculate mass fluxes across specific boundaries
IMBAL	0	0	Mass balances for each species are not reported hourly
ICPRT	0	0	Do not print concentration fields to the output list file
IDPRT	0	0	Do not print dry flux fields to the output list file
IWPRT	0	0	Do not print wet flux fields to the output list file
ICFRQ	1	24	Concentration fields are printed to output list file every 24 hour
IDFRQ	1	24	Dry flux fields are printed to output list file every 24 hour
IWFRQ	1	24	Wet flux fields are printed to output list file every 24 hour

Table 2D-19 CALPUFF Model Option Group 5(cont'd)

Input Group 5: Output Option(cont'd)

Parameter	Default	PROJECT	Comments
IPRTU	1	3	Units for line printer output are in ug/m^3 for concentration and ug/m^2/s for deposition
IMESG	2	2	Messages tracking the progress of run are written on screen
LDEBUG	F	F	Logical value for debug output
IPFDEB	1	1	First puff to track
NPFDEB	1	1	Number of puffs to track
NN1	1	1	Meteorological period to start output
NN2	10	10	Meteorological period to end output

Species	Concentrations printed (0=no, 1=yes)		Dry Fluxes printed (0=no, 1=yes)		Wet Fluxes printed (0=no, 1=yes)		Mass Flux
	Printed	Saved to disk	Printed	Saved to disk	Printed	Saved to disk	Saved to disk
SO_2	0	1	0	1	0	1	0
SO_4^{2-}	0	1	0	1	0	1	0
NO	0	1	0	1	0	1	0
NO_2	0	1	0	1	0	1	0
HNO_3	0	1	0	1	0	1	0
NO_3^-	0	1	0	1	0	1	0
NOx	0	1	0	1	0	1	0
PM	0	1	0	1	0	1	0
VOC	0	1	0	1	0	1	0
CO	0	1	0	1	0	1	0

Table 2D-20 CALPUFF Model Option Groups 6, 7, and 8

Input Group 6: Sub-Grid Scale Complex Terrain Inputs

Parameter	Default	PROJECT	Comments
NHILL	0	0	Number of terrain features
NCTREC	0	0	Number of special complex terrain receptors
MHILL	-	2	Hill data created by OPTHILL & input below in Subgroup (6b); Receptor data in Subgroup (6c)
XHILL2M	1	1	Conversion factor for changing horizontal dimensions to meters
ZHILL2M	1	1	Conversion factor for changing vertical dimensions to meters
XCTDMKM	-	0	X origin of CTDM system relative to CALPUFF coordinate system (km)
YCTDMKM	-	0	Y origin of CTDM system relative to CALPUFF coordinate system (km)

Input Group 7: Dry Deposition Parameters for Gases

Species	Default	PROJECT	Comments
SO_2	0.1509	0.13719	Diffusivity from RWDI (2005)
	10000.0	1000	Alpha star
	8.0	8.0	Reactivity
	0.0	0.0	Mesophyll resistance
	0.4	0.033108	Henry’s Law coefficient
NO	-	0.22034	Diffusivity from RWDI (2005)
	-	1.0	Alpha star
	-	2	Reactivity
	-	94	Mesophyll resistance
	-	18	Henry’s Law coefficient
NO_2	0.1656	0.15845	Diffusivity from RWDI (2005)
	1.0	1.0	Alpha star
	8.0	8	Reactivity
	5.0	5	Mesophyll resistance
	3.5	3.5	Henry’s Law coefficient for
HNO_3	0.1628	0.1041	Diffusivity from RWDI (2005)
	1.0	1.0	Alpha star
	18.0	18	Reactivity
	0.0	0	Mesophyll resistance
	0.00000008	0.00000008	Henry’s Law coefficient

Table 2D-20 CALPUFF Model Option Groups 6, 7, and 8 (cont'd)

Input Group 8: Dry Deposition Parameters for Particles

Species	Default	PROJECT	Comments
SO_4^{2-}	0.48	0.48	Geometric mass mean diameter of SO_4^{2-} [µm]
SO_4^{2-}	2.0	2.0	Geometric standard deviation of SO_4^{2-} [µm]
NO_3^-	0.48	0.48	Geometric mass mean diameter of NO_3^-[µm]
NO_3^-	2.0	2.0	Geometric standard deviation of NO_3^- [µm]

NOTE:

'-' Symbol indicates that the parameter was not applicable to the Project.

Table 2D-21 CALPUFF Model Option Groups 9, 10, and 11

Input Group 9: Miscellaneous Dry Deposition Parameters

Parameters	Default	PROJECT	Comments
RCUTR	30	30	Reference cuticle resistance (s/cm)
RGR	10	10	Reference ground resistance (s/cm)
REACTR	8	8	Reference pollutant reactivity
NINT	9	9	Number of particle size intervals for effective particle deposition velocity
IVEG	1	1	Vegetation in non-irrigated areas is active and unstressed

Input Group 10: Wet Deposition Parameters

Species	Default	PROJECT	Comments
SO_2	3.21E-05	3.21E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	0.0	0.0	Scavenging coefficient for frozen precipitation [s^{-1}]
SO_4^{2-}	1.0E-04	1.0E-04	Scavenging coefficient for liquid precipitation [s^{-1}]
	3.0E-05	3.0E-05	Scavenging coefficient for frozen precipitation [s^{-1}]
NO	2.847E-05	2.9E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	0.0	0.0	Scavenging coefficient for frozen precipitation [s^{-1}]
NO_2	5.13E-05	5.1E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	0.0	0.0	Scavenging coefficient for frozen precipitation [s^{-1}]
HNO_3	6.0E-05	6.0E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	0.0	0.0	Scavenging coefficient for frozen precipitation [s^{-1}]
NO_3^-	1.0E-04	1.0E-04	Scavenging coefficient for liquid precipitation [s^{-1}]
	0.00003	3.0E-05	Scavenging coefficient for frozen precipitation [s^{-1}]

Table 2D-21 CALPUFF Model Option Groups 9, 10, and 11 (cont'd)

Input Group 11: Chemistry Parameters

Parameters	Default	PROJECT	Comments
MOZ	1	1	Hourly ozone values from Lamont (2002)were used
BCKO3	12*80	Not Applicable	Background ozone concentration (ppb)
BCKNH3	12*10	4.60,4.10,3.40,5.20,5.20,6.10,6.80, 8.10,5.30, 4.80, 3.50,6.10	Background ammonia concentration (ppb) (Based on FAP measurements, see Appendix 2B)
RNITE1	0.2	0.2	Night-time NO_2 loss rate in percent/hour
RNITE2	2	2	Night-time NO_X loss rate in percent/hour
RNITE3	2	2	Night-time HNO_3 loss rate in percent/hour
MH202	1	1	H2O2 data input option
BCKH202	12*1	12*1	Monthly background H_2O_2 concentrations (Aqueous phase transformations not modelled)
BCKPMF	-	-	Fine particulate concentration for Secondary Organic Aerosol Option
OFRAC	-	-	Organic fraction of fine particulate for SOA Option
VCNX	-	-	VOC/NO_x ratio for SOA Option

Table 2D-22 CALPUFF Model Option Group 12

Input Group 12: Diffusion/Computational Parameters

Parameters	Default	PROJECT	Comments
SYTDEP	550	550	Horizontal size of a puff in metres beyond which the time dependant dispersion equation of Heffter (1965) is used
MHFTSZ	0	0	Do not use Heffter formulas for sigma z
JSUP	5	5	Stability class used to determine dispersion rates for puffs above boundary layer
CONK1	0.01	0.01	Vertical dispersion constant for stable conditions
CONK2	0.1	0.1	Vertical dispersion constant for neutral/stable conditions
TBD	0.5	0.5	Use ISC transition point for determining the transition point between the Schulman-Scire to Huber-Snyder Building Downwash scheme
ISIGMAV	1	1	Sigma-v is read for lateral turbulence data
IMIXCTDM	0	0	Predicted mixing heights are used
XMXLEN	1	1	Maximum length of emitted slug in meteorological grid units
XSAMLEN	1	10	Maximum travel distance of slug or puff in meteorological grid units during one sampling unit
MXNEW	99	60	Maximum number of puffs or slugs released from one source during one time step
MXSAM	99	60	Maximum number of sampling steps during one time step for a puff or slug
NCOUNT	2	2	Number of iterations used when computing the transport wind for a sampling step that includes transitional plume rise
SYMIN	1	1	Minimum sigma y in metres for a new puff or slug
SZMIN	1	1	Minimum sigma z in metres for a new puff or slug

Stability Class	Parameter			
	SVMIN		SWMIN	
	Minimum turbulence (σ_v) (m/s)		Minimum turbulence (σ_w) (m/s)	
	Land	Water	Land	Water
A	0.5	0.37	0.2	0.2
B	0.5	0.37	0.12	0.12
C	0.5	0.37	0.08	0.08
D	0.5	0.37	0.06	0.06
E	0.5	0.37	0.03	0.03
F	0.5	0.37	0.016	0.016

Table 2D-22 CALPUFF Model Option Group 12 (cont'd)

Input Group 12: Diffusion/Computational Parameters (cont'd)

Parameters	Default	PROJECT	Comments
CDIV	0.0, 0.0	0.0, 0.0	Divergence criteria for dw/dz in met cells
WSCALM	0.5	0.5	Minimum wind speed allowed for non-calm conditions (m/s)
XMAXZI	3000	3000	Maximum mixing height in metres
XMINZI	50	50	Minimum mixing height in metres
WSCAT	1.54	1.54	wind speed category 1 [m/s]
	3.09	3.09	wind speed category 2 [m/s]
	5.14	5.14	wind speed category 3 [m/s]
	8.23	8.23	wind speed category 4 [m/s]
	10.80	10.80	wind speed category 5 [m/s]

Stability Class	Parameter	
	PLX0	PPC (see text)
	Wind speed profile exponent	Plume path coefficient
A	0.07	0.8
B	0.07	0.7
C	0.10	0.6
D	0.15	0.5
E	0.35	0.4
F	0.55	0.3

Parameters	Default	PROJECT	Comments
PTG0	0.020	0.020	potential temperature gradient for E stability [K/m]
	0.035	0.035	potential temperature gradient for F stability [K/m]
SL2PF	10	10	Slug-to-puff transition criterion factor equal to sigma y/length of slug
NSPLIT	3	3	Number of puffs that result every time a puff is split
IRESPLIT	0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0	0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0	Time(s) of day when split puffs are eligible to be split once again
ZISPLIT	100	100	Minimum allowable last hour's mixing height for puff splitting
ROLDMAX	0.25	0.25	Maximum allowable ratio of last hour's mixing height and maximum mixing height experienced by the puff for puff splitting

Table 2D-22 CALPUFF Model Option Group 12 (cont'd)

Input Group 12: Diffusion/Computational Parameters (cont'd)

Parameters	Default	PROJECT	Comments
NSPLITH	5	5	Number of puffs that result every time a puff is horizontally split
SYSPLITH	1	1	Minimum sigma-y of puff before it may be horizontally split
SHSPLITH	2	2	Minimum puff elongation rate due to wind shear before it may be horizontally split
CNSPLITH	1.0e-7	1.0e-7	Minimum concentration of each species in puff before it may be horizontally split
EPSSLUG	1.00E-04	1.00E-04	Fractional convergence criterion for numerical SLUG sampling iteration
EPSAREA	1.00E-06	1.00E-06	Fractional convergence criterion for numerical AREA sampling iteration
DRISE	1.0	1.0	Trajectory step length for numerical rise
HTMINBC	500	500	Minimum height (m) to which BC puffs are mixed as they are emitted (MBCON=2 ONLY)
RSAMPBC	10	15	Search radius (km) about a receptor for sampling nearest BCpuff.
MDEPBC	1	0	Concentration is NOT adjusted for depletion

NOTE:
'-' symbol indicates that the parameter was not applicable to the Project.

Table 2D-23 CALPUFF Model Option Groups 13, 14, and 15

Input Group 13: Point Source Parameters

Parameters	Default	PROJECT	Comments
NPT1	-	Varies by scenario	Number of point sources with constant stack parameters or variable emission rate scale factors
IPTU	1	1	Units for point source emission rates are g/s
NSPT1	0	0	Number of source-species combinations with variable emissions scaling factors
NPT2	-	0	Number of point sources with variable emission parameters provided in external file

NOTES:
Point source parameters are given in Appendix 2A.
'-' symbol indicates that the parameter was not applicable to the Project assessment.

Table 2D-23 CALPUFF Model Option Groups 13, 14, and 15 (cont'd)

Input Group 14: Area Source Parameters

Parameters	Default	PROJECT	Comments
NAR1	-	Varies by scenario	Number of polygon area sources
IARU	1	1	Units for area source emission rates are g/m^2/s
NSAR1	0	0	Number of source species combinations with variable emissions scaling factors
NAR2	-	0	Number of buoyant polygon area sources with variable location and emission parameters

NOTES:

Area source parameters are given in Part A.

'-' symbol indicates that the parameter was not applicable to the Project assessment.

Input Group 15: Line Source Parameters

Parameters	Default	PROJECT	Comments
NLN2	-	-	Number of buoyant line sources with variable location and emission parameters
NLINES	-	-	Number of buoyant line sources
ILNU	1	-	Units for line source emission rates is g/s
NSLN1	0	-	Number of source-species combinations with variable emissions scaling factors
MXNSEG	7	-	Maximum number of segments used to model each line
NLRISE	6	-	Number of distance at which transitional rise is computed
XL	-	-	Average line source length (m)
HBL	-	-	Average height of line source height (m)
WBL	-	-	Average building width (m)
WML	-	-	Average line source width (m)
DXL	-	-	Average separation between buildings (m)
FPRIMEL	-	-	Average buoyancy parameter (m^4/s^3)

NOTE:

'-' symbol indicates that the parameter was not applicable to the Project assessment.

Table 2D-24 CALPUFF Model Option Groups 16 and 17

Input Group 16: Volume Source Parameters

Parameter	Default	PROJECT	Comments
NVL1	-	Varies by scenario	Number of volume sources
IVLU	1	1	Units for volume source emission rates is grams per second
NSVL1	0	0	Number of source-species combinations with variable emissions scaling factors
IGRDVL	-	-	Gridded volume source data is not used
VEFFHT	-	-	Effective height of emissions (m)
VSIGYI	-	-	Initial sigma y value (m)
VSIGZI	-	-	Initial sigma z value (m)

NOTE:
'-' symbol indicates that the parameter was not applicable to the Project.

Input Group 17: Discrete Receptor Information

Parameter	Default	PROJECT	Comments
NREC	-	27205	Number of non-gridded receptors

NOTE:
Discrete receptors are identified on Figure 2D-1 and Figure 2D-2.

2D7 Literature Cited

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APPENDIX 2E: PROJECT ONLY PREDICTIONS

TABLE OF CONTENTS

TABLES

FIGURES

2E1 Introduction

The purpose of this appendix is to show the incremental contribution of the North American Upgrader (the Project) emissions on ambient air quality. The CALPUFF predictions are based on the meteorological information presented in Appendix 2C and the model approach presented in Appendix 2D. For the purpose of comparison, the SCREEN3 and ISCST3 model predictions are also presented. Only North American emission source predictions are presented in this appendix. Overlapping effects with other sources are considered in Volume 2, Section 2 - Air.

2E1.1 Continuous Sources (SCREEN3)

While the CALMET/CALPUFF system is the primary model used to assess the Project, the simpler SCREEN3 model (US EPA, 1995) was used to evaluate each stack to determine the relative contributions from each source. The SCREEN3 model is a first tier model that can be used to evaluate single sources (AENV, 2003a).

SCREEN3 predictions for the continuous regulatory phase combustion sources on an individual stack basis are provided in Table 2E-1. The distances refer to the locations downwind of the stack where the maximum concentrations are predicted. PG class refers to the atmospheric stability category (A to F) (see Appendix 2C for a description of the classes) associated with the maximum predicted concentrations. Wind speed refers to the 10 m level wind speed associated with the maximum concentrations (1 m/s = 3.6 km/h). The results indicate:

- The highest SO_2 concentrations are associated with the incinerator stack emissions (i.e., ~100 $\mu g/m^3$ due to each of the 5 incinerator stacks). The contribution from the other stacks on an individual basis is minor (i.e., less than 1 $\mu g/m^3$ on a per stack basis). The SO_2 emission rates associated with the incinerator stacks are based on a 99.5% sulphur recovery efficiency.

- The maximum NO_x concentrations are associated with the DCU Coker Heaters (i.e., ~14 $\mu g/m^3$ on a per stack basis). On an individual stack basis, the maximum associated NO_x concentrations are in the 1.5 to 8.1 $\mu g/m^3$ range for the other stacks.

The maxima depicted in Table 2E-1 are predicted to occur at different locations and at different times, and the predicted maximum values typically occur within 1000 m of the respective stacks. Assuming the individual maxima are additive, the maximum combined SO_2 concentration of 532 $\mu g/m^3$ is greater than the 1-hour 450 $\mu g/m^3$ AAAQO for SO_2. On the other hand, the maximum combined NO_x concentration of 132 $\mu g/m^3$ is less than the 400 $\mu g/m^3$ AAAQO for NO_2.

2E1.2 Continuous Sources (ISCST3)

The ISCST3 model system was applied to the Project stacks to predict ambient SO_2 (1-hour, 24-hour, and annual) concentrations. The model was applied with the same nested receptor grid that was used for the CALPUFF model and for five years of meteorological data from Edmonton Namao Airport. The meteorological data are available from AENV for air quality assessment purposes, and the model was run separately for each of the five years.

The maximum predicted SO_2 concentrations within the plant Property line (PPL), along the PPL, and outside the PPL are provided in Table 2E-2. The maximum (213 ug/m^3) and 9th highest (152 ug/m^3) predicted 1-hour average SO_2 concentrations are less than the 531.5 ug/m^3 inferred from the SCREEN3 assessment. This is because the ISCST3 model accounts for temporal and spatial variations that were not accounted for in the SCREEN3 assessment. The maximum predicted values are less than the respective AAAQO for the different averaging periods shown.

Table 2E-1 Maximum Predicted SO_2 and NO_x Concentrations due to Project Sources Based on the SCREEN3 Model

Stack	Description	SO_2 (ug/m^3)	NO_X (ug/m^3)	Distance (m)	PG Class	Wind speed (m/s)
1	DRU-1 Heater	0.55	5.66	881	A	1.0
2	DCU 1- Coker Heater 1	0.66	14.14	780	A	1.0
3	DCU 1- Coker Heater 2	0.66	14.14	780	A	1.0
4	NHT Heater 1	0.25	1.48	324	A	1.5
5	DHT Heater 1	0.14	1.90	336	A	2.5
6	DHT Heater 2	0.14	1.90	336	A	3.5
7	Hydrogen Plant	0.094	8.06	951	A	1.5
9	Utility Boiler 1	0.58	5.71	843	A	1.0
10	Utility Boiler 2	0.58	5.71	843	A	1.0
11	Tail Gas Incinerator 1 (UP1)	107.6	4.12	955	A	1.5
17	DRU-2 Heater	0.57	5.73	914	A	1.0
18	DRU-3 Heater	0.49	4.87	772	A	1.0
19	DCU 2 – Coker Heater 1	0.32	7.02	1031	A	1.0
20	DCU-2 – Coker Heater 2	0.32	7.02	1031	A	1.0
21	NHT Heater 2	0.24	1.58	330	A	1.5
22	GO HT/HK Heater 1	0.12	1.52	358	A	2.5
23	GO HT/HK Heater 2	0.12	1.52	358	A	2.5
24	VGO HT/HK Heater 1	0.15	1.51	353	A	2.0
25	VGO HT/HK Heater 2	0.15	1.51	353	A	2.0
26	Vacuum Heater	0.59	5.76	816	A	1.0
28	Utility Boiler 1	0.58	5.81	843	A	1.0
29	Utility Boiler 2	0.58	5.81	843	A	1.0
30	Utility Boiler 3	0.58	5.81	843	A	1.0
33	Tail Gas Incinerator 2 (UP2)	107.6	4.12	955	A	1.5
34	Tail Gas Incinerator 3 (UP3)	107.6	4.12	955	A	1.5
47	TGTU Thermal Oxidizer (GAS1)	100.1	2.94	836	A	1.0
65	TGTU Thermal Oxidizer (GAS2)	100.1	2.94	836	A	1.0
Total		**531.5**	**132.4**	**-**	**-**	**-**
AAAQO		**450**	**400**	**-**	**-**	**-**

Note:
The SO_2 predictions due to the incinerator stacks are based on 99.5% sulphur recovery efficiency.
Assuming 100% NO to NO_2 conversion, the predicted total NO_x concentration can be compared to the NO_2 AAAQO. See Appendix 2D for how the models can account for the NO to NO_2 conversion.

Table 2E-2 Maximum Predicted SO_2 Concentrations due to Project Sources Based on the ISCST3 Model

SO_2 Emission Rate (t/d)	Average Period	SO_2 Concentrations (ug/m^3)			AAAQO (ug/m^3)
		Inside PPL	PPL	Outside PPL	
0.748 t/h (17.96 t/d)	One hour (1st)	121.5	127.6	212.8	-
	One hour (9th)	96.4	90.2	152.4	450
17.96 t/d	24-hour	27.4	24.0	29.9	150
7.18 t/d	Annual	0.61	0.62	1.90	30

Note:
PPL = Project Property Line

2E1.3 Sensitivity to SO_2 Emission rates

As the SO_2 emission rates depend on the SRU/TGTU sulphur recovery efficiencies, the maximum predicted SO_2 concentrations (based on the CALMET/CALPUFF model system) for eleven SO_2 emission cases are provided for 1-hour, 24-hour and annual average periods. The SO_2 emissions rates (Figure 2E-1) and the predicted SO_2 concentrations for the eleven cases are given in Table 2E-3. The results indicate:

- If all five SRU/TGTU units are operating simultaneously at the 99.8% sulphur recovery (case A), then the maximum 1-hour SO_2 concentration is about 50% of the 1-hour AAAQO; the maximum 24-hour SO_2 concentration is about 40% of the 24-hour AAAQO; and the maximum annual SO_2 concentration is about 7% of the annual AAAQO.
- If one Upgrader (UP1) SRU/TGTU unit and one Gasifier (GAS1) SRU/TGTU unit are operating at 99.5% sulphur recovery, and the remaining SRU/TGTU units are operating at 99.8% (Case E), then the maximum 1-hour SO_2 concentration is about 82% of the1-hour AAAQO; the maximum 24-hour SO_2 concentration is about 69% of the 24-hour AAAQO; and the maximum annual SO_2 concentration is about 10% of the annual AAAQO.
- If all SRU/TGTU units are operating simultaneously at the 99.5% sulphur recovery, (Case H), then the maximum 1-hour SO_2 concentration and the maximum 24-hour SO_2 concentration are predicted to exceed the respective AAAQOs; and the maximum annual SO_2 concentration is about 16% of the annual AAAQO.
- Two hypothetical SO_2 emission rate cases based on meeting the EUB sulphur recovery guideline (Cases I and J) are shown. In these cases, the 1-hour and 24-hour AAAQOs are predicted to be exceeded by a factor of about three.

The Project SO_2 emissions are typically expected to be represented by the Case A scenario. As one moves down the table towards Case J, the SO_2 emission rate and the associated SO_2 concentration predictions become more improbable.

As the SO_2 emission rate depends on the SRU/TGTU sulphur recovery efficiency, the following SO_2 emission rates were selected to provide an indication of the Project impact on ambient air quality:

- For the purposes of estimating annual average SO_2 concentrations and PAI deposition, the annual average SO_2 emission rate is based on the 99.8 % sulphur recovery assumption. The corresponding SO_2 emission rate from the five SRU/TGTU facilities operating at this rate is 7.18 t/d.

- For the purposes of estimating 24-hour and 1-hour average SO_2 concentrations, the 24-hour and 1-hour average SO_2 emission rates are based on the 99.5 % sulphur recovery assumption. The corresponding SO_2 emission rate from the five SRU/TGTU facilities operating at this rate is 17.96 t/d. This is viewed as conservative (i.e., overstating the SO_2 emissions) as it is unlikely that all SRU/TGTU complexes will simultaneously be operating as low as 99.5 %.

2E1.4 Continuous Sources (CALPUFF)

The CALMET/CALPUFF model system was applied to predict ambient SO_2 (1-hour, 24-hour and annual), NO_2 (1-hour, 24-hour and annual), $PM_{2.5}$ (24-hour), CO (1-hour and 8-hour) and Total VOC (1-hour, 24-hour and annual) concentrations; and annual PAI deposition due to the Project. The maximum predicted concentrations within the Project property (PPL), along the PPL, and outside the PPL are provided in Table 2E-4. The AAAQO are not applicable within the plant fence line since this region is where access is controlled and the occupational health and safety criteria are applicable.

The maximum 1-hour average SO_2 concentrations predicted by the CALPUFF model outside the PPL are virtually identical to that predicted by the SCREEN3 model, but are larger than those predicted by ISCST3 model.

Corresponding concentration and deposition contours for the identified substances and averaging periods are presented in Figures 2E-2 to 2E-11. The figures represent a 50 km by 50 km area centered on the Project. The predictions in the tables and the figures assume the Project operates in isolation with no contributions from other sources.

The distances to where the predicted ambient concentrations are 10% of the AAAQO is sometimes used to define an air quality study area (AENV, 2003a). The largest distances to 10% AAAQO concentrations associated with the Project are due to SO_2 emissions, and this maximum distance is 18 km. The application of this distance indicates a need for a minimum study area of 36 km by 36 km. The selected study area of 50 km by 50 km is more than sufficient to cover this minimum area.

In summary, all maximum concentrations are predicted to occur near the plant, and specifically inside the PPL area. The high PAI deposition values are also predicted to occur in the plant development area; the high PAI values are due to wet deposition.

Table 2E-3 Sensitivity of predicted SO_2 concentrations (ug/m^3) to various SO_2 emission rates.

Case	**SO_2 Emission Rate (t/d)**						**Predicted SO_2 Concentration (ug/m^3)**						**Comment**
	UP1	**UP2**	**UP3**	**GAS1**	**GAS2**	**Sum**	**1-hour (9th)**		**24-hour**		**Annual**		
							PPL	**Outside PPL**	**PPL**	**Outside PPL**	**PPL**	**Outside PPL**	
A	1.89	1.89	1.89	0.76	0.76	7.18	229	224	61	60	2.0	2.0	Annual Project Case = 99.8%
B	1.89	1.89	1.89	1.91	0.76	8.34	319	297	87	85	2.4	2.4	1 Gas=99.5%, others =99.8%
C	1.89	1.89	1.89	2.67	0.76	9.10	394	374	104	101	2.86	2.86	1 Gas=99.5%*1.4, others = 99.8%
D	4.72	1.89	1.89	0.76	0.76	10.02	366	354	77	72	2.74	2.72	1 SRU=99.5%, others = 99.8%
E	4.72	1.89	1.89	1.91	0.76	11.17	374	369	105	103	3.04	3.01	1 SRU & 1 Gas=99.5%, others = 99.8%
F	6.60	1.89	1.89	0.76	0.76	11.90	**467**	440	96	80	3.22	3.20	1 SRU =99.5%*1.4, others = 99.8%
G	6.60	1.89	1.89	2.67	0.76	13.81	**475**	444	125	121	3.74	3.70	1 SRU & 1 Gas =99.5%*1.4, others=99.8%
H	4.72	4.72	4.72	1.91	1.91	17.98	**559**	**548**	**152**	**150**	4.81	4.80	1-hour and 24-hour Project Case=99.5%
I	11.42	11.42	11.42	4.61	4.61	43.48	**1341**	**1314**	**367**	**360**	11.4	11.4	EUB 2003, Everything = 98.79% (long term)
J	14.25	14.25	14.25	5.75	5.75	54.25	**1674**	**1640**	**458**	**450**	14.24	14.2	EUB 2003, Everything = 98.49% (Quarterly)
AAAQO							450		150		30		

Note:

- Case A where all SRU/TGTU complexes are operating at 99.8% is used to represent the Project when calculating annual average SO_2 concentrations.
- CaseH where all SRU/TGTU complexes are operating at 99.5% is used to represent the Project when calculating 1-hour and 24-hour average SO_2 concentrations and depositions.
- Predicted SO_2 concentrations that are provided are bias high (~10%) as chemical conversion and deposition were not considered for the sensitivity runs.

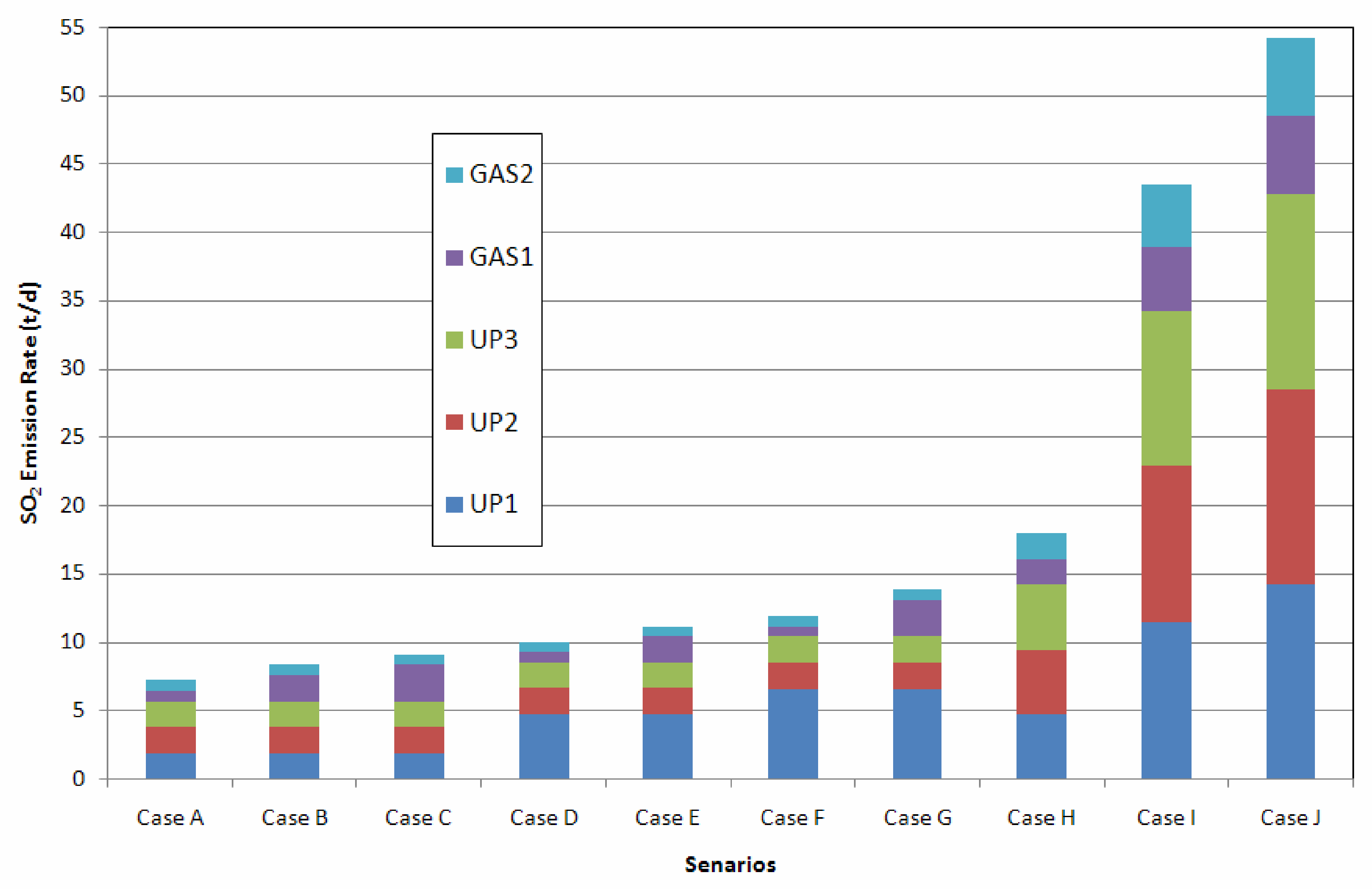


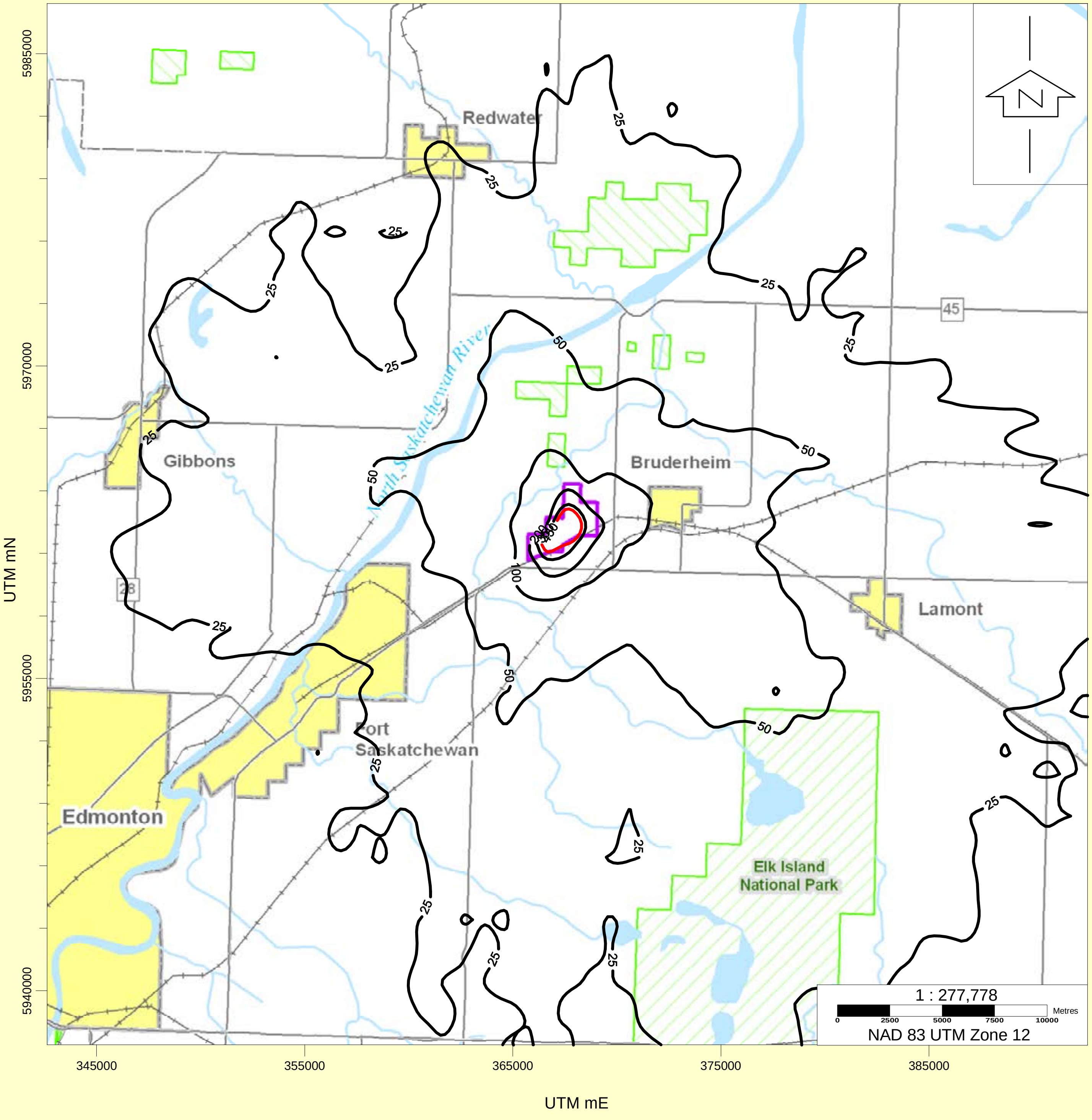
Figure 2E-1 Sensitivity of SO_2 Emission Rates to SRU/TGTU sulphur recovery assumptions. A description of the cases is presented in Table 2E-3.

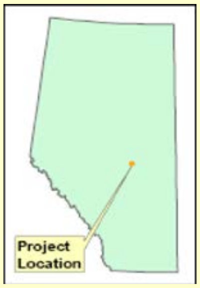
Table 2E-4 Maximum Predicted SO_2, NO_2, $PM_{2.5}$, CO, and Total VOC Concentrations; and PAI Deposition Associated with the North American Upgrader Sources (CALPUFF).

Substance	**Averaging Period**	**SO_2 Emission Rate**	**Maximum Concentration (ug/m^3)**			**AAAQO or CWS (ug/m^3)**
			Inside PPL Areas	**PPL Area**	**Outside PPL area**	
SO_2	One-hour (9th)	0.748 t/h (17.96 t/d)	**876**	**543**	**533**	450
	24-hour	17.96 t/d	**235**	145	142	150
	Annual	7.18 t/d	2.00	1.98	1.97	30
NO_2	One-hour (9th)	-	**585**	168	159	400
	24-hour	-	**325**	111	110	200
	Annual	-	18.1	3.1	2.9	60
$PM_{2.5}$	24-hour (98th percentile)	-	43.6	10.7	10.1	30
	Annual	-	16.6	1.9	1.7	NA
CO	One-hour (9th)	-	1567	320	314	15000
	8-hour	-	885	296	266	6000
Total VOC	One-hour (9th)	-	393	80	80	NA
	24-hour	-	180	60.1	58.0	NA
	Annual	-	1.7	0.31	0.29	NA

SO_2 and NO_x emissions	**Averaging Period**	**SO_2 Emission Rate**	**Maximum PAI Deposition (keq H$^+$/ha/a)**			
			Inside PPL Areas	**PPL Areas**	**Outside PPL Areas**	
PAI	Annual	7.18 t/d	0.374	0.155	0.148	NA

Note: The 1-hour and 24-hour SO_2 concentration predictions are based on the 99.5% quarterly sulphur recovery rate. The annual SO_2 concentration and the annual PAI deposition predictions are based on the 99.8% annual sulphur recovery rate (based on total 1796 t/d sulphur inlet).





Legend

🟪 Project Property Line

🟨 Community/Town

🟩 Natural Area

AAAQO: 450 ug/m³

Title:

1-HOUR SO_2 CONCENTRATION
(SO_2 = 17.98 t/d)
(PROJECT ONLY CASE)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved:	Revision Date:
MD	05/10/2007

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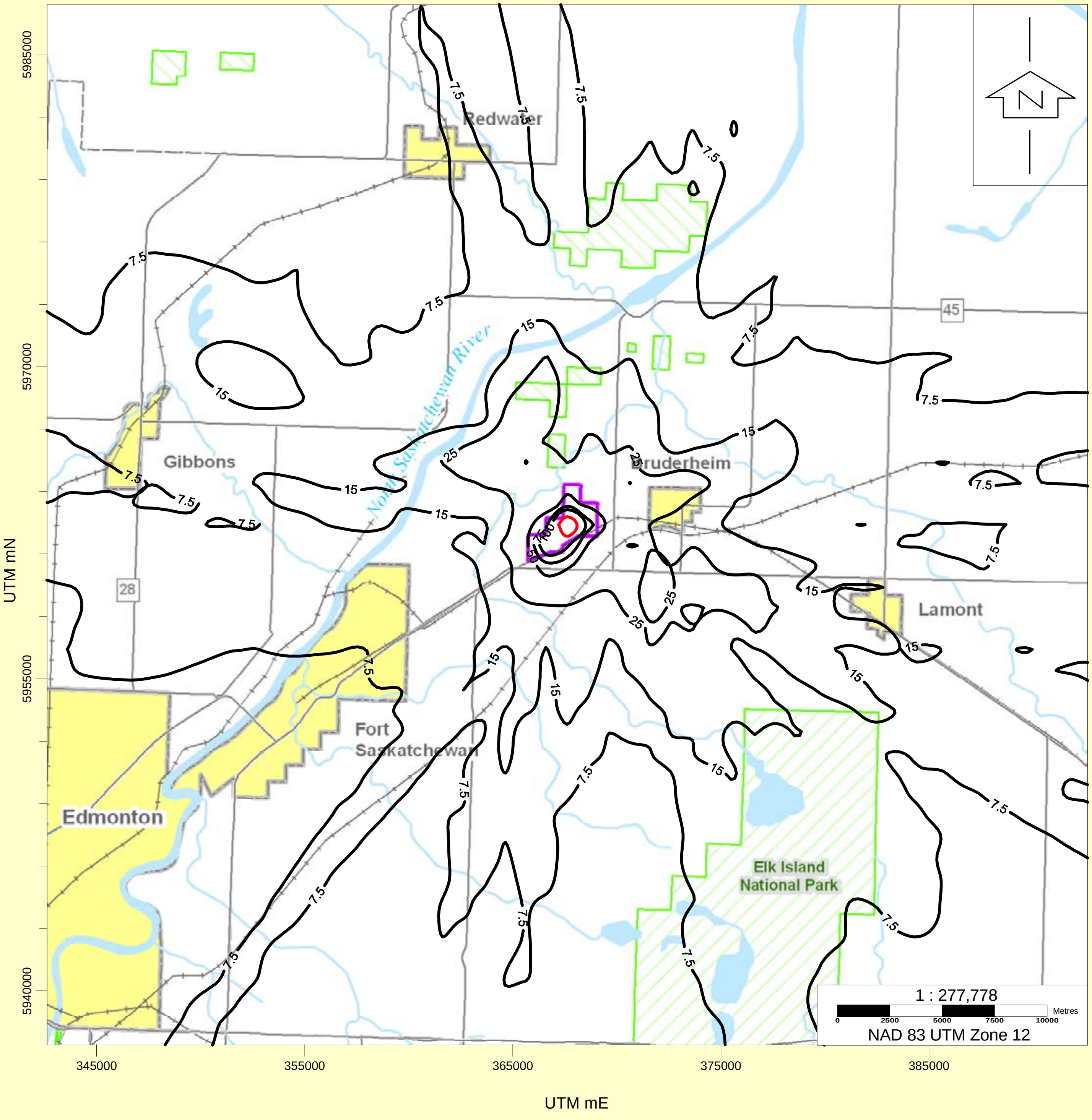

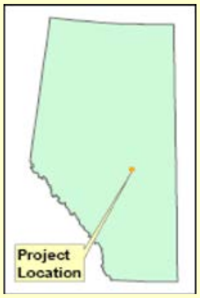

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▭ Project Property Line

▨ Community/Town

▭ Natural Area

AAAQO: 150 ug/m³

Title:

24-HOUR SO_2 CONCENTRATION
(SO_2 = 17.98 t/d)
(PROJECT ONLY CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

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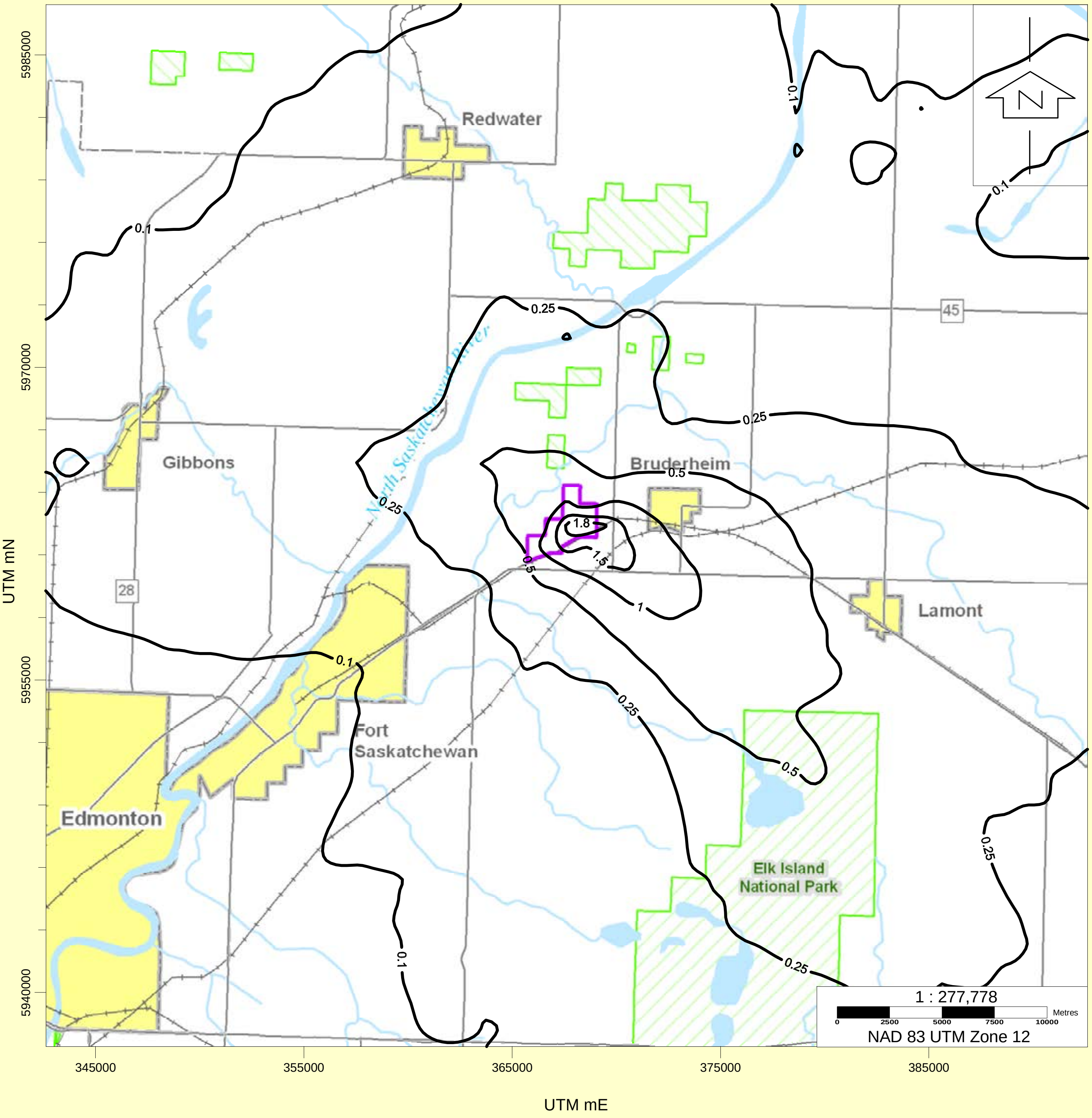

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🟪 Project Property Line

🟨 Community/Town 🟩 Natural Area

AAAQO: 30 ug/m^3

Title:

ANNUAL SO_2 CONCENTRATION
(SO_2 = 7.18 t/d)
(PROJECT ONLY CASE)

NORTH AMERICAN
OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

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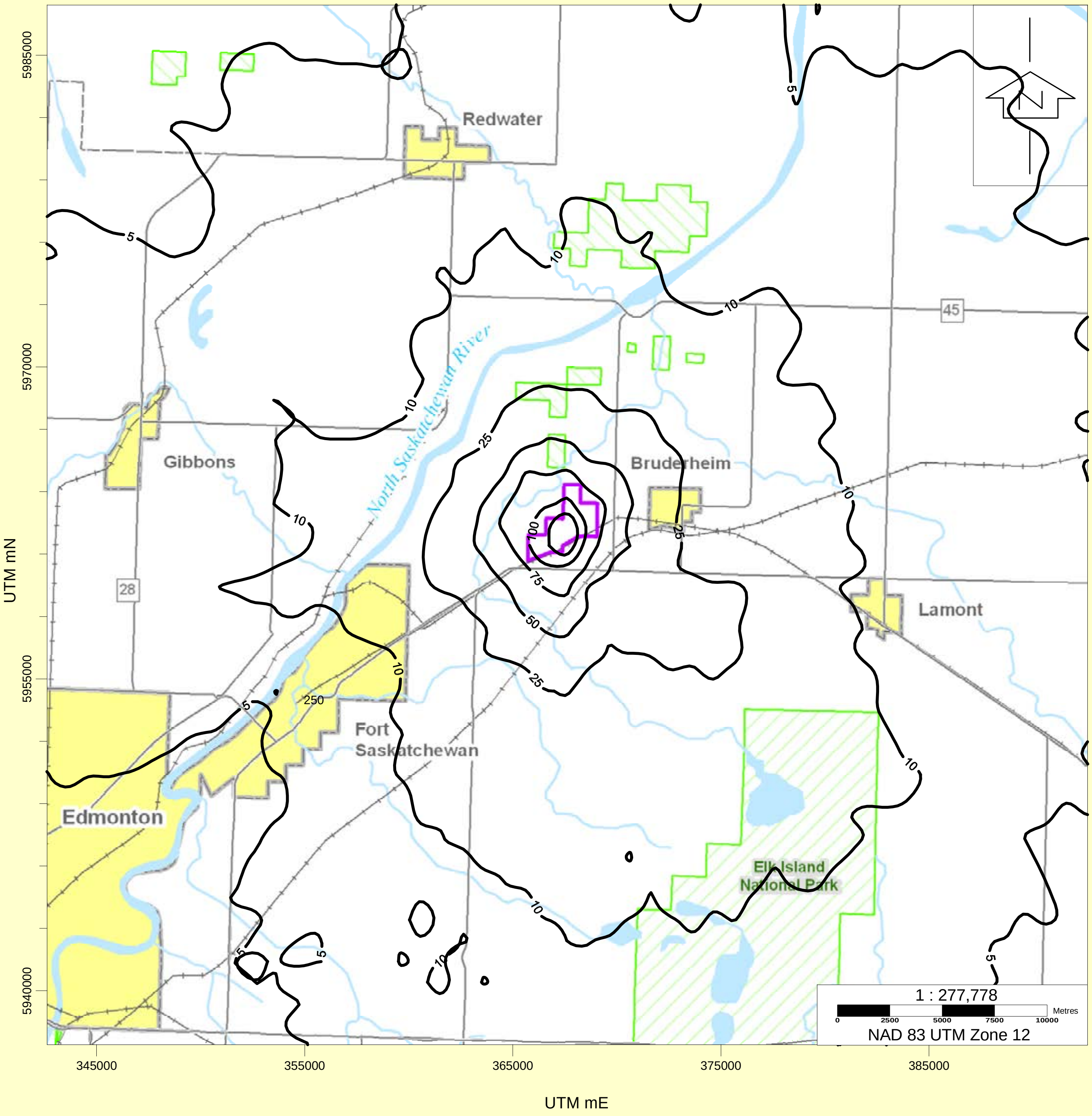

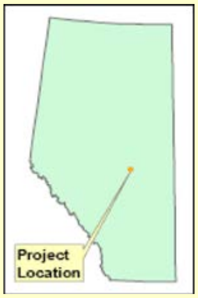

Legend

▭ Project Property Line

🟨 Community/Town

▭ Natural Area

AAAQO: 400 ug/m³

Title:

1-HOUR NO$_2$ CONCENTRATION (PROJECT ONLY CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

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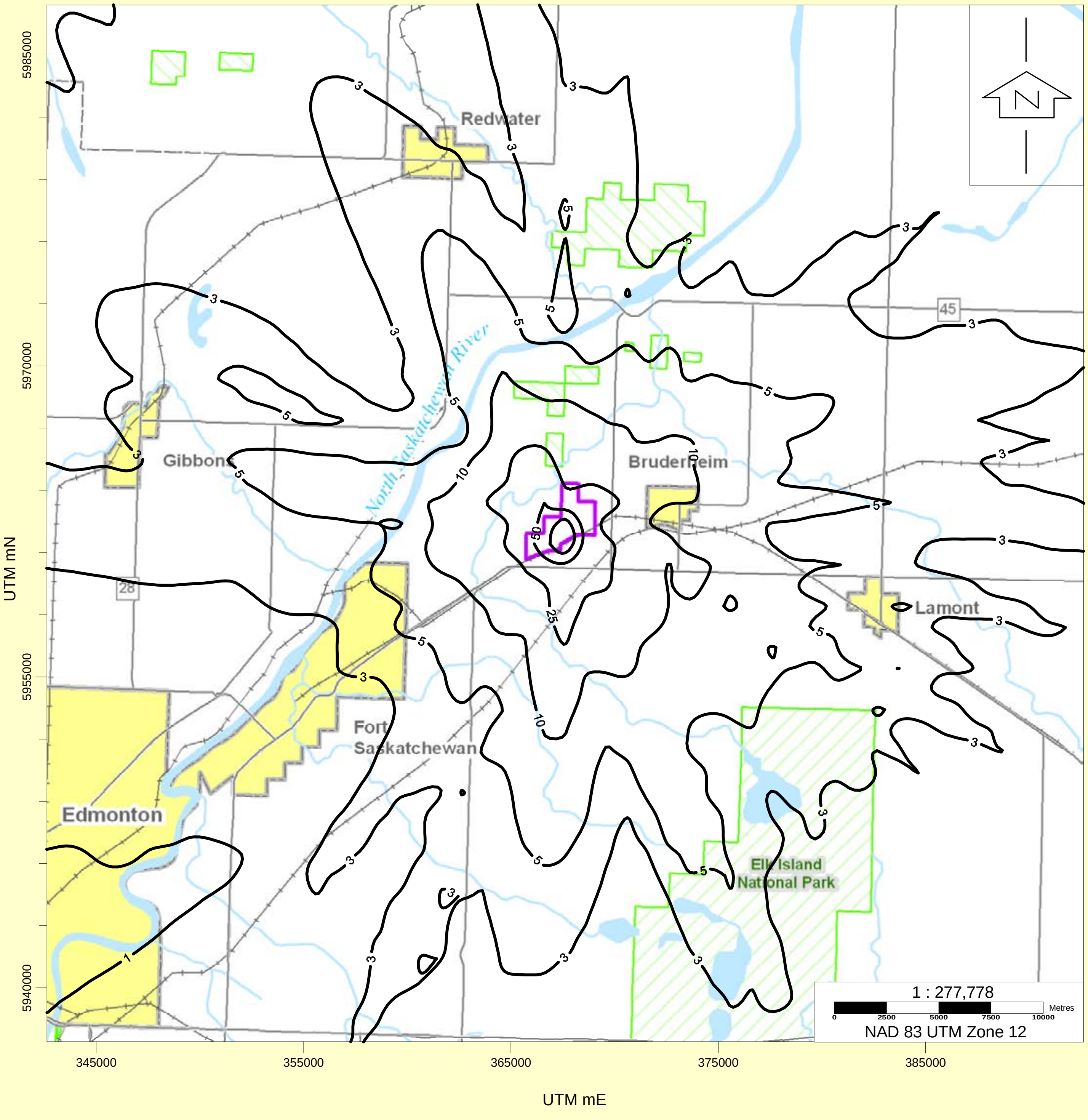

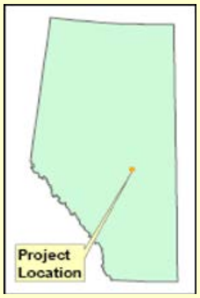

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▭ Project Property Line

🟨 Community/Town

▭ Natural Area

AAAQO: 200 ug/m³

Title:

24-HOUR NO$_2$ CONCENTRATION (PROJECT ONLY CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved:	Revision Date:
MD	05/10/2007

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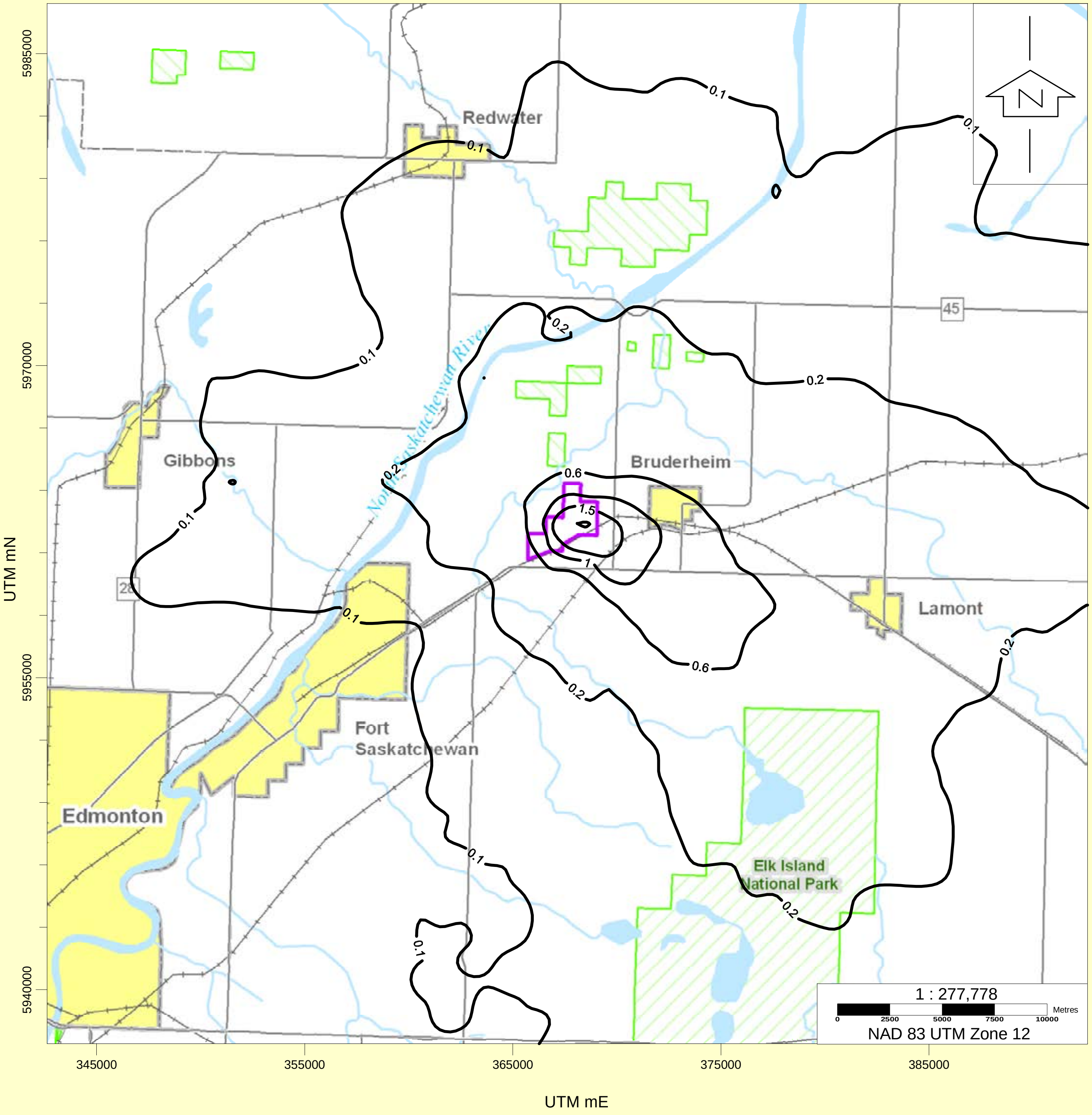

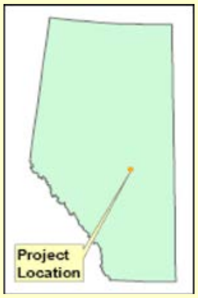

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Project Property Line

Community/Town

Natural Area

AAAQO: 60 ug/m^3

Title:

ANNUAL NO$_2$ CONCENTRATION (PROJECT ONLY CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

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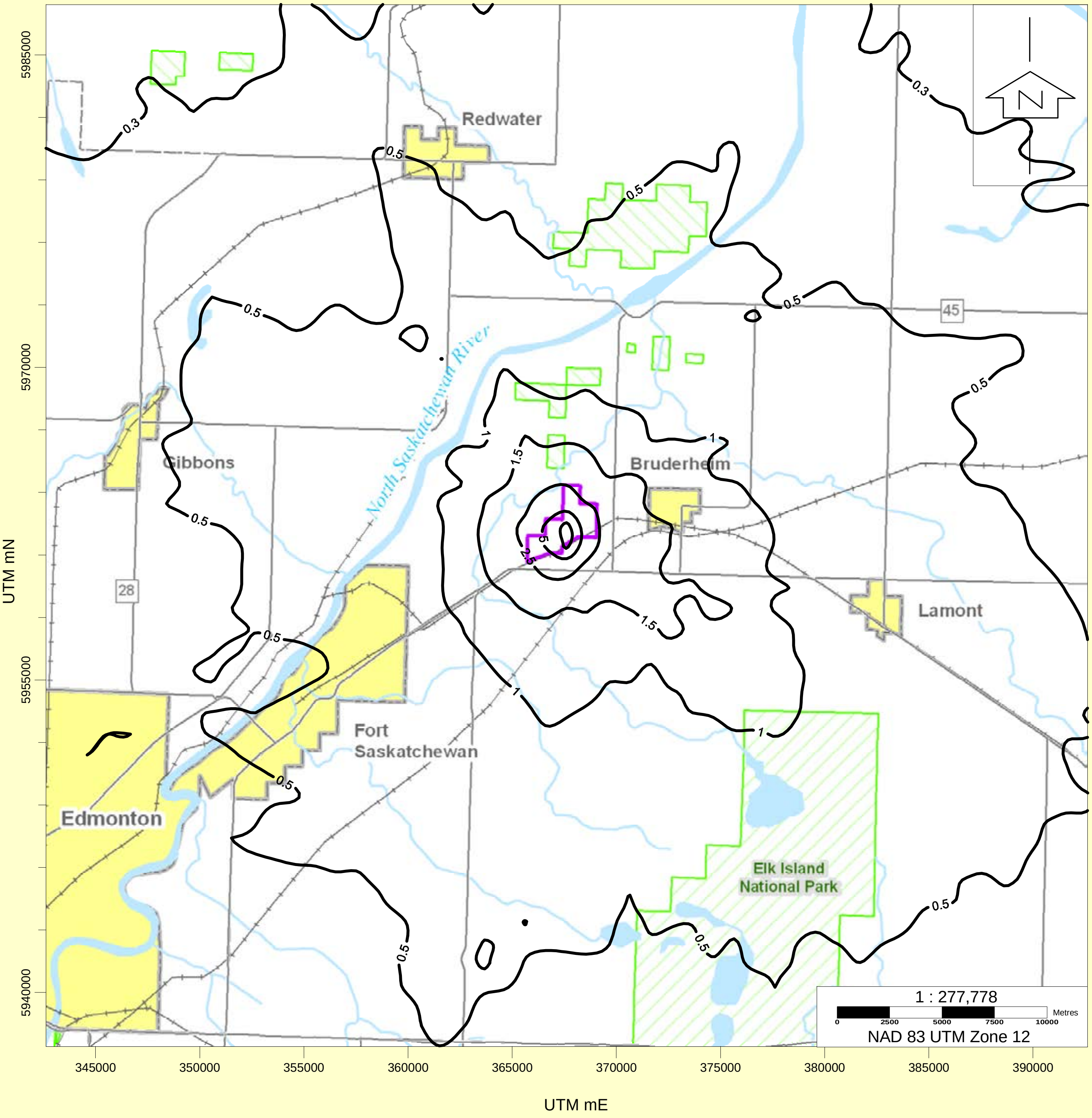

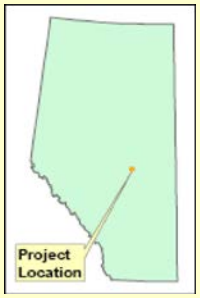

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▭	Project Property Line
▭	Community/Town
▭	Natural Area

CWS: 30 ug/m³

Title:

24-HOUR PM$_{2.5}$ CONCENTRATION (PROJECT ONLY CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

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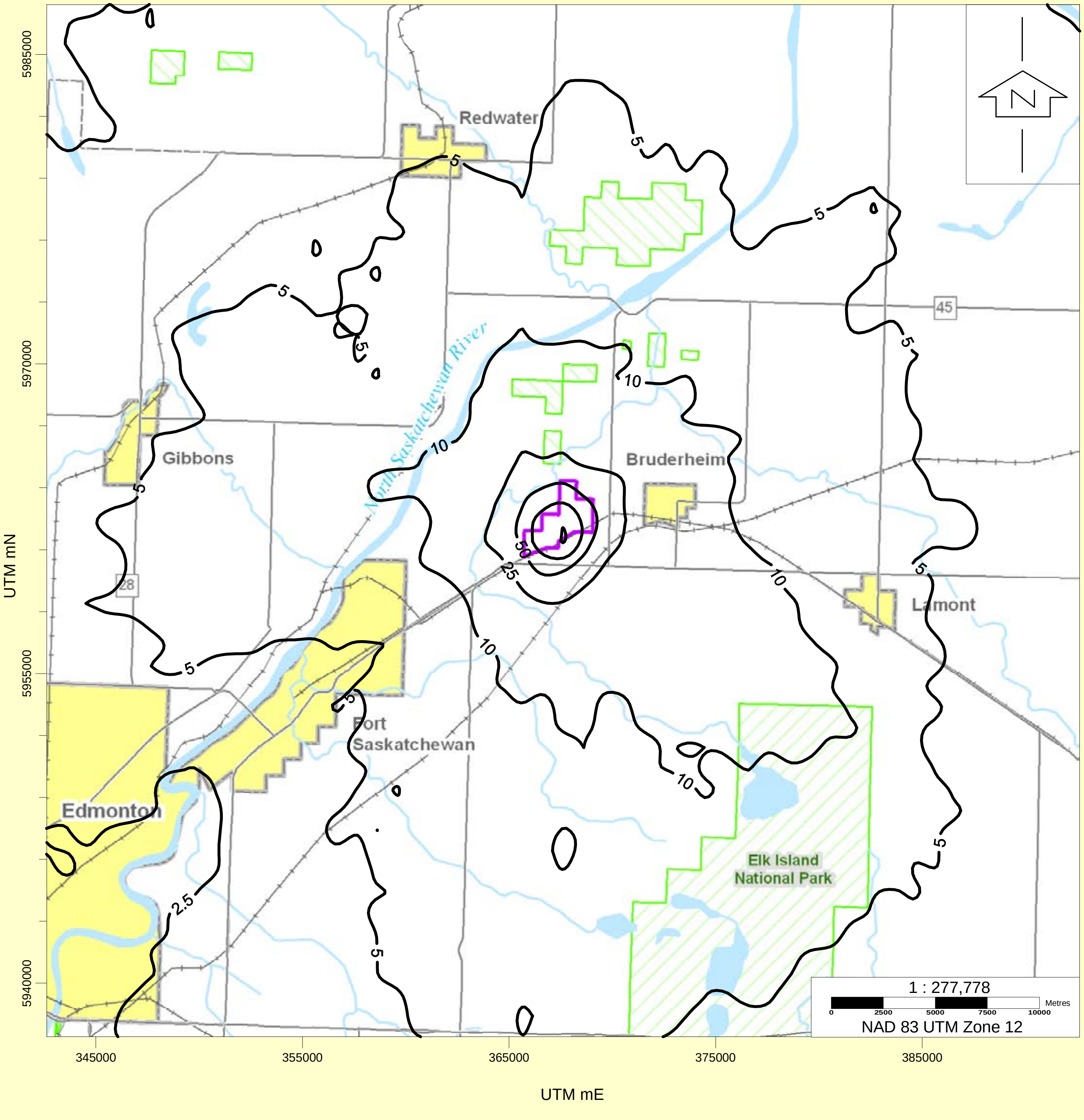

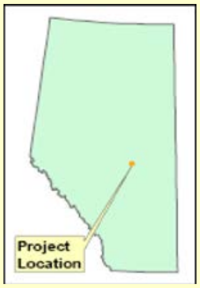

Legend

▭ Project Property Line

▨ Community/Town

▭ Natural Area

AAAQO: 15000 ug/m³

Title:

1-HOUR CO CONCENTRATION (PROJECT ONLY CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007

File:
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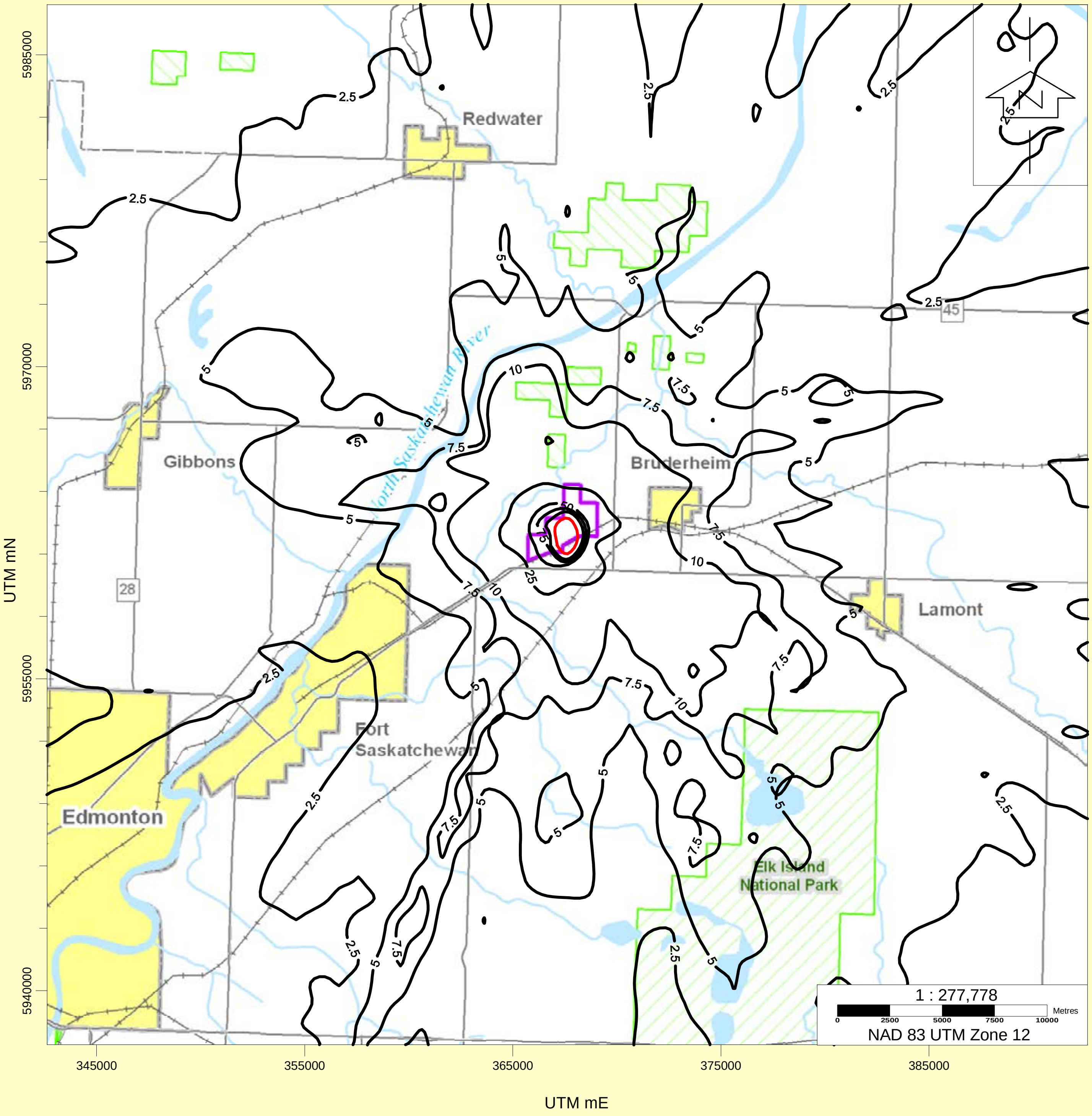
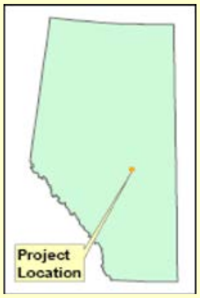
Drawn by:	Checked:	Fig. No.:
HZ	MD	**2E-9**





Legend

🟪 Project Property Line

🟨 Community/Town

🟩 Natural Area

AAAQO: 6000 ug/m³

Title:

8-HOUR CO CONCENTRATION (PROJECT ONLY CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD

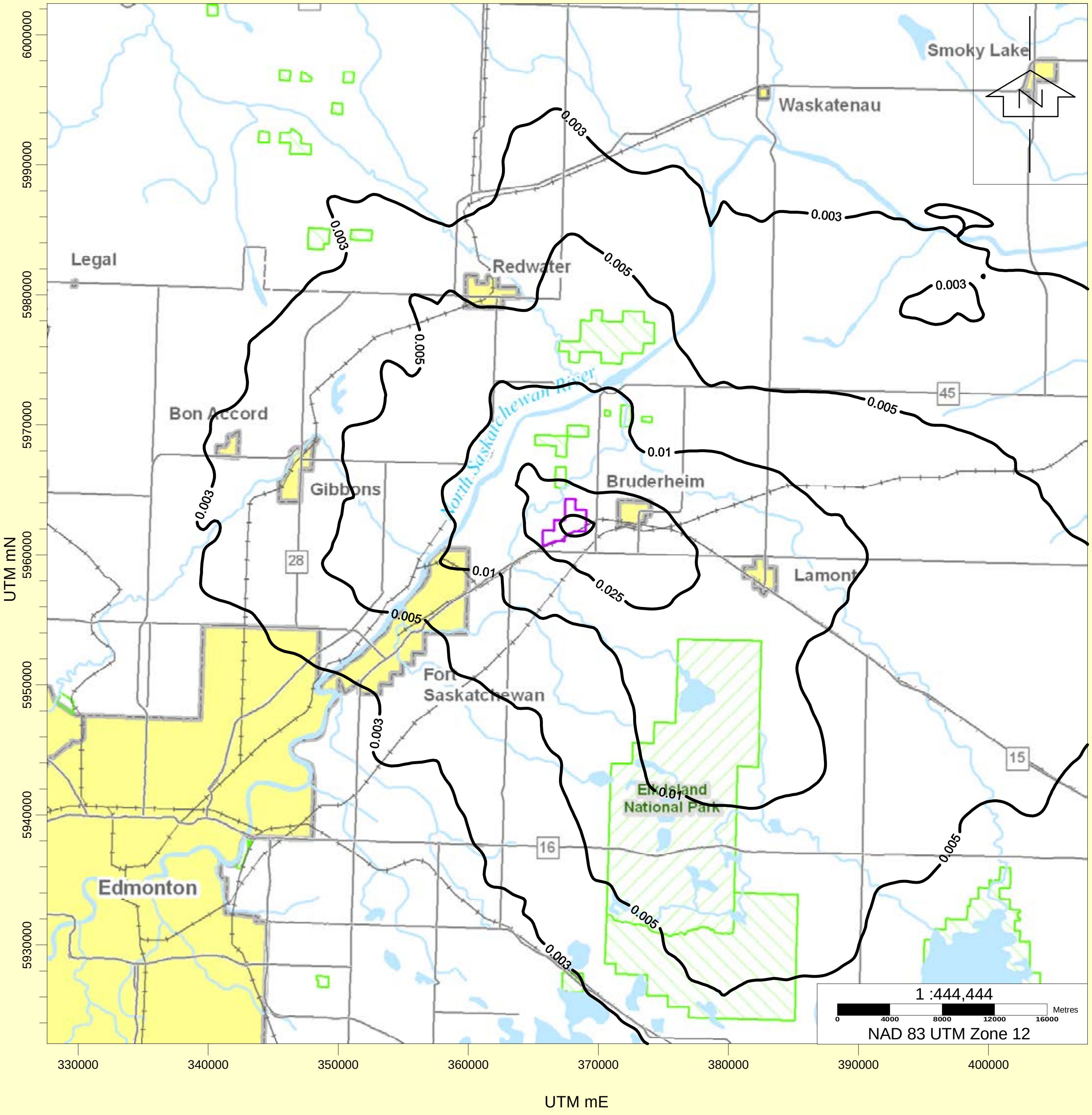
Revision Date: 05/10/2007

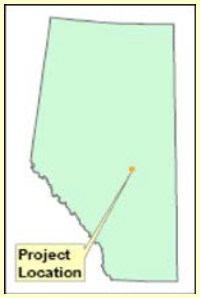
File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897 CALPUFF /CALPUFF/Case3/Total_receptors/CO_8h.srf

Drawn by: HZ

Checked: MD

Fig. No.: **2E-10**





Legend

▭ Project Property Line

▨ Community/Town ▭ Natural Area

Title:

PAI Deposition
(keq H⁺ /ha/y)
(PROJECT ONLY CASE)

NORTH AMERICAN OIL SANDS CORPORATION

Approved: MD	Revision Date: 05/10/2007
File: H:/AQ/Shared/1018897 NAOSC Matrix/N8897 CALPUFF /CALPUFF/Case3/Total_receptors/PAI_a.srf	

Drawn by:	Checked:	Fig. No.:
HZ	MD	**2E-11**

2E1.5 Upset/Emergency Flare Sources (SCREEN3 and CALPUFF)

Abnormally high SO_2 emissions may periodically occur with upset or emergency situations, and emissions associated with these scenarios are discussed in Appendix 2A. The upset scenarios in Appendix 2A assume the following: the maximum available supplemental natural gas flow rate is 1120 x 10^3 m^3/d; the minimum heat content of the gas streams to the flares is 12 MJ/m^3; the initial stack height estimates are those provided in Appendix 2A; the flaring durations are those indicated in Appendix 2A; and the simultaneous occurrence of the intermittent flaring event and the worst case meteorological conditions will occur.

For flaring durations less than one hour, the SO_2 emission rates were adjusted to reflect a 1-hour averaging period in accordance with Alberta Environment guidance (2003b). For flaring events of 1-hour or less in duration, the CALPUFF model was applied on such a manner that consecutive hours were not allowed to overlap. For flaring events that were greater than 1-hour in duration, puffs from adjacent hours were allowed to overlap. The CALPUFF 99.9th percentile values are compared to the AAAQO, based on AENV model guidance.

The SCREEN3 and CALPUFF models were applied to 14 upset/emergency flaring scenarios to predict ambient 1-hour average SO_2 concentrations. Table 2E-5 compares the maximum concentrations predicted using the CALPUFF and SCREEN3 models. The shaded rows indicate the expected duration of the flaring period. Both models indicate the benefit of reducing the flaring period to reduce the ambient 1-hour average SO_2 concentrations. CALPUFF is predicting maximum values that are higher (i.e., 85% to 2016%) than the SCREEN3 values. The CALPUFF 99.9th percentile values are less than the SCREEN3 predictions in some cases; and larger than the SCREEN3 predictions in other cases.

The predicted exceedances of the AAAQO are shown in the table as **red bold-face text**. Ambient 1-hour average SO_2 concentrations are predicted to exceed the AAAQO for two flaring scenarios:

- Scenario 4: Flare 14, Blower Failure, Once/ 2 years; Duration: 20 minutes.
- Scenario 9: Flare 36, Blower Failure, Once/ 2 years, Duration: 20 minutes.

Flare 14 is the PH1 Hydrocarbon Flare, and Flare 36 is the Hydrocarbon Flare stack. Both these flaring events are associated with the disposal of a gas stream with a H_2S concentration of 46 percent and a H_2O concentration of 52 percent. Natural gas was assumed to be added to bring the heating value of the combined gas streams to 24.9 MJ/m^3. The SO_2 emission rate for the 20 minute duration is 842 t/d; for an equivalent one-hour period, the average SO_2 emission rate is 281 t/d. The SO_2 concentrations are predicted to be less than the AAAQO if the flaring duration is reduced to 5 minutes. These predictions assume the simultaneous occurrence of the flaring event with poor dispersion conditions.

Table 2E-5 Maximum Predicted SO_2 Concentrations Associated with the Regulatory Phase H_2S Emergency Flaring based on the SCREEN3 and CALPUFF models.

Scenario 1: Flare 12; Power Failure/Startup; Once/2 years; Duration: 1 day; SO_2 = 98 t/d

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m³)		
10^3 m³/d	10^3 m³/d	MJ/m³	(min)	SCREEN3	CALPUFF	
					Max	99.9th
96.8	1120	32.46	24 hours	205	**559**	111
96.8	1120	32.46	60	205	**559**	98.8
96.8	1120	32.46	30	102.5	279.5	49.4
96.8	1120	32.46	15	51.3	139.8	24.7
96.8	1120	32.46	10	34.2	93.2	16.5
96.8	1120	32.46	5	17.1	46.6	8.2

Scenario 2: Flare 13; VRU Failure; Once/2 years; Duration: 15 minutes; SO_2 = 23 t/d (5.7 t/d as a 1-h average)

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m³)		
10^3 m³/d	10^3 m³/d	MJ/m³	(min)	SCREEN3	CALPUFF	
					Max	99.9th
293	1120	46.36	60	30.5	88.4	19
293	1120	46.36	30	15.3	44.2	9.5
293	1120	46.36	15	7.6	22.1	4.8
293	1120	46.36	10	5.1	14.7	3.2
293	1120	46.36	5	2.5	7.4	1.6

Scenario 3: Flare 14; Power Failure; Once/5 years; Duration: 20 minutes; SO_2= 1848 t/d (616 t/d as a 1-h average)

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m³)		
10^3 m³/d	10^3 m³/d	MJ/m³	(min)	SCREEN3	CALPUFF	
					Max	99.9th
16537	1120	55.2	60	123	**1994**	342
16537	1120	55.2	30	62	**997**	171
16537	1120	55.2	20	41	**665**	114
16537	1120	55.2	15	31	**499**	86
16537	1120	55.2	10	21	332	57
16537	1120	55.2	5	10	166	29

Scenario 4: Flare 14; Blower Failure; Once/2 years; Duration: 20 minutes; SO_2 = 842 t/d (281 t/d as 1-h average)

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m³)		
					CALPUFF	
10³ m³/d	10³ m³/d	MJ/m³	(min)	SCREEN3	Max	99.9th
685.8	1120	24.9	60	**1520**	**7505**	**3785**
685.8	1120	24.9	30	**760**	**3753**	**1893**
685.8	1120	24.9	20	**507**	**2502**	**1262**
685.8	1120	24.9	15	380	**1876**	**946**
685.8	1120	24.9	10	253	**1251**	**631**
685.8	1120	24.9	5	127	**625**	315

Scenario 5: Flare 31; Power Failure/Startup; Once/2 years; Duration: 1 day; SO_2 = 98 t/d

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m³)		
					CALPUFF	
10³ m³/d	10³ m³/d	MJ/m³	(min)	SCREEN3	Max	99.9th
96.8	1120	32.5	24 hours	205	**556**	110
96.8	1120	32.5	60	205	**556**	98
96.8	1120	32.5	30	103	278	49
96.8	1120	32.5	15	51.3	139.0	24.5
96.8	1120	32.5	10	34.2	92.7	16.3
96.8	1120	32.5	5	17.1	46.3	8.2

Scenario 6: Flare 32; Power Failure/Startup; Once/ 2 years; Duration: 1 day; SO_2 = 98 t/d

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m³)		
					CALPUFF	
10³ m³/d	10³ m³/d	MJ/m³	(min)	SCREEN3	Max	99.9th
96.8	1120	32.5	24 hours	205	381	108
96.8	1120	32.5	60	205	381	101
96.8	1120	32.5	30	103	191	51
96.8	1120	32.5	15	51	95	25
96.8	1120	32.5	10	34	64	17
96.8	1120	32.5	5	17	32	8

Scenario 7: Flare 35; VRU Failure; Once/2 years; Duration: 15 minutes; SO_2 = 34 t/d (8.6 t/d as a 1-h average)

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m^3)		
10^3 m^3/d	10^3 m^3/d	MJ/m^3	(min)	SCREEN3	CALPUFF	
					Max	99.9th
440	1120	50.8	60	38.0	94.2	25.8
440	1120	50.8	30	19.0	47.1	12.9
440	1120	50.8	15	9.5	23.6	6.5
440	1120	50.8	10	6.3	15.7	4.3
440	1120	50.8	5	3.2	7.9	2.2

Scenario 8: Flare 36; Power Failure; Once/5 years; Duration: 20 minutes; SO_2 = 1268 t/d (423 t/d as a 1-h average)

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m^3)		
10^3 m^3/d	10^3 m^3/d	MJ/m^3	(min)	SCREEN3	CALPUFF	
					Max	99.9th
11886	1120	82.8	60	68.5	**1449**	99.6
11886	1120	82.8	30	34.2	**725**	49.8
11886	1120	82.8	20	22.8	**483**	33.2
11886	1120	82.8	15	17.1	362	24.9
11886	1120	82.8	10	11.4	242	16.6
11886	1120	82.8	5	5.7	121	8.3

Scenario 9: Flare 36; Blower Failure; Once/2 years; Duration: 20 minutes; SO_2 = 842 t/d (281 t/d as a 1-h average)

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m^3)		
10^3 m^3/d	10^3 m^3/d	MJ/m^3	(min)	SCREEN3	CALPUFF	
					Max	99.9th
685.82	1120	24.9	60	**1505**	**7878**	**3671**
685.82	1120	24.9	30	**753**	**3939**	**1836**
685.82	1120	24.9	20	**502**	**2626**	**1224**
685.82	1120	24.9	15	376	**1970**	**918**
685.82	1120	24.9	10	251	**1313**	**612**
685.82	1120	24.9	5	125	**657**	306

Scenario 10: Flare 37; Blocked Outlet; Once/25 years; Duration: 15 minutes; SO_2 = 9.8 t/d (2.4 t/d as a 1-h average)

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m³)		
10^3 m³/d	10^3 m³/d	MJ/m³	(min)	SCREEN3	CALPUFF	
					Max	99.9th
286.1	1120	28.3	60	20.6	78	31.8
286.1	1120	28.3	30	10.3	39.0	15.9
286.1	1120	28.3	15	5.2	19.5	8.0
286.1	1120	28.3	10	3.4	13.0	5.3
286.1	1120	28.3	5	1.7	6.5	2.7

Scenario 11: Flare 37; Startup, Once/2 years; Duration: 12 hours; SO_2 = 0.18 t/d

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m³)		
10^3 m³/d	10^3 m³/d	MJ/m³	(min)	SCREEN3	CALPUFF	
					Max	99.9th
69.9	1120	32.3	12 hours	0.4	2.2	0.9
69.9	1120	32.3	60	0.4	1.8	0.4
69.9	1120	32.3	30	0.20	0.90	0.20
69.9	1120	32.3	15	0.10	0.45	0.10
69.9	1120	32.3	10	0.07	0.30	0.07
69.9	1120	32.3	5	0.03	0.15	0.03

Scenario 12: Flare 48; Startup; Once/2 years; Duration: 24 hours; SO_2 = 42.2 t/d

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m³)		
10^3 m³/d	10^3 m³/d	MJ/m³	(min)	SCREEN3	CALPUFF	
					Max	99.9th
37.68	1120	33.2	24 hours	90.2	268.8	47.3
37.68	1120	33.2	60	90.2	268.8	41.1
37.68	1120	33.2	30	45.1	134.4	20.6
37.68	1120	33.2	15	22.6	67.2	10.3
37.68	1120	33.2	10	15.0	44.8	6.9
37.68	1120	33.2	5	7.5	22.4	3.4

Scenario 13:Flare 55; Emergency; Once/25 years; Duration: 15 minutes; SO_2 = 7.7 t/d

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m^3)		
10^3 m^3/d	10^3 m^3/d	MJ/m^3	(min)	SCREEN3	CALPUFF	
					Max	99.9th
255.5	1120	29.0	60	16.4	63.6	24.6
255.5	1120	29.0	30	8.2	31.8	12.3
255.5	1120	29.0	15	4.1	15.9	6.2
255.5	1120	29.0	10	2.7	10.6	4.1
255.5	1120	29.0	5	1.4	5.3	2.1

Scenario 14:Flare 55; Startup; Once/2 years; Duration: 12 hours; SO_2 = 0.18 t/d (0.045 t/d as a 1-h average)

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m^3)		
10^3 m^3/d	10^3 m^3/d	MJ/m^3	(min)	SCREEN3	CALPUFF	
					Max	99.9th
69.9	1120	32.29	12 hours	0.4	2.2	0.88
69.9	1120	32.29	60	0.4	1.8	0.75
69.9	1120	32.29	30	0.20	0.90	0.38
69.9	1120	32.29	15	0.10	0.45	0.19
69.9	1120	32.29	10	0.07	0.30	0.13
69.9	1120	32.29	5	0.03	0.15	0.06

Scenario 15:Flare 66; Emergency; Once/2 years; Duration: 24 hours; SO_2 = 42.2 t/d

Acid Gas Flow Rate	Natural Gas Flow Rate	Heat of Combustion	Flaring Duration	Predicted 1-hour SO_2 (ug/m^3)		
10^3 m^3/d	10^3 m^3/d	MJ/m^3	(min)	SCREEN3	CALPUFF	
					Max	99.9th
37.7	1120	33.2	24 hours	90.2	214.6	45.0
37.7	1120	33.2	60	90.2	214.6	43.9
37.7	1120	33.2	30	45.1	107.3	22.0
37.7	1120	33.2	15	22.6	53.7	11.0
37.7	1120	33.2	10	15.0	35.8	7.3
37.7	1120	33.2	5	7.5	17.9	3.7

2E2 Summary and Conclusions

The CALPUFF, SCREEN3 and ISCST3 models were applied to North American emissions to determine maximum concentrations that could be associated with the Project only case. Continuous and emergency flaring emissions are considered. The CALPUFF model tends to predict higher concentrations for continuous sources than the SCREEN3 and ISCST3 models. While the CALPUFF model was shown to predict higher values associated with the continuous sources, the same trend is not evident for the emergency flaring scenarios.

Model results indicate that there is a potential to exceed the 1-hour SO_2 AAAQO outside the PPL areas when low sulphur recovery efficiency are assumed. The other predicted concentrations are less than the applicable AAAQO or CWS.

The assessment indicated high SO_2 concentrations associated with two flaring scenarios. The SCREEN3 and CALPUFF models indicate that limiting the flaring duration would be a successful mitigation strategy. A more detailed mitigation strategy specific to the Project was not undertaken since it would have to be re-evaluated prior to operation based on more refined engineering information.

2E3 References/Literature Cited

AENV. 2003a. Air Quality Model Guideline. Publication Number T/689. Available from www.gov.ab.ca/env/air/airquality/airmodelling.html. pp 36.

AENV. 2003b. Emergency/Process Upset Flaring Management: Modelling Guidance. Publication Number T/690. Available from www.gov.ab.ca/env/air/airquality/airmodelling.html. pp. 6.

US EPA. 1995. SCREEN Model User's Guide. Document EPA-454/B-95-004. Office of Air Quality Planning and Standards. Emissions Monitoring and Analyses Division. Research Triangle Park, NC. 56 pp.

Appendix 3A The Assessment of Environmental Noise (General)

TABLE OF CONTENTS

3A1 Sound Pressure Level

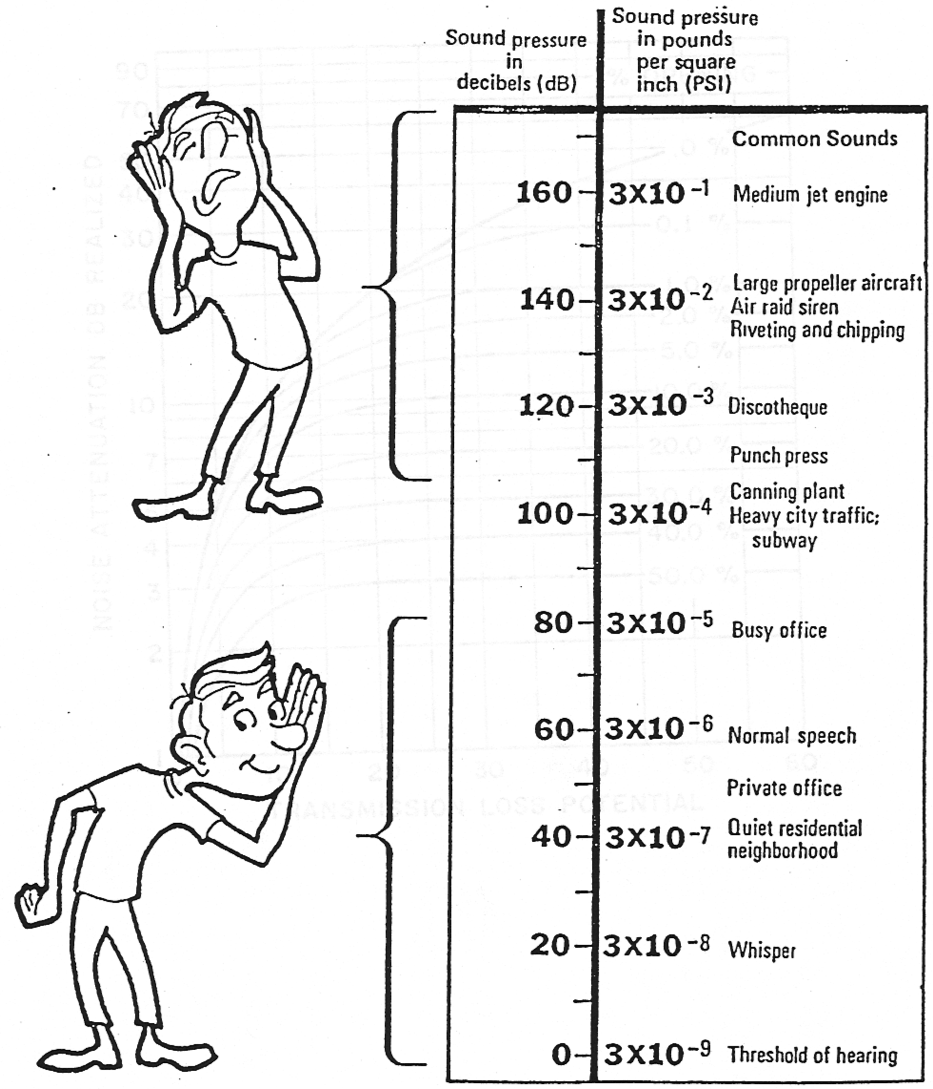
Sound pressure is initially measured in Pascals (Pa). Humans can hear several orders of magnitude in sound pressure levels, so a more convenient scale is used. This scale is known as the decibel (dB) scale, named after Alexander Graham Bell (telephone guy). It is a base 10 logarithmic scale. When we measure pressure, we typically measure the RMS sound pressure.

$$SPL = 10\log_{10}\left[\frac{P_{RMS}^{2}}{P_{ref}^{2}}\right] = 20\log_{10}\left[\frac{P_{RMS}}{P_{ref}}\right]$$

Where:
SPL = Sound Pressure Level in dB
P_{RMS} = Root Mean Square measured pressure (Pa)
P_{ref} = Reference sound pressure level ($P_{ref} = 2\text{x}10^{-5}$ Pa = 20 uPa)

This reference sound pressure level is an internationally agreed-upon value. This value represents the threshold of human hearing for “typical” people based on numerous tests. It is possible to have a threshold which is lower than 20 uPa which will result in negative dB levels. As such, zero dB does not mean there is no sound!

In general, a difference of 1–2 dB is the threshold for humans to notice that there has been a change in sound level. A difference of 3 dB (factor of 2 in acoustical energy) is perceptible, and a change of 5 dB is strongly perceptible. A change of 10 dB is typically considered a factor of 2. This is quite remarkable, considering that 10 dB is 10 times the acoustical energy!


Sound pressure in decibels (dB)
Sound pressure in pounds per square inch (PSI)
Common Sounds
160
3X10 -1
Medium jet engine
140
3X10 -2
Large propeller aircraft
Air raid siren
Riveting and chipping
120
3X10 -3
Discotheque
Punch press
Canning plant
100
3X10 -4
Heavy city traffic; subway
80
3X10 -5
Busy office
60
3X10 -6
Normal speech
Private office
40
3X10 -7
Quiet residential neighborhood
20
3X10 -8
Whisper
0
3X10 -9
Threshold of hearing

3A2 Frequency

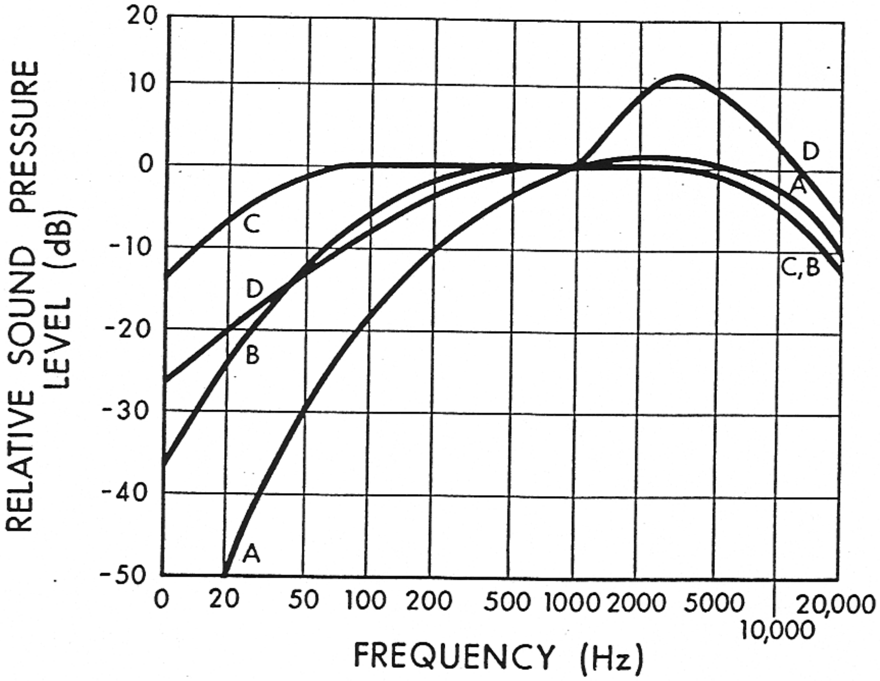
The range of frequencies audible to the human ear ranges from approximately 20 Hz to 20 kHz. Within this range, the human ear does not hear equally at all frequencies. It is not very sensitive to low-frequency sounds, is very sensitive to mid-frequency sounds and is slightly less sensitive to high-frequency sounds. Due to the large frequency range of human hearing, the entire spectrum is often divided into 31 bands, each known as a 1/3 octave band.

The internationally agreed-upon center frequencies and upper and lower band limits for the 1/1 (whole octave) and 1/3 octave bands are as follows:

Whole Octave		
Lower Band Limit	**Center Frequency**	**Upper Band Limit**
11	**16**	22
22	**31.5**	44
44	**63**	88
88	**125**	177
177	**250**	355
355	**500**	710
710	**1,000**	1,420
1,420	**2,000**	2,840
2,840	**4,000**	5,680
5,680	**8,000**	11,360
11,360	**16,000**	22,720

1/3 Octave		
Lower Band Limit	**Center Frequency**	**Upper Band Limit**
14.1	**16**	17.8
17.8	**20**	22.4
22.4	**25**	28.2
28.2	**31.5**	35.5
35.5	**40**	44.7
44.7	**50**	56.2
56.2	**63**	70.8
70.8	**80**	89.1
89.1	**100**	112
112	**125**	141
141	**160**	178
178	**200**	224
224	**250**	282
282	**315**	355
355	**400**	447
447	**500**	562
562	**630**	708
708	**800**	891
891	**1,000**	1,122
1,122	**1,250**	1,413
1,413	**1,600**	1,778
1,778	**2,000**	2,239
2,239	**2,500**	2,818
2,818	**3,150**	3,548
3,548	**4,000**	4,467
4,467	**5,000**	5,623
5,623	**6,300**	7,079
7,079	**8,000**	8,913
8,913	**10,000**	11,220
11,220	**12,500**	14,130
14,130	**16,000**	17,780
17,780	**20,000**	22,390

Human hearing is most sensitive at approximately 3,500 Hz, which corresponds to the ¼ wavelength of the ear canal (approximately 2.5 cm). Because of this range of sensitivity to various frequencies, we typically apply various weighting networks to the broadband measured sound to account more appropriately for the way humans hear. By default, the most common weighting network used is the so-called “A-weighting.” It can be seen in the figure that the low-frequency sounds are reduced substantially with the A-weighting.



3A3 Combination of Sounds

When combining multiple sound sources the general equation is:

$$\Sigma SPL_n = 10\log_{10}\left[\sum_{i=1}^{n} 10^{\frac{SPL_i}{10}}\right]$$

Examples:

- Two sources of 50 dB each add together to result in 53 dB.
- Three sources of 50 dB each add together to result in 55 dB.
- Ten sources of 50 dB each add together to result in 60 dB.
- One source of 50 dB added to another source of 40 dB results in 50.4 dB.

It can be seen that, if multiple similar sources exist, removing or reducing only one source will have little effect.

3A4 Sound Level Measurements

Over the years a number of methods for measuring and describing environmental noise have been developed. The most widely used and accepted is the concept of the Energy Equivalent Sound Level (L_{eq}), which was developed in the US (1970s) to characterize noise levels near US air force bases. This is the level of a steady state sound which, for a given period of time, would contain the same energy as the time-varying sound. The concept is that the same amount of annoyance occurs from a sound having a high level for a short period of time as from a sound at a lower level for a longer period of time.

The L_{eq} is defined as:

$$L_{eq} = 10\log_{10}\left[\frac{1}{T}\int_0^T 10^{\frac{dB}{10}}\, dT\right] = 10\log_{10}\left[\frac{1}{T}\int_0^T \frac{P^2}{P_{ref}^2}\, dT\right]$$

We must specify the time period over which to measure the sound, i.e., 1 second, 10 seconds, 15 seconds, 1 minute, 1 day, etc. **An L_{eq} is meaningless if there is no time period associated**.

In general there a few very common L_{eq} sample durations which are used in describing environmental noise measurements. These include:

Leq24	- Measured over a 24-hour period
LeqNight	- Measured over the nighttime (typically 22:00–07:00)
LeqDay	- Measured over the daytime (typically 07:00–22:00)
LDN	- Same as Leq24 with a 10 dB penalty added to the nighttime

3A5 Statistical Descriptor

Another method of conveying long-term noise levels utilizes statistical descriptors. These are calculated from a cumulative distribution of the sound levels over the entire measurement duration, and then by determining the sound level at xx% of the time.

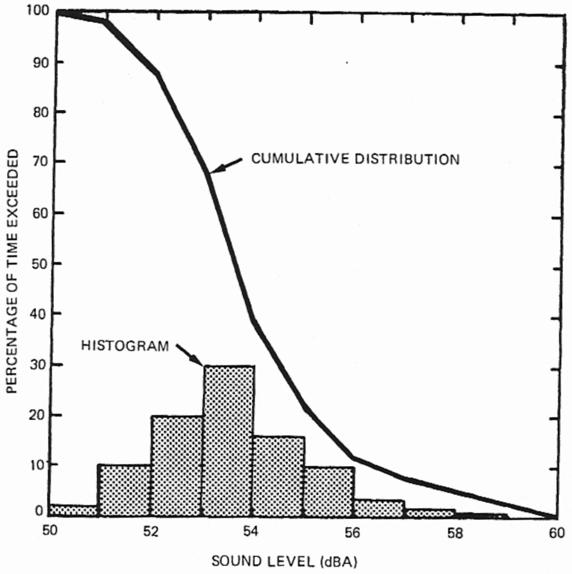


Figure 16.6 Statistically processed community noise showing histogram and cumulative distribution of A weighted sound levels.

Industrial Noise Control, Lewis Bell, Marcel Dekker, Inc. 1994

The most common statistical descriptors are:

L_{min} - minimum sound level measured
L_{01} - sound level that was exceeded only 1% of the time
L_{10} - sound level that was exceeded only 10% of the time
    - Good measure of intermittent or intrusive noise
    - Good measure of traffic noise
L_{50} - sound level that was exceeded 50% of the time (arithmetic average)
    - Good to compare to L_{eq} to determine steadiness of noise
L_{90} - sound level that was exceeded 90% of the time
    - Good indicator of typical "ambient" noise levels
L_{99} - sound level that was exceeded 99% of the time
L_{max} - maximum sound level measured

These descriptors can be used to provide a more detailed analysis of the varying noise climate:

- If there is a large difference between the Leq and the L50 (Leq can never be any lower than the L50), then it can be surmised that one or more short-duration, high-level sound(s) occurred during the time period.

- If the gap between the L10 and L90 is relatively small (less than 15–20 dBA), then it can be surmised that the noise climate was relatively steady.

3A6 Sound Propagation

In order to understand sound propagation, the nature of the source must first be discussed. In general, there are three types of sources. These are known as “point,” “line,” and “area.” This discussion will concentrate on point and line sources, since area sources are much more complex and can usually be approximated by point sources at large distances.

3A6.1 Point Source

As sound radiates from a point source, it dissipates through geometric spreading. The basic relationship between the sound levels at two distances from a point source is:

$$\therefore SPL_1 - SPL_2 = 20\log_{10}\left(\frac{r_2}{r_1}\right)$$

Where: SPL_1 = sound pressure level at location 1, SPL_2 = sound pressure level at location 2
r_1 = distance from source to location 1, r_2 = distance from source to location 2

Thus, the reduction in sound pressure level for a point source radiating in a free field is **6 dB per doubling of distance**. This relationship is independent of reflectivity factors, provided they are always present. Note that this only considers geometric spreading and does not take into account atmospheric effects. Point sources still have some physical dimension associated with them, and typically do not radiate sound equally in all directions in all frequencies. The directionality of a source is also highly dependent on frequency. As frequency increases, directionality increases.

<u>Examples (note no atmospheric absorption):</u>

- A point source measuring 50 dB at 100 m will be 44 dB at 200 m.
- A point source measuring 50 dB at 100 m will be 40.5 dB at 300 m.
- A point source measuring 50 dB at 100 m will be 38 dB at 400 m.
- A point source measuring 50 dB at 100 m will be 30 dB at 1,000 m.

3A6.2 Line Source

A line source is similar to a point source in that it dissipates through geometric spreading. The difference is that a line source is equivalent to a long line of many point sources. The basic relationship between the sound levels at two distances from a line source is:

$$SPL_1 - SPL_2 = 10\log_{10}\left(\frac{r_2}{r_1}\right)$$

The difference from the point source is that the “20” term in front of the “log” is now only 10. Thus, the reduction in sound pressure level for a line source radiating in a free field is **3 dB per doubling of distance**.

Examples (note no atmospheric absorption):

- A line source measuring 50 dB at 100 m will be 47 dB at 200 m.
- A line source measuring 50 dB at 100 m will be 45 dB at 300 m.
- A line source measuring 50 dB at 100 m will be 34 dB at 400 m.
- A line source measuring 50 dB at 100 m will be 40 dB at 1,000 m.

3A7 Atmospheric Absorption

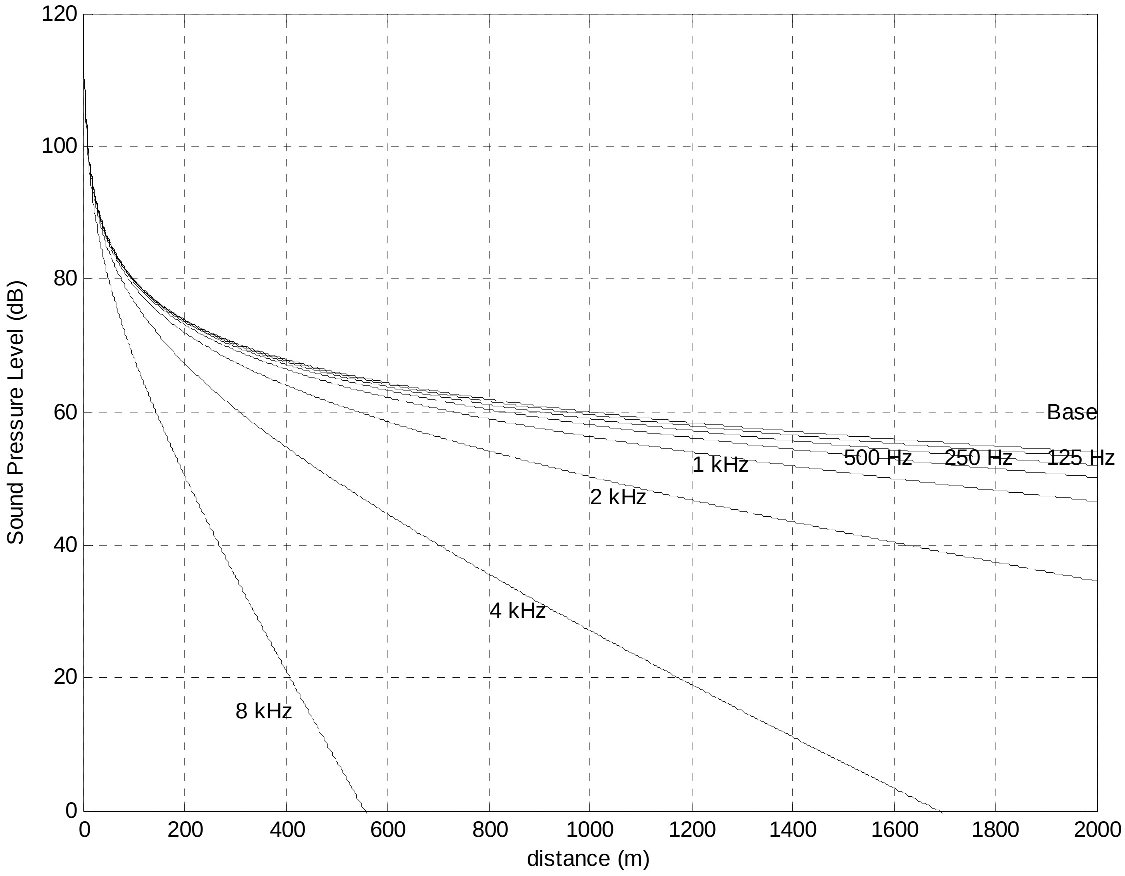
As sound transmits through a medium, there is an attenuation (or dissipation of acoustic energy) which can be attributed to three mechanisms:

1) **Viscous Effects** - Dissipation of acoustic energy due to fluid friction which results in thermodynamically irreversible propagation of sound.
2) **Heat Conduction Effects -** Heat transfer between high- and low-temperature regions in the wave which result in non-adiabatic propagation of the sound.
3) **Inter Molecular Energy Interchanges** - Molecular energy relaxation effects which result in a time lag between changes in translational kinetic energy, as well as the energy associated with rotation and vibration of the molecules.

The following table illustrates the attenuation coefficient of sound at standard pressure (101.325 kPa) in units of dB/100 m.

Temperature °C	**Relative Humidity (%)**	**Frequency (Hz)**					
		125	**250**	**500**	**1,000**	**2,000**	**4,000**
30	20	0.06	0.18	0.37	0.64	1.40	4.40
	50	0.03	0.10	0.33	0.75	1.30	2.50
	90	0.02	0.06	0.24	0.70	1.50	2.60
20	20	0.07	0.15	0.27	0.62	1.90	6.70
	50	0.04	0.12	0.28	0.50	1.00	2.80
	90	0.02	0.08	0.26	0.56	0.99	2.10
10	20	0.06	0.11	0.29	0.94	3.20	9.00
	50	0.04	0.11	0.20	0.41	1.20	4.20
	90	0.03	0.10	0.21	0.38	0.81	2.50
0	20	0.05	0.15	0.50	1.60	3.70	5.70
	50	0.04	0.08	0.19	0.60	2.10	6.70
	90	0.03	0.08	0.15	0.36	1.10	4.10

- As frequency increases, absorption increases.
- As relative humidity increases, absorption decreases.
- There is no direct relationship between absorption and temperature.
- **The net result of atmospheric absorption is to modify the sound propagation of a point source from 6 dB/doubling-of-distance to approximately 7–8 dB/doubling-of-distance (based on anecdotal experience).**



Atmospheric Absorption at 10^{o}C and 70% RH

3A8 Meteorological Effects

There are many meteorological factors which can affect how sound propagates over large distances. These various phenomena must be considered when trying to determine the relative impact of a noise source, either after installation or during the design stage.

3A8.1 Wind

- Can greatly alter the noise climate away from a source depending on direction.
- Sound levels downwind from a source can be increased due to refraction of sound back down towards the surface. This is due to the generally higher velocities as altitude increases.
- Sound levels upwind from a source can be decreased due to a “bending” of the sound away from the earth’s surface.
- Sound level differences of ±10 dB are possible depending on severity of wind and distance from source.
- Sound levels crosswind are generally not disturbed by an appreciable amount.
- Wind tends to generate its own noise, however, and can provide a high degree of masking relative to a noise source of particular interest.

3A8.2 Temperature

- Temperature effects can be similar to wind effects.
- Typically, the temperature is warmer at ground level than it is at higher elevations.
- If there is a very large difference between the ground temperature (very warm) and the air aloft (only a few hundred meters), then the transmitted sound refracts upward due to the changing speed of sound.
- If the air aloft is warmer than the ground temperature (known as an inversion), the resulting higher speed of sound aloft tends to refract the transmitted sound back down towards the ground. Essentially, this works on Snell’s law of reflection and refraction.
- Temperature inversions typically happen early in the morning and are most common over large bodies of water or across river valleys.
- Sound level differences of ±10 dB are possible depending on gradient of temperature and distance from source.

3A8.3 Rain

- Rain does not affect sound propagation by an appreciable amount unless it is very heavy.
- The larger concern is the noise generated by the rain itself. A heavy rain striking the ground can cause a substantial amount of highly broadband noise. The amount of noise generated is difficult to predict.
- Rain can also affect the output of various noise sources such as vehicle traffic.

3A8.4 Summary

- In general, these wind and temperature effects are difficult to predict.
- Empirical models (based on measured data) have been generated to attempt to account for these effects.
- Environmental noise measurements must be conducted with these effects in mind. Sometimes it is desirable to have completely calm conditions, while at other times a “worst-case” of downwind noise levels is desired.

3A9 Topographical Effects

Similar to the various atmospheric effects outlined in the previous section, the effect of various geographical and vegetative factors must also be considered when examining the propagation of noise over large distances.

3A9.1 Topography

- One of the most important factors in sound propagation.
- Can provide a natural barrier between source and receiver (i.e., if berm or hill in between).
- Can provide a natural amplifier between source and receiver (i.e., large valley in between or hard reflective surface in between).
- Must look at location of topographical features relative to source and receiver to determine importance (i.e., small berm 1 km away from source and 1 km away from receiver will make negligible impact).

3A9.2 Grass

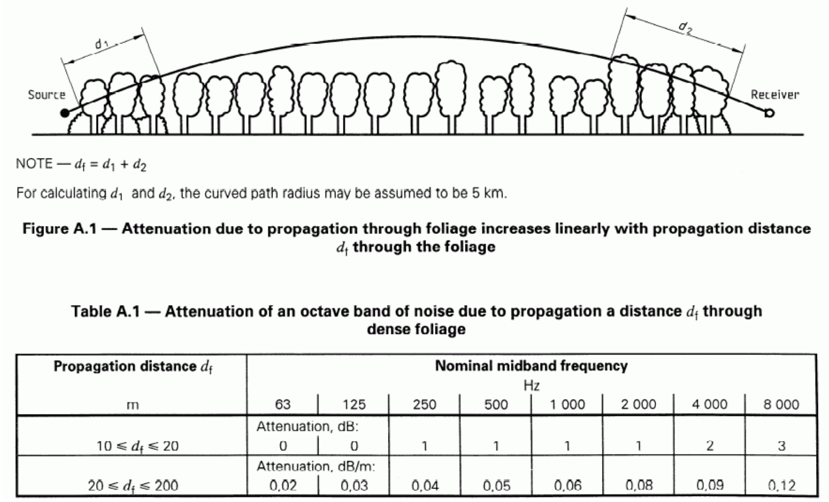
- Can be an effective absorber due to large area covered.
- Only effective at low height above ground. Does not affect sound transmitted directly from source to receiver if there is line-of-sight.
- Typically less absorption than atmospheric absorption when there is line-of-sight.
- Approximate rule of thumb based on empirical data is:

$$A_g = 18\log_{10}(f) - 31 \qquad (dB/100m)$$

Where: A_g is the absorption amount

3A9.3 Trees

- Provide absorption due to foliage.
- Deciduous trees are essentially ineffective in the winter.
- Absorption depends heavily on density and height of trees.
- No data found on absorption of various kinds of trees.
- Large spans of trees are required to obtain even minor amounts of sound reduction.
- In many cases, trees can provide an effective visual barrier, even if the noise attenuation is negligible.



NOTE — $d_f = d_1 + d_2$

For calculating d_1 and d_2, the curved path radius may be assumed to be 5 km.

Figure A.1 — Attenuation due to propagation through foliage increases linearly with propagation distance d_f through the foliage

Table A.1 — Attenuation of an octave band of noise due to propagation a distance d_f through dense foliage

Propagation distance d_f m	**Nominal midband frequency** Hz 63	125	250	500	1 000	2 000	4 000	8 000
$10 \leq d_f \leq 20$	Attenuation, dB: 0	0	1	1	1	1	2	3
$20 \leq d_f \leq 200$	Attenuation, dB/m: 0,02	0,03	0,04	0,05	0,06	0,08	0,09	0,12

Tree/Foliage attenuation from ISO 9613-2:1996

3A9.4 Bodies of Water

- Large bodies of water can provide the opposite effect to grass and trees.
- Reflections caused by small incidence angles (grazing) can result in larger sound levels at great distances (increased reflectivity, Q).
- Typically, air temperatures are warmer high aloft, since air temperatures near water surface tend to be more constant. Result is a high probability of temperature inversion.
- Sound levels can “carry” much further.

3A9.5 Snow

- Covers the ground for much of the year in northern climates.
- Can act as an absorber or reflector (and varying degrees in between).
- Freshly fallen snow can be quite absorptive.
- Snow which has been sitting for a while and is hard packed due to wind can be quite reflective.
- Falling snow can be more absorptive than rain, but does not tend to produce its own noise.
- Snow can cover grass which might have provided some means of absorption.
- Typically, sound propagates with less impedance in winter due to hard snow on ground and no foliage on trees/shrubs.

Appendix 3B Sound Levels of Familiar Noise Sources

Source[1]	**Sound Level (dBA)**
Bedroom of a country home	30
Soft whisper at 1.5 m	30
Quiet office or living room	40
Moderate rainfall	50
Inside average urban home	50
Quiet street	50
Normal conversation at 1 m	60
Noisy office	60
Noisy restaurant	70
Highway traffic at 15 m	75
Loud singing at 1 m	75
Tractor at 15 m	78-95
Busy traffic intersection	80
Electric typewriter	80
Bus or heavy truck at 15 m	88-94
Jackhammer	88-98
Loud shout	90
Freight train at 15 m	95
Modified motorcycle	95
Jet taking off at 600 m	100
Amplified rock music	110
Jet taking off at 60 m	120
Air-raid siren	130

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[1] Cottrell, Tom, 1980, *Noise in Alberta*, Table 1, p.8, ECA80 - 16/1B4 (Edmonton: Environment Council of Alberta). Used with Permission, Obtained from EUB Guide 38: Noise Control Directive User Guide (November 1999).

SOUND LEVELS GENERATED BY COMMON APPLIANCES

Source[1]	**Sound level at 3 feet (dBA)**
Freezer	38-45
Refrigerator	34-53
Electric heater	47
Hair clipper	50
Electric toothbrush	48-57
Humidifier	41-54
Clothes dryer	51-65
Air conditioner	50-67
Electric shaver	47-68
Water faucet	62
Hair dryer	58-64
Clothes washer	48-73
Dishwasher	59-71
Electric can opener	60-70
Food mixer	59-75
Electric knife	65-75
Electric knife sharpener	72
Sewing machine	70-74
Vacuum cleaner	65-80
Food blender	65-85
Coffee mill	75-79
Food waste disposer	69-90
Edger and trimmer	81
Home shop tools	64-95
Hedge clippers	85
Electric lawn mower	80-90

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[1] Reif, Z. F., and Vermeulen, P. J., 1979, “Noise from domestic appliances, construction, and industry,” Table 1, p.166, in Jones, H. W., ed., *Noise in the Human Environment*, vol. 2, ECA79-SP/1 (Edmonton: Environment Council of Alberta). Used with Permission, Obtained from EUB Guide 38: Noise Control Directive User Guide (November 1999).

Appendix 3C Measurement Equipment and Calibration Information

Larson Davis

The environmental noise-monitoring equipment used at Receptor Locations #20, #23 and #11 consisted of Larson Davis System 824 Precision Integrating Sound Level Meters enclosed in environmental cases with tripods, weather-protective microphone hoods and external batteries. The systems acquired data in 5-second L_{eq} samples using 1/3 octave band frequency analysis and overall A-weighted and C-weighted sound levels. The sound level meters conform to Type 1, ANSI S1.4, IEC 60651 and IEC 60804. The 1/3 octave filters conform to S1.11–Type 1C, and IEC 61260–Class 1. The calibrators conform to IEC 60942 and ANSI S1.40. The sound level meters, pre-amplifiers, microphones and calibrators (type Larson Davis CAL 200) were re-certified on December 7, 2006, by a NIST NVLAP Accredited Calibration Laboratory for all requirements of ISO 17025: 1999 and relevant requirements of ISO 9002: 1994 and ANSI/NCSL Z540: 1994 Part 1. All measurement methods and instrumentation conform to the requirements of the EUB ID99-8. Simultaneous digital audio recording was conducted with Marantz PMD-670 professional-grade audio recorders, utilizing a sample rate of 48 kHz and an MP3 conversion rate of 80 kbps. The audio signal was passed directly from the sound level meters. The next section in the Appendix provides a detailed description of the various acoustical descriptive terms used.

Brüel and Kjær 2250

The environmental noise-monitoring equipment used at Receptor Locations #34, #5, #24 and #14 consisted of Brüel and Kjær Type 2250 Precision Integrating Sound Level Meters enclosed in environmental cases with tripods, weather-protective microphone hoods and external batteries. The systems acquired data in 5-second L_{eq} samples using 1/3 octave band frequency analysis and overall A-weighted and C-weighted sound levels. The sound level meters conform to Type 1, ANSI S1.4, ANSI S1.43, IEC 61672-1, IEC 60651, IEC 60804 and DIN 45657. The 1/3 octave filters conform to S1.11–Type 0-C, and IEC 61260–Class 0. The calibrators conform to IEC 942 and ANSI S1.40. The sound level meters, pre-amplifiers and microphones were certified on June 9, 2005 / February 26, 2007, and the calibrators (type B&K 4231) were certified on June 23, 2006 / February 15, 2007, by a NIST NVLAP Accredited Calibration Laboratory for all requirements of ISO 17025: 1999 and relevant requirements of ISO 9002:1994, ISO 9001:2000 and ANSI/NCSL Z540: 1994 Part 1. All measurement methods and instrumentation conform to the requirements of the EUB ID99-8. Simultaneous digital audio was recorded directly on the sound level meters using a 8 kHz sample rate for more detailed post-processing analysis. Refer to the next section in the Appendix for a detailed description of the various acoustical descriptive terms used.

Brüel and Kjær 2260

The environmental noise-monitoring equipment used at Receptor Locations #2 and #17 consisted of a Brüel and Kjær Type 2260 Precision Integrating Sound Level Meter enclosed in an environmental case with a tripod, a weather-protective microphone hood and an external battery. The system acquired data in 5-second L_{eq} samples using 1/3 octave band frequency analysis and overall A-weighted and C-weighted sound levels. The sound level meter conforms to Type 1, ANSI S1.4, ANSI S1.43, IEC 61672-1, IEC 60651, IEC 60804 and DIN 45657. The 1/3 octave filters conform to S1.11–Type 0-C and IEC 61260–Class 0. The calibrator conforms to IEC 942 and ANSI S1.40. The sound level meter, pre-amplifier, microphone and calibrator (B&K Type 4230) were certified on December 18, 2006, by a NIST NVLAP Accredited Calibration Laboratory for all requirements of ISO 17025: 1999 and relevant requirements of ISO 9002:1994, ISO 9001:2000 and ANSI/NCSL Z540: 1994 Part 1. All measurement methods and instrumentation conform to the requirements of the EUB ID99-8. Simultaneous digital audio recording was conducted with a Marantz PMD-670 professional-grade audio recorder utilizing a sample rate of 48 kHz and an MP3 conversion rate of 80 kbps. The audio signal was passed directly from the sound level meter. The next section in the Appendix provides a detailed description of the various acoustical descriptive terms used.

Weather Monitor

The weather-monitoring equipment used for the study consisted of a NovaLynx 110-WS-16D data acquisition box, with a 200-WS-02E wind speed and wind direction sensor, a 110-WS-16TH temperature and relative humidity sensor and a 110-WS-16THS solar radiation shield. The data acquisition box and a battery were located in a weather-protective case. The sensors were mounted on a tripod at approximately 2.5 m above ground. The system was set up to record data in 5-minute averages to obtain average wind speed, peak wind speed, wind direction, temperature and relative humidity.

Table 3C-1 Calibration Spreadsheet

Description	Date	Time	Pre / Post	Calibration Level	Calibrator Model	Serial Number
Receptor #34 Monitor	March 13, 2007	10:48	Pre	93.9 dBA	B&K 4231	2478139
Receptor #34 Monitor	March 14, 2007	11:15	Post	93.7 dBA	B&K 4231	2478139
Receptor #5 Monitor	March 13, 2007	11:30	Pre	93.9 dBA	B&K 4231	2575493
Receptor #5 Monitor	March 14, 2007	11:45	Post	93.8 dBA	B&K 4231	2575493
Receptor #2 Monitor	March 13, 2007	12:15	Pre	93.9 dBA	B&K 4230	566599
Receptor #2 Monitor	March 14, 2007	12:00	Post	93.9 dBA	B&K 4230	566599
Receptor #20 Monitor	March 13, 2007	13:00	Pre	114.0 dBA	Larson Davis Cal200	3657
Receptor #20 Monitor	March 14, 2007	12:30	Post	114.1 dBA	Larson Davis Cal200	3657
Receptor #23 Monitor	March 22, 2007	13:50	Pre	114.0 dBA	Larson Davis Cal200	4092
Receptor #23 Monitor	March 23, 2007	12:35	Post	114.1 dBA	Larson Davis Cal200	4092
Receptor #24 Monitor	March 22, 2007	14:30	Pre	93.9 dBA	B&K 4231	2478139
Receptor #24 Monitor	March 23, 2007	13:00	Post	93.9 dBA	B&K 4231	2478139
Receptor #14 Monitor	March 22, 2007	14:45	Pre	93.9 dBA	B&K 4231	2575493
Receptor #14 Monitor	March 23, 2007	13:30	Post	93.8 dBA	B&K 4231	2575493
Receptor #17 Monitor	March 22, 2007	14:45	Pre	93.9 dBA	B&K 4230	566599
Receptor #17 Monitor	March 23, 2007	13:30	Post	93.8 dBA	B&K 4230	566599
Near Receptor #11 Monitor	March 22, 2007	15:00	Pre	114.0 dBA	Larson Davis Cal200	3657
Near Receptor #11 Monitor	March 23, 2007	14:20	Post	114.0 dBA	Larson Davis Cal200	3657

Appendix 3D A-Weighted Sound Levels

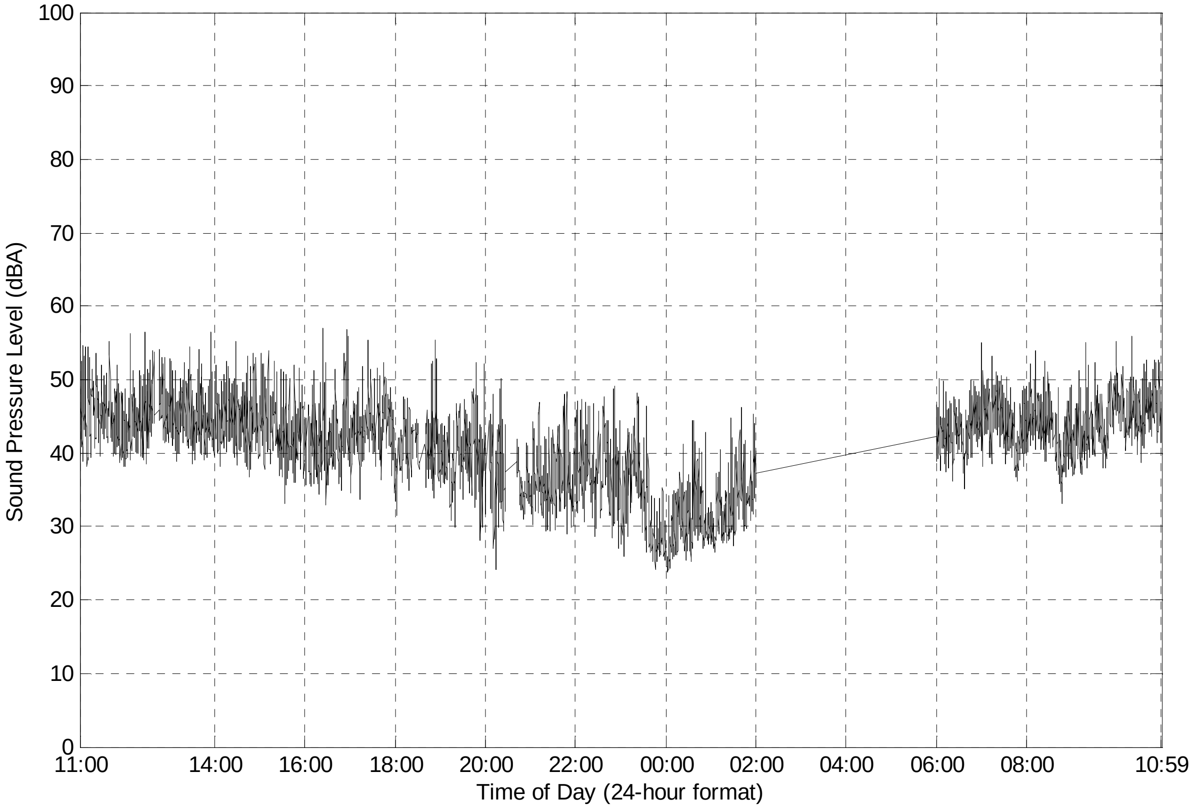

Figure 3D-1 Broadband A-Weighted Sound Levels at Noise Monitor #1 (Receptor #34)

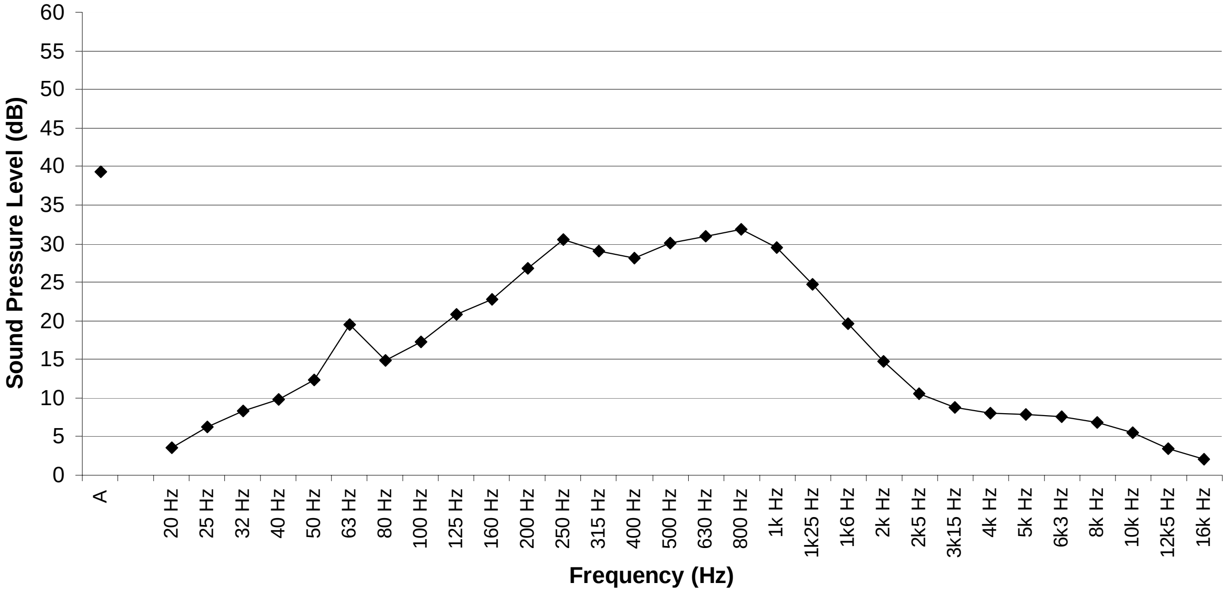

Figure 3D-2 A-Weighted 1/3 Octave Band Nighttime Sound Levels at Noise Monitor #1 (Receptor #34)

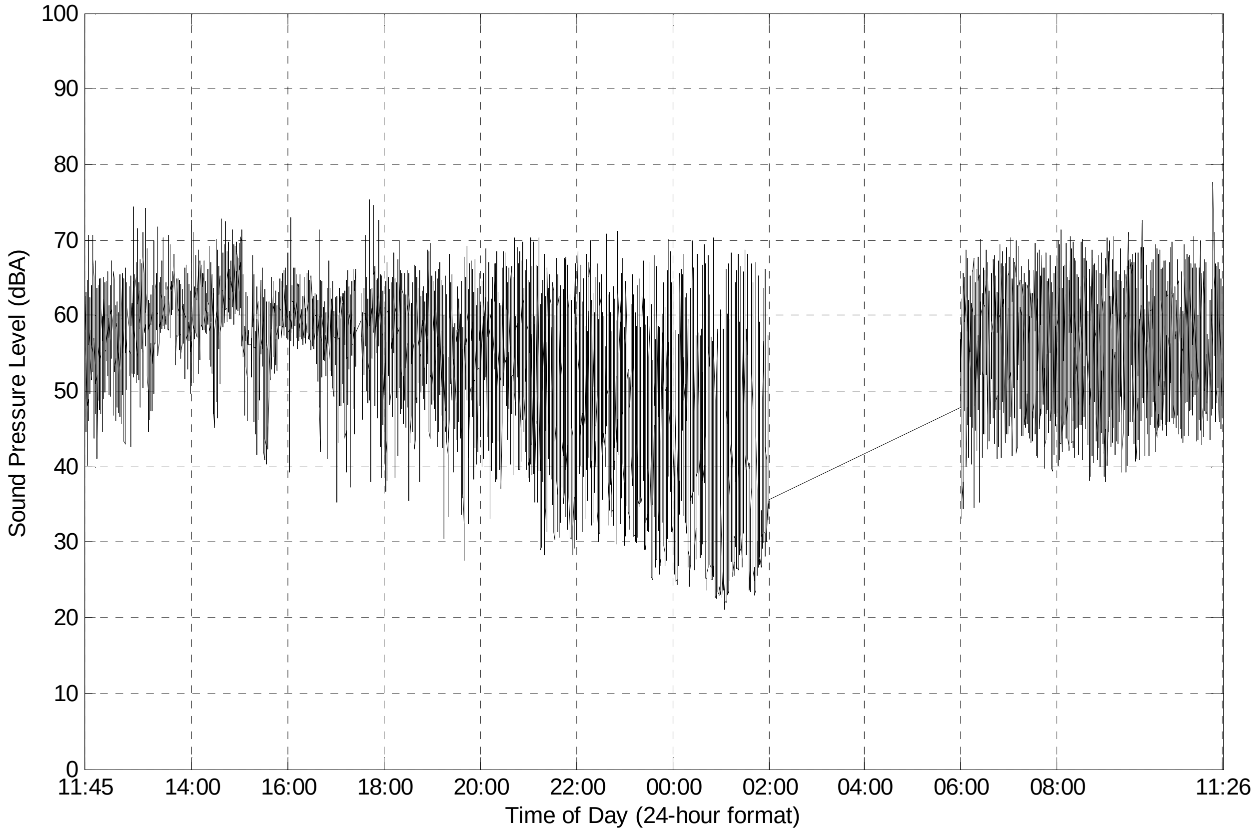

Figure 3D-3 Broadband A-Weighted Sound Levels at Noise Monitor #2 (Receptor #5)

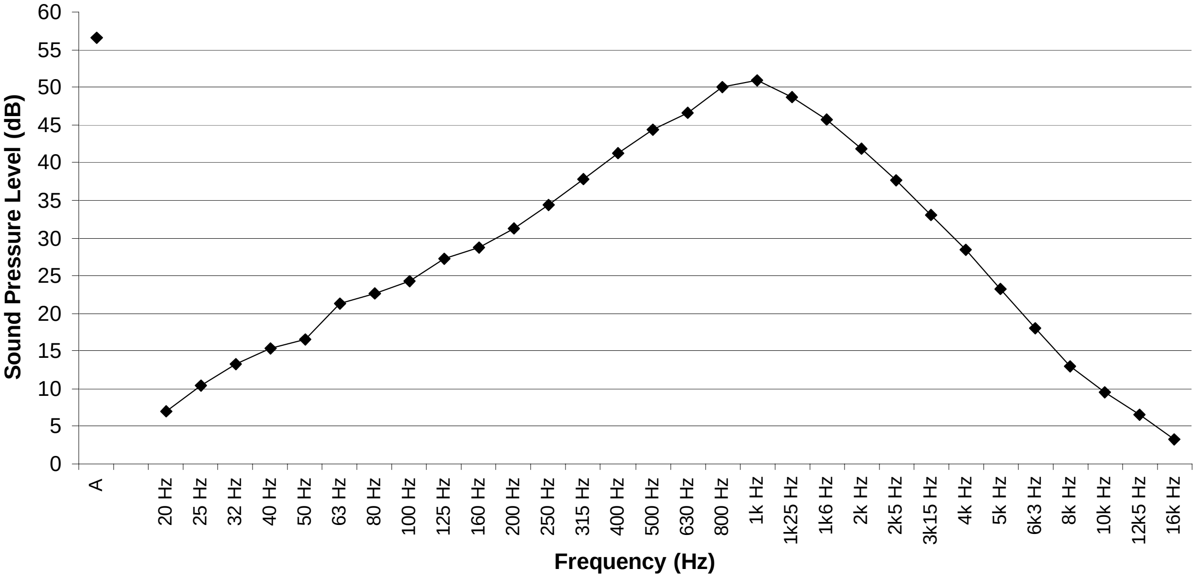

Figure 3D-4 A-Weighted 1/3 Octave Band Nighttime Sound Levels at Noise Monitor #2 (Receptor #5)

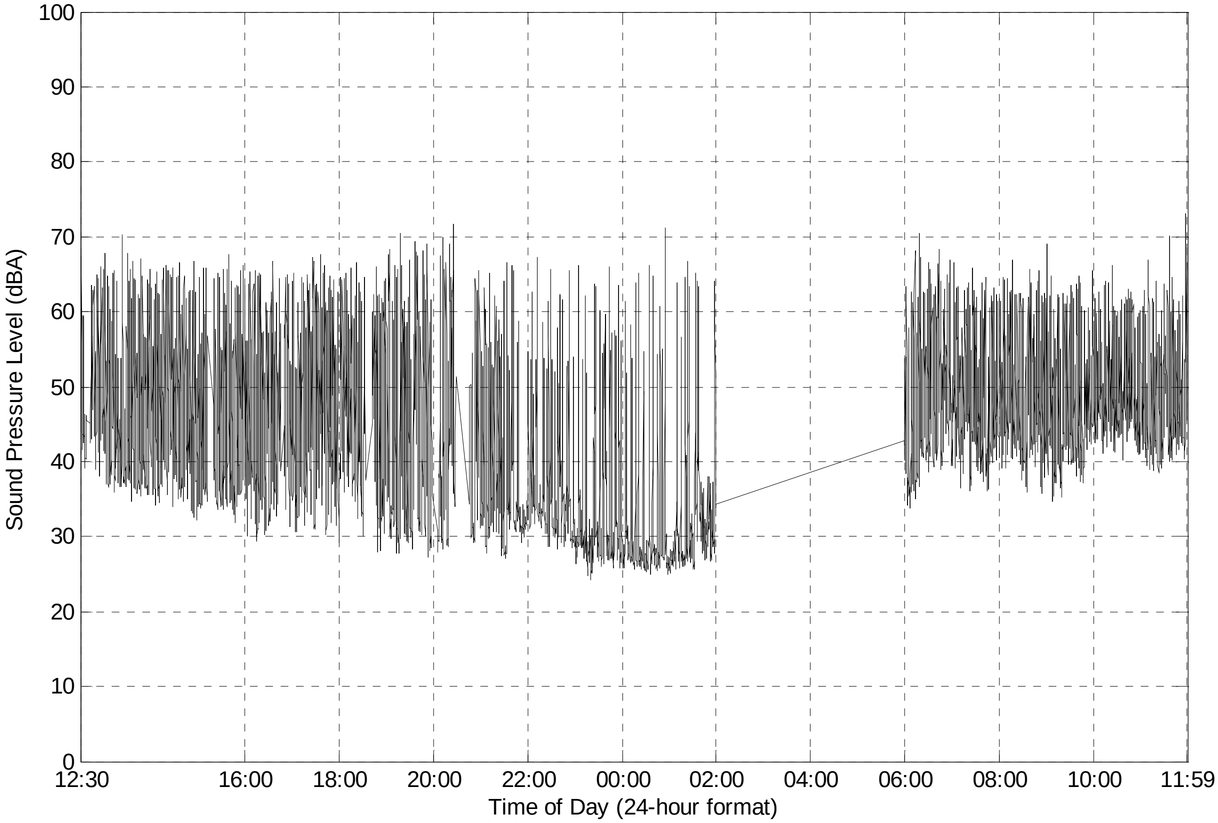

Figure 3D-5 Broadband A-Weighted Sound Levels at Noise Monitor #3 (Receptor #2)

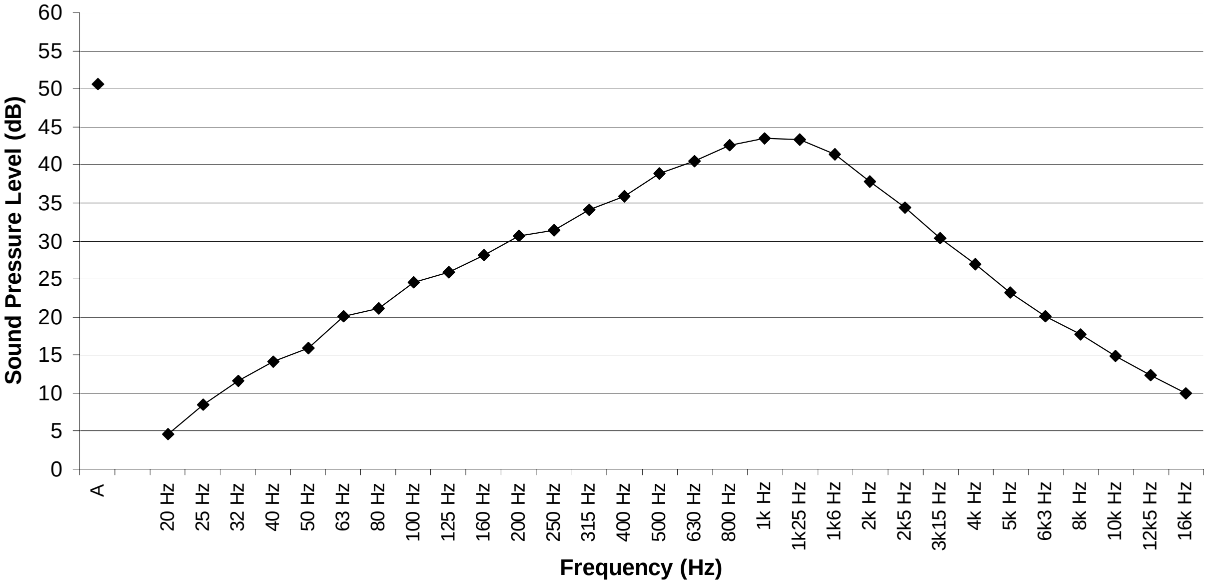

Figure 3D-6 A-Weighted 1/3 Octave Band Nighttime Sound Levels at Noise Monitor #3 (Receptor #2)

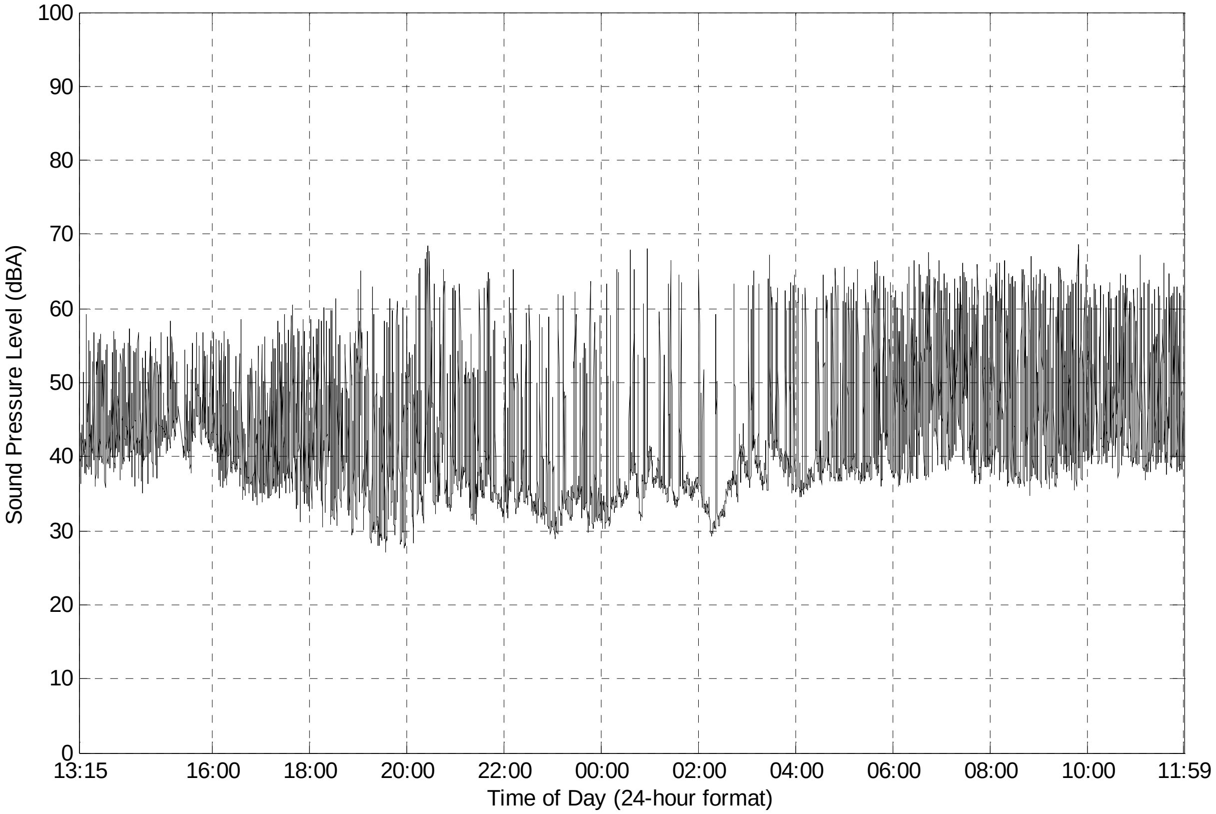

Figure 3D-7 Broadband A-Weighted Sound Levels at Noise Monitor #4 (Receptor #20)

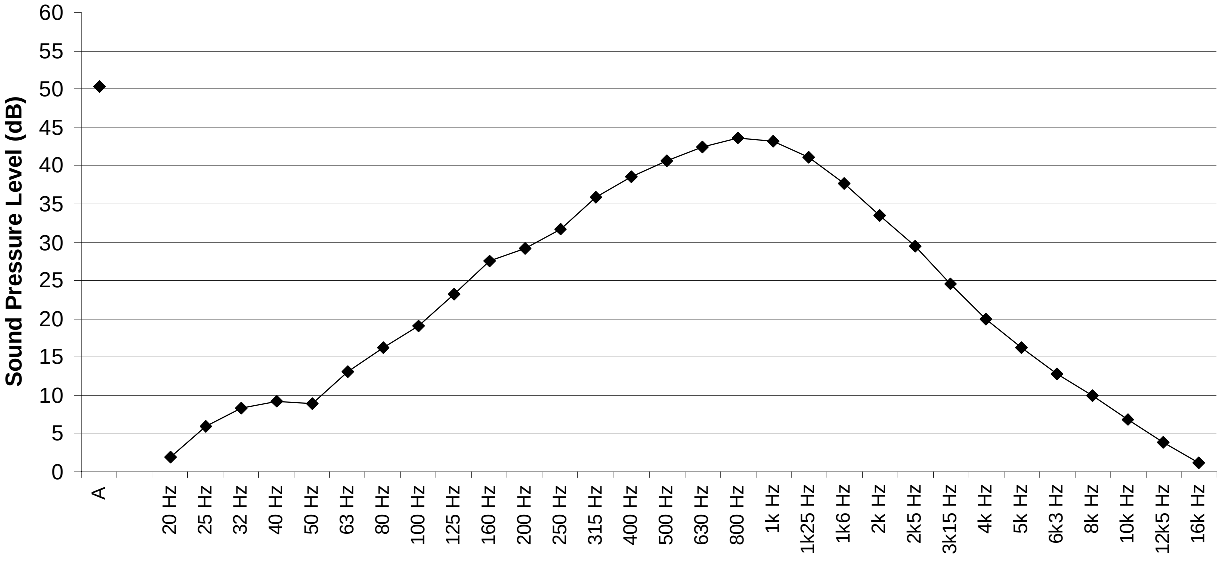

Figure 3D-8 A-Weighted 1/3 Octave Band Nighttime Sound Levels at Noise Monitor #4 (Receptor #20)

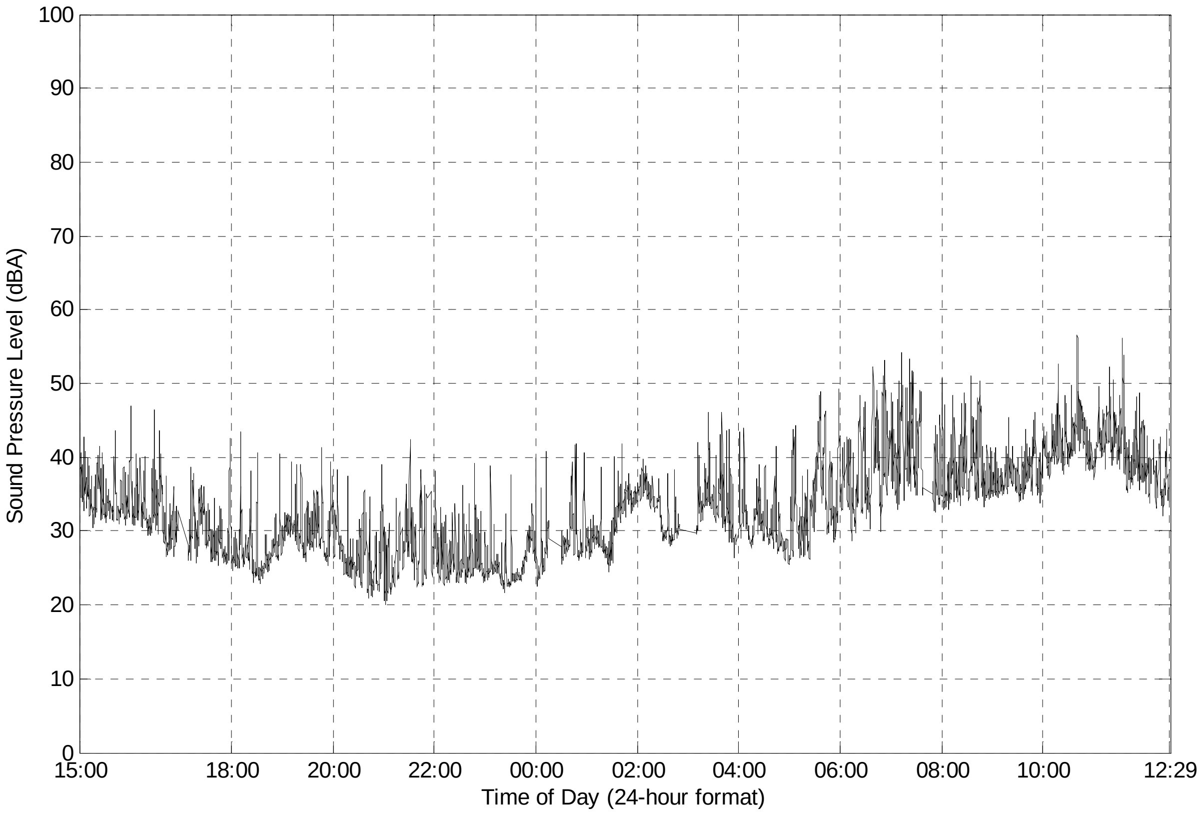

Figure 3D-9 Broadband A-Weighted Sound Levels at Noise Monitor #5 (Near Receptor #23)

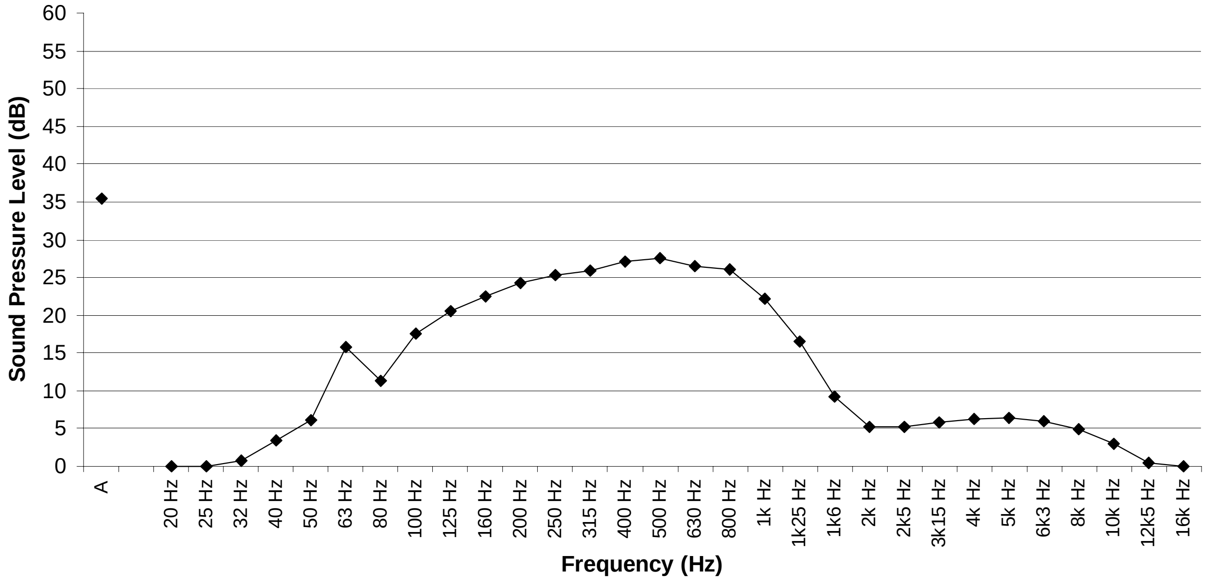

Figure 3D-10 A-Weighted 1/3 Octave Band Nighttime Sound Levels at Noise Monitor #5 (Near Receptor #23)

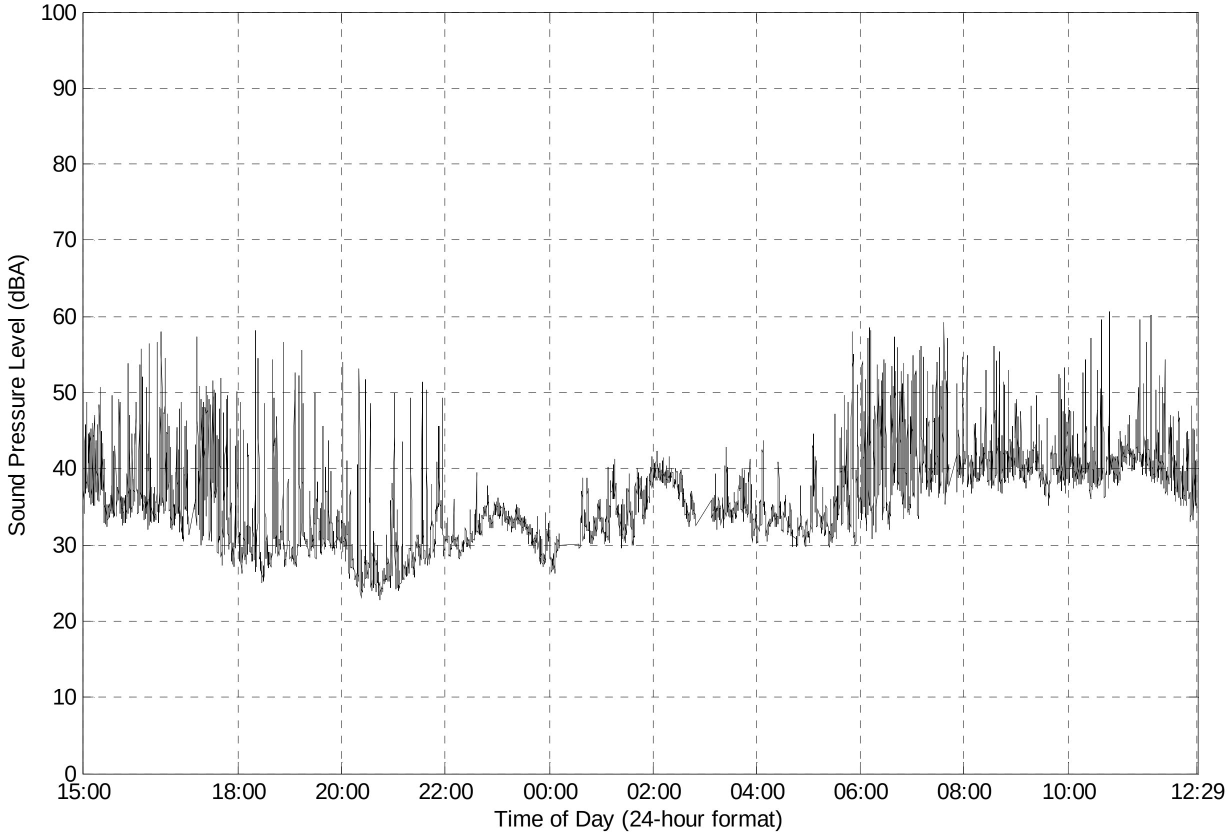

Figure 3D-11 Broadband A-Weighted Sound Levels at Noise Monitor #6 (Receptor #24)

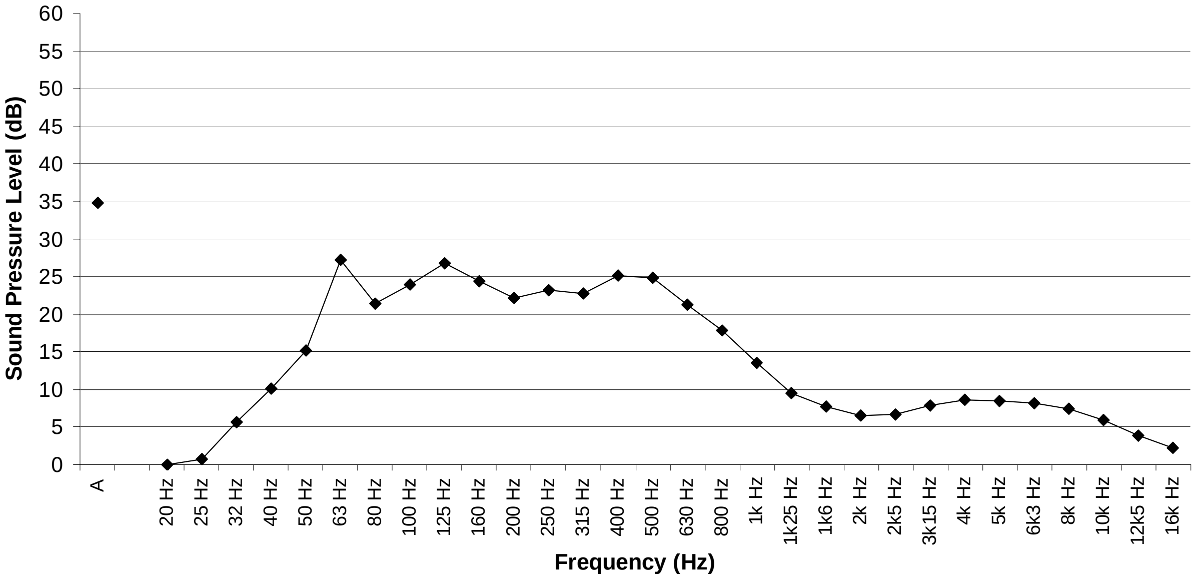

Figure 3D-12 A-Weighted 1/3 Octave Band Nighttime Sound Levels at Noise Monitor #6 (Receptor #24)

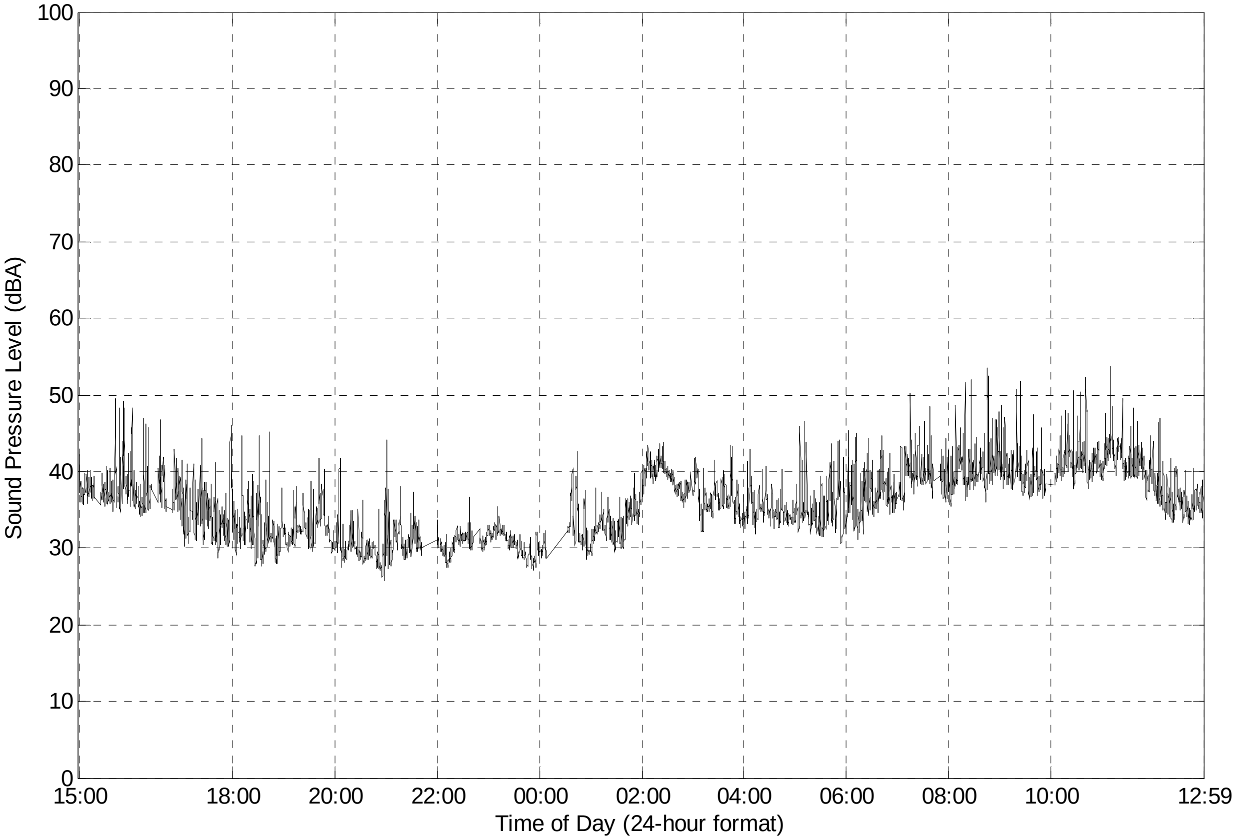

Figure 3D-13 Broadband A-Weighted Sound Levels at Noise Monitor #7 (Receptor #14)

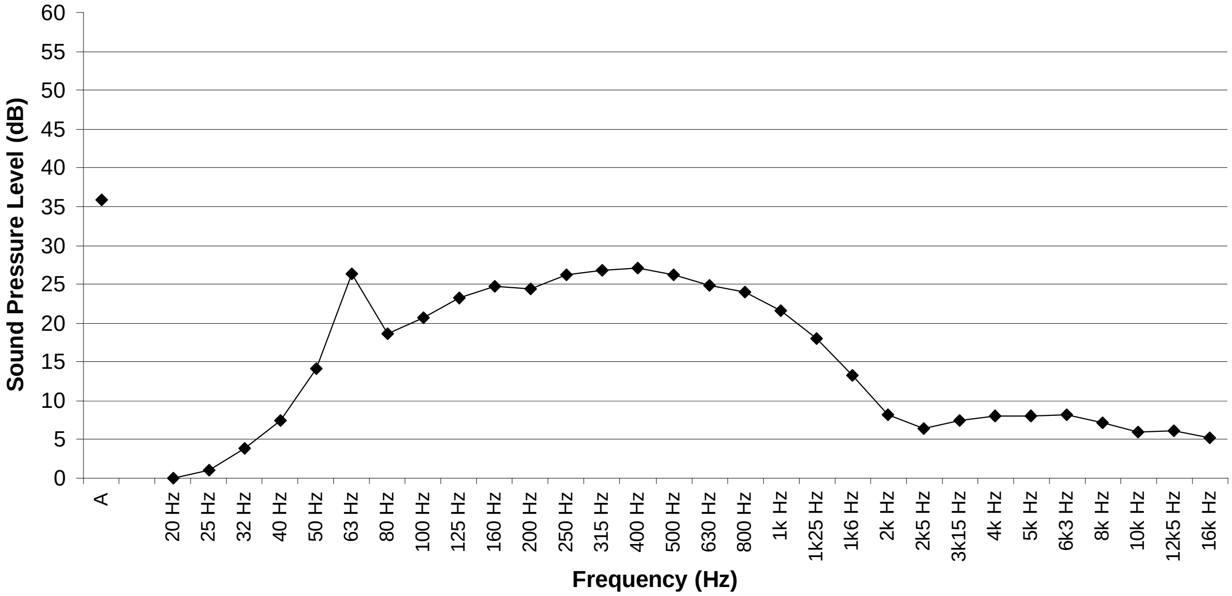

Figure 3D-14 A-Weighted 1/3 Octave Band Nighttime Sound Levels at Noise Monitor #7 (Receptor #14)

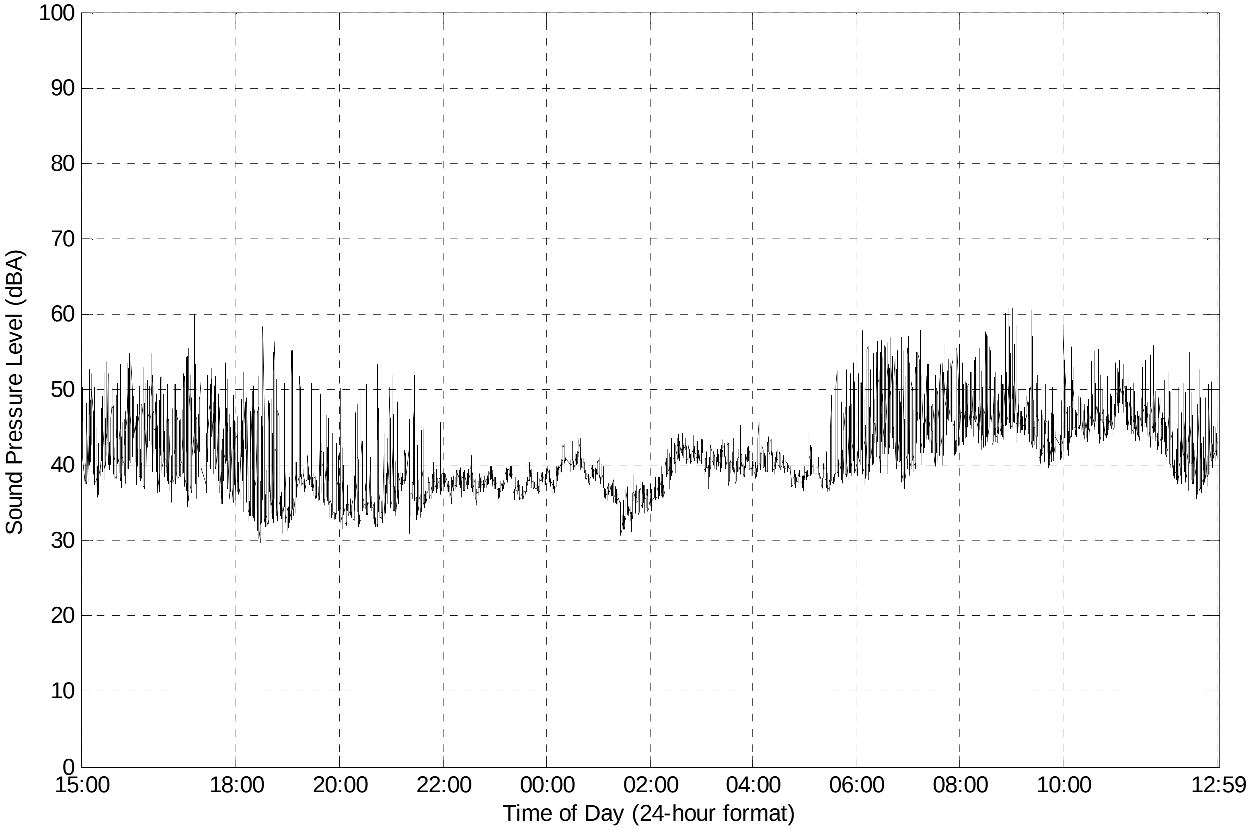

Figure 3D-15 Broadband A-Weighted Sound Levels at Noise Monitor #8 (Receptor #17)

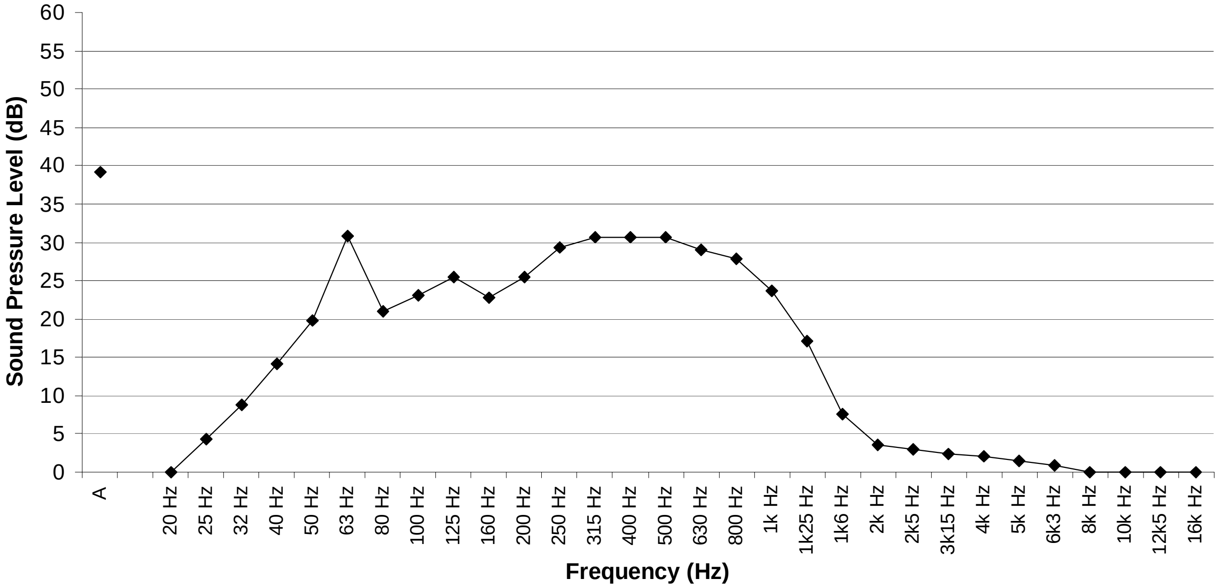

Figure 3D-16 A-Weighted 1/3 Octave Band Nighttime Sound Levels at Noise Monitor #8 (Receptor #17)

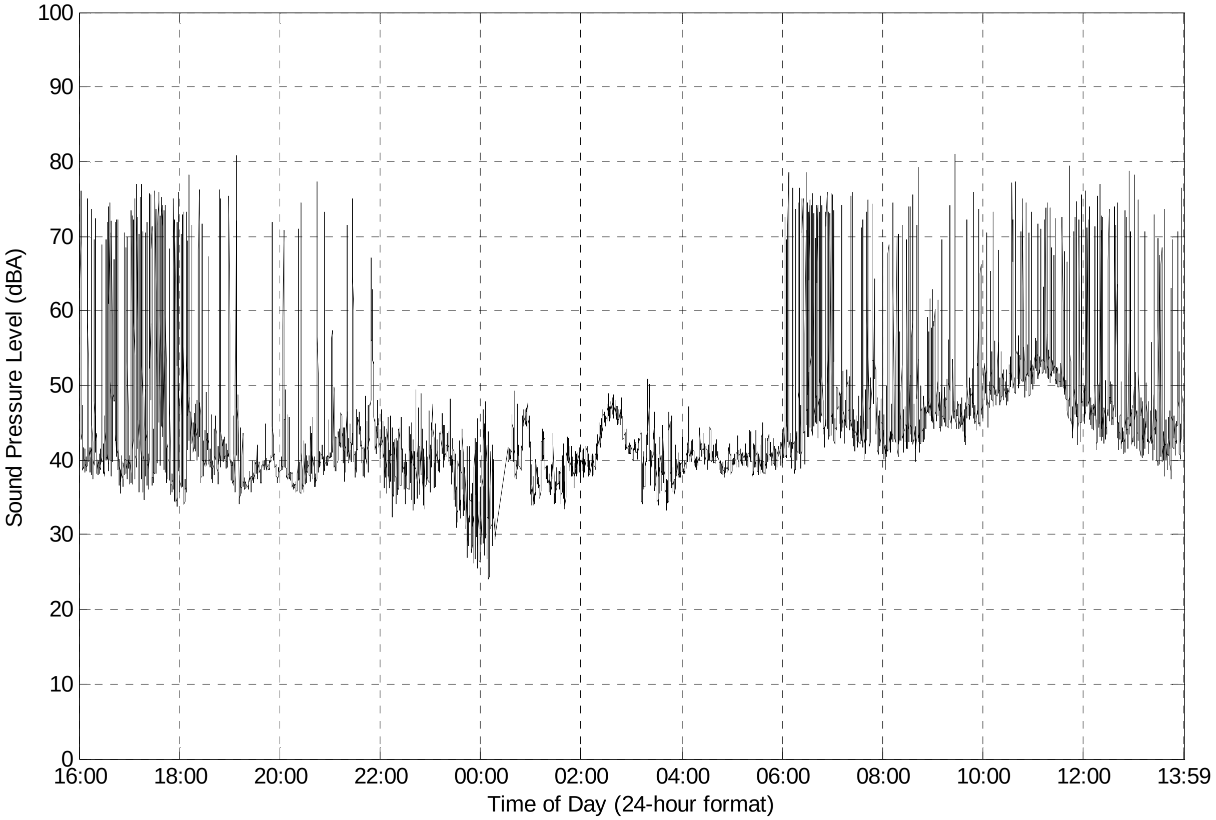

Figure 3D-17 Broadband A-Weighted Sound Levels at Noise Monitor #9 (Near Receptor #11)

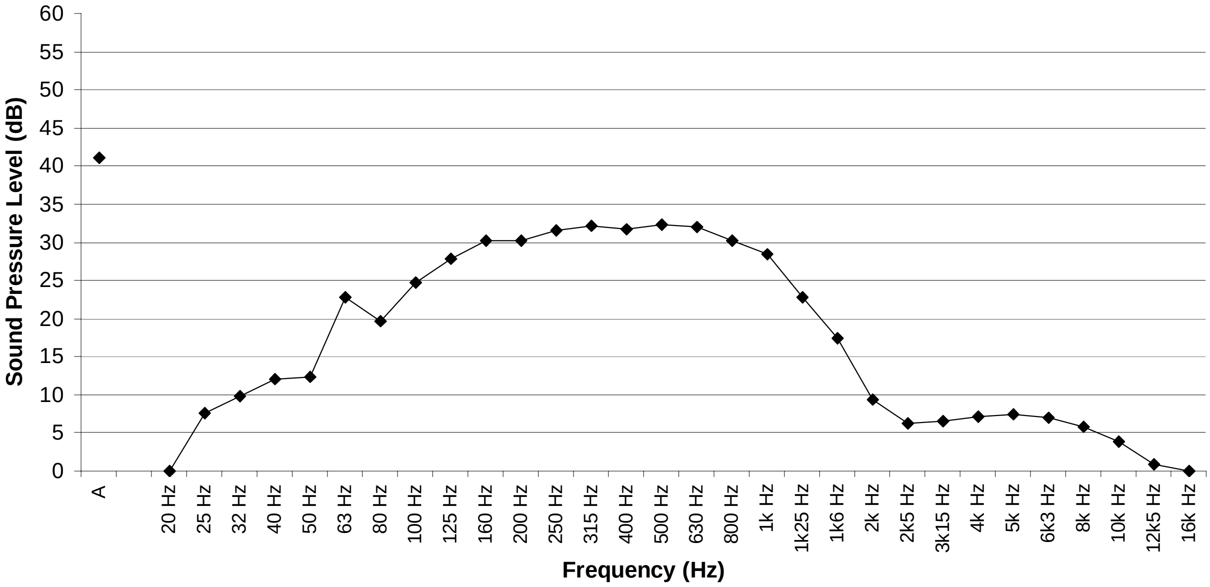

Figure 3D-18 A-Weighted 1/3 Octave Band Nighttime Sound Levels at Noise Monitor #9 (Near Receptor #11)

Appendix 3E Noise Modelling Parameters

Table 3E-1 Existing and Approved and Planned Facility Noise Levels

Facility	SWL (dBA)	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Agrium	128.7	89	107	120	123	126	121	117	111
North West Upgrader	120.0	101	115	113	114	114	115	112	94
Degussa	108.7	69	87	100	103	106	101	97	91
Shell Upgrader + Refinery	130.0	107	121	122	124	126	124	120	110
Shell Scotford Upgrader Expansion 1	126.1	107	121	119	120	120	121	118	100
Shell Scotford Upgrader 2 (each) [1]	128.5	112	119	125	124	121	99	90	90
Provident (Williams Energy)	115.5	91	99	102	106	112	110	105	93
BA Energy	122.0	103	117	115	116	116	117	114	96
Petro-Canada Upgrader	126.1	107	121	119	120	120	121	118	100
Synenco Northern Lights Upgrader[2]	120.6	101	110	115	117	113	93	90	90

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[1] Data for the new Shell Upgraders was provided in the form of numerous octave band point sources in CADNA/A model. This data was incorporated into the Project noise model. The information presented in the table is an equivalent simplification to a single point source.

[2] Data for the Northern Lights Upgrader was obtained from the Noise portion of the EIA prepared for Synenco, and includes numerous octave band point sources which have been incorporated into the Project noise model. The information presented in the table is an equivalent simplification to a single point source.

Table 3E-2 Construction Noise Levels

Item	Rating / Capacity	SPL @ 15m (dBA)	SWL[3] (dBA)	Operation
Earth-moving Crawler Tractors & Dozers	101 - 250 HP	79	113.5	Day / Night
Front-end Loaders	1.6 - 3.4 Cubic Metres	81	115.5	Day / Night
Graders	176 - 350 HP	77	111.5	Day / Night
Earth Haulers	54 - 104 Metric Tons	84	118.5	Day Only
Mobile Cranes	10 - 18 Metric Tons	77	111.5	Day / Night
Concrete Batch Plants		79	113.5	Day / Night
Vibratory Conveyors		74	108.5	Day / Night
Concrete Vibrators		76	110.5	Day / Night
Impact Pile Drivers	16 - 24 KN.m	90	124.5	Day Only
Blasting Equipment		88	122.5	Day Only
Jackhammers	unsilenced	79	113.5	Day Only
Air Compressors	800 - 1575 CPM	81	115.5	Day / Night
Warning Horns		96	130.5	Day Only
Overall Daytime SWL (dBA)			**128.6**	
Overall Nighttime SWL (dBA)			**122.1**	

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[3] SWL = Sound Power Level in dBA, referenced to 10^{-12} Watts

North American Oil Sands Upgrader Project Noise Levels

Information presented shows equipment, quantity, power ratings, height from ground, calculated sound power levels (re 10^{-12} Watts), noise reduction from building (if applicable) and resultant equipment sound power level. Since the noise levels imposed by North American on the equipment vendors is 85 dBA at 0.9 m, a calculation of the approximate noise level reduction to meet this target is provided along with the final modelled sound power level.

Diluent Recovery Units

DRU-1 Unit 0100.

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Heater Charge Pump	1	741	KW	1	106.6	0.0	106.6	10.6	96.0
Diluent Recovery Pump	1	103	KW	1	104.0	0.0	104.0	8.0	96.0
DCU Feed Pump	1	412	KW	1	105.8	0.0	105.8	9.8	96.0
LGO Pump	1	288	KW	1	105.4	0.0	105.4	9.4	96.0
Desalting Water Pump	1	82	KW	1	103.7	0.0	103.7	7.7	96.0
Heater Exhaust	1	311	GJ/h	30	100.0	0.0	100.0	4.0	96.0
Heater Casing	1	311	GJ/h	3	100.0	0.0	100.0	4.0	96.0
Heater ID Fan	1	173	KW	1	102.7	0.0	102.7	6.7	96.0
Heater FD Fan	1	124	KW	1	101.6	0.0	101.6	5.6	96.0
Brine Air Cooler	2	25	KW	15	105.2	0.0	105.2	9.2	96.0
Overhead Condenser	16	25	KW	15	114.2	0.0	114.2	18.2	96.0

DRU-2 Desalter & DRU

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Heater Charge Pump	1	844	KW	1	106.8	0.0	106.8	10.8	96.0
Diluent Recovery Pump	1	117	KW	1	104.2	0.0	104.2	8.2	96.0
DCU Feed Pump	1	469	KW	1	106.0	0.0	106.0	10.0	96.0
LGO Pump	1	328	KW	1	105.5	0.0	105.5	9.5	96.0
Desalting Water Pump	1	94	KW	1	103.9	0.0	103.9	7.9	96.0
Heater Exhaust	1	354	GJ/h	30	100.9	0.0	100.9	4.9	96.0
Heater Casing	1	354	GJ/h	3	100.9	0.0	100.9	4.9	96.0
Heater ID Fan	1	197	KW	1	103.1	0.0	103.1	7.1	96.0
Heater FD Fan	1	141	KW	1	102.0	0.0	102.0	6.0	96.0
Brine Air Cooler	2	25	KW	15	105.2	0.0	105.2	9.2	96.0
Overhead Condenser	16	25	KW	15	114.2	0.0	114.2	18.2	96.0

DRU-3 Desalter & DRU

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Heater Charge Pump	1	417	KW	1	105.9	0.0	105.9	9.9	96.0
Diluent Recovery Pump	1	58	KW	1	103.3	0.0	103.3	7.3	96.0
DCU Feed Pump	1	232	KW	1	105.1	0.0	105.1	9.1	96.0
LGO Pump	1	162	KW	1	104.6	0.0	104.6	8.6	96.0
Desalting Water Pump	1	46	KW	1	103.0	0.0	103.0	7.0	96.0
Heater Exhaust	1	175	GJ/h	30	96.3	0.0	96.3	0.3	96.0
Heater Casing	1	175	GJ/h	3	96.3	0.0	96.3	0.3	96.0
Heater ID Fan	1	97	KW	1	100.9	0.0	100.9	4.9	96.0
Heater FD Fan	1	70	KW	1	99.9	0.0	99.9	3.9	96.0
Brine Air Cooler	2	25	KW	15	105.2	0.0	105.2	9.2	96.0
Overhead Condenser	16	25	KW	15	114.2	0.0	114.2	18.2	96.0

Vacuum Unit
VAC

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Liquid Ring Pump	1	97	KW	1	104.0	0.0	104.0	8.0	96.0
LVGO Pump	1	194	KW	1	104.9	0.0	104.9	8.9	96.0
HVGO PA Pump	1	680	KW	1	106.5	0.0	106.5	10.5	96.0
HVGO Pump	1	97	KW	1	104.0	0.0	104.0	8.0	96.0
Recycle Pump	1	73	KW	1	103.6	0.0	103.6	7.6	96.0
Vac Resid Pump	1	1214	KW	1	107.3	0.0	107.3	11.3	96.0
Heater Exhaust	1	248	GJ/h	30	98.6	0.0	98.6	2.6	96.0
Heater Casing	1	248	GJ/h	3	98.6	0.0	98.6	2.6	96.0
Heater ID Fan	1	97	KW	1	100.9	0.0	100.9	4.9	96.0
Heater FD Fan	1	73	KW	1	100.0	0.0	100.0	4.0	96.0
LVGO Air Cooler	4	30	KW	15	108.8	0.0	108.8	12.8	96.0
HVGO Air Cooler	4	30	KW	15	108.8	0.0	108.8	12.8	96.0
Offgas Compressor	1	680	KW	1	117.3	0.0	117.3	21.3	96.0

Naphtha Hydrotreating Units
NHT-1 Unit - 0500

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Charge Pump	1	376	KW	1	105.7	0.0	105.7	9.7	96.0
Recycle Pump	1	84	KW	1	103.8	0.0	103.8	7.8	96.0
Product Condenser	4	25	KW	15	108.2	0.0	108.2	12.2	96.0
Misc Air Coolers	6	25	KW	15	110.0	0.0	110.0	14.0	96.0
Heater Exhaust	1	16	GJ/h	30	80.7	0.0	80.7	0.0	80.7
Heater Casing	1	16	GJ/h	3	80.7	0.0	80.7	0.0	80.7
Recycle Compressor (T)	1	2011	KW	1	122.0	0.0	122.0	26.0	96.0

(T) = Turbine Driven

NHT-2 NHT

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Charge Pump	1	400	KW	1	105.8	0.0	105.8	9.8	96.0
Recycle Pump	1	89	KW	1	103.8	0.0	103.8	7.8	96.0
Product Condenser	4	25	KW	15	108.2	0.0	108.2	12.2	96.0
Misc Air Coolers	6	25	KW	15	110.0	0.0	110.0	14.0	96.0
Heater Exhaust	1	17	GJ/h	30	81.1	0.0	81.1	0.0	81.1
Heater Casing	1	17	GJ/h	3	81.1	0.0	81.1	0.0	81.1
Recycle Compressor (T)	1	2137	KW	1	122.3	0.0	122.3	26.3	96.0

(T) = Turbine Driven

Gas Oil Hydroprocessing Units
BHT (Mod), Unit - 0600

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Charge Pump	1	2950	KW	1	108.4	0.0	108.4	12.4	96.0
Wash Water Pump	1	274	KW	1	105.3	0.0	105.3	9.3	96.0
Lean Amine Pump	1	1427	KW	1	107.5	0.0	107.5	11.5	96.0
Stripper Bottoms Pump	1	130	KW	1	104.3	0.0	104.3	8.3	96.0
Product Condenser	8	25	KW	15	111.2	0.0	111.2	15.2	96.0
Heater Exhaust	1	34.1	GJ/h	30	85.6	0.0	85.6	0.0	85.6
Heater Casing	1	34.1	GJ/h	3	85.6	0.0	85.6	0.0	85.6
Misc Air Coolers	8	25	KW	15	111.2	0.0	111.2	15.2	96.0
Recycle Compressor (T)	1	2833	KW	1	123.5	0.0	123.5	27.5	96.0
Makeup Compressor A	1	10803	KW	1	129.3	0.0	129.3	33.3	96.0
Makeup Compressor B	1	10803	KW	1	129.3	0.0	129.3	33.3	96.0

(T) = Turbine Driven

HDC-1, GOHT

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Charge Pump	1	2910	KW	1	108.4	0.0	108.4	12.4	96.0
Wash Water Pump	1	270	KW	1	105.3	0.0	105.3	9.3	96.0
Lean Amine Pump	1	1407	KW	1	107.4	0.0	107.4	11.4	96.0
Stripper Bottoms Pump	1	128	KW	1	104.3	0.0	104.3	8.3	96.0
Product Condenser	8	25	KW	15	111.2	0.0	111.2	15.2	96.0
Heater Exhaust	2	33.7	GJ/h	30	88.6	0.0	88.6	0.0	88.6
Heater Casing	2	33.7	GJ/h	3	88.6	0.0	88.6	0.0	88.6
Misc Air Coolers	8	25	KW	15	111.2	0.0	111.2	15.2	96.0
Recycle Compressor (T)	1	2794	KW	1	123.5	0.0	123.5	27.5	96.0
Makeup Compressor A	1	10653	KW	1	129.3	0.0	129.3	33.3	96.0
Makeup Compressor B	1	10653	KW	1	129.3	0.0	129.3	33.3	96.0

(T) = Turbine Driven

HDC-2, VGOHT

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Charge Pump	1	2074	KW	1	108.0	0.0	108.0	12.0	96.0
Wash Water Pump	1	192	KW	1	104.8	0.0	104.8	8.8	96.0
Lean Amine Pump	1	1003	KW	1	107.0	0.0	107.0	11.0	96.0
Stripper Bottoms Pump	1	91	KW	1	103.9	0.0	103.9	7.9	96.0
Product Condenser	8	25	KW	15	111.2	0.0	111.2	15.2	96.0
Heater Exhaust	2	25	GJ/h	30	86.6	0.0	86.6	0.0	86.6
Heater Casing	2	25	GJ/h	3	86.6	0.0	86.6	0.0	86.6
Misc Air Coolers	8	25	KW	15	111.2	0.0	111.2	15.2	96.0
Recycle Compressor (T)	1	1991	KW	1	122.0	0.0	122.0	26.0	96.0
Makeup Compressor A	1	7592	KW	1	127.8	0.0	127.8	31.8	96.0
Makeup Compressor B	1	7592	KW	1	127.8	0.0	127.8	31.8	96.0

(T) = Turbine Driven

Hydrogen Plant

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Boiler Water Circ Pump (T)	1	150	KW	1	104.5	0.0	104.5	8.5	96.0
BFW Pump (T)	1	933	KW	1	106.9	0.0	106.9	10.9	96.0
Raw Gas Cooler	8	35	KW	15	112.4	0.0	112.4	16.4	96.0
Recycle Hydrogen Cooler	1	5	KW	15	96.6	0.0	96.6	0.6	96.0
Heater Exhaust	1	850.5	GJ/h	61	106.6	0.0	106.6	10.6	96.0
Heater Casing	1	850.5	GJ/h	3	106.6	0.0	106.6	10.6	96.0
Heater ID Fan	1	250	KW	1	103.8	0.0	103.8	7.8	96.0
Heater FD Fan	1	650	KW	1	106.7	0.0	106.7	10.7	96.0

Sulphur Forming Unit
SFU

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Rotoforming Unit Motors (BLDG)	4	150	KW	1	114.6	25.0	89.6	0.0	89.6

Building Dims = 36 x 21 x 5

Delayed Coking Units
DCU-1, Unit -0300

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Heater Charge Pump	1	1226	KW	1	107.3	0.0	107.3	11.3	96.0
Unstab Naphtha Pump	1	82	KW	1	103.7	0.0	103.7	7.7	96.0
LCGO Pump	1	286	KW	1	105.4	0.0	105.4	9.4	96.0
HCGO Pump	1	572	KW	1	106.3	0.0	106.3	10.3	96.0
Jet Pump	1	3730	KW	1	108.7	0.0	108.7	12.7	96.0
Quench Pump	1	102	KW	1	104.0	0.0	104.0	8.0	96.0
Blowdown Oil Pump	1	82	KW	1	103.7	0.0	103.7	7.7	96.0
LCGO PA Pump	1	102	KW	1	104.0	0.0	104.0	8.0	96.0
Stripper Feed Pump	1	123	KW	1	104.3	0.0	104.3	8.3	96.0
Stab Naphtha Pump	1	163	KW	1	104.6	0.0	104.6	8.6	96.0
Frac Overhead Condenser	16	25	KW	15	114.2	0.0	114.2	18.2	96.0
Blowdown Condenser	16	25	KW	15	114.2	0.0	114.2	18.2	96.0
Blowdown Oil Cooler	2	20	KW	15	104.4	0.0	104.4	8.4	96.0
HCGO Product Cooler	4	25	KW	15	108.2	0.0	108.2	12.2	96.0
LCGO Product Cooler	4	30	KW	15	108.8	0.0	108.8	12.8	96.0
LCGO PA Cooler	2	15	KW	15	103.4	0.0	103.4	7.4	96.0
Comp Interstage Cooler	4	15	KW	15	106.4	0.0	106.4	10.4	96.0
Abs Feed Condenser	6	30	KW	15	110.6	0.0	110.6	14.6	96.0
Naphtha Cooler	6	25	KW	15	110.0	0.0	110.0	14.0	96.0
Debutanizer OH Condenser	6	30	KW	15	110.6	0.0	110.6	14.6	96.0
C3/C4 Splitter Condenser	2	20	KW	15	104.4	0.0	104.4	8.4	96.0
Fuel Gas Cooler	2	10	KW	15	102.0	0.0	102.0	6.0	96.0
Heater 1 Exhaust	1	268.7	GJ/h	61	99.1	0.0	99.1	3.1	96.0
Heater 1 Casing	1	268.7	GJ/h	3	99.1	0.0	99.1	3.1	96.0
Heater 2 Exhaust	1	268.7	GJ/h	61	99.1	0.0	99.1	3.1	96.0
Heater 2 Casing	1	268.7	GJ/h	3	99.1	0.0	99.1	3.1	96.0
Heater 1 ID Fan	1	113	KW	1	101.4	0.0	101.4	5.4	96.0
Heater 1 FD Fan	1	139	KW	1	102.0	0.0	102.0	6.0	96.0
Heater 2 ID Fan	1	113	KW	1	101.4	0.0	101.4	5.4	96.0
Heater 2 FD Fan	1	139	KW	1	102.0	0.0	102.0	6.0	96.0
Vent Gas Compressor	1	572	KW	1	116.6	0.0	116.6	20.6	96.0
Coker Gas Compressor	1	8990	KW	1	128.5	0.0	128.5	32.5	96.0

DCU-2

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Heater Charge Pump	1	1407	KW	1	107.4	0.0	107.4	11.4	96.0
Unstab Naphtha Pump	1	94	KW	1	103.9	0.0	103.9	7.9	96.0
LCGO Pump	1	328	KW	1	105.5	0.0	105.5	9.5	96.0
HCGO Pump	1	657	KW	1	106.5	0.0	106.5	10.5	96.0
Jet Pump	1	3730	KW	1	108.7	0.0	108.7	12.7	96.0
Quench Pump	1	117	KW	1	104.2	0.0	104.2	8.2	96.0
Blowdown Oil Pump	1	94	KW	1	103.9	0.0	103.9	7.9	96.0
LCGO PA Pump	1	117	KW	1	104.2	0.0	104.2	8.2	96.0
Stripper Feed Pump	1	141	KW	1	104.4	0.0	104.4	8.4	96.0
Stab Naphtha Pump	1	188	KW	1	104.8	0.0	104.8	8.8	96.0
Frac Overhead Condenser	16	25	KW	15	114.2	0.0	114.2	18.2	96.0
Blowdown Condenser	16	25	KW	15	114.2	0.0	114.2	18.2	96.0
Blowdown Oil Cooler	2	20	KW	15	104.4	0.0	104.4	8.4	96.0
HCGO Product Cooler	4	25	KW	15	108.2	0.0	108.2	12.2	96.0
LCGO Product Cooler	4	30	KW	15	108.8	0.0	108.8	12.8	96.0
LCGO PA Cooler	2	15	KW	15	103.4	0.0	103.4	7.4	96.0
Comp Interstage Cooler	4	15	KW	15	106.4	0.0	106.4	10.4	96.0
Abs Feed Condenser	6	30	KW	15	110.6	0.0	110.6	14.6	96.0
Naphtha Cooler	6	25	KW	15	110.0	0.0	110.0	14.0	96.0
Debutanizer OH Condenser	6	30	KW	15	110.6	0.0	110.6	14.6	96.0
C3/C4 Splitter Condenser	2	20	KW	15	104.4	0.0	104.4	8.4	96.0
Fuel Gas Cooler	2	10	KW	15	102.0	0.0	102.0	6.0	96.0
Heater 1 Exhaust	1	322.6	GJ/h	61	100.3	0.0	100.3	4.3	96.0
Heater 1 Casing	1	322.6	GJ/h	3	100.3	0.0	100.3	4.3	96.0
Heater 2 Exhaust	1	322.6	GJ/h	61	100.3	0.0	100.3	4.3	96.0
Heater 2 Casing	1	322.6	GJ/h	3	100.3	0.0	100.3	4.3	96.0
Heater 1 ID Fan	1	129	KW	1	101.8	0.0	101.8	5.8	96.0
Heater 1 FD Fan	1	160	KW	1	102.4	0.0	102.4	6.4	96.0
Heater 2 ID Fan	1	129	KW	1	101.8	0.0	101.8	5.8	96.0
Heater 2 FD Fan	1	160	KW	1	102.4	0.0	102.4	6.4	96.0
Vent Gas Compressor	1	657	KW	1	117.2	0.0	117.2	21.2	96.0
Coker Gas Compressor	1	10317	KW	1	129.1	0.0	129.1	33.1	96.0

Sulphur Degassing Unit
SDU-1

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
L.P. Steam Condenser 1	1	56	KW	5	105.0	0.0	105.0	9.0	96.0
L.P. Steam Condenser 2	1	56	KW	5	105.0	0.0	105.0	9.0	96.0

SDU-2

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
L.P. Steam Condenser 1	1	56	KW	5	105.0	0.0	105.0	9.0	96.0
L.P. Steam Condenser 2	1	56	KW	5	105.0	0.0	105.0	9.0	96.0

SDU-3

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
L.P. Steam Condenser 1	1	56	KW	5	105.0	0.0	105.0	9.0	96.0
L.P. Steam Condenser 2	1	56	KW	5	105.0	0.0	105.0	9.0	96.0

Sulphur Recovery Unit

SRU-1

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Sulphur Degassing Pumps	2	37	KW	1	102.7	0.0	102.7	6.7	96.0
Combustion Air Blowers	2	1119	KW	15	111.4	0.0	111.4	15.4	96.0
Waste Steam Condenser 1	2	11	KW	15	102.3	0.0	102.3	6.3	96.0
Waste Steam Condenser 2	2	11	KW	15	102.3	0.0	102.3	6.3	96.0

SRU-2

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Sulphur Degassing Pumps	2	37	KW	1	102.7	0.0	102.7	6.7	96.0
Combustion Air Blowers	2	1119	KW	15	111.4	0.0	111.4	15.4	96.0
Waste Steam Condenser 1	2	11	KW	15	102.3	0.0	102.3	6.3	96.0
Waste Steam Condenser 2	2	11	KW	15	102.3	0.0	102.3	6.3	96.0

SRU-3

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Sulphur Degassing Pumps	1	37	KW	1	99.7	0.0	99.7	3.7	96.0
Combustion Air Blowers	1	1119	KW	15	108.3	0.0	108.3	12.3	96.0
Waste Steam Condenser 1	2	11	KW	15	102.3	0.0	102.3	6.3	96.0
Waste Steam Condenser 2	2	11	KW	15	102.3	0.0	102.3	6.3	96.0

Sulphur Handling Unit

SHU

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Motors	3	60	KW	1	109.4	25.0	84.4	0.0	84.4

Raw Water Supply and Pretreatment

RWS-1, RWS-2, RWS-3

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Firewater Pump (Diesel) (BLDG (1))	2	741	KW	1	109.6	25.0	84.6	0.0	84.6
Firewater Pump (Electric) (BLDG (1))	2	741	KW	1	109.6	25.0	84.6	0.0	84.6
Raw Water Transfer Pump (BLDG (1))	3	110	KW	1	108.9	25.0	83.9	0.0	83.9
Firewater Jockey Pump (BLDG (1))	2	22	KW	1	100.4	25.0	75.4	0.0	75.4
Utility Water Pump	3	73	KW	1	108.4	0.0	108.4	12.4	96.0
RO Unit Feed Pump	3	73	KW	1	108.4	0.0	108.4	12.4	96.0
Potable Water Pump	2	25	KW	1	101.0	0.0	101.0	5.0	96.0
Raw Water Transfer Pump (Turbine) (BLDG (1))	3	110	KW	1	108.9	25.0	83.9	0.0	83.9
Utility Water Pump (Turbine)	3	73	KW	1	108.4	0.0	108.4	12.4	96.0
RO Unit Feed Pump (Turbine)	3	73	KW	1	108.4	0.0	108.4	12.4	96.0

Building Dims = 5 x 14 x 5

Tail Gas Treating Unit
TGTU-1

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Contact Condenser Circulating Pumps	1	93	KW	1	103.9	0.0	103.9	7.9	96.0
Desuperheater Circulating Pumps	1	45	KW	1	100.5	0.0	100.5	4.5	96.0
Rich Amine Pumps	1	37	KW	1	99.7	0.0	99.7	3.7	96.0
Lean Amine Pumps	1	56	KW	1	101.5	0.0	101.5	5.5	96.0
Regenerator Pumparound Pumps	1	30	KW	1	98.7	0.0	98.7	2.7	96.0
RGG Combustion Air Blowers	1	187	KW	1	102.9	0.0	102.9	6.9	96.0
Start Up Blower	1	187	KW	1	102.9	0.0	102.9	6.9	96.0
Contact Condenser Air Cooler	8	22	KW	15	110.8	0.0	110.8	14.8	96.0
Spent Caustic Air Cooler	2	11	KW	15	102.3	0.0	102.3	6.3	96.0
Lean Amine Air Cooler	4	37	KW	15	109.6	0.0	109.6	13.6	96.0
Refrigerator Pumparound Cooler	4	22	KW	15	107.8	0.0	107.8	11.8	96.0

TGTU-2

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Contact Condenser Circulating Pumps	1	93	KW	1	103.9	0.0	103.9	7.9	96.0
Desuperheater Circulating Pumps	1	45	KW	1	100.5	0.0	100.5	4.5	96.0
Rich Amine Pumps	1	37	KW	1	99.7	0.0	99.7	3.7	96.0
Lean Amine Pumps	1	56	KW	1	101.5	0.0	101.5	5.5	96.0
Regenerator Pumparound Pumps	1	30	KW	1	98.7	0.0	98.7	2.7	96.0
RGG Combustion Air Blowers	1	187	KW	1	102.9	0.0	102.9	6.9	96.0
Start Up Blower	1	187	KW	1	102.9	0.0	102.9	6.9	96.0
Contact Condenser Air Cooler	8	22	KW	15	110.8	0.0	110.8	14.8	96.0
Spent Caustic Air Cooler	2	11	KW	15	102.3	0.0	102.3	6.3	96.0
Lean Amine Air Cooler	4	37	KW	15	109.6	0.0	109.6	13.6	96.0
Refrigerator Pumparound Cooler	4	22	KW	15	107.8	0.0	107.8	11.8	96.0

TGTU-3

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Contact Condenser Circulating Pumps	1	93	KW	1	103.9	0.0	103.9	7.9	96.0
Desuperheater Circulating Pumps	1	45	KW	1	100.5	0.0	100.5	4.5	96.0
Rich Amine Pumps	1	37	KW	1	99.7	0.0	99.7	3.7	96.0
Lean Amine Pumps	1	56	KW	1	101.5	0.0	101.5	5.5	96.0
Regenerator Pumparound Pumps	1	30	KW	1	98.7	0.0	98.7	2.7	96.0
RGG Combustion Air Blowers	1	187	KW	1	102.9	0.0	102.9	6.9	96.0
Start Up Blower	1	187	KW	1	102.9	0.0	102.9	6.9	96.0
Contact Condenser Air Cooler	8	22	KW	15	110.8	0.0	110.8	14.8	96.0
Spent Caustic Air Cooler	2	11	KW	15	102.3	0.0	102.3	6.3	96.0
Lean Amine Air Cooler	4	37	KW	15	109.6	0.0	109.6	13.6	96.0
Refrigerator Pumparound Cooler	4	22	KW	15	107.8	0.0	107.8	11.8	96.0

Cooling Water System
CWS_1, CWS-2, CWS-3

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Cooling Water Circulation Pump	3	708	KW	1	111.3	0.0	111.3	15.3	96.0
Cooling Water Circulation Pump (Turbine)	3	708	KW	1	111.3	0.0	111.3	15.3	96.0

Sour Water Stripper

SWS-1

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Sour Water Stripper Feed Pumps	1	56	KW	1	101.5	0.0	101.5	5.5	96.0
Sour Water Stripper Bottom Pumps	1	56	KW	1	101.5	0.0	101.5	5.5	96.0
SWS Pumparound Pumps	1	56	KW	1	101.5	0.0	101.5	5.5	96.0
SWS Pumparound Cooler	6	30	KW	15	110.6	0.0	110.6	14.6	96.0
Recovery Water Cooler	4	22	KW	15	107.8	0.0	107.8	11.8	96.0

SWS-2

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Sour Water Stripper Feed Pumps	1	56	KW	1	101.5	0.0	101.5	5.5	96.0
Sour Water Stripper Bottom Pumps	1	56	KW	1	101.5	0.0	101.5	5.5	96.0
SWS Pumparound Pumps	1	56	KW	1	101.5	0.0	101.5	5.5	96.0
SWS Pumparound Cooler	6	30	KW	15	110.6	0.0	110.6	14.6	96.0
Recovery Water Cooler	4	22	KW	15	107.8	0.0	107.8	11.8	96.0

SWS-3

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Sour Water Stripper Feed Pumps	1	56	KW	1	101.5	0.0	101.5	5.5	96.0
Sour Water Stripper Bottom Pumps	1	56	KW	1	101.5	0.0	101.5	5.5	96.0
SWS Pumparound Pumps	1	56	KW	1	101.5	0.0	101.5	5.5	96.0
SWS Pumparound Cooler	6	30	KW	15	110.6	0.0	110.6	14.6	96.0
Recovery Water Cooler	4	22	KW	15	107.8	0.0	107.8	11.8	96.0

BFW Treatment and Condensate Recovery

BFWT-1, BFWT-2, BFWT-3

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
RO Water Pump	3	37	KW	0	104.5	0.0	104.5	8.5	96.0
BFW Pump	3	668	KW	0	111.2	0.0	111.2	15.2	96.0
RO Water Pump (Turbine)	3	37	KW	0	104.5	0.0	104.5	8.5	96.0
BFW Pump (Turbine)	3	668	KW	0	111.2	0.0	111.2	15.2	96.0
Boilers Exhaust	1	273	GJ/h	30	99.2	0.0	99.2	3.2	96.0
Boilers Casing	1	273	GJ/h	3	99.2	0.0	99.2	3.2	96.0
Boilers Exhaust	1	273	GJ/h	30	99.2	0.0	99.2	3.2	96.0
Boilers Casing	1	273	GJ/h	3	99.2	0.0	99.2	3.2	96.0
Boilers Exhaust	1	273	GJ/h	30	99.2	0.0	99.2	3.2	96.0
Boilers Casing	1	273	GJ/h	3	99.2	0.0	99.2	3.2	96.0
Boilers Exhaust	1	273	GJ/h	30	99.2	0.0	99.2	3.2	96.0
Boilers Casing	1	273	GJ/h	3	99.2	0.0	99.2	3.2	96.0
Boilers Exhaust	1	273	GJ/h	30	99.2	0.0	99.2	3.2	96.0
Boilers Casing	1	273	GJ/h	3	99.2	0.0	99.2	3.2	96.0

Amine Regeneration Unit

ARU-1

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Amine Circulation Pumps	1	933	KW	1	106.9	0.0	106.9	10.9	96.0
Rich Amine Pumps	1	187	KW	1	104.8	0.0	104.8	8.8	96.0
Lean Amine Cooler	16	37	KW	15	115.6	0.0	115.6	19.6	96.0
Amine Regenerator Overhead Cooler	6	22	KW	15	109.5	0.0	109.5	13.5	96.0

ARU-2

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Amine Circulation Pumps	1	933	KW	1	106.9	0.0	106.9	10.9	96.0
Rich Amine Pumps	1	187	KW	1	104.8	0.0	104.8	8.8	96.0
Lean Amine Cooler	16	37	KW	15	115.6	0.0	115.6	19.6	96.0
Amine Regenerator Overhead Cooler	6	22	KW	15	109.5	0.0	109.5	13.5	96.0

ARU-3

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Amine Circulation Pumps	1	933	KW	1	106.9	0.0	106.9	10.9	96.0
Rich Amine Pumps	1	187	KW	1	104.8	0.0	104.8	8.8	96.0
Lean Amine Cooler	16	37	KW	15	115.6	0.0	115.6	19.6	96.0
Amine Regenerator Overhead Cooler	6	22	KW	15	109.5	0.0	109.5	13.5	96.0

Tank Farm

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Tank Farm Area 1									
Desalter Feed Pump	3	647	KW	1	111.2	0.0	111.2	15.2	96.0
Distillate Product Pump	3	280	KW	1	110.1	0.0	110.1	14.1	96.0
Bulk Hydrotreater Feed Pump	3	101	KW	1	108.8	0.0	108.8	12.8	96.0
Reject Tank Pump	2	275	KW	1	108.3	0.0	108.3	12.3	96.0
Tank Farm Area 2									
Naphtha-Diluent Transfer Pump	2	424	KW	1	108.9	0.0	108.9	12.9	96.0
Synthetic Crude Transfer Pump	2	1069	KW	1	110.1	0.0	110.1	14.1	96.0
DCU Feed Pump	2	212	KW	1	108.0	0.0	108.0	12.0	96.0

Gasification
Gasification-1

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Grinding Mills	1	2205	KW	1	110.0	0.0	110.0	14.0	96.0
Slurry Run Tank Agitator Motor	1	55	KW	1	104.2	0.0	104.2	8.2	96.0
Slag Crusher (BLDG (1))	1	110	KW	1	107.3	25.0	82.3	0.0	82.3
Mill Discharge Tank Pumps	1	129	KW	1	104.3	0.0	104.3	8.3	96.0
Grinding Sump Pumps	1	55	KW	1	101.4	0.0	101.4	5.4	96.0
Slurry Feed Pumps	1	368	KW	1	105.7	0.0	105.7	9.7	96.0
Feed Injector Cooling Water Pumps	1	44	KW	1	100.4	0.0	100.4	4.4	96.0
Syngas Scrubber Circulating Pumps	1	129	KW	1	104.3	0.0	104.3	8.3	96.0
Purge Water Pumps	1	368	KW	1	105.7	0.0	105.7	9.7	96.0
Grey Water Pumps	1	29	KW	1	98.7	0.0	98.7	2.7	96.0
Recycle Condensate Pumps	1	129	KW	1	104.3	0.0	104.3	8.3	96.0
Slag Sump Pumps	1	92	KW	1	103.9	0.0	103.9	7.9	96.0
Trim Cooler KO Drum Pumps	1	74	KW	1	103.6	0.0	103.6	7.6	96.0
Process Condensate Pumps	1	129	KW	1	104.3	0.0	104.3	8.3	96.0
AGR Lean Solvent Booster Pumps	1	515	KW	1	106.1	0.0	106.1	10.1	96.0
AGR Lean Solvent Pumps	1	294	KW	1	105.4	0.0	105.4	9.4	96.0
Steam Condensate Pump	1	37	KW	1	99.7	0.0	99.7	3.7	96.0
Semi Lean Solvent Pump	1	7350	KW	1	109.6	0.0	109.6	13.6	96.0
CO2 Recycle Compressor (BLDG (1))	1	1470	KW	1	120.7	25.0	95.7	0.0	95.7
CO2 Vacuum Compressor (BLDG (1))	1	735	KW	1	117.7	25.0	92.7	0.0	92.7
Rich Flash Gas Compressor (BLDG (1))	1	588	KW	1	116.7	25.0	91.7	0.0	91.7
Stripping Gas Compressor (BLDG (1))	1	110	KW	1	109.4	25.0	84.4	0.0	84.4
AGR Refrigeration Compressor (BLDG (1))	1	7350	KW	1	127.7	25.0	102.7	6.7	96.0
Main Air Compressor (BLDG (1))	1	44100	KW	1	135.4	25.0	110.4	14.4	96.0
Booster Air Compressor (BLDG (1))	1	22050	KW	1	132.4	25.0	107.4	11.4	96.0
Nitrogen Compressor (BLDG (1))	1	6615	KW	1	127.2	25.0	102.2	6.2	96.0
AGR Stripper OH Condenser	1	37	KW	15	103.5	0.0	103.5	7.5	96.0

(1) - BLDG dimensions unknown at this stage

Gasification-2

Item	QTY	Rating	Units	Height (m)	SWL (dBA)	Building Reduction (dBA)	Resultant SWL (dBA)	Mitigation Required to Meed 85 dBA @ 0.9m	Modelled SWL (dBA)
Grinding Mills	1	2205	KW	1	110.0	0.0	110.0	14.0	96.0
Slurry Run Tank Agitator Motor	1	55	KW	1	104.2	0.0	104.2	8.2	96.0
Slag Crusher (BLDG (1))	1	110	KW	1	107.3	25.0	82.3	0.0	82.3
Mill Discharge Tank Pumps	1	129	KW	1	104.3	0.0	104.3	8.3	96.0
Grinding Sump Pumps	1	55	KW	1	101.4	0.0	101.4	5.4	96.0
Slurry Feed Pumps	1	368	KW	1	105.7	0.0	105.7	9.7	96.0
Feed Injector Cooling Water Pumps	1	44	KW	1	100.4	0.0	100.4	4.4	96.0
Syngas Scrubber Circulating Pumps	1	129	KW	1	104.3	0.0	104.3	8.3	96.0
Purge Water Pumps	1	368	KW	1	105.7	0.0	105.7	9.7	96.0
Grey Water Pumps	1	29	KW	1	98.7	0.0	98.7	2.7	96.0
Recycle Condensate Pumps	1	129	KW	1	104.3	0.0	104.3	8.3	96.0
Slag Sump Pumps	1	92	KW	1	103.9	0.0	103.9	7.9	96.0
Trim Cooler KO Drum Pumps	1	74	KW	1	103.6	0.0	103.6	7.6	96.0
Process Condensate Pumps	1	129	KW	1	104.3	0.0	104.3	8.3	96.0
AGR Lean Solvent Booster Pumps	1	515	KW	1	106.1	0.0	106.1	10.1	96.0
AGR Lean Solvent Pumps	1	294	KW	1	105.4	0.0	105.4	9.4	96.0
Steam Condensate Pump	1	37	KW	1	99.7	0.0	99.7	3.7	96.0
Semi Lean Solvent Pump	1	7350	KW	1	109.6	0.0	109.6	13.6	96.0
CO2 Recycle Compressor (BLDG (1))	1	1470	KW	1	120.7	25.0	95.7	0.0	95.7
CO2 Vacuum Compressor (BLDG (1))	1	735	KW	1	117.7	25.0	92.7	0.0	92.7
Rich Flash Gas Compressor (BLDG (1))	1	588	KW	1	116.7	25.0	91.7	0.0	91.7
Stripping Gas Compressor (BLDG (1))	1	110	KW	1	109.4	25.0	84.4	0.0	84.4
AGR Refrigeration Compressor (BLDG (1))	1	7350	KW	1	127.7	25.0	102.7	6.7	96.0
Main Air Compressor (BLDG (1))	1	44100	KW	1	135.4	25.0	110.4	14.4	96.0
Booster Air Compressor (BLDG (1))	1	22050	KW	1	132.4	25.0	107.4	11.4	96.0
Nitrogen Compressor (BLDG (1))	1	6615	KW	1	127.2	25.0	102.2	6.2	96.0
AGR Stripper OH Condenser	1	37	KW	15	103.5	0.0	103.5	7.5	96.0

(1) - BLDG dimensions unknown at this stage

Appendix 3F Noise-Monitoring Weather Data

Figure 3F-1 Monitored Wind Speed, March 13–14, 2007

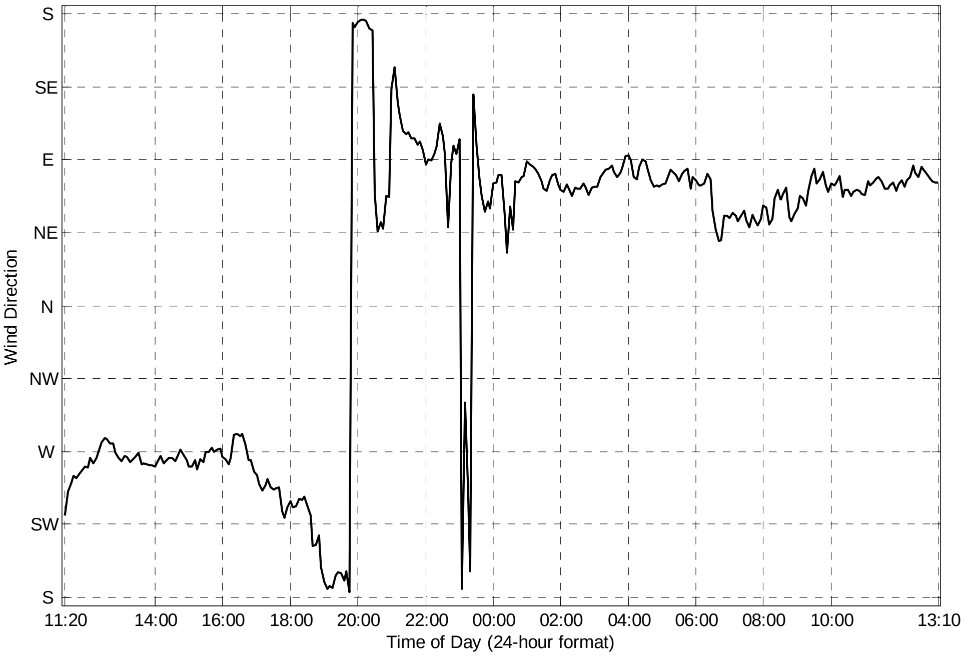

Figure 3F-2 Monitored Wind Direction, March 13–14, 2007

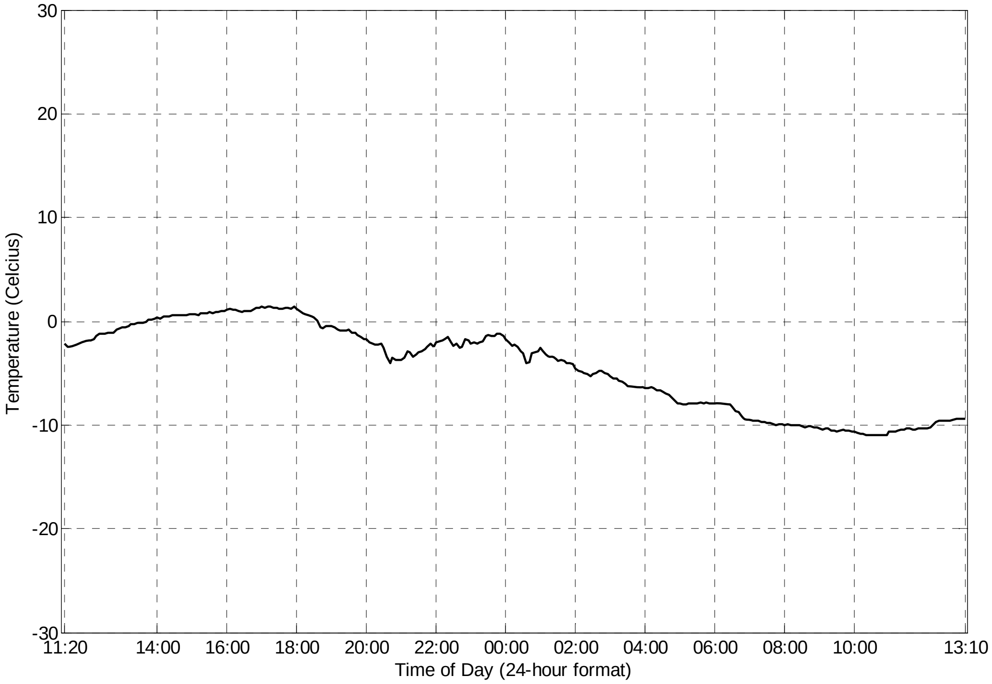

Figure 3F-3 Monitored Temperature, March 13–14, 2007

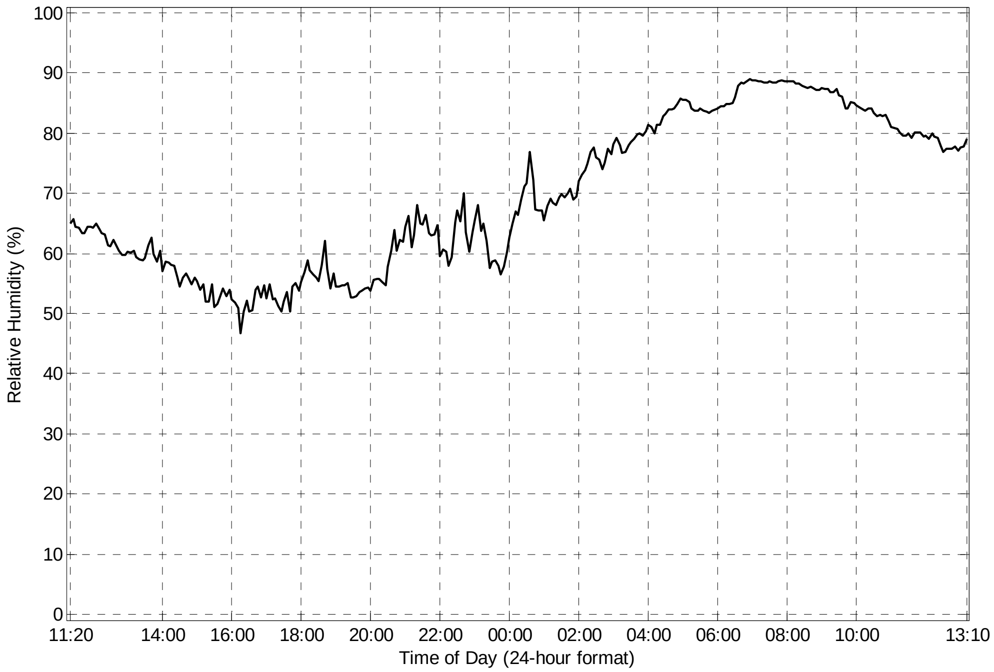

Figure 3F-4 Monitored Relative Humidity, March 13–14, 2007

Figure 3F-5 Monitored Wind Speed, March 22–23, 2007

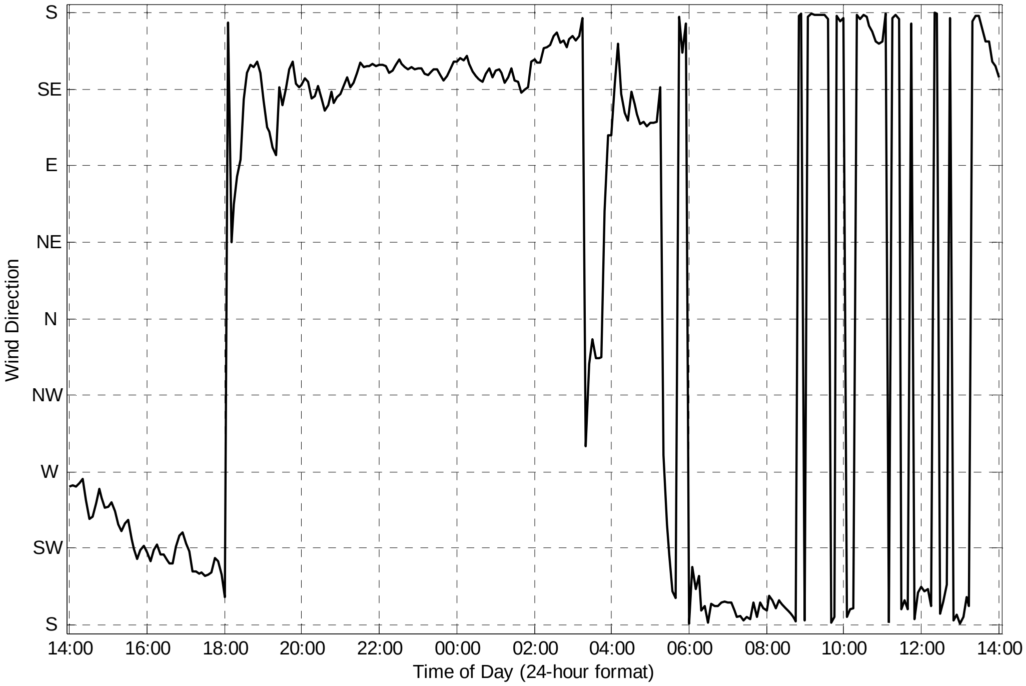

Figure 3F-6 Monitored Wind Direction, March 22–23, 2007

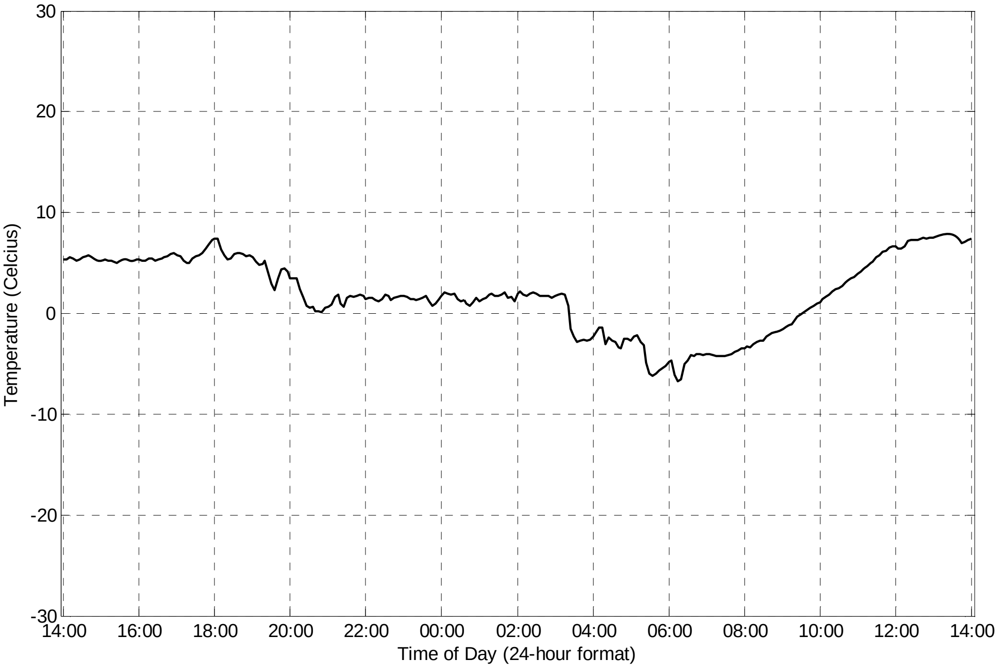

Figure 3F-7 Monitored Temperature, March 22–23, 2007

Figure 3F-8 Monitored Relative Humidity, March 22–23, 2007

TABLE OF CONTENTS

TABLES

4A1 INTRODUCTION

This appendix provides additional information regarding the available exposure limits for the chemicals of potential concern (COPCs) identified within the human health risk assessment (HHRA) and the toxicological endpoints of concern upon which they are based.

4A1.1 Selection of Chemicals of Potential Concern

The complete inventory of chemicals that may be emitted from the Project is presented in Table 4A-1, listed by category. Only airborne releases of COPCs were determined to be relevant to the Project.

In some instances there is a COPC for which little or no toxicological information exists to be predicted on the basis of information available on another chemical of similar molecular structure. The second chemical is often termed a ‘surrogate’. The principle is often applied to groups of chemicals of similar structure in which toxicity data on many of the individual constituents of the group may be lacking. In such cases, all of the constituents are assumed to share the same toxic potency as the most toxic chemical in the group for which toxicity information is known. Also, toxicological information for a similar mixture of substances also may be available and serve as the basis for an exposure limit.

Table 4A-1 Inventory of Identified Chemicals of Potential Concern

Chemical	Surrogate Chemical (if applicable)	Chemical Constituent(s)
1,3-Butadiene	NA	1,3-Butadiene
2-Chloronaphthalene	NA	2-Chloronaphthalene
Acetaldehyde	NA	Acetaldehyde
Acrolein	NA	Acrolein
Aliphatic C_5-C_8 group	NA[1]	1-heptene; 1-hexene; 1-methylcyclopentene; 1-pentene; 2,3,4-trimethylpentane; 2,2-dimethylbutane; 2,2-dimethylhexane; 2,2-dimethylpropane; 2,3,4-trimethylpentane; 2,3-dimethylbutane; 2,4,4-trimethyl-1-pentene; 2,4-dimethylhexane; 2,4-dimethylpentane; 2,5-dimethylhexane; 2-methyl-1-butene; 2-methyl-1-pentene, 2-methyl-2-butene; 2-methyl-2-pentene; 2-methylhexane; 2-methylpentane; 3-methyl-1-butene; 3-methyl-1-pentene; 3-methyl-trans-2-pentene; 3-methylhexane; 3-methylpentane; 4-methyl-1-pentene; 4-methyl-trans-2-pentene; 4-methylheptane; 3-heptene; C6 olefins; C7 olefins; C8H14; cis-1-trans-2,3-trimethylcyclopentane, cis-2-hexene; cis-2-pentene; cyclohexane; cyclohexene; cyclopentane; cyclopentene; dimethylbutene; dimethylcyclohexane; dimethylcyclopentane; dimethylhexadiene; dimethylhexanes; dimethylpentane; ethylcyclopentane; heptene; methylbutadiene; methylpentenes; isopentane; methylcyclohexane; methylcyclopentane; n-heptane; n-hexane; n-pentane; trans-2-hexene; trans-2-pentene; trans-3-hexene;

Chemical	**Surrogate Chemical (if applicable)**	**Chemical Constituent(s)**
Aliphatic C_9-C_{16} group		1,1,3-trimethylcyclohexane; 1-nonene; 1-octene; 2-methylheptane; 2,2,5-trimethylhexane; 2,3,5-trimethylhexane; 2,3-dimethylhexane; 2,3-dimethylpentane; 2,4-dimethylheptane; 2,4-dimethyloctane; 3,5-dimethylheptane; 3-ethylhexane; 3-methyloctane; 4-methyloctane; C-3-Hexene; dimethyloctanes; ethylmethylcyclohexanes; heptylcyclohexane; hexadecane; hexylcyclohexane; isopropylcyclohexane; n-undecane; nonadiene; n-decane; n-dodecane; n-nonane; n-octane; nonylcyclohexane; octycyclohexane; pentadecane; pentylcyclohexane; tetradecane; tridecane
Aliphatic C_{17}-C_{34} group		Eicosane; heneicosane; nonadecane; octadecane
Aliphatic alcohol group	Methanol	Ethyl alcohol
Aliphatic aldehyde group	Propionaldehyde	2-methyl-2-propenal; butyraldehyde; crotonaldehyde; diacetyl; glyoxal; heptanal; hexaldehyde; isovaleraldehyde; methylglyoxal; octanal; propionaldehyde
Aliphatic ketone group	Methyl ethyl ketone	Acetone; methyl ethyl ketone (2-butanone)
Ammonia	NA	Ammonia
Aromatic C_9-C_{16} group		1-methyl-2-ethylbenzene; 1-methyl-3-ethylbenzene; 1-methyl-4-ethylbenzene; (1-methylpropyl)benzene; 1-methylnaphthalene; 1,2-diethylbenzene (ortho); 1,2,3,4-tetramethylbenzene; 1,2,3-trimethylbenzene; 1,2,4-trimethylbenzene (1,3,4-trimethylbenzene); 1,3,5-trimethylbenzene; 2-methylanthracene; 2-methylnaphthalene; acenaphthene; anthracene (acute basis only) ; benzo(ghi)fluoranthene; C2 alkyl indan; C5-alkylbenzenes; ethylbenzene; ethyltoluenes (methylethylbenzenes); fluoranthene (acute basis only); fluorene (acute basis only); indan; isomers of diethylbenzene; isopropylbenzene (cumene); methylindans; methylindene; naphthalene; n-butylbenzene; n-pentylbenzene; n-propylbenzene; phenanthrene; p-tolualdehyde; pyrene; tetramethylbenzene,
Aromatic C_{17}-C_{34} group	Pyrene	1-methylphenanthrene; 2-methylcholanthrene; 3-methyl-3-phenanthrene; 9-methylphenanthrene; benz(a)anthracene (acute basis only); benzo(a)pyrene (acute basis only); benzo(b)fluoranthene (acute basis only); benzo(k)fluoranthene (acute basis only); chrysene (acute basis only); cyclopenta(cd)pyrene; dibenz(ah)anthracene (acute basis only); indeno(1,2,3-cd)pyrene (acute basis only); phenanthrene;
Benzaldehyde	NA	Benzaldehyde
Benzene	NA	Benzene
Benzo(a)pyrene IPM group	Benzo(a)pyrene	Anthracene; benz(a)anthracene; benzo(a)pyrene; benzo(e)pyrene; benzo(b)fluoranthene; benzo(g,h,i)perylene; benzo(k)fluoranthene; chrysene; dibenz(a,h)anthracene; fluoranthene; fluorene; indeno(1,2,3-cd)pyrene; phenanthrene; pyrene
Benzo(a)pyrene WMM group	Benzo(a)pyrene	Benzo(a)pyrene (used to represent all carcinogenic PAHs in this mixture)
Biphenyl	NA	Biphenyl
Carbon disulphide group	Carbon disulphide	Carbon disulphide, carbonyl sulphide
Carbon monoxide	NA	Carbon Monoxide
Cyclohexane	NA	Cyclohexane
Dichlorobenzenes	1,4-dichlorobenzene	Dichlorobenzenes
Diethanolamine	NA	Diethanolamine
Ethylbenzene	NA	Ethylbenzene

Chemical	**Surrogate Chemical (if applicable)**	**Chemical Constituent(s)**
Formaldehyde	NA	Formaldehyde
N-hexane	NA	N-hexane
Hydrogen sulphide	NA	Hydrogen sulphide
Isopropylbenzene	NA	Isopropylbenzene
Methylene chloride	NA	Methylene chloride
Naphthalene	NA	Naphthalene
Nitrogen dioxide	NA	Nitrogen dioxide
Particulate matter	NA	Particulate matter
Propylene oxide	NA	Propylene oxide
Styrene	NA	Styrene
Sulphur dioxide	NA	Sulphur dioxide
Toluene	NA	Toluene
Xylenes		*m*-xylene; *o*-xylene

Notes:

1 A surrogate was not required for the aliphatic C_5-C_8 group, aliphatic C_9-C_{16} group, aromatic C_9-C_{16} group and aromatic C_{17}-C_{34} group on a chronic basis since CCME (2000a) provides chronic exposure limits for the chemical mixtures.

NA – not applicable

IPM – Individual PAH Method

WMM – Whole Mixture Model

4A1.2 Selection of Exposure Limits

In general, chemicals can be categorized into two separate groups based on the nature of their toxic response. Threshold chemicals make up the largest category and consist of virtually all types of toxic responses and chemicals. Where as, non-threshold chemicals are a select group of substances which potentially can produce cancer through genetically mediated mechanisms. For threshold chemicals, a minimum dose or ‘threshold’ must be exceeded for a toxic response to be produced. The severity or magnitude of the toxic response increases with increasing dose. Whereas, for non-threshold chemicals, regulatory policies in effect in many jurisdictions suggest that there is no safe level of exposure other than zero exposure.

The toxicity assessment ultimately requires an understanding of the toxic effects that can be caused by the COPCs. This knowledge is typically obtained through reviewing scientific literature that describes the responses witnessed in:

- laboratory animals or human subjects following administration of the chemicals at various doses for varying periods of time under controlled conditions
- as part of community health studies (i.e., epidemiological investigations) examining the incidence of disease in relation to chemical exposures

Exposure limits or ‘safe’ levels of exposure can be derived based on the identification of a no-observed-adverse-effect level (NOAEL), which is the dose at which no adverse health effects are observed in the most sensitive species for the most sensitive health endpoint. A number of ‘uncertainty’ or safety factors are applied to the NOAEL to provide an added level of protection, which results in an exposure limit, calculated as follows:

$$\text{Exposure Limit} = \frac{\text{NOAEL}}{\text{Uncertainty Factor(s)}}$$

Uncertainty factors can vary from 10-fold to several thousand-fold, to ensure adequate protection of any exposed population. The most common uncertainty factors applied are a 10-fold uncertainty factor to account possible differences in sensitivity between species (i.e., interspecies differences), and a 10-fold uncertainty factor to account for differences in sensitivity between individuals of the same species (i.e., intra-species differences). Table 4A-2 provides a more detailed list of the most common forms of uncertainty factors.

Uncertainty factors are required due to the practical constraints that apply to conventional toxicological research (i.e., the study of the harmful effects of chemicals). The most common research species are laboratory rodents (e.g., rats, mice, guinea pigs, rabbits), mainly because of their large numbers, low cost, and the ease with which they can be housed and handled. The use of the 10-fold interspecies factor accommodates the uncertainty in extrapolating the laboratory rodent data to the human condition. It assumes that humans will be 10 times more responsive to the chemical than even the most sensitive laboratory animals. The use of the 10-fold intra-species factor recognizes the fact that the test populations of laboratory animals used in toxicity studies are specially bred to confer genetic uniformity. These animals tend to respond to chemicals in a similar manner, with only limited differences in responses between individual animals. Using the intra-species uncertainty factor respects the heterogeneity that exists among human populations and is intended to accommodate sensitive individuals who might be especially vulnerable to chemical exposures.

Table 4A-2 Commonly Used Uncertainty Factors in Determining Exposure Limits

Nature of Uncertainty	Size	Comments
Differences in sensitivity between species	3 to 10 fold	Used to accommodate the uncertainty around the use of laboratory animal data to predict potential human responses. It assumes that humans are 10 times more sensitive to the chemical than the laboratory animal.
Differences in sensitivity within a species	3 to 10 fold	Used to account for individuals within the human population that may be more sensitive to a chemical than the average person. It assumes that the sensitive individual is 10 times more responsive than the average person. This exposure limit is specific to human health assessments, as ecological assessments are concerned about the health of population as a whole, rather than the individual.
LOAEL1 to a NOAEL	3 to 10 fold	Used to account for the uncertainty surrounding the use of a LOAEL when a NOAEL is not available for the most sensitive test species. It assumes that at a dose 10 times lower than the lowest dose used in the most definitive toxicity study, no responses would be observed in the test species.
Subchronic to Chronic	3 to 10 fold	Used to account for the uncertainty surrounding the use of data involving shorter exposure periods to predict the responses that might occur over longer periods of exposure. Subchronic data is only used when exposures are expected to occur for long periods and chronic toxicity data (i.e., repeated exposures of test animals for most of their lifespan) is not available.

Refers to the lowest dose of the chemical that produces an observable adverse response in the most sensitive test species for the most sensitive health endpoint.

In general, an exposure limit (or toxicological reference value –TRV) represents the dose of a substance to which a person could be exposed without significant risk of adverse effects. Given the level of conservatism incorporated into the derivation of these values (i.e., selection of sensitive endpoints, application of uncertainty factors, slope based on upper confidence limit from low-dose extrapolation), it is reasonable that these values are protective of sensitive individuals within a population. The terminology assigned to exposure limits may vary in relation to the exposure route (ingestion, inhalation) or with regulatory jurisdiction. Exposure limits may be described as the following:

- Reference Concentration (RfC) – Refers to the safe levels of airborne chemicals in which the primary (and almost exclusive) avenue of exposure is through inhalation (e.g., gases, vapours, aerosols, suspended dusts). The RfC is expressed as a concentration of the chemical in air (e.g., microgram per cubic metre -u/m^3).

- Reference Dose (RfD) – Refers to the ‘safe’ levels of threshold-type chemicals to which exposure occurs through multiple pathways, both primary and secondary. It is most commonly expressed as the dose of the chemical per unit body weight of the receptor per day (i.e., microgram per kilogram of body weight per day - ug/kg·bw/d).

- Risk-specific Concentration (RsC)/Risk-specific Dose (RsD) – Reserved for non-threshold carcinogens, and refers to the dose or concentration of the carcinogen that corresponds to an increase of one extra case in a population of 100,000 people.

Chemicals of potential concern were assessed on an individual basis if a standard, guideline or objective was available from a regulatory agency or leading scientific authority that is protective of air quality and human health. Selection of each exposure limit required that the limit be:

- Protective of the health of the general public based on the current scientific understanding of the health effects known to be associated with exposures to the COPC;

- Protective of sensitive individuals, including children and the elderly, through the use of safety or uncertainty factors;

- Established or recommended by reputable scientific authorities; and,

- Supported by adequate documentation.

In the case that the above criteria were supported by more than one standard, guideline or objective, the most scientifically defensible limit was selected. The rationale for selection of an alternative exposure limit (limit other than the most stringent) is provided.

4A1.2.1 Selection of Acute Exposure Limits

For acute exposure durations, the sources of the exposure limits that were evaluated for this HHRA include:

- Ambient Air Quality Objectives (AAQOs) developed by Alberta Environment (AENV);

- Acute Minimal Risk Levels (MRLs) for Hazardous Substances developed by the Agency for Toxic Substances and Disease Registry (ATSDR);

- Reference Levels (RELs) recommended by the California Office of Environmental Health Hazard Assessment (OEHHA);

- Ontario Reg. 419/05 Standards and POI Standards, Ambient Air Quality Criteria (AAQCs) of the Ontario Ministry of the Environment (OMOE); and

- Air Quality Guidelines for Europe (Second Edition) developed by the World Health Organization (WHO).

If an acute exposure limit that meets the four selection criteria (listed above) could not be identified from any of these regulatory agencies, then the search was expanded to include:

- Intermediate inhalation MRLs for Hazardous Substances developed by the Agency for Toxic Substances and Disease Registry (ATSDR);

- Ceiling and short-term exposure limits (STEL) developed by the American Conference of Governmental Industrial Hygienists (ACGIH).

4A1.2.2 Chronic Exposure Limits

The sources of the chronic exposure limits used in the HHRA include the regulatory agencies outlined by Health Canada in the “Federal Contaminated Site Risk Assessment in Canada” (Health Canada, 2004a):

- Toxicological Reference Values (TRVs) and Health-Based Guidance Values established by Health Canada (Health Canada)

- MRLs for Hazardous Substances developed by the U.S. Agency for Toxic Substances and Disease Registry (ATSDR)

- Maximum Permissible Risk Levels established by the Netherlands National Institute of Public Health and the Environment (RIVM)

- TRVs presented in the Integrated Risk Information System (IRIS) developed by the United States Environmental Protection Agency (U.S. EPA)

- Air Quality Guidelines for Europe (Second Edition) developed by the World Health Organization (WHO)

Similar to the acute assessment, chronic exposure limits were required to satisfy the four selection criteria listed above. If a limit that met each of these criteria was not available from the aforementioned agencies, the search for a chronic exposure limit was expanded to the following agencies:

- Chronic RELs recommended by the California Office of Environmental Health Hazard Assessment (OEHHA)

- Documentation of the Threshold Limit Values and Biological Exposure Indices (Sixth Edition) developed by the American Conference of Governmental Industrial Hygienists (ACGIH)

4A1.2.3 Chemical Mixtures

As exposure to chemicals typically does not occur in isolation, consideration was given to the potential health risks that might be presented by chemicals acting in combination. The interaction between chemicals can take many forms, all of which are of toxicological interest and some of which might be relevant to assessing potential health risks. The most common forms of interaction are:

- **Additivity**: where the effect may be estimated through the addition of the potency-weighted exposure levels (dose addition), or of the response (response addition);
- **Synergism:** the combined effects of two chemicals are much greater than additive;
- **Antagonism**: the effect of the mixture is less than additive;
- **Potentiation:** one chemical does not have a toxic effect but in the presence of a second chemical, increases the effect of the second chemical; or
- **Masking:** the mixture components produce opposite effects on an organ system, decreasing or cancelling the effects of one or more of the components (ATSDR 2004a; U.S. EPA 2000).

Toxicological interactions between mixture components depend on each component, their mode of action, and their concentrations. The primary mechanisms for chemical interactions are chemical-chemical, pharmacokinetic, and pharmacodynamic (ATSDR 2004a).

Within this HHRA, as per Health Canada's guidance, chemical interactions were assumed to be additive in nature (Health Canada, 2004a). The mixture types that were evaluated are summarized in Table 4A-73 at the end of this Appendix.

For carcinogenic PAH mixtures, two different modeling approaches were used to evaluate carcinogenic potential - The whole mixture model (WMM) and the individual PAH model (IPM). The WMM approach is based on the assumption that the potency of the PAH fraction of any environmental mixture is proportional to its benzo(a)pyrene content (OMOE 1997), while the IPM approach is based on the sum of the attributable risks for each individual PAH. Additional information is available in the benzo(a)pyrene summary below.

4A2 CHEMICAL PROFILES

4A2.1 1,3-Butadiene

4A2.1.1 Acute Exposure Limit

Table 4A-3 Acute Inhalation Exposure Limits for 1,3-Butadiene

Regulatory Agency	Value (ug/m^3)	Averaging Time	Source
AENV	--	--	AENV, 2005
ATSDR	--	--	ATSDR, 2006a
OEHHA	--	--	OEHHA, 2000
OMOE	--	--	OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

The Texas Commission on Environmental Quality (TCEQ 2007) provides an acute Reference Value (ReV) of 800 ug/m^3 (360 ppb) and an acute Effects Screening Level (acute$_{ESL}$) of 240 ug/m^3 (110 ppb). The acute ReV and ^{acute}ESL were derived based on maternal toxicity in mice. Pregnant CD-1 mice were administered 0 ppm, 40 ppm, 200 ppm or 1,000 ppm

1,3-butadiene via inhalation for 6 hours per day on gestational days 6 to 15. The benchmark responses of a 5% reduction in extragestational weight gain and maternal weight gain were modelled and considered NOAELs (TCEQ, 2007). The average benchmark concentration level ($BMCL_{05}$) for the most sensitive endpoint, reduction in extra-gestational weight gain was calculated as 5.860 ppm. The TCEQ (2007) adjusted the average $BMCL_{05}$ from a 6-hour exposure to a 1-hour exposure using Haber's Rule.

$$C_2 = C_1^n \times (T_1/T_2)^{1/n}$$

$$10.65 \text{ ppm} = (5.860 \text{ ppm})^3 \times (6\text{-hours}/1\text{-hour})^{1/3}$$

Where:

C_1 = concentration of exposure (5.860 ppm)

C_2 = duration-adjusted concentration

T_1 = time of exposure (6-hours)

T_2 = desired time of exposure (1-hour)

n = chemical-specific modification factor to account for the toxicity of the chemical being concentration and/or duration dependent. The TCEQ (2007) assumed an n-value of 3 where both concentration and duration play a role in toxicity.

The dosimetric adjustment from animal-to-human exposure was applied to the duration-adjusted $BMCL_{05}$ of 10.65 ppm. The dosimetric adjustment used by the TCEQ (2007) was determined by the following equation.

$$RGDR = (H_{b/g})_A / H_{b/g})_H$$

Where:

$H_{b/g}$ = ratio of blood:gas partition coefficient

A = animal

H = human

The TCEQ (2007) provides a mean $H_{b/g}$ for mice of 1.67 and a mean $H_{b/g}$ for humans of 1.22. When the $(H_{b/g})_A/(H_{b/g})_H$ is greater than 1, a default value of 1 is used for the RGDR. The RGDR is then multiplied by the duration-adjusted $BMCL_{05}$, resulting in a HEC $BMCL_{05}$ of 10.65 ppm. The TCEQ (2007) applied an uncertainty factor of 30 to the HEC $BMCL_{05}$ to account for interspecies variability (3-fold) and intra-species variability (10-fold). This results in a 1-hour acute ReV value of 800 ug/m^3 (0.36 ppm) for a target hazard quotient of 1. The acute ReV value of **800 ug/m^3** was used as a 1-hour exposure limit in the acute effects assessment of 1,3-butadiene.

4A2.1.2 Chronic Exposure Limits

Table 4A-4 Chronic Inhalation Exposure Limits for 1,3-Butadiene

Regulatory Agency	Value (ug/m^3)	Type	Source
ATSDR	--	--	ATSDR, 2006a
Health Canada	1.7	RsC	Health Canada, 2004c
RIVM	--	--	RIVM, 2001
U.S. EPA	0.3	RsC	U.S. EPA 2002a
WHO	--	--	WHO, 2000

-- not available

Both Health Canada and the U.S. EPA classify 1,3-butadiene as a human carcinogen via inhalation based on an observed increase in leukemia in both epidemiological studies and investigations in experimental animals (CEPA 2000a; U.S. EPA 2002a)). An RsC of 1.7 ug/m^3 was developed by Health Canada from a tumorigenic concentration (TC_{01}) of 1.7 mg/m^3 based on the incidence of leukemia in 15,649 workers in an epidemiological study (Health Canada, 2004c). The Health Canada RsC represents the daily dose via inhalation that is associated with an increased cancer risk of one in 100,000.

The U.S. EPA bases its inhalation unit risk of 3 x 10^{-5} per ug/m^3 on the Health Canada analysis of the leukemia incidence rates in styrene-butadiene rubber workers (U.S. EPA 2002a). The U.S. EPA inhalation unit risk equates to an RsC of **0.3 ug/m^3**. Although the risk estimates for the two agencies are based on the same epidemiological study, the U.S. EPA (2002a) made a number of adjustments in the derivation of their unit risk, including:

- accounting for the difference in the amount of air inhaled per day between a worker exposed over an 8-hour work shift and the general public exposed for an entire 24-hour period (10 m^3/d versus 20 m^3/d);

- considering the increased incidence of getting leukemia as opposed to dying from leukemia (i.e., Health Canada based its risk estimates on the excess probability of dying from leukemia, not of getting leukemia); and,

- the application of an adjustment factor of two, as animal data suggests that 1,3-butadiene may be a multi-site carcinogen and female animals may present additional tumour types. Extrapolation of risk based upon male data only may underestimate the overall cancer risk to the general population.

Based upon the above, the more stringent U.S. EPA RsC of 0.3 ug/m^3 was selected for use in the assessment of long-term health risks associated with 1,3-butadiene.

1,3-Butadiene was not incorporated into the multiple-pathway exposure model as it did not exceed the persistence and bioaccumulation parameters established by Environment Canada (2007). Moreover, 1,3-butadiene is in a gaseous state at room temperature and pressure, making oral exposure unlikely (U.S. EPA 2002a). On this basis, a chronic oral exposure limit was not required for 1,3-butadiene.

4A2.2 2-Chloronaphthalene

4A2.2.1 Acute Exposure Limits

Table 4A-5 Summary of Acute Inhalation Exposure Limits for 2-Chloronaphthalene

Regulatory Agency	Value (μg/m^3)	Averaging Time	Reference
AENV	–	–	AENV, 2005
ATSDR	–	–	ATSDR, 2006a
OEHHA	–	–	OEHHA, 2000
OMOE	–	–	OMOE, 2005a
WHO	–	–	WHO, 2000

-- not available

An acute criterion or guideline is not provided by any of the above regulatory agencies for 2-chloronaphthalene. Consequently, the toxicity search was expanded to include intermediate MRLs provided by the ATSDR and occupational exposure values established by the ACGIH. As no appropriate acute exposure limits were identified for 2-chloronaphthalene, it was not evaluated on an acute basis.

4A2.2.2 Chronic Exposure Limits

Table 4A-6 Summary of Chronic Inhalation Exposure Limits for 2-Chloronaphthalene

Regulatory Agency	Value (μg/m^3)	Type	Reference
Health Canada	–	–	Health Canada, 2004b,c
ATSDR	–	–	ATSDR, 2006a
RIVM	1	RfC	RIVM, 2001
U.S. EPA	–	–	U.S. EPA, 2007
WHO	–	–	WHO, 2000

-- not available

The RIVM has developed a provisional TCA for 2-chloronaphthalene of **1 ug/m^3** based on a LOAEC of 1.3 mg/m^3 for liver effects (RIVM, 2001). Rats were exposed via inhalation to di- and tri-chloronaphthalenes for 16 hours per day for 134 days. The LOAEC was adjusted to account for discontinuous exposure (16 hours/24 hours). An uncertainty factor of 1,000 was applied to the duration-adjusted LOAEC to account for extrapolation of the LOAEC for the di- and tri-chloronaphthalenes to a NOAEC for the monochloronapthalenes (3-fold), interspecies differences (10-fold), intra-species differences (10-fold) and for database restrictions (3-fold). The RIVM considers this TCA to be provisional due to limitations associated with the data, and evidence that suggests that the higher chlorinated naphthalenes (i.e., di- and tri-chloronaphthalenes) are more toxic than the monochloronaphthalenes after inhalation exposure.

A chronic oral exposure limit was not required for the assessment of 2-chloronaphthalene as it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007) and was not incorporated into the multiple exposure pathway model.

4A2.3 Acetaldehyde

4A2.3.1 Acute Exposure Limits

Table 4A-7 Acute Inhalation Exposure Limits for Acetaldehyde

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	90	1-hour	AENV, 2005
ATSDR	--	--	ATSDR, 2006a
OEHHA	--	--	OEHHA, 2000
OMOE	500	½-hour, 1-hour	OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

The AENV (2005) recommends a 1-hour AAQO for exposure to acetaldehyde of 90 ug/m^3. However, this objective was adopted from the Texas Natural Resource Conservation Commission, which is odour based (TCEQ, 2003). Given that this guideline is not health-based, and limited information is available regarding its basis, this value was not used in the current assessment.

The OMOE (2005a) provides both a ½-hour and 24-hour standard of 500 ug/m^3, presumably because the short-term toxicity of acetaldehyde is more dependent on concentration than duration of exposure (CEPA, 2000a). These AAQC were not used in the acute effects assessment as the adequate supporting documentation is not available.

As a result, the toxicity search was expanded to include intermediate MRLs provided by the ATSDR and occupational exposure values established by the ACGIH and the U.S. DOE for acetaldehyde.

The ACGIH provides a 15-min TLV-Ceiling of 25 ppm (45 mg/m^3) for eye and upper respiratory tract irritation (ACGIH 1996; 2006). A TLV-Ceiling represents the chemical concentration that should not be exceeded during the workday. Sensitive individuals are reported to experience eye irritation at concentrations as low as 25 ppm of acetaldehyde after a short exposure, with most people only experiencing irritation at concentrations greater than 50 ppm. On this basis, the ACGIH developed the TLV-Ceiling of 25 ppm (45 mg/m^3).

While this TLV-Ceiling is based on 15-minute exposure, the effects of a ceiling limit may feasibly be considered to occur almost immediately. Thus, the TLV-ceiling may reasonably be assumed to represent a 3-minute exposure (as in the odour assessment). The TLV-Ceiling was adjusted from 3-minute exposure to 1-hour exposure using a modified Haber's Law (OEHHA, 1999).

$$C_{ADJ}^n \times T_{ADJ} = C^n \times T$$

$$C^1 \times 60 \text{ minutes} = 45^1 \text{ mg/m}^3 \times 3 \text{ minutes}$$

where:

C_{ADJ} = duration-adjusted concentration

T_{ADJ} = desired time of exposure (60 minutes)

C = concentration of exposure (45 mg/m^3)

T = time of exposure (3 minutes)

n = chemical-specific modification factor designed to account for the toxicity of a chemical being concentration and/or deputation dependant (1)

The OEHHA (1999a) recommends using a default "n" value of 1 in the adjustment for less than 1 hour exposure. Based on the above conversion factor, the TLV-Ceiling is adjusted to a concentration of 2.3 mg/m^3.

Generally, a 10-fold uncertainty factor would be applied by the study team to this limit, however, as the study was completed in sensitive individuals, the application of this factor was not necessary. Thus, a modified 1 hour limit of **2,300 ug/m^3** was adopted as the short-term exposure limit for this assessment.

4A2.3.2 Chronic Exposure Limits

Table 4A-8 Chronic Inhalation Exposure Limits for Acetaldehyde

Regulatory Agency	Value (ug/m^3)	Type	Reference
ATSDR	--	--	ATSDR, 2006a
Health Canada	390 17.2	RfC RsC	Health Canada, 2004c
RIVM	--	--	RIVM, 2001
U.S. EPA	9 5	RfC RsC	U.S. EPA, 2007
WHO	--	--	WHO, 2000

-- not available

The Health Canada and the International Association for Research on Cancer (IARC) classify acetaldehyde as possibly carcinogenic to humans (CEPA, 2000a; IARC, 1999). As a result, acetaldehyde was included as a carcinogen in the chronic effects assessment.

An RsC of 17.2 ug/m^3 was developed from a tumorigenic concentration (TC_{05}) of 86 mg/m^3, which was associated with a 5% increase in nasal adenocarcinomas and squamous cell carcinomas (combined) in the most sensitive sex (males) of Wistar rats exposed for up to 28 months (Health Canada, 2004c; CEPA 2000a). The TC_{05} was derived by Health Canada using a multistage model, with adjustment for intermittent to continuous exposure (6 hours/24 hours × 5 days/7 days). The RsC represents the daily dose via inhalation that is associated with an increased cancer risk of one in 100,000.

The U.S. EPA (2007) also presents a quantitative estimate of carcinogenic risk from inhalation exposure. Its inhalation unit risk of 2.2×10^{-6} per ug/m^3 equates to an RsC of 5 ug/m^3 (corresponding to a risk level of one in 100,000). This unit risk was not used for the current assessment for the following reasons.

- The U.S. EPA last reviewed the carcinogenicity of acetaldehyde in 1991, while the Health Canada value is more recent (published in 2000).

- The Health Canada and U.S. EPA limits are based on studies conducted by the same researchers. However, the Health Canada limit is based on a 1986 study by Woutersen et al. (1986), which is more recent than the work completed by Woutersen and Appelman in 1984, upon which the U.S. EPA limit is based.

- The scientific rationale for the Health Canada limit is considerably more detailed than what the U.S. EPA provides in support of its limit.

Therefore, the Health Canada RsC of **17.2 ug/m^3** was selected for the chronic inhalation assessment of acetaldehyde. The mechanism of action appears to be mediate through genotoxicity (GENETOX, 2007).

A chronic oral exposure limit was not required for the assessment of acetaldehyde, because it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007) and thus was not incorporated into the multiple exposure pathway model. As well, acetaldehyde is expected to remain in the medium to which it is discharged (i.e., air). Fugacity modelling predicts that when acetaldehyde is released into ambient air, the distribution of mass is 97.1% in air, 2.6% in water and 0.3% in soil (CEPA, 2000a).

4A2.4 Acrolein

4A2.4.1 Acute Exposure Limits

Table 4A-9 Acute Inhalation Exposure Limits for Acrolein

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	--	--	AENV, 2005
ATSDR	6.9	1-hour	ATSDR, 2006a
OEHHA	0.19	1-hour	OEHHA, 2000
OMOE	0.24 0.08	½-hour 24-hour	OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

The OEHHA provides an acute REL of 0.19 ug/m^3 based on a LOAEL of 0.06 ppm for eye irritation in 36 healthy human workers exposed to acrolein for 5 minutes (Darley et al., 1960; OEHHA 1999; 2000). In deriving the REL, the OEHHA adjusted the LOAEL to a 1 hour concentration of 0.005 ppm using a modified Haber's Law.

$$C_{ADJn} \times T_{ADJ} = C_n \times T$$

$$C1 \times 60 \text{ minutes} = 0.061 \text{ ppm} \times 5 \text{ minutes}$$

where:

C_{ADJ} = duration-adjusted concentration

T_{ADJ} = desired time of exposure (60 minutes)

C = concentration of exposure (0.06 ppm)

T = time of exposure (5 minutes)

n = chemical-specific modification factor designed to account for the toxicity of a chemical being concentration and/or deputation dependant (1)

According to Haber's Law, the magnitude of "n" is determined by evaluating the concentration versus response relationships for several different exposure durations (OEHHA 1999). The time-concentration-response relationship will depend on the time-frame considered as well as the endpoint measured. Thus, there are many "n" values for a single chemical that are applicable to different endpoints. The OEHHA (1999) provides an example using ammonia which has an "n" value of 4.6 for irritation and 2 for lethality. In the case of acrolein, an "n" value of 1.2 is reported for lethality, but an "n" value is not reported for irritation. As such, in all likelihood by defaulting to an "n" value of 1 the OEHHA is overestimating the actual toxicity of acrolein on a 1 hour basis. The study team suggests examining the range of 1 hour concentrations calculated using more probable values of n for irritation, such as 1.2 (actual value identified for lethality) to 2.

Using an "n" value of 1.2 in combination with the cumulative uncertainty factor of 60 applied by the OEHHA in the original REL derivation, a modified 1 hour exposure limit of **0.29 ug/m^3** was calculated, and was used in the acute effects assessment for acrolein.

4A2.4.2 Chronic Exposure Limits

Table 4A-10 Chronic Inhalation Exposure Limits for Acrolein

Regulatory Agency	Value (ug/m^3)	Type	Reference
ATSDR	--	--	ATSDR, 2006a
Health Canada	0.4	TC	Health Canada, 2004c
OEHHA	0.06	REL	OEHHA, 2005
RIVM	--	--	RIVM, 2001
U.S. EPA	0.02	RfC	U.S. EPA, 2007
WHO	--	--	WHO, 2000

-- not available

Health Canada provides a tolerable concentration (TC) of 0.4 ug/m^3 based on the lower benchmark concentration of 0.14 mg/m^3 associated with a 5% increase in non-neoplastic lesions in the nasal respiratory epithelium of rats exposed for 6 hours/day for 3 consecutive days (Health Canada, 2004c; CEPA 2000c; Cassee et al., 1996). A safety factor of 100 was incorporated to account for interspecies variation (10-fold) and intra-species variation (10-fold). The limit was further adjusted by Health Canada to account for continuous exposure (6 hours/24 hours). Given that Health Canada's tolerable concentration is based on a short-term exposure (3 days), it was not used in the current chronic assessment of acrolein.

The OEHHA (2005) provides a chronic REL of 0.06 ug/m^3 based on a LOAEL of 0.4 ppm for histological lesions in the upper airways of male Fischer-344 rats exposed for 6 hours/day, 5 days/week for 62 days (Kutzman 1981; Kutzman et al., 1985; OEHHA, 2005). The OEHHA (2005) adjusted the studies' LOAEL for continuous exposure (6 hours/24 hours x 5 days/7 days) to a concentration of 0.071 ppm. In addition, the OEHHA (2005) calculated the LOAEL$_{HEC}$ using the RGDR approach, a factor of 0.14, to determine a human equivalency concentration. The resultant LOAEL$_{HEC}$ of 0.0099 ppm was then divided by an uncertainty factor of 300 to account for interspecies variability (3-fold), intra-species variability (10-fold), subchronic to chronic (3-fold), and for use of a minimal LOAEL (3-fold).

The U.S. EPA (2007) provides an inhalation RfC of 0.02 ug/m^3 based upon a subchronic (i.e., 3 month) rat inhalation study conducted by Feron et al., in 1978. The U.S. EPA adjusted the study LOAEL of 900 ug/m^3 by adjusting for continuous exposure (6 hours/24 hours x 5 days/7 days) and a factor of 0.14 to determine a human equivalency concentration. The resultant LOAEL$_{HEC}$ of 20 ug/m^3 was then divided by an uncertainty factor of 1,000 to account for extrapolation from rat to human (3-fold), intra-species variability (10-fold), subchronic to chronic (10-fold), and for use of a minimal LOAEL (3-fold).

Both the OEHHA (2005) and U.S. EPA (2007) provide guidelines based on a LOAEL of 0.4 ppm. However, the U.S. EPA provides a more conservative uncertainty factor for extrapolation from subchronic to chronic. For this reason the current assessment adopted the U.S. EPA RfC of **0.02 ug/m^3** to evaluate the long-term health risks associated with acrolein.

A chronic oral exposure limit was not required for the assessment of acrolein, because it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007) and thus was not incorporated into the multiple exposure pathway model.

4A2.5 Aliphatic C_5-C_8 Group

4A2.5.1 Acute Exposure Limits

Table 4A-11 Acute Inhalation Exposure Limits for the Aliphatic C_5-C_8 Group

Regulatory Agency	Value (ug/m^3)	Averaging Time	Source
AENV	--	--	AENV, 2005
ATSDR	--	--	ATSDR, 2006a
OEHHA	--	--	OEHHA, 2000
OMOE	2,500[1]	24-hour	OMOE, 2005a
WHO	--	--	WHO, 2000

Note:

1 The OMOE standard was developed for an n-hexane mixture (OMOE, 2005b).

-- not available

The OMOE provides a 24-hour standard of 2,500 ug/m^3 for an n-hexane mixture (OMOE, 2005a,b). This standard was developed from a NOAEL of 58 ppm (204 mg/m^3) for polyneuropathy in humans (Sanagi et al., 1980). Workers were exposed to low concentrations of n-hexane and acetone in a tungsten carbide alloys facility for an average of 6.2 years. Significant decreases in mean motor nerve conduction velocities and slowed residual latency of motor conduction of lower extremity. The NOAEL was adjusted from an eight-hour time weighted average for occupational exposure to a value of 73 mg/m^3 for continuous exposure in the general population as follows.

$$NOAEL_{ADJ} = NOAEL \times \frac{MV_{ho}}{MV_h} \times \frac{Exp_{ho}}{Exp_h}$$

Where:

NOAEL$_{ADJ}$ = NOAEL in the human population from continuous exposure (mg/m^3)

NOAEL = NOAEL for discontinuous exposure in an occupational setting (204 mg/m^3)

MV$_{ho}$ = amount of air used by a worker during an 8-hour work period (10 m^3/d)

MV_h = amount of air used by an individual in the general population during a day (20 m^3/d)

Exp_{ho} = days per week a worker is exposed (5 days)

Exp_h = days per week an individual in the general population is exposed (7 days)

An uncertainty factor of 30 was applied to the $NOAEL_{ADJ}$ to account for individual sensitivity (10-fold) and potential interaction with other hydrocarbon solvents in commercial n-hexane (3-fold) (OMOE, 2005b). Because the study team does not support the use of chronic toxicity data in the derivation of an acute limit, an alternate acute guideline with supporting documentation was identified for the aliphatic C_5-C8 group.

The CCME (2000a) and TPHCWG (1997) have developed a chronic RfC for C_5-C_8 aliphatics based on a NOAEL of 3,000 ppm (10,000 mg/m^3) identified in four of subchronic and chronic studies. The NOAELs identified from the subchronic studies are based on increased liver weights in rats and mice and nephropathy in rats exposed to 0 ppm, 900 ppm, 3,000 ppm, or 9,000 ppm (0 mg/m^3, 3,000 mg/m^3, 10,000 mg/m^3, 30,000 mg/m^3) commercial hexane for six hours per day, five days per week for 13 weeks (Duffee et al., 1991). An uncertainty factor of 100 was applied to the subchronic NOAEL of 3,000 ppm (10,000 mg/m^3) to account for interspecies and intra-species variability (10-fold each). As the C_5-C_8 aliphatic group includes a variety of organic compounds with six to eight carbon atoms joined together in a straight, cyclic or branched chain and is not limited to n-hexane and its isomers, the limit of **100,000 ug/m^3** was used as a 1-hour exposure limit in the acute effects assessment of the aliphatic C5-C8 group.

The use of a subchronic NOAEL in the derivation of an acute exposure limit is considered conservative since a higher exposure over a shorter time-period (i.e., acute exposure) presumably could occur without risk of adverse effects.

4A2.5.2 Chronic Exposure Limits

In the case of the aliphatic and aromatic petroleum hydrocarbon (PHC) groups, the search for chronic inhalation and oral exposure limits was limited to three regulatory agencies that have developed chronic exposure limits that are representative of the aliphatic and aromatic groups as a whole: CCME (2000a), MA DEP (2003) and TPHCWG (1997).

Table 4A-12 Chronic Inhalation Exposure Limits for the Aliphatic C_5-C_8 Group

Regulatory Agency	Value (ug/m^3)	Type	Source
CCME	18,400	RfC	CCME, 2000a
MA DEP	200	RfC	MA DEP, 2003
TPHCWG	18,400	RfC	TPHCWG, 1997

The CCME (2000a) provides an RfC of 18,400 ug/m^3 for the C_5-C_8 aliphatic group based on the neurotoxic endpoint of commercial hexane. This exposure limit was adopted from the TPHCWG (1997) and was developed from the NOAEL of 10,307 mg/m^3 for two (rat and mice) chronic bioassays involving lifetime exposure. The NOAEL was adjusted for continuous exposure (6 hours/24 hours x 5 days/7 days) to a concentration of 1,840 mg/m^3. An uncertainty factor of 100 was applied by the TPHCWG to account for interspecies (10-fold) and intra-species (10-fold) variability. The TPHCWG (1997) recommends using the RfC derived for commercial hexane over an RfC specific to n-hexane (as is the case of the MA DEP RfC) as it is more representative of the C5-C8 aliphatic fraction. According to the TPHCWG, using n-hexane alone results in an overestimation of the toxicity of the fraction since n-hexane is the most toxic of the group's constituents, it is uniquely toxic, and its interaction with other petroleum compounds influences its toxicity. On this basis, the RfC of **18,400 ug/m^3** for commercial hexane was used to evaluate the risks associated with this petroleum mixture. This RfC corresponds to an inhalation dose of 4,100 ug/kg bw/d based on an average adult body weight of 70.7 kg and an inhalation rate of 15.8 m^3/d (Health Canada, 2004a).

The MA DEP RfC of 200 ug/m^3 was developed from toxicity data specific to n-hexane, which is considered overly conservative and inappropriate when characterizing the toxicity of the aliphatic C5-C8 group as a whole (MA DEP, 2003). Furthermore, the MA DEP adopted the 1993 U.S. EPA RfC for n-hexane, which was increased in 2005 to a value of 700 ug/m^3 for peripheral neuropathy in a subchronic rat inhalation study (U.S. EPA, 2005a).

Based on the Environment Canada (2007) physical and chemical screening, the aliphatic C_5-C_8 group was assessed via multiple exposure pathways requiring an oral exposure limit.

Table 4A-13 Chronic Oral Exposure Limits for the Aliphatic C_5-C_8 Group

Regulatory Agency	Value (ug/kg bw/d)	Type	Source
CCME	5,000	RfD	CCME, 2000a
MA DEP	40	RfD	MA DEP, 2003
TPHCWG	5,000	RfD	TPHCWG, 1997

The CCME (2000a) RfD of 5,000 ug/kg bw/d based on the neurotoxicity of commercial hexane was selected for use in the chronic oral effects assessment. As in the chronic inhalation assessment, this RfD was adopted from the TPHCWG (1997). The TPHCWG developed the oral RfD from the inhalation limit (discussed above), assuming an adult body weight of 70 kg, a breathing rate of 20 m^3/d, and 100% absorption.

The MA DEP recommends an oral RfD of 40 ug/kg bw/d based on reduced body weight and neurotoxicity (MA DEP. 2003). In a subchronic gavage study, a LOAEL of 570 mg/kg bw/d was identified in rats exposed to n-hexane. The LOAEL was adjusted for discontinuous exposure (5 days/7 days) to a concentration of 407 mg/kg bw/d. An uncertainty factor of 10,000 was applied to the duration-adjusted LOAEL to account for interspecies variability (10-fold), intra-species variability (10-fold), subchronic to chronic extrapolation (10-fold) and use of a LOAEL (10-fold). As in the chronic inhalation assessment (discussed above), use of an RfD developed on the basis of n-hexane toxicity alone is overly conservative and inappropriate when characterizing the toxicity of the aliphatic C_5-C_8 group as a whole. In addition, the degree of uncertainty identified by the MA DEP with the application of a 10,000-fold uncertainty factor does not imply a high degree of confidence in the limit. Thus, the CCME RfD of **5,000 ug/kg bw/d** was selected as the chronic oral exposure limit for this aliphatic group.

For incorporation in the multiple-pathway exposure model, inhalation bioavailability was assumed to be 100% (no specific data were identified in the literature regarding the amount of C_5-C_8 aliphatic that is absorbed via inhalation). As well, an oral bioavailability in humans of 80% and a dermal bioavailability of 1% were assumed based on n-hexane as it represents between 7% and 44% of the aliphatic C_5-C_8 mixture (RAIS, 2007).

4A2.6 Aliphatic C_9-C_{16} Group

4A2.6.1 Acute Exposure Limits

As an appropriate guideline or acute exposure limit was not identified for this group of compounds, an acute inhalation exposure limit was developed from the subchronic LOAEL that formed the basis of the MA DEP (2003) chronic RfC.

The MA DEP identified chronic RfC for the aliphatic C9-C16 group from a subchronic inhalation study (MA DEP, 2003; Lund et al., 1995). In the key study associated with the RfC, Sprague-Dawley rats were exposed to 0, 2,600 or 5,300 mg/m^3 (0, 400 or 800 ppm) of de-aromatized white spirits (DAWS) for 6-hours/day, 5-days/week for 6 months. Following a 2-6 month recovery period (i.e. no exposure), neurophysiological, neurobehavioural, and microscopic pathologic examinations were performed.

Exposure-related changes in sensory evoked potentials were observed and a decrease in motor activity during dark periods was observed in the rats. According to the study authors, a six-month exposure to DAWS may result in long-lasting and possibly irreversible effects in the nervous system of the rat.

In the derivation of the modified acute inhalation limit, an uncertainty factor of 1,000 was applied to the LOAEL of 2,600 mg/m^3 to account for interspecies variability (10-fold), intra-species variability (10-fold), and adjusting from a LOAEL to a NOAEL (10-fold). The limit of **2,600 ug/m^3** was used as a modified 1-hour exposure limit for the acute effects assessment of the aliphatic C_9-C_{16} group.

Use of a subchronic LOAEL in the derivation of an acute exposure limit is considered conservative since a higher exposure over a shorter time-period (i.e., acute exposure) presumably could occur without risk of adverse effects.

4A2.6.2 Chronic Exposure Limits

In the case of the aliphatic and aromatic petroleum hydrocarbon (PHC) groups, the search for chronic inhalation and oral exposure limits was limited to three regulatory agencies that have developed chronic exposure limits that are representative of the aliphatic and aromatic groups as a whole: CCME (2000a), MA DEP (2003) and TPHCWG (1997).

Table 4A-14 Chronic Inhalation Exposure Limits for the Aliphatic C_9-C_{16} Group

Regulatory Agency	Value (ug/m^3)	Type	Source
CCME	1,000	RfC	CCME, 2000a
MA DEP	200	RfC	MA DEP, 2003
TPHCWG	1,000	RfC	TPHCWG, 1997

The CCME (2000a) provides an RfC of 1,000 ug/m^3 for the aliphatic C_9-C_{16} group, which was adopted from the TPHCWG (1997). The RfC is based on the hepatic and haematological effects of de-aromatized petroleum streams and JP-8 Jet Fuel, which together cover the entire range of the fraction. Two separate studies were examined by the TPHCWG (1997), and are described further below.

- Phillips and Egan 1984: Sprague-Dawley rats were exposed to 0 ppm, 300 ppm or 900 ppm of C_{10}-C_{11} isoparaffinic solvent for six hours per day, five days per week for

12 weeks. The NOAEL of 900 ppm (5,226 mg/m^3) was adjusted for intermittent exposure (6 hours/24 hours x 5 days/7 days) to a concentration of 933 mg/m^3. An uncertainty factor of 1,000 was applied to the duration-adjusted NOAEL to account for interspecies variability (10-fold), intra-species variability (10-fold), and use of a subchronic study (10-fold). The result is an RfC of 0.9 mg/m^3.

In the same study, Sprague-Dawley rats were exposed to 0 ppm, 300 ppm or 900 ppm of de-aromatized white spirit vapours (DAWS) for six hours per day, five days per week for 12 weeks. The study NOAEL of 5,485 mg/m^3 was adjusted for intermittent exposure (6 hours/24 hours x 5 days/7 days) to a concentration of 979 mg/m^3. An uncertainty factor of 1,000 was applied to the adjusted NOAEL to account for interspecies variability (10-fold), intra-species variability (10-fold), and use of a subchronic study (10-fold). The result is an RfC of 1.0 mg/m^3.

- Matti et al., 1991: Mice and rats were exposed to JP-8 vapours continually for 90 days. A NOAEL of 1,000 mg/m^3 was identified and an uncertainty factor of 1,000 was applied to account for interspecies variability (10-fold), intra-species variability (10-fold), and use of a subchronic study (10-fold). The result is an RfC of 1.0 mg/m^3.

Based on these two studies (RfCs range between 0.9 and 1.0 mg/m^3), an RfC of 1,000 ug/m^3 was selected by the TPHCWG (1997).

MA DEP (2003) examined the two following studies, and developed different RfC values:

- Phillips and Egan 1984: The MA DEP identified the same key study as the TPHCWG; however, the concentration the TPHCWG identified as a NOAEL was reported as a LOAEL by the MA DEP. As a result, the MA DEP applied an additional uncertainty factor of 3 in the derivation of the RfC to account for the use of a LOAEL, resulting in an RfC of 0.3 mg/m^3, instead of 0.9 mg/m^3 or 1.0 mg/m^3.

- Lund et al., 1995: The MA DEP considered a subchronic inhalation study that exposed rats to 0 mg/m^3, 2,620 mg/m^3 or 5,253 mg/m^3 (0 ppm, 400 ppm or 800 ppm) of DAWS for six hour per day, five days per week for six months. Following a 2-6 month exposure-free period, neurophysiological, neurobehavioural, and microscopic pathologic examinations were performed. Exposure-related changes in sensory evoked potentials were observed and a decrease in motor activity during dark periods was reported. According to the authors, a 6-month exposure to DAWS can result in long-lasting and possibly irreversible effects in the nervous system of the rat. The LOAEL of 2,620 mg/m^3 (400 ppm) was adjusted for continuous exposure (6 hours/24 hours x 5 days/7 days) to a concentration of 468 mg/m^3. An uncertainty factor of 3,000 was applied by MA DEP to account for interspecies variability (10-fold), intra-species variability (10-fold), adjusting from a LOAEL to a NOAEL (10-fold), and use of a subchronic study (3-fold). The result is an RfC of 0.2 mg/m^3.

Based on these two studies the MA DEP (2003) established an RfC of 200 ug/m^3 for neurotoxicity.

Upon review of the Phillips and Egan (1984) study, the study team concluded that the MA DEP accurately interpreted the exposure concentration of 300 ppm as a LOAEL, and not a NOAEL as the TPHCWG and CCME reported. Phillips and Egan (1984) observed increase kidney weights and alterations in kidney structure in male rats in the low and high exposure groups for both the C_{10}-C_{11} isoparaffinic solvent- and DAWS-exposed male rats. The effect appeared to be dose related and time dependant (Phillips and Egan 1984). As a result, the MA DEP RfC of **200 ug/m^3**

was selected for the chronic inhalation effects assessment of the aliphatic C_9-C_{16} group. This RfC corresponds to an inhalation dose of 45 ug/kg bw/d based on an average adult body weight of 70.7 kg and an inhalation rate of 15.8 m^3/d (Health Canada, 2004a).

Based on the Environment Canada (2007) fate and persistence screening the aliphatic C_9-C_{16} group was assessed via multiple exposure pathways, requiring an oral exposure limit.

Table 4A-15 Chronic Oral Exposure Limits for the Aliphatic C_9-C_{16} Group

Regulatory Agency	Value (μg/kg bw/d)	Type	Source
CCME	100	RfD	CCME, 2000a
MA DEP	100	RfD	MA DEP, 2003
TPHCWG	100	RfD	TPHCWG, 1997

An RfD of 100 ug/kg bw/d is provided by the CCME for the C_9-C_{16} aliphatic group, which was adopted from the TPHCWG (CCME, 2000a). The RfD is based on hepatic and haematological effects in rats exposed to de-aromatized C_9-C_{13} aliphatics (TPHCWG, 1997). Two separate studies were examined by the TPHCWG.

- Rats were dosed orally with 0 mg/kg, 500 mg/kg, 2,500 mg/kg, or 5,000 mg/kg of C_9-C_{12} aliphatics including isoparaffins, naphthenes and n-alkanes for 90 days. A LOAEL of 500 mg/kg bw/d was identified based on observed reversible hepatic, renal and haematological effects in all dose groups. An uncertainty factor of 5,000 was applied to the study LOAEL to account for interspecies variability (10-fold), intra-species variability (10-fold), use of a subchronic study (10-fold), and use of a LOAEL versus a NOAEL (5-fold). The result is an RfD of 0.1 mg/kg bw/d.

- Rats were exposed to 0 mg/kg, 100 mg/kg, 500 mg/kg or 1,000 mg/kg of C_{10}-C_{13} aliphatic mixture (including isoparaffins, naphthenes and n-alkanes) for 13 weeks. Centrilobular hepatic hypertrophy was observed in the livers of animals from the two highest dose groups. A NOAEL of 100 mg/kg bw/d was thus identified based upon a lack of hepatic effects. The TPHCWG (1997) applied an uncertainty factor of 1,000 to the study NOAEL to account for intra-species variation (10-fold), interspecies variation (10-fold), and use of a subchronic study (10-fold). The result is an RfD of 0.1 mg/kg bw/d.

An RfD of 0.1 mg/kg bw/d was selected from the aforementioned studies by the TPHCWG (TPHCWG, 1997). In addition to the above studies, the TPHCWG considered toxicity data for JP-8 Jet Fuel and C_{11}-C_{17} isoparaffinic solvent, which were less conservative.

Similar to the TPHCWG, the MA DEP RfD of 100 ug/kg bw/d was developed from three separate studies (MA DEP, 2003).

- Anon 1991a: Rats were orally dosed with 0 mg/kg bw/d, 500 mg/kg bw/d, 2,500 mg/kg bw/d or 5,000 mg/kg bw/d of C_9-C_{12} isoparaffins, n-alkanes and naphthalenes for 90 days. A LOAEL of 500 mg/kg bw/d was identified for changes in serum chemistry and liver weight. An uncertainty factor of 5,000 was applied to the LOAEL to account for interspecies variability (10-fold), intra-species variability (10-fold), use of a subchronic study (10-fold) and use of a LOAEL (5-fold). The result is an RfD of 0.1 mg/kg bw/d.

- Anon 1991b: Rats were orally treated with 0 mg/kg bw/d, 100 mg/kg bw/d, 500 mg/kg bw/d or 1,000 mg/kg bw/d of C_{10}-C_{13} isoparaffins, n-alkanes and naphthalenes for 13 weeks. A NOAEL of 100 mg/kg bw/d was identified for changes in serum chemistry and liver weight. An uncertainty factor of 1,000 was applied to the adjusted NOAEL to account for interspecies variability (10-fold), intra-species variability (10-fold), and use of a subchronic study (10-fold). The result is an RfD of 0.1 mg/kg bw/d.

- Anon 1990: Rats were orally treated with 0, 100, 500 or 1,000 mg/kg bw/d of C_{11}-C_{17} isoparaffinic solvent for 13 weeks. A NOAEL of 100 mg/kg bw/d was identified based on observed liver effects. An uncertainty factor of 1,000 was applied to the adjusted NOAEL to account for interspecies variability (10-fold), intra-species variability (10-fold), and use of a subchronic study (10-fold). The result is an RfD of 0.1 mg/kg bw/d.

As in the TPHCWG assessment, an RfD of 0.1 mg/kg bw/d was selected from the above studies by the MA DEP. Thus, an RfD of **100 ug/kg bw/d** was used in the chronic oral effects assessment for the aliphatic C_9-C_{16} group.

For incorporation in the multiple-pathway exposure model, inhalation, oral and dermal bioavailability was assumed to be 100% as limited information was available regarding the relative absorption of aliphatic C_9-C_{16} compounds via these exposure routes.

4A2.7 Aliphatic C_{17}-C_{34} Group

4A2.7.1 Acute Exposure Limits

No acute exposure guidelines or exposure values were identified for the aliphatic C_{17}-C_{34} group specifically. Alternatively, available sub-chronic exposure limits were evaluated. However, neither a sub-chronic chronic inhalation limit was available for this fraction. Thus, the aliphatic C_{17}-C_{34} group was not assessed on an acute basis.

The CCME (2000a) and the TPHCWG (1997) developed a chronic RfD based on a subchronic study where rats were administered white mineral oils in the diet at doses of 2 ppm, 200 ppm, 2,000 ppm and 20,000 ppm (2 mg/kg/d, 20 mg/kg/d, 200 mg/kg/d and 2,000 mg/kg/d) for 90 days (Smith et al., 1996). A range of white mineral oils with different molecular weights were used in the study. A NOAEL of 200 mg/kg/d was identified for liver granulomas in rats administered the low molecular weight oils (C_{17}-C_{34}). No effects were observed in rats administered the high molecular weight oils ($C_{>34}$). As these values are based upon chronic oral exposures, neither value was deemed appropriate for the derivation of an acute inhalation exposure limit.

MA DEP (2003) notes that there is limited inhalation toxicity data for C_{19}-C_{32} aliphatic hydrocarbons (slightly different fraction composition, but similar), and that this is likely due to several compounds within this fraction being non-volatile.

4A2.7.2 Chronic Exposure Limits

No chronic inhalation exposure guidelines or exposure values were identified for the aliphatic C_{17}-C_{34} group specifically.

MA DEP (2003) notes that there is limited inhalation toxicity data for C_{19}-C_{32} aliphatic hydrocarbons (slightly different fraction composition, but similar), and that this is likely due to several compounds within this fraction being non-volatile. However, as for the Aromatic C_{17}-C_{34} group, a chronic oral exposure limit was converted to a chronic inhalation value.

Table 4A-16 Chronic Oral Exposure Limits for the Aliphatic C_{17}-C_{34} Group

Regulatory Agency	Value (ug/kg bw/d)	Type	Source
CCME	-	RfD	CCME, 2000a
MA DEP	2,000	RfD	MA DEP, 2003
TPHCWG	2,000	RfD	TPHCWG, 1997

Chronic oral exposure limits are available for larger aliphatic hydrocarbons. As these compounds may potentially bioaccumulate in environmental media, the aliphatic C_{17}-C_{34} group was evaluated in the multi-pathway model.

The MA DEP (2003) RfD of 2,000 ug/kg is based upon the results of a toxicity assay involving the administration of seven heavy refined mineral oils to animals (study details not specified). Histopathologic effects (granulomas or microgranulomas) in the liver are the critical toxicological effect for this group of compounds, as a significantly higher incidence of these lesions was observed in female rats administered C_{17}-C_{34} mineral oils. A NOAEL for hepatic lesions and autoimmune effects was determined to be 200,000 ug/kg. An uncertainty factor of 1,000 was applied to account for inter- and intra-species differences, and extrapolation from a sub-chronic exposure to a chronic exposure.

The TPHCWG (1997) RfD of 2,000 ug/kg is based upon on a NOAEL for the formation of liver granulomas in F344 rats. In the key study, the rats were divided into groups and administered one of several different types of white mineral oil at the following dose levels: 0 mg/kg-day, 2 mg/kg-day, 20 mg/kg-day, 200 mg/kg-day or 2,000 mg/kg-day over the 90-day study period. An uncertainty factor of 100 was applied to the NOAEL, given that F344 rats are especially sensitive and that human evidence suggests that humans are less sensitive than rats to the effects of ingestion of long-chain hydrocarbons.

The oral RfD used in the chronic multi-pathway assessment of the aliphatic C17-C34 fraction was **2,000 ug/kg**, consistent with both MA DEP (2003) and TPHCWG (1997).

The inhalation, oral and dermal absorption efficiencies were assumed to be 100% for this fraction. Assuming a body weight of 70.7 kg and an inhalation rate of 15.8 m^3 (Health Canada, 2004a), the chronic oral limit is approximately equivalent to a modified chronic inhalation exposure limit of **9,000 ug/m^3**. This modified inhalation limit was used in the chronic effects assessment.

4A2.8 Aliphatic Alcohol Group

Surrogate: Methanol

4A2.8.1 Acute Exposure Limit

Table 4A-17 Summary of Acute Inhalation Exposure Limits for Isopropanol and Methanol

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
Isopropanol			
AENV	7,850	1-hour	AENV, 2005
ATSDR	–	–	ATSDR, 2006a
OEHHA	3,200	1-hour	OEHHA, 2000
OMOE	22,000 7,300	½-hour 24-hour	OMOE, 2005a OMOE, 2005a

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
WHO	–	–	WHO, 2000
Methanol			
AENV	2,600	1-hour	AENV, 2005
ATSDR	–	–	ATSDR, 2006a
OEHHA	3,200	1-hour	OEHHA, 2000
OMOE	12,000 4,000	½-hour 24-hour	OMOE, 2005a OMOE, 2005a
WHO	–	–	WHO, 2000

-- not available

The AENV (2005) provides AAQOs for isopropanol and methanol which were adopted from the Texas Natural Resource Conservation Commission, but no specific basis is provided. As a result, the study team is unable to comment on the scientific merit of these limits and did not use them in the short-term assessment of the aliphatic alcohol group.

The OMOE (2005a) has established guidelines for various alcohols; however, isopropanol is the only chemical for which supporting documentation is provided. The OMOE (2005c) provides a half-hour standard of 22,000 ug/m^3 and a 24-hour AAQC of 7,300 ug/m^3 for isopropanol. The half-hour standard is based on odour perception, while the 24-hour standard is based on adverse renal effects in a two year chronic inhalation study with male rats. A NOAEL of 500 ppm was identified and adjusted for intermittent exposure (6/24 hours x 5/7 days) to a concentration of 90 ppm. An uncertainty factor of 30 was applied to the duration-adjusted NOAEL to account for intra-species variation (10-fold) and interspecies variation (3-fold). Interspecies variation is typically accounted for by a factor of 10 and consists of two components – pharmacokinetics and pharmacodynamics. However, sufficient evidence exists to indicate that the pharmacokinetics of isopropanol in humans and rats are similar. On this basis, the uncertainty factor was reduced to 3 (OMOE, 2005c).

The California OEHHA (2000) has established acute RELs for both isopropanol and methanol. The acute REL of 3,200 ug/m^3 for isopropanol is based on a NOAEL of 200 ppm for mild irritation of the eyes, nose and throat in ten human subjects exposed to isopropanol vapour for 4 minutes (OEHHA, 1999). The NOAEL was adjusted to a 1-hour concentration of 13 ppm (4 minutes/60 minutes) and an uncertainty factor of 10 was applied to the adjusted NOAEL to account for intra-species variation.

The California OEHHA has established an acute REL of 28,000 ug/m3 for methanol based on subtle neurologic effects in male volunteers (OEHHA 1999; 2000). Twelve healthy male volunteers were exposed to 250 mg/m^3 (192 ppm) methanol for 75 minutes and administered 20 neurobehavioural and neurophysiological tests before, during, and after exposure. To obtain the REL, the NOAEL of 192 ppm was extrapolated to a 1-hour concentration of 214 ppm and the OEHHA applied an uncertainty factor of 10 to account for intra-species variability.

The OEHHA REL for isopropanol of **3,200 ug/m^3** was used in the assessment, as it represents the most conservative and defensible value out of the limits evaluated.

4A2.8.2 Chronic Exposure Limits

Table 4A-18 Summary of Chronic Inhalation Exposure Limits for the Isopropanol and Methanol

Regulatory Agency	Value (ug/m^3)	Type	Reference
Isopropanol			
Health Canada		-	Health Canada, 2004b,c
ATSDR		-	ATSDR, 2006a
RIVM		-	RIVM, 2001
U.S. EPA		-	U.S. EPA, 2007
WHO		-	WHO, 2000
OEHHA	7,000	RfC	OEHHA, 2005
Methanol			
Health Canada	–	-	Health Canada, 2004b,c
ATSDR	–	-	ATSDR, 2006a
RIVM	–	-	RIVM, 2001
U.S. EPA	–	-	U.S. EPA, 2007
WHO	–	-	WHO, 2000
OEHHA	4,000	RfC	OEHHA, 2005

-- not available

The OEHHA (2005) provides chronic RELs for both isopropanol (7,000 ug/m^3) and methanol (4,000 ug/m^3). The chronic inhalation REL for methanol was employed in the current assessment since it is the more conservative of the two available chronic inhalation guidelines.

The REL for methanol is based on a NOAEL of 1,000 ppm for developmental effects in mice (OEHHA, 2005). Pregnant mice were exposed to methanol 7 hours per day on days 6 to 15 of gestation. The most sensitive developmental toxicity endpoint of abnormal cervical ribs was associated with a benchmark concentration with a 5% added risk above background (BMC_{05}) of 305 ppm. The BMC_{05} was adjusted to continuous exposure (7 hours/24 hours) and a HEC was calculated assuming a regional gas dose ratio of 1.0, resulting in a BMC_{05}(HEC) of 89 ppm. The OEHHA (2005) applied an uncertainty factor of 30 to account for interspecies variability (3-fold) and intra-species variability (10-fold). The chronic REL of **4,000 ug/m^3** was used in the chronic inhalation effects assessment.

A chronic oral exposure limit was not required for the assessment of the aliphatic alcohol group as the persistence and bioaccumulation parameters for isopropanol and methanol did not exceed any of Environment Canada's (2006) screening parameters and thus was not incorporated into the multiple exposure pathway model.

A chronic inhalation criterion or guideline is not provided by any of the above regulatory agencies for isopropanol or methanol. Consequently, the toxicity search was expanded to include the OEHHA (2005) for isopropanol and methanol (Table 4A-18).

The OEHHA (2005) provides chronic RELs for both isopropanol (7,000 ug/m^3) and methanol (4,000 ug/m^3). The chronic inhalation REL for methanol was employed in the current assessment since it is the more conservative of the two available chronic inhalation guidelines.

The REL for methanol is based on a NOAEL of 1,000 ppm for developmental effects in mice (OEHHA, 2005). Pregnant mice were exposed to methanol 7 hours per day on days 6 to 15 of gestation. The most sensitive developmental toxicity endpoint of abnormal cervical ribs was associated with a benchmark concentration with a 5% added risk above background (BMC_{05}) of 305 ppm. The BMC_{05} was adjusted to continuous exposure (7 hours/24 hours) and a HEC was calculated assuming a regional gas dose ratio of 1.0, resulting in a BMC_{05}(HEC) of 89 ppm. The OEHHA (2005) applied an uncertainty factor of 30 to account for interspecies variability (3-fold) and intra-species variability (10-fold). The chronic REL of 4,000 ug/m^3 was used in the chronic inhalation effects assessment.

A chronic oral exposure limit was not required for the assessment of the aliphatic alcohol group since the persistence and bioaccumulation parameters for isopropanol and methanol did not exceed any of Environment Canada's (2006) screening parameters and thus was not incorporated into the multiple exposure pathway model.

4A2.9 Aliphatic Aldehyde Group

Surrogate:, , Propionaldehyde

4A2.9.1 Acute Exposure Limit

Table 4A-19 Summary of Acute Inhalation Exposure Limits for the Aliphatic Aldehyde Group

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	–	–	AENV, 2005
ATSDR	–	–	ATSDR, 2006a
OEHHA	–	–	OEHHA, 2000
OMOE	–	–	OMOE, 2005a
WHO	–	–	WHO, 2000

-- not available

An acute criterion or guideline was not identified from any of the above regulatory agencies for propionaldehyde. Consequently, the toxicity search was expanded to include intermediate MRLs provided by the ATSDR and occupational exposure values established by the ACGIH.

An acute criterion or guideline was not identified from any of the above regulatory agencies for propionaldehyde. Consequently, the toxicity search was expanded to include values for other aliphatic aldehydes, intermediate MRLs provided by the ATSDR and occupational exposure values established by the ACGIH.

The ACGIH (1998) has established a ceiling limit of 0.3 ppm (860 ug/m^3) for crotonaldehyde. Crotonaldehyde is recognized as an irritant, as eye and upper respiratory tract irritation has been noted to occur within 30-seconds of exposure to 4.1 ppm. In addition, the RD50 values in mice for irritation for crotonaldehyde have been observed to be similar to those of formaldehyde. On this basis, the ACGIH has adopted the ceiling limit for formaldehyde of 0.3 ppm for crotonaldehyde, assuming that the two substances are equipotent.

However, the basis of the ACGIH limit is not well substantiated, and the surrogate compound used by ACGIH is not part of this aldehydes group. Thus, as no defensible acute exposure limit was identified for the aliphatic aldehydes, this group was not evaluated on an acute basis.

4A2.9.2 Chronic Exposure Limits

Table 4A-20 Summary of Chronic Inhalation Exposure Limits for Aliphatic Aldehydes

Regulatory Agency	Value (ug/m^3)	Type	Reference
Health Canada	–	–	Health Canada, 2004b,c
ATSDR	–	–	ATSDR, 2006a
RIVM	–	–	RIVM, 2001
U.S. EPA	–	–	U.S. EPA, 2007
WHO	–	–	WHO, 2000
OEHHA	–	–	OEHHA, 2005

-- not available

A chronic inhalation criterion or guideline is not provided by any of the above regulatory agencies for propionaldehyde. Consequently, the toxicity search was expanded to include chronic oral criteria or guidelines provided by any of the above regulatory agencies for propionaldehyde.

Table 4A-21 Summary of Chronic Oral Exposure Limits for Aliphatic Aldehydes

Regulatory Agency	Value (ug/kg bw/d)	Type	Reference
Health Canada	–	–	Health Canada, 2004b,c
ATSDR	–	–	ATSDR, 2006a
RIVM	–	–	RIVM, 2001
U.S. EPA	–	–	U.S. EPA, 2007
WHO	–	–	WHO, 2000

-- not available

Finally, the toxicity search was extended to occupational exposure values established by the ACGIH. The same ACGIH TLV–TWA occupational exposure limit of 47,500 ug/m^3 that formed the basis of the acute exposure limit was used to derive the chronic inhalation exposure limit (ACGIH 2002; 2006b). ACGIH (2002) notes that the TLV-TWA of 20 ppm also is protective in relation to the incidence of nasal lesions following, as the threshold for lesion formation is estimated to be between 90 ppm and 150 ppm.

Similar to the acute exposure limit, the TLV-TWA was adjusted using a 10-fold safety factor to ensure that the value is protective of sensitive individuals. In addition, the TLV–TWA was adjusted from an 8-hour time-weighted average occupational exposure over one day to a continuous exposure using the following calculation (U.S. EPA 2002):

$$\text{TLV–TWA}_{adj} = \text{TLV–TWA} \times \frac{MV_{ho}}{MV_h} \times \frac{Exp_{ho}}{Exp_h}$$

Where:

TLV–TWAadj = chemical-specific TLV–TWA for chronic exposure via inhalation (ug/m^3)

TLV–TWA = chemical-specific TLV–TWA (ug/m^3)

MV_{ho} = amount of air used by a worker during an 8-hour work period (10 m^3/d)

MV_h = amount of air used by an individual in the general population during a day (20 m^3/d)

Exp_{ho} = days per week a worker is exposed (5 days)

Exp_h = days per week an individual in the general population is exposed (7 days)

The above adjustments result in a modified chronic exposure limit of **1,700 ug/m^3.** This RfC was used in the chronic inhalation effects assessment of the aliphatic aldehyde group.

A chronic oral exposure limit was not required for the assessment of the aliphatic aldehyde group since the persistence and bioaccumulation parameters for propionaldehyde did not exceed any of Environment Canada's (2006) screening parameters and thus was not incorporated into the multiple exposure pathway model.

4A2.10 Aliphatic Ketone Group

Surrogate: Methyl ethyl ketone

4A2.10.1 Acute Exposure Limit

Table 4A-22 Summary of Acute Inhalation Exposure Limits for Methyl Ethyl Ketone

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	–	–	AENV, 2005
ATSDR	–	–	ATSDR, 2006a
OEHHA	13,000	1-hour	OEHHA, 2000
OMOE	3,000 1,000	½-hour 24-hour	OMOE, 2005a OMOE, 2005a
WHO	–	–	WHO, 2000

-- not available

Although the OMOE (2005a) provides ½-hour and 24-hour standards for methyl ethyl ketone, no scientific basis is provided for these standards. As a result, the study team is unable to comment on the scientific merit of these limits and did not use them in the short-term assessment of methyl ethyl ketone.

The California OEHHA provides an acute REL of **13,000 ug/m^3** for methyl ethyl ketone based on eye, nose and throat irritation in four healthy human volunteers (OEHHA 1999; 2000). A LOAEL of 270 ppm was reported for 2-hour exposure. An uncertainty factor of 60 was applied to the study LOAEL to account for intra-species variation (10-fold) and use of a LOAEL (6-fold). Use of a LOAEL is typically accounted for by a factor of 10; however, the LOAEL is based on mild irritation and thus OEHHA considered a factor of 6 to be adequate. This REL was selected as the 1-hour exposure limit for the aliphatic ketone group.

4A2.10.2 Chronic Exposure Limit

Table 4A-23 Summary of Chronic Inhalation Exposure Limits for Methyl Ethyl Ketone

Regulatory Agency	Value (ug/m^3)	Type	Reference
Health Canada	–	–	Health Canada, 2004b,c
ATSDR	–	–	ATSDR, 2006a
RIVM	–	–	RIVM, 2001
U.S. EPA	5,000	RfC	U.S. EPA, 2007
WHO	–	–	WHO, 2000

-- not available

The U.S. EPA (2007) has developed an RfC of 5,000 μg/m^3 for methyl ethyl ketone based on developmental effects. This RfC is developed from a lowest-exposure-concentration (LEC) of 5,202 mg/m^3 for reduced fetal birth rate in a mice exposed 7 hours per day on days 6 through 15 of gestation (Schwetz et al., 1991; Mast et al., 1989). The LEC was adjusted for intermittent exposure (7 hours/24 hours) to a value of 1,517 mg/m^3. An uncertainty factor of 300 was applied to account for intra-species variability (10-fold), interspecies extrapolation (3-fold) and database deficiencies (10-fold). The uncertainty factor for interspecies extrapolation embodies two areas of uncertainty: pharmacokinetics and pharmacodynamics. In this assessment, the pharmacokinetic component is addressed by the calculation of the HEC according to the procedures in the RfC methodology. Accordingly, only the pharmacodynamic area of uncertainty remains as a partial factor for interspecies uncertainty and thus a partial uncertainty factor was incorporated. This inhalation RfC of **5,000** ug/**m^3** was selected as the chronic exposure limit for the aliphatic ketone group.

A chronic oral exposure limit was not required for the assessment of the aliphatic ketone group since the persistence and bioaccumulation parameters for methyl ethyl ketone did not exceed any of Environment Canada’s (2006) screening parameters and thus it was not incorporated into the multiple exposure pathway model.

4A2.11 Ammonia

4A2.11.1 Acute Exposure Limits

Table 4A-24 Acute Inhalation Exposure Limits for Ammonia

Regulatory Agency	Value (ug/m^3)	Averaging Time	Source
AENV	1,400	1-hour	AENV, 2005
ATSDR	1,200	24-hour	ATSDR, 2006a
OEHHA	3,200	1-hour	OEHHA, 2000
OMOE	100	24-hour	OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

Although the OMOE provides a 24-hour standard for ammonia, the scientific basis was not provided (OMOE, 2005a). As a result, the study team is unable to comment on the scientific merit of this standard and did not use it in the short-term assessment of ammonia.

The AENV provides a 1-hour AAQO for ammonia of 1,400 ug/m^3, however, this value is based on odour rather than health-related effects (AENV, 2005). On this basis, this AAQO was not used in the acute effects assessment for ammonia.

The ATSDR provides an acute MRL of 1.7 ppm (1.2 mg/m^3) for mild irritation of the eyes, nose and throat in humans exposed to ammonia gas. Sixteen human volunteers were exposed to 50 ppm, 80 ppm, 110 ppm or 140 ppm (34 mg/m^3, 54 mg/m^3, 75 mg/m^3 or 95 mg/m^3) for two hours (ATSDR, 2004b; 2006a). Eight of the volunteers (experts) knew of the effects of ammonia from the literature, but had no personal contact, while the remaining eight volunteers (non-experts) were students from a non-science faculty and were not familiar with ammonia. Exposure to 140 ppm (95 mg/m^3) was considered to be 'unbearable' for all eight of the non-experts, resulting in the termination of exposure after 30 to 75 minutes. The eight experts tolerated these exposures for the full 2-hour period. The testing was repeated with a 1-week interval. During exposure, each volunteer recorded subjective feelings every 15 minutes. Immediately prior to and following exposure, vital capacity, forced expiratory volume, and forced inspiratory volume were measured. A LOAEL of 50 ppm (34 mg/m^3) was reported. The LOAEL was not adjusted to a 24-hour exposure as the effects observed were local irritation effects and thus not time-dependent but rather concentration-dependent (ATSDR 2004b). An uncertainty factor of 30 was applied to the LOAEL to account for use of a minimal LOAEL (3-fold) and intra-species variation (10-fold).

The OEHHA has established an acute REL of 3,200 ug/m^3 for eye and respiratory irritation in humans (OEHHA 1999; 2000). The REL was calculated by a benchmark concentration approach using a log-normal probit analysis. The exposure concentrations were obtained from several studies: Industrial Biotest Laboratories 1973; MacEwan et al., 1970; Silverman et al., 1949. Each of the exposure concentrations was adjusted to a 1-hour duration using Haber's Law, which assumed an "n" value of 4.6 based on the best fit using a chi-square analysis of human irritation data. The 95% lower confidence limit of the concentration expected to produce a response rate of 5% (BM_{05}) of 13.6 ppm (9.7 mg/m^3) was calculated. An uncertainty factor of 3 was applied to the BM_{05} to account for intra-species variation in the human population. An uncertainty factor was not applied for interspecies variability since the benchmark concentration accounts for some degree of variation and comparison of human irritation thresholds with concentration lethal to mice indicates that humans are not more susceptible than mice to ammonia toxicity. This acute REL of **3,200 ug/m^3** was used as a 1-hour exposure limit in the acute effects assessment for ammonia, as it was based upon more than one study and is thus more representative of the potential effects of ammonia in humans than the ATSDR value.

4A2.11.2 Chronic Exposure Limits

Table 4A-25 Chronic Inhalation Exposure Limits for Ammonia

Regulatory Agency	Value (ug/m^3)	Type	Source
ATSDR	70	RfC	ATSDR, 2006a
Health Canada	--	--	Health Canada, 2004b,c
RIVM	--	--	RIVM, 2001
U.S. EPA	100	RfC	U.S. EPA, 1991b
WHO	--	--	WHO, 2000

-- not available

The ATSDR provides a chronic MRL of 0.1 ppm (70 ug/m^3) based on the respiratory effects of ammonia (ATSDR, 2004a; 2006a). Sense of smell, prevalence of respiratory symptoms, eye and throat irritation, and lung function parameters were measured in humans exposed for an average of 12.2 years in a soda ash plant (ATSDR, 2004a). The cohort included 52 workers and 35 controls. The subjects were assessed on the first and last workday of their workweek. Exposure levels were determined by sampling exposed and control workers over one work shift. The average sample collection period was 8.4 hours. The mean time-weighted average exposure concentration of 9.2 ppm (6.4 mg/m^3) was identified as the NOAEL for decreased pulmonary function and changes in subjective symptomology. The NOAEL was adjusted for continuous exposure (8 hours/24 hours x 5 days/7 days) and divided by an uncertainty factor of 10 for the protection of sensitive individuals. As well, a modifying factor of 3 was used to account for the lack of reproductive and developmental studies (ATSDR 2004a).

The U.S. EPA has developed an RfC of 100 μg/m^3 based on the same study (Holness et al., 1989) as the ATSDR (U.S. EPA, 1991; ATSDR, 2004a). The minor discrepancy between the limit values of the U.S. EPA and the ATSDR arises from the different ways of extrapolating from working-week exposure conditions to continuous exposure conditions. The U.S. EPA (1991b) converted the NOAEL of 9.2 ppm (6.4 mg/m^3) from an 8-hour time-weighted average occupational exposure to continuous exposure using the following calculation:

$$\text{NOAEL}_{\text{HEC}} = \text{NOAEL} \times \frac{\text{MV}_{\text{ho}}}{\text{MV}_{\text{h}}} \times \frac{\text{Exp}_{\text{ho}}}{\text{Exp}_{\text{h}}}$$

Where:

$\text{NOAEL}_{\text{HEC}}$ = NOAEL in the human population from continuous exposure to ammonia (mg/m^3)

NOAEL = NOAEL for discontinuous exposure in an occupational setting (6.4 mg/m^3)

MV_{ho} = amount of air used by a worker during an 8-hour work period (10 m^3/d)

MV_{h} = amount of air used by an individual in the general population during a day (20 m^3/d)

Exp_{ho} = days per week a worker is exposed (5 days)

Exp_{h} = days per week an individual in the general population is exposed (7 days)

An uncertainty factor of 30 was applied to the $\text{NOAEL}_{\text{HEC}}$ of 2.3 mg/m^3 to account for intra-species variability (10-fold) and database inadequacy (3-fold). Database deficiencies included the lack of chronic data, the proximity of the LOAEL to the NOAEL, and the lack of reproductive and developmental toxicology studies. A partial uncertainty factor of 3 was deemed to be adequate by the U.S. EPA since studies in rats have not demonstrated an increase in blood ammonia levels at exposures of 32 ppm (22 mg/m^3) and only minimal increases at 300 ppm to 1,000 ppm (200 mg/m^3 to 700 mg/m^3), suggesting that no significant distribution is likely to occur at the HEC level. The result is an RfC of 77 μg/m^3 for ammonia; however, the U.S. EPA rounds this limit to one significant digit (100 μg/m^3). In the chronic inhalation effects assessment of ammonia, the RfC (prior to rounding) of **77 ug/m^3** was used.

Ammonia was not incorporated into the multiple-pathway exposure model as it did not exceed the persistence and bioaccumulation parameters established by Environment Canada (2007). As a result, a chronic oral exposure limit was not required for ammonia.

4A2.12 Aromatic C_9-C_{16}

4A2.12.1 Acute Exposure Limits

After reviewing available information and determining that an acute inhalation limit was not available for this group of compounds, a modified acute inhalation exposure limit was developed from the sub-chronic NOAEL that formed the basis of the CCME's chronic RfC.

The CCME and TPHCWG developed a chronic RfC for the aliphatic C_9-C_{16} group from a sub-chronic inhalation study, in which rats were exposed to a mixture of C_9 aromatics (high flash aromatic naphtha [HFAN]) at concentrations of 0 mg/m^3, 450 mg/m^3, 900 mg/m^3 or 1,800 mg/m^3 for six hours per day, five days per week for 12 months (CCME; 2000a; TPHCWG, 1997; Clark et al., 1989). Increased liver and kidney weights were reported for male rats in the 1,800 mg/m^3 exposure group. The MA DEP also reviewed the Clark et al. (1989) study and, in addition to liver toxicity, identified central nervous system (CNS) effects associated with the LOAEL of 1,800 mg/m^3 (MA DEP, 2003).

In the derivation of the modified acute inhalation exposure limit, an uncertainty factor of 100 was applied to the NOAEL of 900 mg/m^3 to account for the intra-species variability (10-fold) and interspecies variability (10-fold). The result is an acute inhalation exposure limit of **9,000 ug/m^3**. This modified limit was used as a 1 hour exposure limit in the acute effects assessment of the aromatic C_9-C_{16} group.

Use of a sub-chronic study in the derivation of an acute exposure limit is considered conservative since a higher exposure over a shorter time-period (i.e., acute exposure) presumably could occur without risk of adverse effects.

The search for chronic inhalation and oral exposure limits was limited to three regulatory agencies: CCME (2000a), MA DEP (2003) and TPHCWG (1997). These agencies have developed chronic exposure limits for the aliphatic and aromatic groups as a whole.

4A2.12.2 Chronic Exposure Limits

Table 4A-26 Summary of Chronic Inhalation Exposure Limits for the Aromatic C_9-C_{16} Group

Regulatory Agency	Value (ug/m^3)	Type	Reference
CCME	200	RfC	CCME, 2000a
MA DEP	50	RfC	MA DEP, 2003
TPHCWG	200	RfC	TPHCWG, 1997

The CCME (2000a) provides a chronic RfC for C_9-C_{16} aromatics of 200 ug/m^3 based on increased liver and kidney weights in male rats exposed to high flash aromatic naphtha (HFAN), which is primarily composed of 9-carbon aromatic compounds. The RfC was adopted from the TPHCWG (1997) and derived from a study that exposed rats to a mixture of C_9 aromatics at concentrations of 0 mg/m^3, 450 mg/m^3, 900 mg/m^3 or 1,800 mg/m^3 for six hours per day, five days per week for 12 months (Clark et al., 1989). A NOAEL of 900 mg/m^3 was derived and converted to continuous exposure (6 hours/24 hours × 5 days/7 days). An uncertainty factor of 1,000 was applied to the duration-adjusted NOAEL of 160 mg/m^3 to account for the most sensitive (10-fold), interspecies variability (10-fold), and use of a sub-chronic study (10-fold).

The MA DEP (2003) provides an RfC of 50 ug/m^3 based on the same Clark et al. (1989) study as the TPHCWG and the CCME. However, the MA DEP applies an extra 3-fold uncertainty factor for database deficiency. The partial uncertainty factor was applied to account for the lack of toxicity information on non-PAH compounds in the C_9-C_{16} aromatic fraction range (MA DEP, 2003).

For the purpose of assessing chronic inhalation effects, the TPHCWG and CCME both consider there to be an adequate database for the derivation of an RfC that is representative of the C_9-C_{16} aromatics. As a result, the CCME RfC of **200 ug/m^3** was used in the chronic inhalation effects assessment. This RfC equates to an inhaled dose of 45 ug/kg bw/d based on an average adult body weight of 70.7 kg and an inhalation rate of 15.8 m^3/d (Health Canada, 2004a).

Table 4A-27 Summary of Chronic Oral Exposure Limits for the Aromatic C_9-C_{16} Group

Regulatory Agency	Value [ug/kg bw/d]	Type	Source
CCME	40	RfD	CCME, 2000a
MA DEP	30	RfD	MA DEP, 2003
TPHCWG	40	RfD	TPHCWG, 1997

The CCME (2000a) recommends an oral RfD of 40 ug/kg bw/d for the C_9-C_{16} Aromatics compounds based on the RfD for eight individual compounds for which the U.S. EPA has established oral RfDs (isopropylbenzene, acenaphthene, biphenyl, fluorene, anthracene, fluoranthene, naphthalene, pyrene). The CCME adopted this value from the TPHCWG (1997), who examined the aforementioned RfDs for liver and kidney effects together with toxicity data for naphthalenes/methylnaphthalenes to determine the RfD of 0.04 mg/kg bw/d. At the time of the TPHCWG (1997) assessment, four of the eight individual compounds (isopropylbenzene, naphthalene, fluorene and fluoranthene) presented RfDs of 0.04 mg/kg bw/d, while the remaining compounds had RfDs ranging from 0.03 mg/kg bw/d to 0.3 mg/kg bw/d.

Alternatively, the MA DEP (2003) selected the U.S. EPA RfD for pyrene of 0.03 mg/kg bw/d to represent the entire range of compounds. The U.S. EPA RfD for pyrene is based on kidney effects (renal tubular pathology, decreased kidney weights) observed in a subchronic mouse oral bioassay. This value has not been updated since the MA DEP assessment (U.S. EPA, 2007).

Although the U.S. EPA has revised the isopropylbenzene (0.1 mg/kg bw/d) and naphthalene (0.02 mg/kg bw/d) RfDs since the TPHCWG’s assessment (U.S. EPA, 1997; 1998), it is important that the RfD of the group reflect the toxicity of the group as a whole and not a single compound within the group. On this basis, the CCME (2000a) oral RfD of **40 ug/kg-d** was used in the chronic oral effects assessment of the aromatic C_9-C_{16} group.

In order to incorporate the aromatic C_9-C_{16} group in the multiple-pathway exposure model, bioavailability was assessed via a surrogate (naphthalene) for the various exposure pathways (i.e., inhalation, ingestion and dermal contact). No specific data were identified regarding the inhalation bioavailability of this group, thus it was assumed to be 100%. Oral bioavailability in humans was assumed to be 80% and dermal bioavailability was assumed to be 13% for this assessment (RAIS, 2007).

4A2.13 Aromatic C_{17}-C_{34} Group

4A2.13.1 Acute Exposure Limits

An acute inhalation guideline or exposure limit was not available from the sources evaluated. Alternatively, a modified acute inhalation limit was developed from the sub-chronic oral NOAEL that formed the basis of the CCME's chronic RfD.

The CCME and TPHCWG identified pyrene as a surrogate for this aromatic fraction because it has a lower carbon number than any of the compounds in the group (CCME, 2000a; TPHCWG, 1997). Both CCME and TPHCWG adopted the U.S. EPA RfD as their RfD values for this fraction. The U.S. EPA identified a NOAEL of 75 mg/kg bw/d for kidney effects (renal tubular pathology, decreased kidney weights) in a mouse sub-chronic oral bioassay. In the key study, male and female CD-1 mice (20/sex/group) were gavaged with 0 mg/kg bw/d, 75 mg/kg bw/d, 125 mg/kg bw/d or 250 mg/kg bw/d pyrene in corn oil for 13 weeks. Given that this study is based upon a chronic oral exposure, the above values were not used in the acute assessment.

4A2.13.2 Chronic Exposure Limits

The search for chronic inhalation and oral exposure limits was limited to three regulatory agencies: CCME (2000a), MA DEP (2003) and TPHCWG (1997). These agencies have developed chronic exposure limits for the aliphatic and aromatic groups as a whole.

According to CCME (2000a), appropriate inhalation toxicity data were not identified for the individual constituents or fractions in the C_{17}-C_{34} carbon range. The CCME suggests that this could be the result of the hydrocarbons in this group not being volatile and inhalation not being the likely exposure pathway. The MA DEP (2003) has not established RfC for exposure to C_{19}-C_{32} aromatics due to the limited volatility of the compounds within the group. Nevertheless, the C_{17}-C_{34} aromatics will be emitted to the atmosphere from the proposed facility and thus requires an inhalation limit. Given that a chronic inhalation limit is not provided by CCME (2000a), MA DEP (2003) or TPHCWG (1997), the toxicity search was expanded to include the chronic oral criteria or guidelines provided by any of these regulatory agencies (Table 4A-28).

Table 4A-28 Chronic Oral Exposure Limits for the Aromatic C_{17}-C_{34} Group

Regulatory Agency	Value (ug/kg bw/d)	Type	Reference
CCME	30	RfD	CCME, 2000a
MA DEP	30	RfD	MA DEP, 2003
TPHCWG	30	RfD	TPHCWG, 1997

The CCME (2000a) recommends an oral RfD of **30 ug/kg bw/d** for the aromatic C_{17}-C_{34} fraction. This RfD was adopted from the TPHCWG (1997) and is based on the nephrotoxicity of pyrene. There are no previously developed RfDs or appropriate data for compounds within the C_{17}-C_{34} fraction. The RfD for pyrene was derived from a NOAEL of 75 mg/kg bw/d with an uncertainty factor of 1,000 applied to the NOAEL to account for interspecies variability (10-fold), intra-species variability (10-fold), and use of a sub-chronic study (10-fold). A modifying factor of 3 was applied to the RfD because of the lack of adequate toxicity data. The oral RfD provided by CCME (2000a) was converted to a modified chronic inhalation limit of **130 ug/m^3** based on the following adjustments and assumptions:

- Inhalation bioavailability and oral bioavailability of 100% (assumed)

- Adult body weight of 70.7 kg (Health Canada, 2004a)
- Adult inhalation rate of 15.8 m^3/d (Health Canada, 2004a)

As no data were identified in the literature regarding the absorption of aromatic C_{17}-C_{34} group or any of the individual constituents, oral and dermal bioavailability were assumed to be 100% in the multiple-pathway exposure model. The CCME (2000a) RfD of 30 ug/kg bw was used in the multi-pathway assessment.

4A2.14 Benzaldehyde

4A2.14.1 Acute Exposure Limits

Table 4A-29 Acute Inhalation Exposure Limits for Benzaldehyde

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	--	--	AENV, 2005
ATSDR	-	-	ATSDR, 2006a
OEHHA	-	-	OEHHA, 2000
OMOE	-	-	OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

No values from the above agencies were available for benzaldehyde. Thus, the search was expanded to include acute and intermediate limits from the ACGIH and ATSDR. As no appropriate limits were identified, this suggests that the toxicological database regarding the acute toxicity of benzaldehyde is limited. Thus, benzaldehyde was not evaluated on an acute basis.

4A2.14.2 Chronic Exposure Limits

Table 4A-30 Chronic Inhalation Exposure Limits for Benzaldehyde

Regulatory Agency	Value (ug/m^3)	Type	Reference
ATSDR	--	--	ATSDR, 2006a
Health Canada	-	-	Health Canada, 2004c
OEHHA	-	-	OEHHA, 2005
RIVM	-	-	RIVM, 2001
U.S. EPA	-	-	U.S. EPA, 2007
WHO	-	-	WHO, 2000

-- not available

There are no published guidelines available for subchronic or chronic inhalation exposure. However, the U.S. EPA assessment of benzaldehyde reports an RfD of 0.1 mg/kg bw/d based on a NOAEL of 200 mg/kg bw/d for stomach lesions and kidney toxicity in a subchronic oral toxicity study in rats (U.S. EPA, 2007). The NOAEL was dose-adjusted for gavage schedule of 5 days per week to a concentration of 143 mg/kg bw/d (i.e., 5 days/7 days). An uncertainty factor of 1,000 was applied to the NOAEL to account for interspecies variation (10-fold), intra-species variation (10-fold), and extrapolation from subchronic to chronic exposure (10-fold). The result is a chronic exposure limit of 100 ug/kg bw/d for benzaldehyde.

The chronic exposure limit of 100 ug/kg bw/d is equivalent to an air concentration of 360 ug/m^3, based on the following adjustments and assumptions:

- Inhalation bioavailability of 100% (assumed)
- Oral bioavailability of 80% (RAIS, 2007)
- Adult body weight of 70.7 kg (Health Canada, 2004a)
- Adult inhalation rate of 15.8 m^3/d (Health Canada, 2004a)

This modified exposure limit of **360 ug/m^3** was used in the chronic inhalation effects assessment.

A chronic oral exposure limit was not required for the assessment of benzaldehyde, because it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007) and thus was not incorporated into the multiple exposure pathway model.

4A2.15 Benzene

4A2.15.1 Acute Exposure Limits

Table 4A-31 Acute Inhalation Exposure Limits for Benzene

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	30	1-hour	AENV, 2005
ATSDR	28.8	24-hour	ATSDR, 2006a
OEHHA	1,300	6-hour	OEHHA, 2000
OMOE	--	--	OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

The current assessment used the AENV 1 hour exposure limit of 30 ug/m^3 (AENV, 2005). Alberta's AAQO was adopted from the Texas Natural Resource Conservation Commission, but the specific basis of the derivation remains unknown. Although supporting documentation is not available, this AAQO was used in the current short-term assessment of benzene in air, as per discussions with Alberta Health and Wellness. As a result, the study team is unable to comment on the scientific merit of this limit, and it was not used in this assessment.

The ATSDR (2005, 2007) provides an acute MRL of 0.009 ppm (0.03 mg/m^3) based on immunological effects. Male C57BL/6J mice (7 or 8/concentration) were exposed to 0 ppm, 10.2 ppm, 31 ppm, 100 ppm, or 301 ppm (0 mg/m^3, 32.6 mg/m^3, 99 mg/m^3, 320 mg/m^3 or 960 mg/m^3) benzene in whole-body dynamic inhalation chambers for six hours per day on six consecutive days. The control group was exposed to filtered, conditioned air only. Significant depression of femoral lipopolysaccharide-induced B-colony-forming ability was observed at the 10.2 ppm exposure level in the absence of a significant depression of total number of B cells. Peripheral lymphocyte counts were depressed at all exposure levels. A LOAEL of 10.2 ppm (32.6 mg/m^3) was identified and adjusted from intermittent to continuous exposure (6 hours/24 hours) to a concentration of 2.55 ppm (8.16 mg/m^3). The duration-adjusted LOAEL (LOAEL$_{ADJ}$) was converted to a HEC (LOAEL$_{HEC}$) for a category 3 gas causing respiratory effects. The average ratio of the animal-blood:air partition coefficient would be greater than 1; thus, a default value of 1 was used in calculating the HEC. As a result, the $LOAEL_{HEC}$ of 2.55 ppm (8.16 mg/m^3) also was identified. Finally, a cumulative uncertainty factor of 300 was applied to the $LOAEL_{HEC}$ to account for interspecies variability (3-fold), intra-species variability (10-fold), and use of a LOAEL (10-fold). A factor of 3 was applied for the extrapolation of laboratory animal data to humans since the calculation of a HEC addressed the pharmacokinetic aspects of the interspecies uncertainty factor. Accordingly, only the pharmacodynamic aspects of uncertainty remain as a partial factor for interspecies uncertainty. The acute inhalation MRL of **30 ug/m^3** was used as a 24 hour limit in the acute effects assessment of benzene.

4A2.15.2 Chronic Exposure Limits

Table 4A-32 Chronic Inhalation Exposure Limits for Benzene

Regulatory Agency	Value (ug/m^3)	Type	Reference
ATSDR	9.6	RsC	ATSDR, 2006a
Health Canada	3	RsC	Health Canada, 2004b
RIVM	20	RsC	RIVM, 2001
U.S. EPA	1.3 to 4.5	RsC	U.S. EPA, 2007
WHO	1.7	RsC	WHO, 2000

An RsC of 3 ug/m^3 is reported by Health Canada (2004b) based on an inhalation unit risk of 0.0033 per mg/m^3. This RsC represents the daily dose via inhalation that is associated with an increased cancer risk of 1 in 100,000.

The WHO (2000) provides an RsC of 1.7 ug/m^3, which is associated with an increased cancer risk of one in 100,000. Using multiplicative risk estimates and a cumulative exposure model, a unit risk for lifetime exposure of 1.4 to 1.5 x 10^{-5} per ppb was derived with the Paustenbach exposure matrix and 2.4 x 10^{-5} per ppb with the Crump and Allen exposure matrix (WHO, 2000). These unit risks equate to a range of 4.4 x 10^{-6} per ug/m^3 to 7.5 x 10^{-6} per ug/m^3. From this the WHO (2000) selected a representative unit risk of 6 x 10^{-6} per μg/m^3.

The U.S. EPA (2007) presents a range of potential carcinogenic risks from inhalation of benzene based on the incidence of leukemia from human occupational studies. Its inhalation unit risks of 2.2 x 10^{-6} to 7.8 x 10^{-6} per μg/m^3 equate to an RsC of 1.3 to 4.5 ug/m^3 (corresponding to risk levels of one in 100,000). Benzene is noted to have a genotoxic mechanism of action that is potentially mediated via the primary benzene metabolites phenol, hydroquinone and catechol and possibly an intermediate – benzene oxide. The most stringent RsC of **1.3 ug/m^3** has been selected for use in this assessment.

A chronic oral exposure limit was not required for the assessment of benzene, because it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007) and thus was not incorporated into the multiple exposure pathway model.

4A2.16 Benzo(a)pyrene Group

4A2.16.1 Acute Exposure Limits

Table 4A-33 Acute Inhalation Exposure Limits for Benzo(a)pyrene

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	--	--	AENV, 2005
ATSDR	--	--	ATSDR, 2006a
OEHHA	--	--	OEHHA, 2000
OMOE	0.0011	24-hour	OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

The only regulatory agency that has a public acute exposure limit for benzo(a)pyrene is the OMOE (2005a), which provides a 24-hour standard of 0.0011 ug/m^3 for benzo(a)pyrene. This limit is based on the carcinogenic potential for benzo(a)pyrene and was derived based on an annual exposure limit of 0.00022 ug/m^3 for protection against carcinogenic effects using a simple extrapolation factor generally considered to be overly conservative. This limit was not used in the acute effects assessment for the benzo(a)pyrene group, as it did not account for the influence of duration of exposure on the carcinogenic action of a chemical. As no other appropriate limits were identified, an acute effects assessment was not completed for the benzo(a)pyrene group.

4A2.16.2 Chronic Exposure Limits

As recommended in OMOE (1997), the assessment of carcinogenic PAHs can be based on two approaches: the Whole-Mixture Model (WMM), and the Individual PAH Model (IPM).

The WMM approach is based on the conservative assumption that the potency of the PAH fraction of any environmental mixture is proportional to the benzo(a)pyrene content of the mixture (OMOE 1997). The WMM was derived from the methodology of the OMOE (1997), using the concentration of benzo(a)pyrene together with the toxic potency of the PAH-WMM group. The cancer slope factor for oral exposure to benzo(a)pyrene was estimated by OMOE, based on an examination of the composition and toxic potency of PAH mixtures derived from many different sources (e.g., coal tar, coke oven emissions, diesel emissions and wood burning). The unit risk for inhalation exposure to benzo(a)pyrene was developed based on a weight-of-evidence review of numerous epidemiology and rodent toxicity studies of benzo(a)pyrene. Critical effects included lung cancer and genitourinary tract cancer in humans. This approach, used in conjunction with the IPM, ensures that potential risks are not underestimated in the current assessment (OMOE 1997).

The IPM approach is based upon the addition of the risks for each individual PAH. The first step in the IPM requires an estimate of the inhalation potency of benzo(a)pyrene and other PAHs relative to benzo(a)pyrene. This step involves the use of Toxic Equivalency Factors (TEFs) to denote the cancer potency of specific PAH compounds relative to the potency of benzo(a)pyrene (Bostrom et al., 2002). Toxic Equivalency Factors allow large groups of compounds with a common mechanism of action such as PAHs to be assessed when limited data is available for all but one of the compounds (i.e., benzo(a)pyrene). Table 4A-34 shows the TEFs used in the current assessment of PAHs via the IPM approach.

Table 4A-34 Relative Potency of Individual Polycyclic Aromatic Hydrocarbons Compared with Benzo(a)pyrene

Compound[1]	Toxic Equivalency Factors (TEFs)[2]
Anthracene	0.0005
Benz(a)anthracene	0.005
Benzo(a)pyrene	1
Benzo(e)pyrene	0.002
Benzo(b)fluoranthene	0.1
Benzo(g,h,i)perylene	0.02
Benzo(k)fluoranthene	0.05
Chrysene	0.03
Dibenz(a,h)anthracene	1.1
Fluoranthene	0.05
Fluorene	0.0005
Indeno(1,2,3-cd)pyrene	0.1
Perylene	0.02
Phenanthrene	0.0005
Pyrene	0.001

Notes:

1 All compounds for which TEFs were identified in Larsen and Larsen (1998) were assessed as a part of the IPM approach.

2 Source: Larsen and Larsen (1998).

Table 4A-35 Chronic Inhalation Exposure Limits for Benzo(a)pyrene

Regulatory Agency	Value (ug/m^3)	Type	Reference
ATSDR	--	--	ATSDR, 2006a
Health Canada	0.32	RsC	Health Canada, 2004b
U.S. EPA	--	--	U.S. EPA, 2007
WHO	0.00012	RsC	WHO, 2000

-- not available

The WHO (2000) recommends an inhalation unit risk of 0.087 per ug/m^3 based on a benzo(a)pyrene concentration of 1 ug/m^3 in air as a component of benzene-soluble coke-oven emissions. This RsC of **0.00012 ug/m^3** is associated with an acceptable incremental lifetime cancer risk of development of lung tumours of one in 100,000. This RsC was selected for the chronic effects assessment of benzo(a)pyrene (WMM). It is equivalent to an inhaled dose of 0.000026 ug/kg bw/d based on the following assumptions:

- Inhalation bioavailability and oral bioavailability of 100% (assumed)
- Adult body weight of 70.7 kg (Health Canada, 2004a)
- Adult inhalation rate of 15.8 m^3/d (Health Canada, 2004a)

The Health Canada (2004b) provided an inhalation unit risk of 0.0033 per ug/m^3. The RsC of **0.32 ug/m^3** is associated with an incidence of lung tumours of one in 100,000. This RsC was selected for the chronic effects assessment of benzo(a)pyrene (IPM) and is equivalent to an inhaled dose of 0.072 ug/kg bw/d (based on the above adjustments).

Although Health Canada (2004b) has established inhalation unit risks for benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-cd)pyrene, these TRVs were not used in the current assessment of PAHs. The IPM approach provides a more conservative assessment of the potential cancer risk to humans than the inhalation unit risk values for the same end point (i.e., cancer). As well, the scientific basis for these inhalation unit risk values is unknown.

Based on the Environment Canada (2007) fate and persistence screening benzo(a)pyrene (IPM and WMM) was assessed via multiple exposure pathways, requiring an oral exposure limit.

Table 4A-36 Chronic Oral Exposure Limits for Benzo(a)pyrene

Regulatory Agency	Value (ug/kg bw/d)	Type	Reference
ATSDR	--	--	ATSDR, 2006a
Health Canada	0.0043	RsD	Health Canada, 2004b
RIVM	0.5	RsD	RIVM, 2001
U.S. EPA	0.0014	RsD	U.S. EPA, 2007
WHO	0.023	RsD	WHO, 2000

-- not available

Health Canada provides an oral slope factor of 2.3 per mg/kg bw/d based on the Canadian guidelines for drinking water quality of 0.00001 mg/L (Health Canada, 2004b 1988). The Canadian drinking water quality guideline for benzo(a)pyrene was established based on an increased incidence of stomach tumours (squamous cell papillomas and some carcinomas) (Health Canada, 1988; Neal and Rigdon, 1967). In the key study, male and female CFW-Swiss mice were fed concentrations of 0 ppm, 1 ppm, 10 ppm, 20 ppm, 40 ppm, 45 ppm, 50 ppm, 100 ppm or 250 ppm benzo(a)pyrene in the diet (purity was not reported). The control group contained 289 mice (number of mice/sex was not specified). No forestomach tumours were reported in the 0 ppm, 1 ppm, or 10 ppm dose groups. The incidence of forestomach tumours in the 20 ppm, 40 ppm, 45 ppm, 50 ppm, 100 ppm or 250 ppm dose groups were 1/23, 0/37, 1/40, 4/40, 23/40, 19/23 and 66/73, respectively. Incorporating a surface area correction and using the robust linear extrapolation model, the unit lifetime risk associated with the ingestion of 1 ug/L benzo(a)pyrene in drinking water was estimated as 5×10^{-5}. Using an adult body weight of 70.7 kg and an adult water ingestion rate of 1.5 L/d (Health Canada, 2004a), an oral slope factor of 2.3 per mg/kg bw/d was calculated. The Health Canada oral slope factor equates to an RsD of 0.0043 ug/kg bw/d that is associated with an acceptable incremental lifetime cancer risk of 1 in 100,000.

The U.S. EPA provides an oral slope factor of 7.3 per mg/kg bw/d based on the geometric mean of four slope factors obtained by different modelling procedures and multiple datasets from two different studies, including the Neal and Rigdon (1967) study that was used in the Health Canada assessment (U.S. EPA, 2007; Health Canada, 1988). The U.S. EPA considered each of these datasets to be acceptable for the derivation of an oral slope factor, but less-than-optimal. As a result, the use of a geometric mean of the four slope factors was preferred because it made use of more of the available data (U.S. EPA, 2007). The four slope factors were calculated as follows.

- The Neal and Rigdon (1967) data was fit to a two-stage dose response model that included a term to permit the modeling of benzo(a)pyrene as its own promoter (modification of Moolgavkar-Venson-Knudson, generalized forms of two-stage model). In this model, the transition rates and the growth rate of pre-neoplastic cells were both considered to be exposure-dependent. In addition to the Neal and Rigdon (1967) control group, historical control stomach tumour data from a related, but not identical, mouse strain (SWR/J Swill) was used in the modeling (Rabstein et al., 1973). In the historical control data, the forestomach tumour incidence rate was 2/268 and 1/402 for males and females, respectively. The lifetime unit risk for humans was calculated based on the following standard assumptions: mouse food consumption was 13% of its body weight per day, human body weight was assumed to be 70 kg, and the assumed body weight of the mouse 0.034 kg. The standard assumption of surface area equivalence between mice and humans was the cube root of 70 kg/0.034 kg. A conditional upper-bound estimate was calculated to be 5.9 per mg/kg bw/day.

- The same dataset as above was used to generate an upper-bound estimate extrapolated linearly from the 10% response point to the background of an empirically fitted dose-response curve (modification of Moolgavkar-Venson-Knudson, generalized forms of two-stage model). An upper-bound was calculated to be 9.0 per mg/kg bw/day.
- In order to reflect the partial lifetime exposure pattern over different parts of the animals' lifetimes, a generalized Weibull-type dose-response model was selected to assess the Neal and Rigdon (1967) data alone (i.e., excluding the two additional control groups from Rabstein et al.). An upper-bound was calculated to be 4.5 per mg/kg bw/d.
- A linearized multistage procedure was used to calculate an upper bound estimate for humans from the Brune et al. (1981) rat dataset. Thirty-two Sprague-Dawley (rats/sex/group) were fed 0.15 mg/kg benzo(a)pyrene (reported to be highly pure) in the diet of either every 9th day or five times per week. These treatments resulted in annual average doses of 6 or 39 mg/kg, respectively. The control group contained 32 rats per sex. Treatment continued until the rats were moribund or dead; survival was similar in all groups. The combined incidence of tumours of the forestomach, oesophagus and larynx was 3/64, 3/64 and 10/64 in the control group, the group fed benzo(a)pyrene every 9th day, and the group fed benzo(a)pyrene five times per week, respectively. A trend analysis showed a statistically significant tendency for the proportion of animals with tumours of the forestomach, oesophagus or larynx to increase steadily with dose. An oral slope factor of 11.7 per mg/kg bw/d was calculated.

The U.S. EPA IRIS value differs from the other available limits as a result of various factors considered in its development of an oral slope factor (i) different modelling procedures, (ii) multiple datasets from two different studies, and (iii) both sexes of more than one strain of mice and species of outbred rodents, the U.S. EPA RsD of **0.0014 ug/kg bw/d** was selected as the chronic oral limit for benzo(a)pyrene (IPM).

The toxicity search was expanded to include the OMOE (1997) for the benzo(a)pyrene (WMM) since the chronic oral limits listed in Table 4A-36 were developed for benzo(a)pyrene alone and thus are not representative of the whole PAH mixture. The OMOE (1997) provides an oral slope factor of 4.2 x 10^{-8} per ug/day for stomach tumours. Assuming an adult body weight of 70.7 kg, an RsD of **0.0034 ug/kg bw/d** was calculated that is associated with an acceptable incremental lifetime cancer risk of one in 100,000. The OMOE RsD of 0.0034 ug/kg bw/d was selected as the chronic oral limit for benzo(a)pyrene (WMM).

The bioavailability of benzo(a)pyrene was assessed for the various exposure pathways (i.e., inhalation, ingestion and dermal contact). In order to incorporate benzo(a)pyrene in the multiple exposure pathway model, bioavailability was assessed for the various exposure pathways (i.e., inhalation, ingestion and dermal contact). No specific data were identified in the literature regarding the amount of benzo(a)pyrene that is absorbed via inhalation; therefore it was conservatively assumed that 100% of the inhaled group is absorbed. Oral bioavailability in humans was assumed to be 31% and dermal bioavailability was assumed to be 13% for this assessment (RAIS, 2007).

4A2.17 Biphenyl

4A2.17.1 Acute Exposure Limits

Table 4A-37 Acute Inhalation Exposure Limits for Biphenyl

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	--	--	AENV, 2005
ATSDR	--	--	ATSDR, 2006a
OEHHA	--	--	OEHHA, 2000
OMOE	--	--	OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

Acute exposure limits were not identified from the above governmental organizations for 1,1'-biphenyl. Thus, the search was expanded to include intermediate MRLs from the ATSDR and occupational exposure limits.

The ACGIH has developed an 8-hour TLV-TWA limit of 0.2 ppm (1,300 ug/m^3) based on the appearance of respiratory difficulties in mice following repeated inhalation exposure of six hours per day for 64 days to 1 ppm (5,000 ug/m^3) 1,1'-biphenyl dust (ACGIH 1991; 2006). However, given the sub-chronic duration of this study, and that the TLV-TWA has been developed to be protective of long-term workers, this value was not used in the acute assessment.

4A2.17.2 Chronic Exposure Limits

Table 4A-38 Chronic Inhalation Exposure Limits for Biphenyl

Regulatory Agency	Value (ug/m^3)	Type	Reference
ATSDR	--	--	ATSDR, 2006a
Health Canada	--	--	Health Canada, 2004b
U.S. EPA	--	--	U.S. EPA, 2007
WHO	--	--	WHO, 2000

-- not available

There are no published guidelines available for subchronic or chronic inhalation exposure to 1,1'-biphenyl.

The ACGIH (1991; 2006) provides a TLV-TWA for biphenyl of 0.2 ppm (1.3 mg/m^3) for respiratory irritation. The TLV-TWA was developed respiratory difficulties in the most susceptible animal species, the mouse, following repeated inhalation exposure at 5 mg/m^3 (1 ppm), seven hours per day for 64 days (ACGIH 1991). The TLV-TWA is considered to be protective of a worker repeatedly exposed during an 8-hour workday and a 40-hour workweek (ACGIH 2006a,b). The TLV-TWA was adjusted from an 8-hour time-weighted average occupational exposure to continuous exposure using the following calculation (U.S. EPA, 2002a):

$$TLV\text{-}TWA_{ADJ} = TLV\text{-}TWA \times \frac{MVho}{MVh} \times \frac{Expho}{Exph}$$

Where:

$TLV\text{-}TWA_{ADJ}$ = chemical-specific TLV-TWA for chronic exposure via inhalation (mg/m^3)

TLV-TWA = chemical-specific TLV-TWA (1.3 mg/m^3)

MV_{ho} = amount of air used by a worker during an 8-hour work period (10 m^3/d)

MV_h = amount of air used by an individual in the general population during a day (20 m^3/d)

Exp_{ho} = days per week a worker is exposed (5 days)

Exp_h = days per week an individual in the general population is exposed (7 days)

An uncertainty factor of 10 was applied to the $TLV\text{-}TWA_{ADJ}$ of 0.46 mg/m^3 to account for intra-species variability, resulting in a modified chronic inhalation limit of **46 ug/m^3**. This modified limit was used in the chronic inhalation effects assessment of biphenyls.

Table 4A-39 Chronic Oral Exposure Limits for Biphenyl

Regulatory Agency	Value (ug/kg bw/d)	Type	Reference
ATSDR	--	--	ATSDR, 2006a
Health Canada	--	--	Health Canada, 2004b
RIVM	--	--	RIVM, 2001
U.S. EPA	50	RfD	U.S. EPA, 2007
WHO	--	--	WHO, 2000

-- not available

The U.S. EPA has developed an oral RfD of 0.05 mg/kg bw/d for kidney damage in a chronic oral study in rats (U.S. EPA, 2007). This RfD is based on a NOAEL of 50 mg/kg bw/d (0.1% of diet). Eight experimental groups made up of 15 weanling albino rats of each sex were exposed to 0.0%, 0.001%, 0.005%, 0.01%, 0.05%, 0.10%, 0.50% or 1.0% biphenyl in the diet. Dietary levels of 0.5% biphenyl and greater were associated with kidney damage, reduced haemoglobin levels, decreased food intake, and decreased longevity. An uncertainty factor of 100 was applied to the NOAEL to account for intra-species variability (10-fold) and interspecies variability (10-fold). An additional modification factor of ten was applied to further account for intra-species variability demonstrated by uncertainty in the threshold data in the critical study. The result is an RfD of 50 ug/kg bw/d.

The oral RfD of **50 ug/kg-d** for renal effects from the USEPA was used in the chronic multi-pathway assessment. An inhalation bioavailability of 100% and oral bioavailability of 50% (RAIS, 2007) were assumed.

4A2.18 Carbon Ddisulphide Group

Surrogate: Carbon Disulphide

As no exposure limits were identified for carbonyl sulphide, carbon disulphide and carbonyl sulphide were assessed as a group.

4A2.18.1 Acute Exposure Limits

Table 4A-40 Acute Inhalation Exposure Limits for Carbon Disulphide Group

Regulatory Agency	Value (ug/m^3)	Averaging Time	Source
AENV	30	1-hour	AENV, 2005
ATSDR	--	--	ATSDR, 2006a
OEHHA	6,200	6-hour	OEHHA, 2000
OMOE	330	24-hour	OMOE, 2005a
WHO	100	24-hour	WHO, 2000

-- not available

Both the AENV (2005) 1-hour AAQO and the OMOE (2005a) 24-hour AAQC for carbon disulphide are based on odour, and thus were not employed in the short-term assessment of carbon disulphide.

The WHO (2000) has developed a 24-hour guideline for carbon disulphide of 100 ug/m^3 based on the lowest concentration at which adverse effects were observed in occupational exposure. However, the lowest observed concentration of 10 mg/m^3 is based on a 10 to 15 year duration of exposure and therefore is not appropriate for the derivation of an acute exposure limit. Thus, this guideline was not used in the short-term assessment of the carbon disulphide.

The OEHHA (1999e; 2000) acute REL of 6,200 ug/m^3 for carbon disulphide is based on reproductive, developmental and CNS effects in rats. Pregnant rats were exposed via inhalation to concentrations of 0 ppm, 100 ppm, 200 ppm, 400 ppm, and 800 ppm for six hours per day on days six to 20 of gestation. Significant reductions in fetal weight were reported at 400 ppm and the NOAEL was identified as 200 ppm (620 mg/m^3). A cumulative safety factor of 100 was applied to the NOAEL to account for interspecies differences (10-fold) and intra-species differences (10-fold). The 6-hour REL of **6,200 ug/m^3** was conservatively used in the acute effects assessment as a 1-hour exposure limit.

4A2.18.2 Chronic Exposure Limits

Table 4A-41 Chronic Inhalation Exposure Limits for Carbon Disulphide

Regulatory Agency	Value (ug/m^3)	Type	Source
ATSDR	930	RfC	ATSDR, 2006a
Health Canada	100	RfC	Health Canada, 2004c
RIVM	--	--	RIVM, 2001
U.S. EPA	700	RfC	U.S. EPA, 2007
WHO	--	--	WHO, 2000

-- not available

The chronic inhalation exposure limit of 100 ug/m^3 was based on the tolerable concentration (TC_{05}) for inhalation exposure recommended for carbon disulphide by Health Canada (Health Canada, 2004b; CEPA, 2000d). This TC_{05} was derived from the lower benchmark concentration of 20 mg/m^3, associated with a 5% adverse response for peroneal motor nerve conduction velocity in occupationally exposed workers (Johnson et al., 1983; CEPA, 2000d). The TC_{05} was adjusted by Health Canada for intermittent exposure of eight hours per workday and five days per workweek (8 hours/24 hours x 5 days/7 days). A safety factor of 50 was applied by Health Canada in the derivation of the human exposure limit to account for intra-species variation (10_fold) and for potential effects on neurobehavioral development (5-fold). The resultant TC_{05} of **100 ug/m^3** was used as the chronic inhalation exposure limit for the carbon disulphide group.

Carbon disulphide and carbonyl sulphide were not assessed through multiple pathways as their physical and chemical parameters did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007). On this basis, a chronic oral exposure limit was not required for carbon disulphide.

4A2.19 Carbon Monoxide

4A2.19.1 Acute Exposure Limits

Table 4A-42 Acute Inhalation Exposure Limits for Carbon Monoxide

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	15,000	1-hour	AENV, 2005
	6,000	8-hour	AENV, 2005
ATSDR	--	--	ATSDR, 2006a
OEHHA	23,000	1-hour	OEHHA, 1999
OMOE	36,200	1-hour	OMOE, 2005a
	15,700	8-hour	
WHO	100,000	15-min	WHO, 2000
	60,000	30-min	
	30,000	1-hour	
	10,000	8-hour	

-- not available

AENV has established a 1 hour AAQO of 15,000 ug/m^3 and an 8-hour AAQO of 6,000 ug/m^3 for carbon monoxide (CO) (AENV, 2005). These AAQOs were adopted from the CEPA/FPAC Working Group on Air Quality Objectives and Guidelines, who recommends maximum desirable, accepTable 4A-nd tolerable objectives for CO. These objectives were developed to protect the subpopulation sensitive to cardio-respiratory effects (CEPA/FPAC 1994). Although WHO (2000) presents several acute guidelines for carbon monoxide, values also are available from OEHHA and the OMOE, the AENV values are more conservative and thus were used in the HHRA.

As there were no 24-hour guidelines available, the acute assessment was completed on a 1 hour and 8 hour basis only.

4A2.19.2 Chronic Exposure Limits

Table 4A-43 Chronic Inhalation Exposure Limits for Carbon Monoxide

Regulatory Agency	Value (ug/m^3)	Type	Reference
ATSDR	--	--	ATSDR, 2006a
Health Canada	-	-	Health Canada, 2004
OEHHA			OEHHA, 2000
RIVM	-	-	RIVM, 2000
U.S. EPA			U.S. EPA IRIS, 2007
WHO			WHO, 2000

-- not available

No regulatory exposure limits were available for chronic exposure to CO. The critical effect of CO exposure is the formation of carboxyhemoglobin (COHb) in blood. As COHb concentrations reach a steady-state after six to eight hours of exposure, CO exposure for longer periods of time (i.e., chronic exposure) is not expected to cause accumulation of COHb in the blood (WHO, 2000).

Epidemiological studies have identified associations between ambient low-level CO concentrations and various health effects (Burnett et al., 2000; Moolgavkar, 2000). However, the results across studies are inconsistent and it has been suggested that CO might represent only a surrogate compound for particulate emissions from mobile sources (Sarnat et al., 2001; Schwartz, 1999).

Carbon monoxide was assessed only for the inhalation route of exposure as the principal health effects are strictly related to inhalation, and is unlikely to bioaccumulate into environmental media.

4A2.20 Cyclohexane

4A2.20.1 Acute Exposure Limits

Table 4A-44 Acute Inhalation Exposure Limits for Cyclohexane

Regulatory Agency	Value (ug/m^3)	Averaging Time	Source
AENV	--	--	AENV, 2005
ATSDR	--	--	ATSDR, 2006a
OEHHA	--	--	OEHHA, 2000
OMOE	6,100	24-hour	OMOE, 2005ab
WHO	--	--	WHO, 2000

-- not available

The OMOE provides a 24-hour standard of 6,100 ug/m^3 for cyclohexane based on a NOAEL of 6,886 mg/m^3 for reduced pup weights in the F_1 and F_2 generations in a reproductive and developmental inhalation study (Kreckmann et al., 2000; OMOE, 2005a,c). The NOAEL was revised to a HEC of 1,722 mg/m^3 and the lower confidence of the benchmark concentration (BMCL) was then derived (1,822 mg/m^3). An uncertainty factor of 300 was applied to the BMCL to account for intra-species variability (10-fold), interspecies variability (3-fold), and database deficiencies due to the lack of chronic studies specifically examining developmental neurotoxicity and hepatic effects (10-fold) (OMOE 2005b). An uncertainty factor of three was considered adequate, as opposed to the typical value of 10, because a HEC was calculated from the rat NOAEL to account for pharmacokinetic variation. This results in the 24-hour standard of 6,100 ug/m^3 for cyclohexane.

In the derivation of an acute criterion, the OMOE's incorporation of an uncertainty factor of 10 to account for "database deficiencies due to the lack of chronic studies specifically examining developmental neurotoxicity and hepatic effects" is considered unnecessary (and inappropriate). Removal of this 10-fold uncertainty factor results in a 24-hour criterion of **61,000 ug/m^3**.

Although cyclohexane will be assessed as part of the aliphatic C_5-C_8 group, the adjusted OMOE standard of 61,000 ug/m^3 for cyclohexane is lower than the modified acute inhalation limit for the aliphatic C_5-C_8 group of 100,000 μg/m^3. As a result, cyclohexane was assessed on an individual basis as well.

4A2.20.2 Chronic Exposure Limits

Table 4A-45 Chronic Inhalation Exposure Limits for Cyclohexane

Regulatory Agency	Value (ug/m^3)	Type	Source
ATSDR	--	--	ATSDR, 2006a
Health Canada	--	--	Health Canada, 2004c
RIVM	--	--	RIVM, 2001
U.S. EPA	6,000	RfC	U.S. EPA, 2003a
WHO	--	--	WHO, 2000

-- not available

The U.S. EPA has established an RfC of 6,000 ug/m^3 based on a NOAEL of 6,886 mg/m^3 for developmental toxicity in rats (U.S. EPA 2003a). In a two-generational reproductive and developmental inhalation study, male and female Crl:CD BR rats (30/sex/concentration) were exposed by whole body inhalation to 0 ppm, 500 ppm, 2,000 ppm, or 7,000 ppm (0 mg/m^3, 1,721 mg/m^3, 6,886 mg/m^3, or 24,101 mg/m^3) cyclohexane vapour for six hours per day, five days per week for 10 weeks. Rats were bred with their respective treatment group and allowed to deliver and rear their offspring until weaning. Females were exposed daily after breeding throughout pregnancy and lactation, with the exception of gestation day 21 until day 4 of lactation when they were not exposed. Neonate rats were not directly exposed to cyclohexane. At weaning, F1 rats were randomly selected to produce the next generation and were treated to the same exposure schedule as the P1 generation. At least 11 weeks after weaning, the F1 rats were bred to produce the F2 litters.

The NOAEL of 6,886 mg/m^3 for reduced pup weight was duration-adjusted from an intermittent exposure to a continuous exposure (6 hours/24 hours), resulting in a $NOAEL_{ADJ}$ of 1,720 mg/m^3. The $NOAEL_{ADJ}$ was converted to a HEC for a category 3 gas causing respiratory effects. The average ratio of the animal-blood:air partition coefficient would be marginally greater than 1; thus, a default value of 1 was used in calculating the $NOAEL_{HEC}$ of 1,822 mg/m^3. Finally, a cumulative uncertainty factor of 300 was applied to the $NOAEL_{HEC}$ to account for interspecies variability (3-fold), intra-species variability (10-fold), and database deficiencies (10-fold). A factor of 3 was applied for the extrapolation of laboratory animal data to humans since the calculation of a HEC addressed the pharmacokinetic aspects of the interspecies uncertainty factor. Accordingly, only the pharmacodynamic aspects of uncertainty remain as a partial factor for interspecies uncertainty (U.S. EPA 2003a). The U.S. EPA RfC of **6,000 ug/m^3** was selected as the chronic inhalation limit for cyclohexane.

The U.S. EPA RfC of 6,000 ug/m^3 for cyclohexane is lower than the chronic inhalation limit of 18,400 μg/m^3 for the aliphatic C_5-C_8 group. As a result, cyclohexane was assessed on both an individual basis as well as apart of the aliphatic C_5-C_8 group.

Cyclohexane was not assessed in the multi-pathway assessment given that its physical and chemical parameters did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007). On this basis, a chronic oral limit was not required for cyclohexane.

4A2.21 Dichlorobenzenes

4A2.21.1 Acute Exposure Limits

Table 4A-46 Acute Inhalation Exposure Limits for Dichlorobenzenes

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	--	--	AENV, 2005
ATSDR	12,000	8-hour	ATSDR, 2006a
OEHHA	--	--	OEHHA, 2000
OMOE	285 95	½-hour 24-hour	OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

The OMOE (2005a) provides ½-hour and 24-hour standards for 1,4-dichlorobenzene; however, no scientific basis is provided. As a result, the study team is unable to comment on the scientific merit of these limits and did not use them in the short-term assessment of 1,4-dichlorobenzene.

The ATSDR has developed an acute inhalation MRL for 1,4-dichlorobenzene of 12,000 ug/m^3 based on a NOAEL of 15 ppm for eye and nose irritation in occupationally exposed workers (ATSDR 2005b; 2006a). The study consisted of 58 men who had worked in unspecified industrial operations involving the handling of 1,4-dichlorobenzene for 8 hours per day, 5 days per week for a period of 8 months to 25 years (average 4.75 years). An uncertainty factor of 10 was applied to the NOAEL to account for intra-species variability.

This MRL of **12,000 ug/m^3** was used as a 24-hour exposure limit in the acute effects assessment of dichlorobenzene in air.

4A2.21.2 Chronic Exposure Limits

Table 4A-47 Chronic Inhalation Exposure Limits for Dichlorobenzenes

Regulatory Agency	Value (ug/m^3)	Type	Reference
ATSDR	60	MRL	ATSDR, 2006a
Health Canada	95	RfC	Health Canada, 2004b
RIVM	670	TCA	RIVM, 2001
U.S. EPA	800	RfC	U.S. EPA, 2007
WHO	--	--	WHO, 2000

-- not available

The ATSDR (2005b; 2006a) has developed a chronic MRL of 0.01 ppm (60 ug/m^3) based upon a BMCL$_{10}$ of 9.51 ppm for the increased incidence of nasal lesions in female rats. This BMCL$_{10}$ was adjusted for exposure duration (6-hours/day, 5-days week) and converted to a HEC of 0.27 ppm. This HEC was divided by a cumulative uncertainty factor of 30 (to account for inter- and intra-species differences) to calculate the MRL.

Health Canada (2004b) provides a tolerable concentration of 95 ug/m3 for 1,4-dichlorobenzene. Although this tolerable concentration is based on health considerations, the specific basis of its derivation remains unknown. As a result, the study team is unable to comment on the scientific merit of this limit.

RIVM presents a tolerable concentration of 670 ug/m^3 for 1,4-dichlorobenzene, based upon a NOAEL of 450 mg/m^3. Following correction for exposure duration (5-hours/day, 5-days/week), this NOAEL was adjusted to 67 mg/m^3. A cumulative uncertainty factor of 100 was applied (presumably for inter-and intra-species differences)

The U.S. EPA has derived an RfC of 800 ug/m^3 based upon increased liver weights in male rats, based upon a NOAEL of 50 ppm (301 mg/m^3). A NOAELHEC of 75 mg/m^3 was derived from the study NOAEL, and a cumulative uncertainty factor of 90 was applied to account for interspecies and intraspecies differences, and the extrapolation of a sub-chronic study.

Of the above listed chronic exposure limits, the chronic MRL of **60 ug/m^3** is the most conservative value that is adequately supported by documentation by ATSDR (2005b).

4A2.22 Diethanolamine

4A2.22.1 Acute Exposure Limits

Table 4A-48 Acute Inhalation Exposure Limits for Diethanolamine

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	--	--	AENV, 2005
ATSDR	--	--	ATSDR, 2006a
OEHHA	--	--	OEHHA, 2000
OMOE	--	--	OMOE, 2005a OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

Acute exposure limits were not identified for diethanolamine from any of the sources identified in Table 4A-48. The search was expanded to include oral and intermediate MRLs and the ACGIH TLVs.

The ACGIH (2006) has established an 8-hour TLV-TWA of 2000 mg/m^3 (0.5 ppm) for diethanolamine based upon a subchronic oral NOAEL of 15 mg/kg-d and a subchronic LOAEL of 26 mg/m^3. However, as these exposure limits are based upon subchronic (~90 day exposures) oral exposure, this value is no appropriate for use as an acute exposure limit.

Acute exposure limits were not available from other sources, thus diethanolamine was not evaluated on an acute basis due to a lack of an appropriate and defensible exposure limits.

4A2.22.2 Chronic Exposure Limits

Table 4A-49 Summary of Chronic Inhalation Exposure Limits for Diethanolamine

Regulatory Agency	Value (ug/m^3)	Type	Reference
Health Canada	--	--	Health Canada, 2004b,c
ATSDR	--	--	ATSDR, 2006a
RIVM	--	--	RIVM, 2001
U.S. EPA	--	--	U.S. EPA, 2007
WHO	--	--	WHO, 2000

-- not available

No chronic exposure limits were identified from the sources noted in Table 4A-49 above. The search was expanded to include available limits from the California OEHHA and oral exposure limits.

The California OEHHA (2005) has derived a chronic inhalation exposure limit of 3 ug/m^3. This value was derived based upon a LOAEL of 15,000 ug/m^3. In the key study, male and female Wistar rats were exposed to 0 ug/m^3, 15,000 ug/m^3, 150,000 ug/m^3, or 400,000 ug/m^3 diethanolamine aerosol for 6-hours/day for 90-days. The lowest dose level (15,000 ug/m^3) was selected as the NOAEL for liver and kidney effects, and the LOAEL for irritation and lesions of the larynx. A cumulative uncertainty factor of 1000 was applied to account for the use of a subchronic study (3), the use of a LOAEL instead of a NOAEL (3), inter-species and intra-species differences (10 each). The result is the limit of **3 ug/m^3**, which was selected for use in the chronic effects assessment.

4A2.23 Ethylbenzene

4A2.23.1 Acute Exposure Limits

Table 4A-50 Acute Inhalation Exposure Limits for Ethylbenzene

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	2,000	1-hour	AENV, 2005
ATSDR	--	--	ATSDR, 2006a
OEHHA	--	--	OEHHA, 2000
OMOE	1,400 1,000	½-hour 24-hour	OMOE, 2005a OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

An AAQO of 2,000 ug/m^3 for a 1-hour average exposure was recommended by AENV (2005). This limit was adopted from the Texas Natural Resource Conservation Commission based on odour perception, but no specific basis was provided. Given that this objective is not health based, the AENV AAQO was not used in the short-term assessment of ethylbenzene.

The OMOE (2005a) provides a lower ½-hour standard based on odour and a health-based 24-hour standard for ethylbenzene. However, no scientific basis is provided for these standards. As a result, the study team is unable to comment on the scientific merit of these limits and did not use them in the short-term assessment of ethylbenzene.

Acute values were not available from ATSDR or WHO. As a result, the toxicity search was therefore expanded to include intermediate MRLs provided by the ATSDR and occupational exposure values established by the ACGIH.

An acute exposure limit for ethylbenzene of **4,340 ug/m^3** corresponds to the MRL recommended for intermediate inhalation exposure to ethylbenzene by the ATSDR (1999a; 2005a). This MRL was derived from a NOAEL of 97 ppm for developmental effects in Wistar mice following inhalation exposure for 7 hours per day, 5 days per week for 3 weeks. The ATSDR applied an uncertainty factor of 100 to the study NOAEL to account for interspecies (10-fold) and intra-species variation (10-fold). Use of an intermediate NOAEL when characterizing acute exposure is typically considered conservative, because a higher exposure over a shorter period (i.e., acute exposure) presumably could occur without the risk of adverse effects. The use of this intermediate MRL as a 24-hour exposure limit is considered appropriate, as the health effects associated with ethylbenzene have been observed to be concentration dependant, rather than duration-dependant.

4A2.23.2 Chronic Exposure Limits

Table 4A-51 Chronic Inhalation Exposure Limits for Ethylbenzene

Regulatory Agency	Value (ug/m^3)	Type	Reference
Health Canada	--	--	Health Canada, 2004b,c
ATSDR	--	--	ATSDR, 2006a
RIVM	770	TCA	RIVM, 2001
U.S. EPA	1,000	RfC	U.S. EPA, 2007
WHO	--	--	WHO, 2000

-- not available

The RIVM (2001) provides a TCA of 770 ug/m^3 based on kidney and liver effects in rats and mice. A NOAEL of 430 mg/m^3 was identified in the 1992 semi chronic NTP study (NTP 1996). The RIVM adjusted the NOAEL of intermittent applied an uncertainty factor of 100 to the NOAEL to account for interspecies variation (10-fold) and intra-species variation (10-fold). An uncertainty factor was not applied to the NOAEL by the RIVM for use of a sub-chronic study because the chronic NTP study reported a higher NOAEL of 1,075 mg/m^3.

The U.S. EPA assessment of ethylbenzene reports an RfC of 1,000 ug/m^3 based on a NOAEL of 434 mg/m^3 for developmental toxicity in rats and rabbits (U.S. EPA, 2007a). Wistar rats and New Zealand white rabbits exposed to concentrations of 0, 100, or 1,000 ppm (434 mg/m^3 or 4,342 mg/m^3) for 6 hours per day to 7 hours per day, 7 days per week during days 1-19 and 1-24 of gestation, respectively. According to the U.S. EPA methodology, a NOAEL based on developmental effects is not adjusted for intermittent exposure. A NOAEL$_{HEC}$ was calculated assuming a default value of 1.0 since b:a lambda values are unknown for the experimental animal species (a) and humans (h) (U.S. EPA, 2007a). An uncertainty factor of 300 was applied to the study $\text{NOAEL}_{\text{HEC}}$ to account for interspecies variation (3-fold), intra-species variation (10-fold), and the absence of multigenerational reproductive and chronic studies (10-fold). A 3-fold uncertainty factor for interspecies variability was considered appropriate by the U.S. EPA since the HEC adjustment addresses the pharmacokinetic component of the extrapolation factor, leaving the pharmacodynamic area of uncertainty (U.S. EPA, 2007).

The TCA of 770 ug/m^3 from RIVM was based upon a sub-chronic NOAEL of 430 mg/m^3 for liver and kidney effects in rats. A chronic inhalation study also was evaluated for ethylbenzene, however, the NOAEL (1,075 mg/m^3) was less conservative than the sub-chronic NOAEL. RIVM adjusted this number for exposure duration (6-hours/day, 5-days/week) to a NOAEL of 77 mg/m^3 and applied a cumulative uncertainty factor of 100 (for inter-and intra-species differences). The TCA provided by RIVM was not used in the chronic inhalation effects assessment as it is based on a NOAEL from a sub-chronic study, rather than based on a NOAEL from a chronic study (i.e., U.S. EPA). As a result, the U.S. EPA RfC of **1,000 ug/m^3** was used in the chronic inhalation effects assessment for ethylbenzene.

A chronic oral exposure limit was not required for the assessment of ethylbenzene because it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007) and thus was not incorporated into the multi-media exposure model.

4A2.24 Formaldehyde

4A2.24.1 Acute Exposure Limits

Table 4A-52 Acute Inhalation Exposure Limits for Formaldehyde

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	65	1-hour	AENV, 2005
ATSDR	49.3	2-hour	ATSDR, 2006a
OEHHA	94	1-hour	OEHHA, 2000
OMOE	65	24-hour	OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

The ATSDR has developed an acute inhalation MRL for formaldehyde of **50 ug/m^3** (0.04 ppm) based on a LOAEL of 0.4 ppm for nasal and eye irritation (ATSDR 1999b; 2005a). Occupationally exposed patients with skin hypersensitivity to formaldehyde and unexposed (control) patients, all of whom were non-smokers, were separated into two groups. The first group included seven male and three female volunteers with skin hypersensitivity to formaldehyde and the second included 11 healthy males with no history of allergic diseases. Nasal washings were performed in both groups immediately before and after a 2 hour exposure to 0 (placebo) or 0.5 mg/m^3 (0.4 ppm) formaldehyde, and again four and 18 hours after the exposure period. A cumulative uncertainty factor of 10 was incorporated by the ATSDR (1999b) to account for the use of a minimal LOAEL (3-fold) and to account for intra-species variability (3-fold). An uncertainty factor of 3 was considered adequately protective of human variability as the observed symptoms of irritation were observed in a potentially sensitive group of subjects. This 2 hour MRL was conservatively used as the 1 hour exposure limit in the acute effects assessment for formaldehyde.

4A2.24.2 Chronic Exposure Limits

Table 4A-53 Chronic Inhalation Exposure Limits for Formaldehyde

Regulatory Agency	**Value (ug/m^3)**	**Type**	**Reference**
Health Canada	1.9	RsC	CEPA 2001
ATSDR	0.01	MRL	ATSDR, 2006a
RIVM	--	--	RIVM, 2001
U.S. EPA	0.8	RsC	U.S. EPA, 2007
WHO	--	--	WHO, 2000

-- not available

The IARC classifies formaldehyde as carcinogenic to humans (Group 1), on the basis of sufficient evidence in humans and sufficient evidence in experimental animals (IARC, 2004). Health Canada previously derived tumourigenic concentration (TC_{05}) of 9.5 mg/m^3 (CEPA, 2001). This TC_{05} represents the total intake associated with a 5% increase in incidence of nasal squamous tumours in rats exposed to formaldehyde for up to 24 months. The TC_{05} corresponds to an RsC of 1.9 ug/m^3, which is associated with an increased cancer risk of one in 100,000.

The U.S. EPA has derived a URE of 1.3 x 10^{-5} (ug/m^3)$^{-1}$ based upon the incidence of squamous cell carcinoma in rats (U.S. EPA, 2007), although this limit is under re-evaluation.

However, there is some controversy over whether carcinogenic effects are the most sensitive and relevant endpoint to humans. A recent review by Health Canada (2005) established an 8 hour indoor air quality objective of 50 ug/m^3 for formaldehyde that was based upon respiratory effects but is also protective of carcinogenic effects (HC 2005). In addition the WHO has established a 30 minute criteria of 100 ug/m^3 based upon respiratory irritation (although the limit also is noted to be protective of upper respiratory tract cancers) (WHO, 2000). The ATSDR (2006a) presents a chronic inhalation MRL of 0.01 ug/m^3

Both Health Canada and the U.S. EPA have determined that formaldehyde is carcinogenic. The most conservative carcinogenic exposure limit is the U.S. EPA URE of 1.3 x 10^{-5} (ug/m^3)$^{-1}$, which translates to a RsD of **0.77 ug/m^3** in association with a 1 in 100,000 ILCR. This limit has been incorporated into the assessment.

4A2.25 n-Hexane

4A2.25.1 Acute Exposure Limits

Table 4A-54 Acute Inhalation Exposure Limits for n-Hexane

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	--	--	AENV, 2005
ATSDR	--	--	ATSDR, 2006a
OEHHA	--	--	OEHHA, 2000
OMOE		*n-Hexane mixture*:	
	7,500	½-hour	OMOE, 2005a
	2,500	24-hour	OMOE, 2005a
		n-Hexane and n-hexane isomers only:	
	22,500	½-hour	OMOE, 2005a
	7,500	24-hour	OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

The OMOE provides a 24-hour standard of 7,500 ug/m^3 for n-hexane and n-hexane isomers (OMOE, 2005a,c). This standard was developed from a NOAEL of 58 ppm (204 mg/m^3) for polyneuropathy in humans (Sanagi et al., 1980). Workers were exposed to a low concentration of n-hexane and acetone in a tungsten carbide alloys facility for an average of 6.2 years. Significant decreases were observed in mean motor nerve conduction velocities and slowed residual latency of motor conduction of the lower extremities. The NOAEL was adjusted from an eight-hour time weighted average for occupational exposure to a value of 73 mg/m^3 for continuous exposure in the general population as follows.

$$\mathrm{NOAEL}_{ADJ} = \mathrm{NOAEL} \times \frac{\mathrm{MV}_{ho}}{\mathrm{MV}_{h}} \times \frac{\mathrm{Exp}_{ho}}{\mathrm{Exp}_{h}}$$

where:

NOAEL_{ADJ} = NOAEL in the human population from continuous exposure (mg/m^3)

NOAEL = NOAEL for discontinuous exposure in an occupational setting (204 mg/m^3)

MV_{ho} = amount of air used by a worker during an 8-hour work period (10 m^3/d)

MV_{h} = amount of air used by an individual in the general population during a day (20 m^3/d)

Exp_{ho} = days per week a worker is exposed (5 days)

Exp_{h} = days per week an individual in the general population is exposed (7 days)

An uncertainty factor of 30 was applied to the NOAEL_{ADJ} to account for individual sensitivity (10-fold) and potential interaction with other hydrocarbon solvents in commercial n-hexane (3-fold) (OMOE 2005c). This results in an AAQC of 2,500 ug/m^3 for an n-hexane mixture. The OMOE (2005c) adjusted this value based on the composition of hexane isomers in n-hexane to derive the AACQ of 7,500 ug/m^3 for n-hexane and n-hexane isomers. As the study team does not support the use of chronic toxicity data in the derivation of an acute limit, this acute guideline was not used in the acute effects assessment.

Thus, the toxicity search was expanded to include intermediate MRLs provided by the ATSDR and short-term occupational limit values (i.e., STEL and Ceiling) (ATSDR, 2006a; ACGIH 2006). After reviewing available information and determining that there are no available criteria, guidelines or objectives for hexane with adequate supporting documentation, a modified acute inhalation limit was developed from the sub-chronic inhalation BMCL that formed the basis of the U.S. EPA's chronic RfC.

The U.S. EPA developed a chronic RfC from a benchmark concentration level (BMCL) of 430 mg/m^3 for peripheral neuropathy (decreased mean cell volume at 12 weeks) in a rat sub-chronic inhalation study. Male Wistar rats (eight/group) were exposed to 0 ppm, 500 ppm, 1,200 ppm, or 3,000 ppm (0 mg/m^3, 1,762 mg/m^3, 4,230 mg/m^3, 10,574 mg/m^3) n-hexane (>99% pure) for 12 hours per day, seven days per week for 16 weeks (Huang et al., 1989). The human equivalent BMCL (BMCL$_{HEC}$) was calculated for an extra-respiratory effect of a category 3 gas. The blood:gas (air) partition coefficient (H$_{b/g}$) value for n-hexane in humans (H) is 0.8, whereas a value of 2.29 has been reported in rats (A). According to the RfC methodology, where the ratio of animal to human blood:air partition coefficients $[(H_{b/g})_A/(H_{b/g})_H]$ is greater than one, a value of one is used for the ratio by default. Thus, the BMCL$_{HEC}$ is equal to 430 mg/m^3. An uncertainty factor of 100 was applied to the BMCL$_{HEC}$ to account for intra-species variation (10-fold), interspecies variation (3-fold), and database deficiencies (3-fold). The result is a modified limit of 4,300 ug/m^3, which was used as a 1 hour inhalation limit in the acute health effects assessment.

The modified acute inhalation limit of **4,300 ug/m^3** for hexane is lower then the modified acute inhalation limit of 100,000 ug/m^3 for the aliphatic C_5-C_8 group. As a result, hexane was assessed on its own.

4A2.25.2 Chronic Exposure Limits

Table 4A-55 Chronic Inhalation Exposure Limits for n-Hexane

Regulatory Agency	Value (ug/m^3)	Type	Reference
ATSDR	2100	MRL	ATSDR, 2006a
Health Canada	-	-	Health Canada, 2004b
RIVM	--	--	RIVM, 2001
U.S. EPA	700	RfC	U.S. EPA, 2007
WHO	--	--	WHO, 2000

-- not available

The U.S. EPA (2007) developed a chronic RfC of 700 ug/m^3 for neurotoxicity. This RfC was based on a benchmark concentration level (BMCL) of 430 mg/m^3 for peripheral neuropathy (decreased mean cell volume at 12 weeks) in a rat sub-chronic inhalation study (U.S. EPA, 2007). The BMCL was adjusted from intermittent to continuous exposure (12 hours/24 hours × 7 days/7 days) to a concentration of 215 mg/m^3 (U.S. EPA, 2007). The human equivalent BMCL (BMCL$_{HEC}$) was calculated for an extra-respiratory effect of a category 3 gas. The blood:gas (air) partition coefficient (H$_{b/g}$) value for n-hexane in humans (H) is 0.8, whereas a value of 2.29 has been reported in rats (A) (U.S. EPA, 2007). According to the RfC methodology, where the ratio of animal to human blood:air partition coefficients $[(H_{b/g})_A/(H_{b/g})_H]$ is greater than one, a value of one is used for the ratio by default. Thus, the BMCL$_{HEC}$ is equal to 215 mg/m^3. The U.S. EPA (2007) applied an uncertainty factor of 300 to the BMCL$_{HEC}$ to account for intra-species variation (10-fold), interspecies variation (3-fold), extrapolation to chronic exposure from data in a less-than lifetime study (3-fold) and database deficiencies (3-fold).

Application of a full uncertainty factor of 10 for interspecies variation depends on two areas of uncertainty (i.e., toxicokinetic and toxicodynamic uncertainties). In this assessment, the toxicokinetic component is mostly addressed by the determination of a human equivalent concentration (HEC) (U.S. EPA, 2007). The toxicodynamic uncertainty is accounted for to a certain degree by the use of the applied dosimetry method. Thus a partial uncertainty factor of 3 was applied.

A sub-chronic (16 weeks) study was used for the derivation of the RfC. However, 16 weeks is half of the time required for a newly synthesized neurofilament protein to be transported from the neuronal cell body to the axon terminal in the longest axons of the CNS and the peripheral nervous system of an adult rat (Griffin et al., 1984). Since the lifetime of neurofilaments (target of toxicity of n-hexane) is shorter than the lifetime of an adult rat, extrapolation from sub-chronic to chronic exposure is not necessary and an uncertainty factor of 3 was applied.

The database for n-hexane lacks a developmental neurotoxicity study and a multi-generation reproductive and developmental toxicity study following inhalation exposure to pure n-hexane alone. On this basis, an uncertainty factor of 3 was applied.

This chronic RfC of **700 ug/m^3** was used in the chronic inhalation effects assessment of n-hexane alone.

A chronic oral exposure limit was not required for the assessment of n-hexane, because it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007), and thus was not incorporated into the multi-media exposure model.

4A2.26 Hydrogen Sulphide

4A2.26.1 Acute Exposure Limits

Table 4A-56 Acute Inhalation Exposure Limits for Hydrogen Sulphide

Regulatory Agency	Value (ug/m^3)	Averaging Time	Source
AENV	14 4	1-hour 24-hour	AENV, 2005
ATSDR	98	1-hour	ATSDR, 2006a
OEHHA	42	1-hour	OEHHA, 2000
OMOE	30	24-hour	OMOE, 2005a
WHO	150	24-hour	WHO, 2000

The AENV (2005) provides 1-hour and 24-hour AAQOs for hydrogen sulphide of 14 ug/m^3 and 4 ug/m^3, respectively. As well, the OMOE (2005a) recommends a 24-hour AAQC of 30 ug/m^3. All of these guidelines were odour-based rather than health-based, and thus were not used in the acute effects assessment for hydrogen sulphide.

The OEHHA (1999; 2000) provides an acute REL of 42 ug/m^3 based on physiological responses to odour, including headache and nausea. Sixteen individuals were exposed to increasing concentrations of hydrogen sulphide until their odour threshold was reached. The LOAEL was based on the range of odour thresholds of 0.012 ppm to 0.069 ppm that was identified among the individuals. The geometric mean of the odour thresholds (0.03 ppm) was used to develop the acute REL. An uncertainty factor of 1 was applied to the geometric mean, resulting in an acute REL of 0.03 ppm (42 ug/m^3).However, it is possible that the symptoms reported are not the result of direct systemic toxicity, and could represent physiological responses associated with odour.

On this basis, the OEHHA acute REL for hydrogen sulphide was not used in the acute effects assessment.

The ATSDR provides an acute inhalation MRL for hydrogen sulphide of 0.07 ppm (98 ug/m^3) (ATSDR, 2006a,b). This MRL was developed based on a LOAEL of 2 ppm for changes in airway resistance and specific airway conductance in excess of 30% in two of the 10 individuals examined. The test subjects all had bronchial asthma requiring medication for 1-13 years, but none of the subjects had severe asthma. The subjects were exposed for ½-hour and their respiratory function in response to a histamine challenge was assessed prior to and following exposure. Although the two subjects showed changes in airway resistance and specific airway conductance, no statistically significant alterations in lung function were observed at this concentration. The ATSDR (2006b) applied a combined uncertainty factor of 30 to account for the use of a minimal LOAEL (3-fold), interspecies differences (3-fold), and the lack of studies in children (3-fold). This acute MRL of **98 ug/m^3** was used as a 1-hour exposure limit in the acute effects assessment for hydrogen sulphide.

4A2.26.2 Chronic Exposure Limits

Table 4A-57 Chronic Inhalation Exposure Limits for Hydrogen Sulphide

Regulatory Agency	Value (ug/m^3)	Type	Source
ATSDR	--	--	ATSDR, 2006a
Health Canada	--	--	Health Canada, 2004b,c
RIVM	--	--	RIVM, 2001
U.S. EPA	2	RfC	U.S. EPA 2003b
WHO	--	--	WHO, 2000

-- not available

The U.S. EPA has developed an RfC of 2 ug/m^3 for nasal lesions of the olfactory mucosa (U.S. EPA 2003b). This RfC is based on a NOAEL of 13.9 mg/m^3 for olfactory loss in adult male CD rats following inhalation exposure to hydrogen sulphide for six hours per day, seven days per week for 10 weeks. The NOAEL was adjusted for intermittent exposure (6 hours/24 hours) to a concentration of 3.48 mg/m^3. The NOAEL$_{ADJ}$ was converted to a HEC using the RGDR methodology.

$$RGDR_{ET} = \frac{(V_E/SA_{ET})_A}{(V_E/SA_{ET})_H}$$

$$RGDR_{ET} = \frac{0.19 \text{ litres/minute}/15 \text{ cm}^2}{13.8 \text{ litres/minute}/200 \text{ cm}^2}$$

Where:

$RGDR_{ET}$ = regional gas dosimetry ratio in the extra-thoracic region

V_E = minute volume in rats $(V_E)_A$ or humans $(V_E)_H$

SA_{ET} = extra-thoracic surface area in rats $(SA_{ET})_A$ or humans $(SA_{ET})_H$

The NOAEL$_{ADJ}$ was then multiplied by the RGDR$_{ET}$ of 0.18 to yield a NOAEL$_{HEC}$ of 0.64 mg/m^3, as follows:

$$NOAEL_{HEC} = NOAEL_{ADJ} \times RGDR_{ET}$$

$$NOAEL_{HEC} = 3.48\ mg/m^3 \times 0.18$$

Finally, an uncertainty factor of 300 was applied to the $NOAEL_{HEC}$ to account for intra-species variability (10-fold), interspecies extrapolation (3-fold), and for subchronic exposure (10-fold). A 3-fold uncertainty factor was used instead of the 10-fold default value for extrapolation from rats to humans because the calculation of a HEC addresses one of the two areas of uncertainty encompassed in an interspecies uncertainty factor. The HEC adjustment addresses the pharmacokinetic component of the extrapolation factor, leaving the pharmacodynamic area of uncertainty. The U.S. EPA RfC of **2 ug/m^3** was selected as the chronic inhalation limit for hydrogen sulphide.

Hydrogen sulphide was not incorporated into the multiple-pathway exposure model as it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007). Thus, a chronic oral exposure limit was not required for hydrogen sulphide.

4A2.27 Isopropylbenzene

Synonym: Cumene

4A2.27.1 Acute Exposure Limits

Table 4A-58 Summary of Acute Inhalation Exposure Limits for Isopropylbenzene

Regulatory Agency	Value (μg/m^3)	Averaging Time	Reference
AENV	500	1-hour	AENV, 2005
ATSDR	–	–	ATSDR, 2006a
OEHHA	–	–	OEHHA, 2000
OMOE	100 400	½-hour 24-hour	OMOE, 2005a OMOE, 2005a
WHO	–	–	WHO, 2000

-- not available

The OMOE (2005a) has developed a ½-hour standard of 100 μg/m^3 and a 24-hour standard of 400 ug/m^3. However, these standards are based on U.S. EPA's chronic exposure limit of 400 ug/m^3 for increased kidney and adrenal weights in rats exposed to isopropylbenzene for 13 weeks (U.S. EPA, 2007). The study team is of the opinion that use of a chronic endpoint in the derivation of short-term exposure limit is an overly conservative methodology since a higher exposure over a shorter time-period (i.e., acute exposure) presumably could occur without risk of adverse effects.

The AENV (2005) has established an AAQO of 500 ug/m^3 for a 1-hour averaging period, which was adopted from the Texas Natural Resource Conservation Commission (TCEQ, 2003). However, the Texas effects screening level of 500 ug/m^3 is based on odour effects and therefore was not used in the acute effects assessment.

As none of the acute criteria or guidelines identified above were determined to be appropriate for the acute effects assessment, the toxicity search was expanded to include intermediate MRLs provided by the ATSDR and occupational exposure values established by the ACGIH and the U.S. DOE for isopropylbenzene.

The ACGIH (1991; 2006) provides a TLV-TWA of 50 ppm (246 mg/m3) for isopropylbenzene based on animal studies citing irritation and CNS effects. The TLV-TWA is considered to be below the level predicted to be irritating to humans and considerably less than levels causing acute nervous system changes. An uncertainty factor of 100 was applied to the TLV-TWA to account for intra-species variability (10-fold) and interspecies variability (10-fold) in the derivation of a short-term limit. However, the TLV-TWA value has been developed to be protective of workers exposed long-term. As there is no STEL available, the ACGIH value has not been used.

Given that there are no available acute exposure limits with defensible supporting documentation, isopropylbenzene was not evaluated on an acute basis.

4A2.27.2 Chronic Exposure Limits

Table 4A-59 Summary of Chronic Inhalation Exposure Limits for Isopropylbenzene

Regulatory Agency	Value (ug/m^3)	Type	Reference
Health Canada	–	–	Health Canada, 2004b,c
ATSDR	–	–	ATSDR, 2006a
RIVM	–	–	RIVM, 2001
U.S. EPA	400	RfC	U.S. EPA, 2007
WHO	–	–	WHO, 2000

-- not available

The U.S. EPA has derived an inhalation RfC of 400 ug/m^3 for increased kidney weights in female rats and increased adrenal weights in male and female rats (U.S. EPA, 2007). This RfC is based on a NOAEL of 2,438 mg/m^3 for kidney effects in rats following inhalation exposure to isopropylbenzene for 6 hours per day, 5 days per week for 13 weeks. The NOAEL was adjusted for intermittent exposure (6/24 x 5/7) to a concentration of 435 mg/m^3. A NOAEL$_{HEC}$ was calculated assuming a default value of 1.0 since b:a lambda values are unknown for the experimental animal species (a) and humans (h) (U.S. EPA, 2007). An uncertainty factor of 1,000 was applied to the NOAEL$_{HEC}$ to account for subchronic-to-chronic extrapolation (10-fold), intra-species variability (10-fold), interspecies extrapolation (3-fold), and for database deficiencies (3-fold). A 3-fold uncertainty factor for interspecies variability was considered appropriate by the U.S. EPA since the HEC adjustment addresses the pharmacokinetic component of the extrapolation factor, leaving the pharmacodynamic area of uncertainty. The RfC of **400 ug/m^3** was used in the chronic inhalation effects assessment of isopropylbenzene.

No chronic oral exposure limit was required for the assessment of isopropylbenzene since it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007), and thus was not incorporated into the multi-media exposure model.

4A2.28 Methylene chloride

4A2.28.1 Acute Exposure Limits

Table 4A-60 Summary of Acute Inhalation Exposure Limits for Methylene Chloride

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	–	–	AENV, 2005
ATSDR	2,080	24-hour	ATSDR, 2006a
OEHHA	14,000	1-hour	OEHHA, 2000
OMOE	660 and 5,300 (interim) 220	½-hour 24-hour	OMOE, 2005a OMOE, 2005a
WHO	3,000	24-hour	WHO, 2000

-- not available

The OMOE (2005a) provides ½-hour and 24-hour standards for methylene chloride. However, no scientific basis is provided for these standards. As a result, the study team is unable to comment on the scientific merit of these limits and did not use them in the short-term assessment of methylene chloride.

The ATSDR (2000a, 2006a) has developed an acute inhalation MRL for methylene chloride of 0.6 ppm (2 ug/m^3) based on a LOAEL of 60 ppm for neurological effects. In a randomized blind clinical chamber experiment, six to 20 volunteers were exposed to either filtered air or to concentrations of 300 ppm, 500 ppm, or 800 ppm of methylene chloride vapours. Subjects were exposed for 3 to 4 hours and tested at 45-minute intervals with standard neurobehavioural tests that measure critical flicker fusion frequency, auditory vigilance performance and psychomotor performance. Decreased critical flicker fusion frequency and auditory vigilance performance were identified at 300 ppm. This LOAEL was duration-adjusted to account for a 24-hour exposure scenario using a physiological-based pharmacokinetic (PBPK) model, resulting in a LOAEL$_{ADJ}$ of 60 ppm. A cumulative uncertainty factor of 100 was applied to the LOAEL to account for using a LOAEL (10-fold) and for human variability (10-fold). This MRL of **2,100 ug/m^3** was used as a 24-hour exposure limit in the acute effects assessment of methylene chloride.

4A2.28.2 Chronic Exposure Limits

Table 4A-61 Summary of Chronic Inhalation Exposure Limits for Methylene Chloride

Regulatory Agency	Value (ug/m^3)	Type	Reference
Health Canada	435 448 to 2,850	RsC RsC	Health Canada, 2004b CEPA 1993
ATSDR	1,000	RfC	ATSDR, 2006a
RIVM	–	–	RIVM, 2001
U.S. EPA	20	RsC	U.S. EPA, 2007
WHO	–	–	WHO, 2000

-- not available

Health Canada's RsC of 435 ug/m^3 is based on its inhalation unit risk of 2.3 x 10^{-5} per mg/m^3 (Health Canada, 2004b). Although Health Canada does not provide the specific derivation of this inhalation unit risk, documentation of a range of tumorigenic concentrations that induced a 5% increase in the incidence of tumours (TC_{05}) was provided in CEPA (1993). Based on multi-stage modelling, a TC_{05} of 326 mg/m^3 for pulmonary adenomas and carcinomas (combined) in female mice and a TC_{05} of 3,574 mg/m^3 for hepatic adenomas and carcinomas (combined) in male mice were estimated (CEPA 1993). The TC_{05} of 326 mg/m^3 is equivalent to an RsC of 65 ug/m^3 and the TC_{05} of 3,574 mg/m^3 is equivalent to an RsC of 715 ug/m^3. Available data on methylene chloride is consistent with the hypothesis that variations in carcinogenic potential in different species are related to difference in the rates of metabolism. Therefore, PBPK modified TC_{05} values were developed, resulting in a TC_{05} of 2,238 mg/m^3 for pulmonary adenomas and carcinomas (combined) in female mice and a TC_{05} of 14,248 mg/m^3 for hepatic adenomas and carcinomas (combined) in male mice (CEPA 1993). The TC_{05} of 2,230 mg/m^3 is equivalent to an RsC of 448 ug/m^3 and the TC_{05} of 14,248 mg/m^3 is equivalent to an RsC of 2,850 ug/m^3.

The U.S. EPA (2007) recommends an inhalation unit risk of 4.7 x 10-4 per mg/m^3, which translates to an RsC of 20 ug/m^3 (in association with a one in 100,000 excess cancer risk). This value is considerably lower than Health Canada's RsC of 435 ug/m^3. The U.S. EPA unit risk is based on the results of the same NTP inhalation study that Health Canada used to identify an increased frequency of combined adenomas and carcinomas in female mice exposed to methylene chloride. The U.S. EPA unit risk also incorporated information on the pharmacokinetics of methylene chloride.

Although the Health Canada and U.S. EPA unit risks are based on the same inhalation study, apparent differences in the interpretation of the results has led to two distinct unit risk values. In the absence of information about the validity of either of the agencies' interpretations of the data, the current assessment adopted the more stringent of the two inhalation unit risks, which is the U.S. EPA RsC of **20 ug/m^3.**

A chronic oral exposure limit was not required for assessing methylene chloride, because it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007), and thus was not incorporated into the multimedia exposure model.

4A2.29 Naphthalene

4A2.29.1 Acute Exposure Limits

Table 4A-62 Acute Inhalation Exposure Limits for Naphthalene

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	--	--	AENV, 2005
ATSDR	--	--	ATSDR, 2006a
OEHHA	--	--	OEHHA, 2000
OMOE	22.5	24-hour	OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

The OMOE (2005a) has developed an AAQC for naphthalene of 22.5 ug/m^3 based on a 24-hour averaging period. Although the 24-hour criterion is based on health consideration, the specific basis of its derivation remains unknown. Thus, the toxicity search was expanded to include intermediate MRLs provided by the ATSDR and short-term occupational limit values (i.e., STEL and Ceiling) (ATSDR, 2006a; ACGIH 2006).

The ACGIH (1991; 2006) recommends a STEL of 15 ppm (79 mg/m^3) based on ocular irritation as a result of occupational exposure to naphthalene. The STEL equates to a 15 minute air concentration that should not be exceeded at any time during a workday. The 15 minute STEL can be adjusted to an equivalent 1 hour concentration using a modified Haber's Law.

$$C_{ADJ}^{n} \times T_{ADJ} = C^{n} \times T$$

$$C^{1} \times 60 \text{ minutes} = (79 \text{ mg/m}^3)^{1} \times 15 \text{ minutes}$$

Where:

C_{ADJ} = duration-adjusted concentration

T_{ADJ} = desired time of exposure (60 minutes)

C = concentration of exposure (79 mg/m^3)

T = time of exposure (15 minutes)

N = chemical-specific modification factor designed to account for the toxicity of a chemical being concentration and/or duration dependant. The OEHHA recommends using a default "n" value of 1 in the adjustment for less than 1-hour exposure (OEHHA 1999).

Based on the above conversion factor, the STEL was adjusted to a concentration of 20 mg/m^3. A cumulative uncertainty factor of 10 was applied to the duration-adjusted STEL to account for intra-species variability (10-fold). On this basis, the modified STEL of **2,000 ug/m^3** was adopted as a 1-hour exposure limit in the acute effects assessment.

4A2.29.2 Chronic Exposure Limit

Table 4A-63 Chronic Inhalation Exposure Limits for Naphthalene

Regulatory Agency	Value (ug/m^3)	Type	Reference
ATSDR	3.7	RfC	ATSDR, 2006a
Health Canada	--	--	Health Canada, 2004b,c
RIVM	--	--	RIVM, 2001
U.S. EPA	3	RfC	U.S. EPA, 2007
WHO	--	--	WHO, 2000

-- not available

The U.S. EPA has derived a chronic inhalation RfC for naphthalene of **3 ug/m^3** (U.S. EPA, 2007). This RfC was estimated from a chronic inhalation mouse study that reported the LOAEL of 9.3 mg/m^3 based on nasal effects including hyperplasia and metaplasia in respiratory and olfactory epithelium (NTP 1992). The U.S. EPA incorporated an uncertainty factor of 3,000 to account for interspecies differences (10-fold), sensitive human individuals in the population (10-fold), to extrapolate from a NOAEL to a LOAEL (10-fold), and for database uncertainties (3-fold). Database uncertainties included the lack of a 2-generation reproductive toxicity study and chronic inhalation data for other animal species. This limit was selected as the exposure limit for the chronic risk assessment.

The ATSDR MRL of 3.7 ug/m^3 is based upon a LOAEL of 10 ppm for the incidence of non-neoplastic lesions in rats. This LOAEL was adjusted for exposure duration (6-hours/day, 5-days/week), and converted to a HEC of 0.2 ppm. A cumulative uncertainty factor of 300 was applied to account for the use of a LOAEL, and inter-and intra-species differences.

Naphthalene exceeded one of the criteria for persistence and bioaccumulation by Environment Canada (2007), and was included in the multi-pathway assessment.

Table 4A-64 Chronic Oral Exposure Limits for Naphthalene

Regulatory Agency	Value (ug/kg)	Type	Reference
ATSDR	600	MRL	ATSDR, 2005
HC	-	-	Health Canada, 2004
RIVM	-	-	RIVM, 2001
U.S. EPA IRIS	20	RfD	U.S. EPA IRIS, 2007

-- not available

The ATSDR has developed an intermediate oral MRL of 600 ug/kg-day for naphthalene based upon a reproductive study in female rats from gestational days 6-15. A LOAEL of 50 mg/kg was established for signs of clinical toxicity in maternal rats. Uncertainty factors were applied for the use of a minimal LOAEL (3), for human variability (3), and a factor of 10 for inter-species differences

An oral RfD for naphthalene is available from the U.S. EPA IRIS (2007), and is based upon decreased body weights in male rats in a 13-week study. A NOAEL of 100 mg/kg was identified, and adjusted to 71 mg/kg due to adjustments for continuous exposure. An uncertainty factor of 3,000 was applied to account for inter-species (10) and intra-species (10) differences, extrapolation from a sub-chronic to a chronic endpoint (10), and a limited toxicological database for oral exposures (3).

Although both values were based upon less-than-chronic exposures, the U.S. EPA IRIS value incorporated an uncertainty factor to account for this. Thus, the U.S. EPA IRIS value of **20 ug/kg-day** was incorporated into the multi-pathway assessment.

Inhalation bioavailability was assumed to be 100%, oral bioavailability 80%, and dermal bioavailability 13% based upon RAIS (2007).

4A2.30 Nitrogen Dioxide

4A2.30.1 Acute Exposure Limits

The exposure limits used for the acute effects assessment of nitrogen dioxide (NO_2) were based on AENV's AAQOs (AENV, 2005). These include a 1-hour objective of **400 ug/m^3** and a 24-hour objective of **200 ug/m^3**. These AAQOs were adopted from the Health Canada's NAAQOs for NO_2. The NAAQOs are developed in 3 tiers: maximum desirable, accepTable 4A-nd tolerable objectives. The Alberta Objectives are based on the maximum acceptable levels, as maximum desirable NAAQOs (i.e., the lowest objectives) have not been developed for NO_2 on an acute-basis. These NAAQOs are health-based, and rely on controlled studies of the most sensitive population (i.e., asthmatics) to NO_2.

Using the above objectives and guidelines, the acute assessment for NO_2 was completed on a 1-hour and 24-hour basis.

4A2.30.2 Chronic Exposure Limits

The chronic exposure limit used for the assessment of NO_2 concentrations in air was based on AENV's AAQO of **60 ug/m^3** (AENV, 2005). This guideline was adopted from Health Canada's NAAQO for NO_2 based on an annual averaging time. The NAAQOs are developed in 3 tiers: maximum desirable, accepTable 4A-nd tolerable objectives. The maximum desirable level (i.e., the lowest objective) was adopted as the annual objective in Alberta. This objective is health-based and relies on controlled studies of the most sensitive population (i.e., asthmatics) to NO_2.

Nitrogen dioxide was assessed only for the inhalation route of exposure as the principal health effects are strictly related to inhalation.

4A2.31 Particulate Matter

Particulate matter (PM) is the generic term applied to a broad class of chemically and physically diverse substances that exist as discrete particles (liquid droplets or solids) over a range of sizes. Particles less than 2.5 micrometres (<2.5 um) are called "fine" particles (i.e., $PM_{2.5}$), while those larger than 2.5 um but smaller than 10 um are known as "coarse" particles (i.e., $PM_{2.5\text{-}10}$). When inhaled, these particles can reach the deepest regions of the lungs (U.S. EPA 2006ab).

A significant amount of research has been, and is being conducted on the health effects associated with both fine and coarse PM in the ambient air. Short-term exposure to ambient PM in numerous urban areas has been associated with a range of health outcomes including:

- Premature death in people with heart and lung disease;
- Non-fatal heart attacks;
- Respiratory and cardiovascular hospitalizations;
- Lung function changes;
- Adverse respiratory symptoms (e.g., cough, wheeze);
- Aggravated asthma; and
- Irregular heartbeats (U.S. EPA 2004b).

Long-term exposure to fine particles ($PM_{2.5}$) has been associated in some studies with cardiovascular and lung cancer mortality, effects on lung function and increases in respiratory symptoms (Brauer et al., 2002; Gauderman et al., 2004; Krewski et al., 2003; 2005a,b; Pope et al., 2002; 2004). These associations do not appear to be explainable by other factors (e.g., weather and other compounds) and after careful review of the evidence, most scientists agree that these seem to be causal in nature (Samet et al., 2000 [reanalyzed in HEI 2003]; CEPA 1999; U.S. EPA 2004a,b). This presents a difficult problem because PM is ubiquitous in the environment and sources are both natural and anthropogenic. Populations identified as being more sensitive to the adverse health effects of PM include individuals with existing respiratory or cardiovascular disease, the elderly, children and asthmatics (U.S. EPA, 2004a,b).

Existing epidemiological studies on large populations have been unable to identify a threshold concentration below which ambient PM has no effect on health. It is likely that thresholds for specific responses exist for specific individuals, but these may vary markedly in the general population resulting in such a wide range in susceptibility that the identification of an explicit threshold for the general population may be impossible (WHO 2003). The U.S. EPA has noted that a convincing mathematical demonstration of a clear threshold in the population studies available is both complex and difficult to verify. They concluded that available evidence does not support or refute the existence of thresholds for the effects of PM on mortality across the range of concentrations in the studies (U.S. EPA, 2004b).

The health impacts from exposure to PM are generally small in terms of measurable or relative risk. For example, the magnitude of the effect of PM exposure is much smaller than the effects of tobacco smoke (HEI, 2001). However, because exposure to PM is widespread, the public health impact of increased air pollution (and in turn PM) can be significant. A recent large study of hospital admissions in 204 counties across the U.S. found a 10 ug/m^3 same day increase in PM$_{2.5}$ was associated with 0.5 to 2 % increased hospital admissions for cardiovascular and respiratory diseases by region (Dominici et al., 2006). Variation in risk across regions was found. For example, positive associations with cardiovascular hospital admissions were found only in the Eastern region of the U.S. By contrast, relative risk estimates for respiratory tract infections were larger in the Western region (Dominici et al., 2006).

The emphasis of PM research has been shifting in recent years to address the many unanswered questions about how particles cause the health effects observed in epidemiological studies. Primary among these are questions related to a) the biological mechanisms responsible for the effects observed and; b) the types and sources of particles most likely causing the effects observed. At present, PM standards are based solely on size fraction (e.g., PM$_{10}$, PM$_{2.5}$, PM$_{2.5\text{-}10}$) but future standards could target the particle components or characteristics that are most toxic.

The primary biological mechanisms thought to underlie the reported health effects from ambient PM include oxidative stress and pulmonary or systemic inflammation (NRC 2004). Clinical and toxicological studies suggest that PM exposure is associated with increased airway hyperactivity, oxidative stress, inflammation, arrhythmias, atherosclerosis, heart rate variability, blood pressure and changes in blood characteristics (e.g., levels of C-reactive protein, fibrinogen, blood viscosity). This provides the important biological plausibility required to explain the morbidity and mortality observed in susceptible individuals in epidemiological studies. However, uncertainty remains in the degree to which toxicological findings from in vitro systems and high dose animal studies apply to real world human exposures, which are often orders of magnitude lower (NRC 2004). The National Research Council (NRC) states that: “The findings from the clinical, animal and in vitro experimental work have often not addressed dose-response relationships, which may provide critical insights into the relevance of the experimental findings for interpreting epidemiological research” (NRC 2004). Many studies used a non-physiologic route of exposure such as intratracheal instillation, which the U.S. EPA (2004b) notes can result in very high individual cellular concentrations, requiring much caution in the extrapolation of findings.

Determining the characteristics of PM that are associated with adverse health effects is challenging. PM in ambient air is a complex mixture that varies in size and chemical composition, as well as varying spatially and temporally. Different types of particles may cause different effects with different time courses, and perhaps only in susceptible individuals. The interaction between PM and gaseous co-pollutants adds additional complexity because in ambient air pollution, a number of pollutants tend to co-occur and have strong inter-relationships with each other (e.g., PM, SO$_2$, NO$_2$, CO, and O$_3$) as well as different levels of measurement error (Peel et al., 2005; U.S. EPA 2004b). As a result it is difficult to attribute the effects of air pollution as a mixture to any one of these particular pollutants. A pollutant that exhibits a relatively strong association in a multi-pollutant model may be acting as a surrogate for an unmeasured or poorly measured pollutant (Metzger et al., 2004). Several investigators have noted that the effects observed in their studies are likely due to the mixture of air pollutants and not just one component (Chen et al., 2004; Goldberg et al., 2006).

Considerable research effort has gone into understanding the PM sources, components and size fractions likely to be responsible for the health effects observed in epidemiology studies. Characteristics that have been found to contribute to toxicity include: metal content, presence of polycyclic aromatic hydrocarbons and other organic components, endotoxin content and small (less than 2.5 um) and extremely small (less than 0.1 um) size (CAFÉ 2004).

Several studies using factor analyses indicate that combustion particles in the fine fraction but not fine crustal particles are associated with increased mortality (Laden et al., 2000; Schwartz et al., 1999; Mar et al., 2000; Tsai et al., 2000; Ozkaynak et al., 1996; Janssen et al., 2002). Crustal particles (also referred to as geological particles) are products of the natural abrasion of the earth's crust and are mainly mechanically generated from agriculture, mining, construction, road dust and related sources. Particles associated with motor vehicle emissions stand out clearly as a source category associated with mortality in the factor analyses studies, but associations with an oil combustion factor, a regional sulphate factor and a source category related to vegetative burning also have been identified. Regional sulphate is highly correlated with $PM_{2.5}$, however, so it may be acting as a surrogate for $PM_{2.5}$ (U.S. EPA, 2004b).

A number of studies have reported significant associations between adverse health effects and either traffic density or close proximity to major roads, including total and cardiopulmonary mortality, heart attacks, and adverse respiratory health effects (Brauer et al., 2002; Finkelstein et al., 2004; Hoek et al., 2002; Kim et al., 2004; Lipfert et al., 2006; Tonne et al., 2006; Venn et al., 2001). For example, in Hamilton, Ontario, living within 100 m of a freeway or 50 m of a major urban road was associated with increased all cause mortality (RR = 1.18; 1.02-1.38) (Finkelstein et al., 2004). The mortality rate advancement associated with residence near a major road was 2.5 years in this study, which is similar to that associated with chronic respiratory and pulmonary diseases and diabetes. In a study of 70,000 male U.S. veterans, Lipfert et al. (2006) reported that county-level traffic density was a better predictor of mortality than with ambient $PM_{2.5}$ levels. In multi-pollutant models including traffic density, the association with $PM_{2.5}$ was reduced and lost statistical significance (Lipfert et al., 2006). Another study reported that time spent in traffic (e.g., cars, public transport, bicycles) two hours prior was much more strongly associated with induction of nonfatal myocardial infarctions (MIs) than any of the air pollutants measured at a central monitoring site (Peters et al., 2005).

Future epidemiological studies and studies currently in progress should provide important information on the relative role of various PM size fractions and components in adverse health effects. A collection of studies in Atlanta is using extensive air quality data, including detailed PM composition and size fraction information from a monitoring station operated by the Aerosol Research and Inhalation Epidemiology Study (ARIES). Parameters measured include several gases and many PM components, including total metals, water-soluble metals, organic carbon (OC) and elemental carbon (EC), sulphates, nitrates, several speciated hydrocarbons, and polar volatile organic compounds (VOCs) (Metzger et al., 2004; Peel et al., 2005). Time series studies using ARIES data that examined associations with emergency department visits suggest the strongest and most consistent associations are with traffic related pollutants such as NO_2, CO, $PM_{2.5}$, OC, EC and oxygenated carbons (Metzger et al., 2004; Peel et al., 2005). Consistent associations with sulphates were not demonstrated.

A recent time-series analysis of PM in California indicated that ambient concentrations of several constituents of $PM_{2.5}$ were associated with daily mortality, specifically EC, OC, nitrates, copper, potassium, titanium and zinc (Ostro et al., 2006). Many of these constituents were associated with higher relative risks than $PM_{2.5}$ mass. The authors noted that their results support the hypothesis that pollution from motor vehicles and other sources of combustion may be of particular concern (Ostro et al., 2006).

Seagrave et al. (2006) examined the lung toxicity of ambient PM from various U.S. sites with different contributing sources and reported on the relationship between composition and effects. Summer and winter samples from each site were collected for toxicity testing, chemical analysis and source apportionment. After instillation into rat lungs, general toxicity, acute cytotoxicity and inflammation were assessed. The results support the concept that $PM_{2.5}$ composition affects its toxicity (Seagrave et al., 2006). Source apportionment suggested that the most potent samples were those with the largest contributions from diesel and gasoline exhaust. Wood burning was only weakly correlated with toxicity end points, while sulphate (SO_4^{2-}), secondary organic aerosols, meat cooking and vegetation burning were not correlated with the biological responses.

Untangling the relationships among components of mixtures of PM requires a sophisticated integration of air quality and health research and a systematic study of PM components (Samet et al., 2005). The Health Effects Institute (HEI) has noted that a systematic approach to these topics will generate more specific PM standards, and ones that target the types and inventories of particles most likely to contribute to health effects. Such a research initiative may lead to the identification of critical PM sources, enabling industry-specific guidance for control of those specific PM components that have been attributed with the greatest fraction of risk to health (HEI, 2005).

4A2.31.1 Acute and Chronic Exposure Limits for Particulate Matter

The Scientific Assessment Document (Part 1) of The National Ambient Air Quality Objectives for Particulate Matter (1999) prepared by the Canadian Environmental Protection Act and Federal Provincial Advisory Committee (CEPA/FPAC) Working Group on Air Quality Objectives and Guidelines concluded that both the mortality and hospitalization studies support the identification of 15 ug/m^3 averaged over 24 hours as the reference level for $PM_{2.5}$ (CEPA/FPAC, 1999). The reference level was considered an estimate of the lowest ambient particulate matter level at which statistically significant increases in health responses can be detected based on data available up to 1996. It was derived based on the average 24-hour concentrations measured in the cities where these effects were found. The CEPA/FPAC Working Group states that reference levels should not be interpreted as thresholds of effects, or levels at which impacts do not occur. They are defined under Canada's National Ambient Air Quality Objectives as levels above which there are demonstrated effects on human health and/or the environment (CEPA/FPAC ,1999).

A Canada-Wide Standard (CWS) of 30 ug/m^3 $PM_{2.5}$ averaged over 24 hours was developed by the CCME under the auspices of the Canadian Environmental Protection Agency (CEPA) (CCME, 2000b). Under this standard, the government is committed to reduce levels of $PM_{2.5}$ significantly by 2010. Achievement of this standard is based on the 24-hour 98th percentile of the ambient measurement annually, measured over three consecutive years. The CWS is considered to be an important step towards the long-term goal of reducing the health risks of $PM_{2.5}$. It represents a balance between achieving the best health and environmental protection possible, and the feasibility and costs of reducing pollutant emissions that contribute to $PM_{2.5}$ in ambient air.

The California Air Resources Board (CARB) has identified an air quality annual average standard for $PM_{2.5}$ of 12 ug/m^3 (CARB, 2002ab). This recommended arithmetic mean value was "based on a growing body of epidemiological and toxicological studies showing significant toxicity (resulting in mortality and morbidity) related to exposure to fine particles". Similar to the CEPA/FPAC reference level, the value was derived mainly based on the average 24 hour concentrations in cities where statistically significant increases in health responses were detected. The CARB staff report recommendation was adopted by the State of California as an ambient air quality standard in June of 2002.

In 1997, the U.S. EPA first set National Ambient Air Quality Standards (NAAQS) for fine particles. Two primary $PM_{2.5}$ standards were set: an annual standard of 15 ug/m^3 to protect against health effects that caused by exposures ranging from days to years, and a 24-hour standard of 65 ug/m^3 to provide additional protection on days with high peak $PM_{2.5}$ concentrations. In September 2006, the U.S. EPA issued a new suite of standards to better protect public health from particle pollution. The revised NAAQS for $PM_{2.5}$ reduced the 24 hour standard from 65ug/m^3 to 35 ug/m^3 and retained the annual standard of 15 ug/m^3 (U.S. EPA 2006b). The 24-hour standard is based on the 98th percentile annual measurement, averaged over 3 years, while the annual standard is met when the 3-year average of the annual average $PM_{2.5}$ concentration is less than or equal to 15 ug/m^3. The U.S. EPA also retained the existing 24-hour NAAQS for PM_{10} of 150 ug/m^3 and revoked the annual PM_{10} standard of 50 ug/m^3.

The final NAAQSs were selected by the U.S. EPA after completing an extensive review of thousands of scientific studies on the impact of fine and course particles on public health. The criteria document (i.e., the review) and the staff paper containing the U.S. EPA's recommendations on the range of alternative standards that should be considered, received extensive review by representatives of the scientific community, industry and public interest groups as well as the Clean Air Scientific Advisory Committee (CASAC) – a group of independent scientific and technical experts established by Congress (U.S. EPA, 2006b).

It is worth noting that the final annual standard for $PM_{2.5}$ selected by the U.S. EPA does not reflect the advice of the CASAC PM panel, who recommended a 24-hour standard in the range of 30 ug/m^3 to 35 ug/m^3 and an annual standard in the range of 13 ug/m^3 to 14 ug/m^3 (CASAC 2006). They noted that clear and convincing scientific evidence as well as the U.S. EPA's own risk analyses (U.S. EPA, 2005) indicated health risks at the current annual standard of 15 ug/m^3. Risk analyses indicated that uncertainties increase rapidly below an annual level of 13 ug/m^3 and that was the basis for CASAC's recommendation of 13 ug/m^3 as the lower bound for the annual $PM_{2.5}$ standard. The provisions do not require U.S. EPA standards to be set at a zero risk level but rather at a level that avoids unacceptable risks to public health. However, previously the U.S. EPA has accepted CASAC's advice with respect to NAAQS decisions (CASAC, 2006).

The WHO (2005) suggests that PM guidelines cannot ensure the complete protection against adverse health effects because thresholds have not been identified and it is unlikely that any PM guideline will provide adequate protection for every individual against all possible adverse effects. Instead, guidelines need to achieve the lowest concentrations possible considering local constraints, capabilities and public health priorities.

With respect to air quality guidelines for $PM_{2.5}$, the WHO recommends an annual average of 10 ug/m^3 and a daily 99th percentile of 25 ug/m^3 for the protection of public health. The WHO (2005) suggests the annual average should take precedence over the daily guideline because at low levels there is less concern for episodic excursions. The annual average guideline is based on long-term exposure studies using the American Cancer Society (ACS) data (Pope et al., 2002) and Harvard Six-Cities data (Dockery et al., 1993). The studies reported a robust association between PM exposure and mortality. Historical mean $PM_{2.5}$ concentrations across cities in these two studies were 18 ug/m^3 and 20 ug/m^3, respectively, but average concentrations in individual cities were as low 11 ug/m^3 over the period of study. An annual mean guideline concentration of 10 ug/m^3 was therefore noted to be below the mean for most likely effects (WHO, 2005). However, both the WHO (2005) and the U.S. EPA (2005b) note that statistical uncertainties in the risk estimates become apparent at concentrations of about 13 ug/m^3, below which confidence bounds significantly widen, indicating the possibility of an effects threshold. In their staff paper, the U.S. EPA (2005b) noted that an annual standard of 12 ug/m^3 would be precautionary, but a standard set below the range of 12 ug/m^3 to 15 ug/m^3 also would be conservative.

It is apparent that the health protection afforded by the reference level for $PM_{2.5}$ of 15 ug/m^3 that was established by the CEPA/FPAC in 1999 should be considered generally equivalent to the intended or effective health protection of the Ambient Air Standard of California (12 ug/m^3), the annual NAAQ standard retained by the U.S. EPA (15 ug/m^3) or the new WHO annual guideline of 10 ug/m^3 $PM_{2.5}$.

The short-term value represented by the CWS of 30 ug/m^3 is analogous to the new 24 hour NAAQS identified by U.S. EPA of 35 ug/m^3, which was determined to better protect the public from the health effects associated with short-term fine particle exposures. The CWS is within the range set by the WHO annual guideline for $PM_{2.5}$ of 10 ug/m^3 and the U.S. EPA NAAQS of 35 ug/m^3. CARB refrained from setting a 24-hour standard in 2002, and has deferred a decision on this matter (CARB, 2002b).

Within the current assessment, predicted 24-hour $PM_{2.5}$ concentrations are compared to the CWS of **30 ug/m^3**, which falls within the range of recent standards recommended by the WHO and the U.S. EPA. Predicted annual average concentrations were compared against the CARB annual standard of **12 ug/m^3,** which falls within the range of standards recommended by the WHO and the U.S. EPA. The selection of values from the middle of the range of available guidelines or standards respects both the need to be conservative and the uncertainty which still remains regarding the types of PM that are most likely to affect health, and the existence of a threshold for PM-associated adverse effects.

Taken together, these health-based limits should offer an acceptable level of protection to the area residents.

4A2.32 Propylene Oxide

4A2.32.1 Acute Exposure Limits

Table 4A-65 Acute Inhalation Exposure Limits for Propylene Oxide

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	480	1-hour	AENV, 2005
ATSDR	–	–	ATSDR, 2006a
OEHHA	3,100	1-hour	OEHHA, 2000
OMOE	4.5 and 450 (interim) 1.5	½-hour 24-hour	OMOE, 2005a OMOE, 2005a
WHO	–	–	WHO, 2000

-- not available

The OMOE (2005a) provides ½-hour and 24-hour standards for propylene oxide. However, no scientific basis is provided for these standards. As a result, the study team is unable to comment on the scientific merit of these limits and, as such, these values were not used in the acute assessment of propylene oxide.

The AENV (2005) developed an AAQO of 480 ug/m^3 based on a 1-hour averaging period. Alberta's AAQO was adopted from the Oklahoma Department of Environmental Quality, which established its 24-hour averaging-time maximum accepTable 4A-mbient concentration by dividing the TLV–TWA of the ACGIH (ACGIH 2006) (an 8-hour time-weighted average occupational exposure limit of 48,000 ug/m^3) by an uncertainty factor of 100. The basis of the 100-fold uncertainty factor is unknown. The ACGIH TWA is based on evidence that suggests that no genetic damage or excess cancer risk could be detected in workers exposed to propylene oxide concentrations no greater than 48,000 ug/m^3. As the basis of this value is chronic (cancer), this value is not appropriate for use in the acute effects assessment.

The OEHHA (2000) provides a 1-hour REL of 3,100 μg/m^3 that is protective against mild adverse effects. In an inhalation chamber 10 mice (5 per sex) were exposed to 387 or 859 ppm of propylene oxide for 4 hours. A LOAEL of 387 ppm was identified based on the breathing difficulties in mice, determined to be attributable to nasal irritation. The OEHHA (2000) extrapolated the 4-hour concentration to a 1-hour concentration of 774 ppm based on the equation that follows.

$$387^2 \text{ ppm x 4 hours} \quad = \quad C^2 \text{ x 1 hour}$$

A cumulative uncertainty factor of 600 was applied to the duration adjusted LOAEL to account for the use of a LOAEL (6-fold), interspecies variation (10-fold) and intra-species variation (10-fold). The result is a 1-hour REL of 1.3 ppm (**3,100 ug/m^3**), which was used in the acute effects assessment of propylene oxide.

4A2.32.2 Chronic Exposure Limits

Table 4A-66 Chronic Inhalation Exposure Limits for Propylene Oxide

Regulatory Agency	Value (ug/m^3)	Type	Reference
Health Canada	–	–	Health Canada, 2004b,c
ATSDR			ATSDR, 2006a
RIVM	–	–	RIVM, 2001
U.S. EPA	30 3	RfC RsC	U.S. EPA, 2007 U.S. EPA, 2007
WHO	–	–	WHO, 2000

-- not available

Both carcinogenic and non-carcinogenic exposure limits were available from the U.S. EPA for propylene oxide. The IARC (1994) classifies propylene oxide as being possibly carcinogenic to humans (Group 2B) based on sufficient evidence in experimental animals. Therefore, the U.S. EPA chronic RsC of **3 ug/m^3** based on nasal cavity hemangioma or hemangiosarcoma in male mice was selected for use in the chronic assessment (U.S. EPA, 2007). The RsC was derived from an inhalation unit risk of 3.7 x 10^{-6} per ug/m^3 and is associated with a risk level of one in 100,000.

A chronic oral exposure limit was not required for assessing propylene oxide, as it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007), and thus was not incorporated into the multimedia exposure model.

4A2.33 Styrene

4A2.33.1 Acute Exposure Limits

Table 4A-67 Acute Inhalation Exposure Limits for Styrene

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	215	1-hour	AENV, 2005
ATSDR	–	–	ATSDR, 2006a
OEHHA	21,000	1-hour	OEHHA, 2000
OMOE	830 690 275	½-hour 1-hour 24-hour	OMOE, 2005a OMOE, 2005a OMOE, 2005a
WHO	–	–	WHO, 2000

-- not available

The AENV has established a 1-hour AAQO of 215 ug/m^3 that was adopted from the Texas Natural Resource Conservation Commission effects screening level for odour perception (AENV, 2005). The Texas Natural Resource Conservation Commission has since updated its effects screening level for styrene to a concentration of 110 ug/m^3 based on odour perception (TCEQ, 2003). These odour-based limits were not used in the acute effects assessment.

The OMOE (2005a) has developed half-hour, 1-hour and 24-hour standards for propylene oxide. However, no scientific basis is provided for these standards. As a result, the study team is unable to comment on the scientific merit of these limits and did not use them in the short-term assessment of styrene.

The California OEHHA has developed a 1-hour acute exposure limit of 21,000 ug/m^3 (OEHHA 1999, 2000). This acute REL was derived from a NOAEL of 99 ppm (210,000 ug/m^3) for eye and throat irritation in three human subjects exposed for 20 minutes via inhalation. A safety factor of 10 was applied by the OEHHA to account for increased susceptibility of sensitive human individuals. The result is a 1-hour exposure limit of **21,000 ug/m^3** that was used in the acute assessment.

4A2.33.2 Chronic Exposure Limits

Table 4A-68 Chronic Inhalation Exposure Limits for Styrene

Regulatory Agency	Value (ug/m^3)	Type	Reference
Health Canada	92	RfC	Health Canada, 2004b
ATSDR	260	RfC	ATSDR, 2006a
RIVM	900	RfC	RIVM, 2001
U.S. EPA	1,000	RfC	U.S. EPA, 2007
WHO	–	–	WHO, 2000

-- not available

The Health Canada tolerable concentration of 92 ug/m^3 for styrene is based on observed effects on body weight changes and manifestations of neurotoxicity in Wistar rats (Health Canada, 2004b). However, as the ATSDR, RIVM and U.S. EPA chronic inhalation exposure limits are based on human occupational data (Mutti et al., 1984), the Health Canada tolerable concentration was not chosen as the chronic exposure limit for the current assessment.

The ATSDR (2006a; 1992) presents a chronic inhalation MRL of 0.06 ppm (260 mg/m^3) based on decreased verbal learning skills. A LOAEL of 25 ppm was identified in 50 workers occupationally exposed to styrene for a mean of 8.6 years (Mutti et al., 1984). The ATSDR (1992) adjusted the LOAEL for intermittent exposure (8 hours/24 hours x 5 days/7days) to a concentration of 6 ppm. An uncertainty factor of 100 was applied to the duration-adjusted LOAEL to account for intra-species variation (10-fold) and use of a LOAEL (10-fold).

The RIVM (2001) has developed a TCA of 900 μg/m^3 based on the same occupational study as the ATSDR (1992). However, the RIVM identifies a NOAEC of 25 ppm (107 mg/m^3) for CNS effects in workers. Following the same methodology as the ATSDR, the RIVM adjusted the NOAEC for intermittent exposure (8 hours/24 hours x 5 days/7days) to a concentration of 6 ppm (26 mg/m^3). An uncertainty factor of 30 was applied to the duration-adjusted NOAEC to account for intra-species variation (10-fold) and extrapolation of a marginal affect to a NOAEC (3-fold).

A chronic inhalation RfC of 1,000 ug/m^3 was developed by U.S. EPA (2007) based the same occupational study as the ATSDR (1992) and RIVM (2001). A NOAEL of 25 ppm (106 mg/m^3) for CNS effects was reported by the U.S. EPA (2007). The NOAEL exposure level is based on a back extrapolation from worker urinary concentration of styrene metabolites reported in the principal study and was adjusted to the lower 95% confidence limit listed in Guillemin et al. (1982), which was 88% [25 ppm x 0.88 = 22 ppm (94 mg/m^3)]. The adjusted NOAEL was converted from an 8-hour time-weighted average occupational exposure to continuous exposure using the following calculation:

$$NOAEL_{HEC} = NOAEL \times \frac{MV_{ho}}{MV_h} \times \frac{Exp_{ho}}{Exp_h}$$

Where:

$NOAEL_{HEC}$ = no-observable-adverse-effects level in the human population from continuous exposure to styrene (mg/m^3)

NOAEL = no-observable-adverse-effects level for discontinuous exposure in an occupational setting (94 mg/m^3)

MV_{ho} = amount of air used by a worker during an 8-hour work period (10 m^3/d)

MV_h = amount of air used by an individual in the general population during a day (20 m^3/d)

Exp_{ho} = days per week a worker is exposed (5 days)

Exp_h = days per week an individual in the general population is exposed (7 days)

An uncertainty factor of 30 was applied to the $NOAEL_{HEC}$ of 34 mg/m^3 to account for database inadequacy (3-fold), intra-species variability (3-fold), and for lack of information on chronic studies (3-fold).

The U.S. EPA RfC of **1,000 ug/m^3** was selected for use in the chronic inhalation effects assessment for styrene as it represents the most appropriate limit with respect to its scientific basis and as a result of the adjustments made for continuous exposure.

A chronic oral exposure limit was not required for assessing styrene, as it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007), and thus was not incorporated into the multimedia exposure model.

4A2.34 Sulphur Dioxide

4A2.34.1 Acute Exposure Limits

The acute exposure limits used for the assessment of sulphur dioxide (SO_2) concentrations in air were based primarily on AENV's AAQOs (AENV, 2005). These include a 1 hour objective of **450 ug/m^3** and a 24 hour objective of **150 ug/m^3**. These AAQOs were adopted from the Health Canada NAAQOs, which recommends maximum desirable, accepTable 4A-nd tolerable objectives for SO_2. The Alberta objectives are based on the maximum desirable levels (i.e., the lowest objective). These guidelines are health-based and rely on controlled studies of the most sensitive population (i.e., asthmatics) to air pollutants such as SO_2.

Sulphur dioxide also was assessed using a 10-minute air quality guideline of **500 ug/m^3** developed by the WHO (2000). This guideline is based on changes in lung function in asthmatics (WHO, 2000).

Using the above objectives and guidelines, the acute assessment for SO_2 was completed on a 10 minute, 1 hour and 24 hour basis.

4A2.34.2 Chronic Exposure Limits

The chronic exposure limit used for the assessment of SO_2 concentrations in air was based on AENV's annual ambient air quality objective for SO_2 of **30 ug/m^3** (AENV, 2005). This AAQO was adopted from the Health Canada annual NAAQO, which includes maximum desirable, accepTable 4A-nd tolerable objectives for SO_2. The Alberta objectives are based on the maximum desirable levels (i.e., the lowest objective). This guideline is health-based and relies on controlled studies of the most sensitive population (i.e., asthmatics) to air pollutants such as SO_2.

Sulphur dioxide was assessed only on an inhalation exposure basis because potential health effects relate directly to inhalation exposure.

4A2.35 Toluene

4A2.35.1 Acute Exposure Limits

Table 4A-69 Acute Inhalation Exposure Limits for Toluene

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	1,880 400	1-hour 24-hour	AENV, 2005 AENV, 2005
ATSDR	3,800	24-hour	ATSDR, 2006a
OEHHA	37,000	1-hour	OEHHA, 2000
OMOE	2,000	½-hour, 24-hour	OMOE, 2005a
WHO	260	1-week	WHO, 2000

The AENV (2005) provides a 1-hour AAQO of 1,880 ug/m^3, which was adopted from the Texas Natural Resource Conservation Commission. The Texas value was based on the ACGIH TLV-TWA of 50 ppm (188 mg/m^3) (ACGIH 1991; 2006). The AENV (2005) adjusted the TLV-TWA by applying a 100-fold uncertainty factor (note: the basis of the 100 fold uncertainty factor is unknown). The 24-hour AAQO was adopted from the Michigan Department of Environmental Quality and the Washington Department of Ecology (AENV, 2005). These regulatory agencies based their 24-hour guidelines on the U.S. EPA chronic inhalation RfC of 400 ug/m^3 (U.S. EPA, 2007). The U.S. EPA RfC has since been revised to an inhalation RfC of 5,000 ug/m^3 for neurological effects. As this 24 hour AAQO was based on a chronic inhalation exposure limit that has recently been raised by more than a factor of 10, this objective was not used in the acute effects assessment.

The OMOE (2005a) has developed a 24-hour AAQC of 2,000 ug/m^3 for toluene based on odour perception, and thus was not used in the acute effects assessment.

The WHO (2000) provides a guideline of 260 ug/m^3 based on a 1-week averaging time. A LOAEL of 332 mg/m^3 (88 ppm) was identified for CNS effects from occupational studies. The LOAEL was adjusted for continuous exposure (8 hour/24 hour x 5 days/7 days) to a concentration of 79 mg/m^3. The duration-adjusted LOAEL was divided by an uncertainty factor of 300 to account for intra-species variation (10-fold), for use of a LOAEL (10-fold) and the given effects on the developing CNS (3-fold). This guideline was not used in the short-term assessment of toluene as the ATSDR (2006a) and OEHHA (2000) both provide acute exposure limits based on a NOAEL.

The ATSDR (2000b; 2006a) has derived an acute MRL 1 ppm (3,800 ug/m^3) for neurological effects. A NOAEL of 40 ppm (150 mg/m^3) was reported based on a study by Andersen et al. (1983), wherein 16 healthy young subjects with no previous exposure to organic solvents were exposed to toluene for six hours per day on four consecutive days. The NOAEL was adjusted for intermittent exposure (8 hour/24 hours x 5 days/7 days). A 10-fold uncertainty factor was applied to the duration-adjusted NOAEL to account for intra-species variation.

The OEHHA (1999; 2000) provides an acute REL of 37,000 ug/m^3 for toluene based on the same study NOAEL identified in the ATSDR assessment. The difference between the limit values of the OEHHA and the ATSDR arises from a different way of extrapolating a 6-hour exposure to an acute exposure duration. The ATSDR adjusts the 6-hour exposure to a 24-hour limit using 8 hours/24 hours x 5 days/7days, which is a common approach for deriving a chronic limit from intermittent occupational exposure of eight hours per day, five days per week; however, this adjustment is inappropriate when deriving a 24-hour limit from 6-hour exposure.

In contrast, the OEHHA converts the 6-hour exposure duration to a 1-hour REL of 98 ppm (370 mg/m^3) based on the following calculation.

$$C \times 1 \text{ hour} = (40 \text{ ppm}) 2 \times 6 \text{ hours}$$

An uncertainty factor of 10 was then applied by the OEHHA to the duration-adjusted NOAEL. This acute REL of **37,000 ug/m^3** was used as the 1-hour exposure limit in acute effects assessment for toluene.

4A2.35.2 Chronic Exposure Limits

Table 4A-70 Chronic Inhalation Exposure Limits for Toluene

Regulatory Agency	Value (ug/m^3)	Type	Reference
ATSDR	300	MRL	ATSDR, 2006a
Health Canada	3,800	RfC	Health Canada, 2004b
RIVM	400	RfC	RIVM, 2001
U.S. EPA	5,000	RfC	U.S. EPA, 2007
WHO	--	--	WHO, 2000

-- not available

The ATSDR (2000; 2005a) chronic inhalation MRL of 0.08 ppm (300 μg/m^3) was based on colour vision impairment in workers exposed to toluene. Three groups of Croatian workers were examined through interviews, medical examinations, and colour vision testing (ATSDR 2000; Zavalic et al., 1998). A LOAEL of 35 ppm (130 mg/m^3) was determined for alcohol- and age-adjusted colour vision impairment. The LOAEL was adjusted for intermittent exposure (8 hours/24 hours x 5 days/7 days) to a concentration of 8 ppm (30 mg/m^3). An uncertainty factor of 100 was applied to the duration-adjusted LOAEL to account for use of a LOAEL (10-fold) and intra-species variation (10-fold). This MRL was not used as the chronic exposure limit for toluene because it was developed from a LOAEL and thus required the use of a 10-fold uncertainty factor acknowledging the uncertainty associated with use of a LOAEL instead of a NOAEL. Thus, the RfCs developed by Health Canada and the U.S. EPA from NOAELs were given preference.

The RIVM also has developed a TCA of 400 ug/m^3 for toluene (RIVM, 2001). This TCA was adopted from the U.S. EPA RfC of 400 ug/m^3, which was revised in 2005 to a value of 5,000 ug/m^3 (U.S. EPA, 2007). As a result, this TCA was not used in the chronic inhalation effects assessment for toluene.

Health Canada developed a chronic tolerable concentration of 3,800 ug/m^3 on the same (see the ATSDR acute MRL) lowest reported NOAEL of 150 mg/m^3 (40 ppm) for neurological effects and respiratory irritation in human volunteers (Andersen et al., 1983; CEPA 1992). The study NOAEL was adjusted from 6-hour daily dosing to continuous exposure and an uncertainty factor of 10 was applied to account for intra-species variation.

The U.S. EPA has derived an inhalation RfC based upon the findings of 10 human studies, each of which examined the neurological effects in occupationally exposed workers (U.S. EPA, 2007). These studies were all more recent than the Andersen et al., 1983 study used in the Health Canada assessment and included the study used as the basis of the ATSDR assessment. The analysis of the multiple studies resulted in an average NOAEL of 34 ppm (128 mg/m^3). This NOAEL was adjusted for the differences in breathing rates between workers and members of the public (i.e., 10/20 m^3/d) and the reduced weekly exposure time (i.e., 5 days/7 days). The U.S. EPA also applied an uncertainty factor of 10 to account for human variation. The U.S. EPA RfC of **5,000 ug/m^3** represents the most recent analysis of the available scientific literature, and this value used in the chronic inhalation assessment.

A chronic oral exposure limit was not required for the assessment of toluene since it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007) and thus was not incorporated into the multi-media exposure model.

4A2.36 Xylenes

4A2.36.1 Acute Exposure Limits

Table 4A-71 Acute Inhalation Exposure Limits

Regulatory Agency	Value (ug/m^3)	Averaging Time	Reference
AENV	2,300 700	1-hour 24-hour	AENV, 2005
ATSDR	8,700	2-hour	ATSDR, 2006a
OEHHA	22,000	1-hour	OEHHA, 2000
OMOE	730	24-hour	OMOE, 2005a
WHO	--	--	WHO, 2000

-- not available

The AENV (2005) adopted the OMOE's ½-hour POI of 2,300 ug/m^3 as its 1-hour AAQO. However, this POI was based on odour perception and has since been updated (OMOE, 2005d). The AENV (2005) also provides a 24-hour AAQO of 700 ug/m^3. This guideline was not used in the acute effects assessment because it was taken from the chronic REL provided by the OEHHA (2005).

The OMOE (2005a) has established a 24-hour limit of 730 ug/m^3 based on adverse neurological effects. A LOAEL of 62 mg/m^3 was established for headaches, eye and nasal irritation, and light headedness (floating sensation) in approximately 300 workers, 175 of whom were occupationally exposed for an average of seven years. The LOAEL was adjusted by the OMOE to account for discontinuous exposure (10 m^3/20 m^3 × 5 days/7 days) to a concentration of 22.1 mg/m^3. It should be noted that the scientific merit for the discontinuous exposure adjustment is questionable, considering that the OMOE standard is intended to be protective of short-term exposures and that the study subjects were exposed to xylene for seven years, on average. Regardless, the OMOE applied an uncertainty factor of 30 to the adjusted LOAEL to account for intra-species variability (10-fold) and use of a LOAEL (3-fold).

The ATSDR recently reviewed the short-term toxicity of xylenes and revised their exposure limits (ATSDR 2005c; 2006a). Based on a study by Ernstgard et al. (2002), 50 ppm (200 mg/m^3) was designated as a LOAEL for slight respiratory effects (e.g., reduced forced vital capacity, increased discomfort in throat and airways in women, and breathing difficulties in both sexes) and subjective symptoms of neurotoxicity (e.g., headache, dizziness, feelings of intoxication). Fifty-six healthy volunteers (28 per sex) between the ages of 20 and 49 years were exposed to 50 ppm m-xylene, clean air (controls) or 150 ppm 2-propanol in a dynamic chamber for 2 hours. Each subject received three treatments separated by intervals of two weeks. The LOAEL was considered minimal because the magnitude of the changes was small. The ATSDR applied an uncertainty factor of 30 for use of a (minimal) LOAEL (3-fold) and human variability (10-fold), resulting in an acute MRL of 2 ppm (8,700 ug/m^3). This 2-hour MRL of **8,700 ug/m^3** was conservatively adopted as the 1 hour exposure limit used in the acute effects assessment.

4A2.36.2 Chronic Exposure Limits

Table 4A-72 Chronic Inhalation Limits for Xylenes

Regulatory Agency	Value (ug/m^3)	Type	Reference
ATSDR	650	RfC	ATSDR, 2006a
Health Canada	180	RfC	Health Canada, 2004b
RIVM	870	RfC	RIVM, 2001
U.S. EPA	100	RfC	U.S. EPA, 2007
WHO	--	--	WHO, 2000

-- not available

Although Health Canada (2004b) recommends a tolerable concentration of 180 ug/m^3 for xylenes, the specific basis is unknown. Therefore, the chronic inhalation RfC derived by the U.S. EPA (2007) of 100 ug/m^3 was used in the chronic effects assessment. The RfC was derived from a NOAEL of 217 mg/m^3 for impaired motor coordination from a sub-chronic inhalation study in male rats (Korsak et al., 1994). The NOAEL was adjusted from intermittent to continuous exposure by the U.S. EPA, resulting in an adjusted NOAEL of 39 mg/m^3. A safety factor of 300 was applied by the U.S. EPA to the adjusted NOAEL to account for laboratory animal-to-human interspecies differences (3-fold), intra-species uncertainty to account for human variability and sensitive populations (10-fold), extrapolation from sub-chronic to chronic duration (3-fold), and uncertainties in the database (3-fold).

A chronic oral exposure limit was not required for the xylenes assessment because it did not exceed any of the persistence and bioaccumulation parameters established by Environment Canada (2007), and thus was not incorporated into the multi-media exposure model.

4A2.37 Chemical Mixtures

Possible additive interactions were identified for those COPCs known to cause irritation (eye, nasal, respiratory), effects on the liver or kidney, neurological or reproductive/developmental effects, and cancer. The inclusion of a COPC in the chemical mixture was based upon the endpoint of the exposure limit used in the current HHRA.

Table 4A-73 Potential Additive Interactions of the COPCs

Exposure Duration and Route	Potential Health Effect of Mixture	Toxicant Designation	COPCs in Mixture
Acute (inhalation)	Irritation	Eye irritants	Acetaldehyde, acrolein, aliphatic alcohols, aliphatic ketones, ammonia, dichlorobenzenes, formaldehyde, naphthalene, styrene
		Nasal irritants	Aliphatic alcohols, aliphatic ketones, dichlorobenzenes, formaldehyde, propylene oxide
		Respiratory irritants	Acetaldehyde, aliphatic alcohols, aliphatic ketones, ammonia, hydrogen sulphide, nitrogen dioxide, styrene, sulphur dioxide, xylenes
	Liver effects	Hepatotoxicants	Aliphatic C_5-C_8 group, aromatic C_9-C_{16} group
	Kidney effects	Renal toxicants	Aliphatic C_5-C_8 group, aromatic C_9-C_{16} group
	Neurological effects	Neurotoxicants	Aliphatic C_9-C_{16} group, aromatic C_9-C_{16} group, carbon disulphide group, n-hexane, methylene chloride, toluene, xylenes
	Reproductive/ Developmental Effects	Reproductive/ Developmental Toxicants	1,3-Butadiene, carbon disulphide group, cyclohexane, ethylbenzene
Chronic (inhalation)	Irritation	Eye irritants	
		Nasal irritants	Acrolein, dichlorobenzenes, hydrogen sulphide, naphthalene
		Respiratory irritants	Aliphatic aldehydes, ammonia, biphenyl, nitrogen dioxide, sulphur dioxide
	Liver effects	Hepatotoxicants	2-Chloronaphthalene, aliphatic C_{17}-C_{34} group, aromatic C_9-C_{16} group
	Kidney effects	Renal toxicants	Aromatic C_9-C_{16} group, aromatic C_{17}-C_{34} group, benzaldehyde, isopropylbenzene
	Neurological effects	Neurotoxicants	Aliphatic C_5-C_8 group, aliphatic C_9-C_{16} group, aromatic C_9-C_{16} group, carbon disulphide, *n*-hexane, styrene, toluene, xylenes
	Reproductive/ Developmental Effects	Reproductive/ Developmental Toxicants	Aliphatic alcohols, aliphatic ketones, cyclohexane, ethylbenzene
	Cancer	Leukemia	1,3-Butadiene, benzene
		Nasal tumours	Acetaldehyde, formaldehyde, propylene oxide
		Lung tumours	Benzo(a)pyrene group, methylene chloride
Chronic (oral)	Liver effects	Hepatotoxicants	Aliphatic C_9-C_{16} group, aliphatic C_{17}-C_{34} group, aromatic C_9-C_{16} group
	Kidney effects	Renal toxicants	Aromatic C_9-C_{16} group, aromatic C_{17}-C_{34} group, biphenyl

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TABLE OF CONTENTS

TABLES

4B1 INTRODUCTION

This appendix provides technical information related to the quantitative assessment of chronic exposure and the potential risks to humans from chemicals associated with the proposed North American Oil Sands Corporation (North American) Upgrader, herein referred to as the "Project".

Exposures to chemicals of potential concern (COPCs) were estimated at specified receptor locations, based on the following factors:

- Background or existing exposure to be estimated with relevant and available measured information;
- Specific physical, chemical and biological factors that determine the rate and amount of uptake of chemicals into the body;
- Physical and chemical characteristics which determine the interaction and behaviour of a chemical with its surrounding environment (e.g., water solubility, volatility, tendency to bind to particles);
- Characteristics of the sites and surrounding areas;
- Characteristics of the environmental media at the sites (e.g., air and soil), as well as the concentrations of chemicals entering the environment from various sources, and their persistence in the environment;
- Behavioural and lifestyle characteristics of potentially exposed human receptors (e.g., respiration rate, body weight); and
- Assumed empirical or theoretical mathematical or statistical relationships between human exposure variables.
- Predictions for existing air quality data were provided for the discrete receptor locations by the Air Quality team to provide an accurate estimate of ambient air predictions.

A summary of the available data (chemical concentrations) in soil, water, plants and game that were used to characterize background exposures is included within this Appendix 4D. Background exposures were estimated separately from exposures associated with the three development cases (i.e., Baseline, Application and CEA) which were estimated from exposure modeling.

Background exposures were added to Baseline, Application and CEA cases for threshold chemicals. Incremental cancer risks (not including background risks) were estimated for non-threshold chemicals (i.e., carcinogens) as recommended by Health Canada (2006) and AENV (2006).

Polycyclic aromatic hydrocarbons (PAHs) have been measured in the region but were seldom detected. Volatile organic compounds (VOCs) have typically not been measured in background assessments, as they are highly volatile and are generally not deposited to the terrestrial or aquatic environments. Background exposures to PAHs and VOCs were estimated from models that predicted uptake to environmental media (i.e., soil, water, plants and game).

4B2 ASSUMPTIONS AND METHODOLOGY

In order to quantify potential human exposures (and associated health impacts) as a result of emissions from the proposed project, measured and predicted chemical concentrations in various environmental media were required to estimate exposures and characterize risks. An inhalation assessment was conducted on both an acute and chronic basis for all identified COPCs. In addition, chemical concentrations in the following media were estimated based on air concentrations:

- Soil;
- Soil pore water;
- Indoor air and dusts;
- Wildlife game (deer, ruffed grouse); and
- Local agricultural foods (beef, dairy, poultry).

Many of the equations and assumptions used to predict environmental media concentrations were provided by the U.S. EPA OSW (2005). In addition to providing the equations and algorithms used to estimate environmental media concentrations, the following sections provide the methods used to estimate human chemical exposures, and to predict risks.

Maximum annual average ground level air concentrations were predicted at several human receptor locations identified in the Problem Formulation of the main report. These locations were divided into different groups in association with receptor type: agricultural (AGR), residential (RES), industrial/commercial (IND), public use areas (PUA) such as parks, monitoring stations (monitoring) representing predicted concentrations at these stations in the future, and fenceline receptors that may be located on or near the North American property boundary on a short-term basis.

The assessment of inhalation exposures alone (acute and chronic) involved the use of the maximum predicted air concentrations for each receptor group. The maximum predicted air concentrations for the agricultural receptor group were used to predict the concentrations of COPCs in agricultural foods. Wild game concentrations were based upon the highest predicted concentrations in the tissues out of the agricultural, residential, public use area, and monitoring receptors for all COPCs.

4B2.1 Concentrations in Soil

4B2.1.1 Background Soil Concentrations

Soil sampling was conducted from within the study area to determine the current background conditions. Six sampling locations were selected. The findings of this sampling are presented in the table below for the COPCs only (results for other substances have been omitted from this Appendix, and are provided in Appendix 4D.

4B2.1.2 Predicted Soil Concentrations

Predicted chemical concentrations in soil were based on predicted maximum annual average ground level air concentrations. Soil concentrations were estimated by applying deposition rates to air quality modeling results, and then calculating soil concentrations based on equations described below. Predicted soil concentrations are presented in Appendix 4E.

4B2.1.2.1 Background Deposition

Atmospheric deposition of organic and inorganic chemicals occurs in two modes: wet and dry deposition (Golomb et al., 1997). In wet deposition, aerosols and gases are dissolved or suspended in precipitation: rain, snow, hail, fog and mist. Dry deposition of particles occurs by direct impaction and gravitational settling on land or water surfaces.

Calculating the Wet Vapour Deposition Velocity:

$$V_{wvd} = P_a \times SR \times CF$$

Where:
V_{wvd} = velocity of wet vapour deposition [m/s]
P_a = annual precipitation rate [m/year]
SR = scavenging ratio [200,000 unitless]
CF = conversion factor from years to seconds [3.1709979E-08 year/s]

The scavenging ratio represents the ratio between the volume of air a typical raindrop will sweep through as it falls to the earth relative to the volume of the rain drop. Therefore, a typical raindrop will fall through a volume equal to 200,000 (Mackay, 1991) times its volume prior to landing on land or water. Canadian climate “normals” recorded at Fort Saskatchewan, Alberta, between 1971 and 2000 provides a precipitation rate of 459.5 mm/year (Environment Canada, 2007). Using this value the wet deposition velocity is estimated to be 0.003 m/s. The human health risk assessment assumed a wet deposition velocity of 0.004 m/s which is conservative and consistent with previous assessments.

Converting the Air Concentration to a Deposition Rate:

Combining the predicted ground level air concentration with the wet vapour deposition velocity will yield the loading rate of chemical to soil.

$$D = C_a \times VP_f \times V \times CF1 \times CF2$$

Where:
D = vapour or particulate deposition rate [mg/m^2/year]
C_a = concentration in air [ug/m^3]
VP_f = vapour or particulate phase fraction [%]
V = vapour or particulate phase deposition velocity [m/s]
CF1 = conversion factor 3.1536E+07 [s/year]
CF2 = conversion factor 0.001 [mg/ug]

4B2.1.2.2 Calculating Chemical Loss Constants

There are several processes by which chemical concentrations may be reduced in soil through losses. These processes may or may not occur simultaneously. The total rate at which a chemical is lost from soil was designated as k_s. There are five mechanisms by which compounds may be lost from soil: leaching, runoff, erosion, biotic and abiotic degradation, and volatilization.

Only abiotic and biotic degradation and volatilization processes were considered for PAHs and VOCs in this assessment.

Chemical Loss via Biotic and Abiotic Degradation:

The degradation rate can be calculated as follows if the soil half-life ($t_{1/2}$) is known:

$$ksg = \frac{0.693}{t_{1/2}}$$

For organics, soil half-life values for abiotic and biotic degradation were obtained from U.S. EPA OSW, 2005; Howard et al., 1991; and Mackay et al., 1992.

Chemical Loss via Volatilization:

The $t_{1/2}$ can also be predicted with established relationships between vapour pressure, water solubility, and soil adsorption coefficient as follows (Swan et al., 1979):

$$t_{1/2} = 1.58 \times 10^{-8} \left(\frac{K_{oc} S}{P_{vp}} \right) \quad days$$

Where:

$t_{1/2}$ = soil half-life (volatilization) [days]
K_{oc} = soil sorption coefficient [(ug/g) / (ug/ml)]
S = water solubility [mg/L]
P_{vp} = vapour pressure [mm Hg]

The half-life is then converted to a rate constant using the following equation:

$$ksv = \frac{0.693}{t_{1/2} / CF}$$

Where:

Ksv = volatilization loss rate [years-1]
t1/2 = volatilization half life [days]
CF = conversion factor [365 days/year]

Total Soil Loss Constant:

$$ks = ksg + ksv$$

Where:

ks = chemical-specific soil loss constant due to all processes (year-1)
ksg = chemical-specific soil loss constant due abiotic and biotic degradation (year-1)
ksv = chemical-specific soil loss constant due to volatilization (year-1)

4B2.1.2.3 Calculating the Deposition Term and Predicted Soil Concentration

The following illustrates the methodology used to derive soil concentrations on a mass per mass basis (ug/g), given the appropriate air dispersion data. Deposition to soil was calculated using the following equation:

$$D_s = \frac{(Ddp + Dwp + Ddv + Dwv)}{Z_s \times BD}$$

Where:
Ds = chemical-specific deposition (mg of chemical /kg of soil/year)
Ddp = chemical-specific dry particle deposition rate (mg/m^2/year)
Dwp = chemical-specific wet particle deposition rate (mg/m^2/year)
Ddv = chemical-specific dry vapour deposition rate (mg/m^2/year)
Dwv = chemical-specific wet vapour deposition rate (mg/m^2/year)
Zs = soil mixing zone depth (m)
BD = soil bulk density (kg soil/m^3 soil)

$$C_s = \frac{D_s \times [1 - \exp(-ks \times tD)]}{ks}$$

Where:
Cs = average soil concentration over exposure duration (mg/kg soil)
Ds = deposition term (mg of chemical/kg soil/year for untilled and tilled soils, respectively)
ks = chemical soil loss constant due to all processes (year-1)
tD = time period over which deposition occurs (years)

4B2.1.2.4 Application Case Deposition

COPC deposition rates were estimated by using methods described above.

4B2.1.3 Surface Water Concentrations

Measured and predicted surface water concentrations of metals were evaluated in Appendix 4D, and no adverse impacts to health are anticipated. All measured surface water concentrations for PAHs available from recent assessments in the area (PCOSI, 2006) were less than analytical detection limits. Due to the lack of a reliable data set of detectable values, surface water concentrations as they relate to plants and animals were predicted from airborne deposition to soil and subsequent runoff.

Predicted Surface Water Concentrations

$$C_w = C_s \text{ x } (BD / (Pw + (K_d * BD) + H * P_a))$$

Where,
C_w = concentration in runoff
P_w = moisture filled porosity for fine soils (0.168, dimensionless) from AENV (2006)
P_a = vapour filled porosity for fine soils (0.32, dimensionless) from AENV (2006)

K_d = soil to water partition coefficient from AENV (2006) and CCME (2006)
BD = soil bulk density (1500 kg/m^3) from AENV (2006)
H = unitless Henry's constant

Due to the effect of dilution in the movement of surface water to a surface water body, Cw is assumed to be diluted by a factor of 10.

$$C_{sw} = C_w/DF$$

Where,
C_w = concentration in runoff
DF = dilution factor (10, unitless).

4B2.1.4 Plant Concentrations

4B2.1.4.1 Background Plant Concentrations

Appendix 4D provides Background conditions from the plant sampling program.

4B2.1.4.2 Predicted Plant Concentrations

The uptake of chemicals into vegetation (*i.e.*, root vegetables, leafy vegetables, forage, grain and fruit) is a topic that has been extensively reviewed in the literature. Chemical emissions to the atmosphere may be taken up by vegetation from three sources: particulate in air (dust or aerosols); vapours in air (gases); and, subsurface compartments (soil, water) (Rolfe, 1972; Baes, 1982; Travis and Hattemer-Frey, 1988; Boon and Sultanpour, 1992; Muller et al., 1993; Schroll and Scheunert, 1993; McCrady and Maggard, 1993). The magnitude of uptake from these sources has been correlated with physical/chemical parameters (vapour pressure, octanol water partition coefficient, etc.), soil parameters (fraction of organic carbon, soil moisture, clay content, etc.), plant parameters (lipid content, moisture content, etc.) and with chemical concentrations in air and other environmental media (U.S. EPA OSW, 2005).

The methodology used to estimate the contribution from each route of chemical uptake in vegetation is described in the following sections. Predicted plant tissue concentrations are presented in Appendix 4D based on the maximum air concentration predicted for each chemical out of the agricultural, residential, public use and monitoring locations. All of these receptor location groups were considered, as it is feasible that larger animals may graze in various locations within the area over a lifetime.

The following sources of chemical uptake into the tissues of plants were considered, and are described in detail below:

- Direct deposition of particles onto plant produce;
- Air to aboveground plant produce (vapour transfer to leaves / foliage);
- Soil to aboveground plant produce; and
- Soil to belowground plant produce.

4B2.1.5 Plant Chemical Concentration Due to Direct Deposition

Atmospheric deposition was only considered for plants whose edible portions are above the ground and where the chemical potentially exists in particulate form. The following equations were used to predict produce concentration due to direct wet and dry deposition processes.

$$Pd = \frac{0.001 \times \left[Ddp + \left(Fw \times Dwp\right)\right] \times R_p \times \left[1.0 - \exp\left(-kp \times Tp\right)\right]}{Yp \times kp}$$

Where:

Pd = plant (aboveground produce) concentration due to direct (wet and dry) deposition (mg of chemical/ kg DW)
Ddp = yearly average dry deposition from particle phase (ug/m^2/year)
Dwp = yearly average wet deposition from particle phase (ug/m^2/year)
0.001 = mg/ug conversion factor
Rp = intercept fraction of edible portions of plant (unitless)
kp = plant surface loss coefficient (year-1)
Tp = length of plant exposure to deposition per harvest of the edible portion of the ith plant group (unitless)
Yp = crop yield or productivity (kg DW(dry weight)/m^2)
Fw = fraction of chemical wet deposition that adheres to plant (unitless; 0.2 for anions and 0.6 for cations and most organics recommended; used 0.6)

4B2.1.5.1 Intercept Fraction

The U.S. EPA OSW recommends the use of the default Rp value since it represents the most current information available with respect to productivity and relative ingestion rates. Experimental studies as summarized by Baes et al. (1984), suggested a correlation between interception fractions and productivity (standing crop biomass (Yp) Chamberlain 1970):

$$Rp = 1 - e^{-\gamma Yp}$$

Where:

Rp = intercept fraction of the edible portion of the plant (unitless)
e = empirical constant Chamberlain (1970) presents a range of 2.3 to 3.3
Yp = yield or standing crop biomass (productivity) (kg WW/m^2)

Initially, Baes et al. (1984) developed intercept fractions values for three classes of vegetation (vegetables, silage and exposed produce). These intercept fractions were independent of plant specific crop yields and as a result led to surface plant concentration predictions that were unreasonable. Baes et al. (1984) used an empirical constant developed by Chamberlain (1970), which was then used to generate class-specific empirical constants (γ). The U.S. EPA (1994c) and U.S. EPA (1995b) proposed a default aboveground Rp value of 0.05. These values were weighted by relative ingestion of each class to derive a weighted average. The relative ingestion rates used by U.S. EPA (1994c) and U.S. EPA (1995b) were not consistent with the Exposure Factors Handbook (U.S. EPA 1997), and therefore the suggested value of 0.05 is no longer used. As a result, produce classes were combined into two groups - exposed fruit and exposed vegetables. The exposed produce constant (γ) of 0.0324 developed by Baes et al. (1984) was used to estimate an Rp value. As the exposed produce category includes leafy vegetables and fruiting vegetables, Rp was calculated for both leafy and fruiting vegetables. For exposed vegetables, Rp was determined by a weighted average of the crop yields of leafy and fruiting vegetables. Relative ingestion rates from the Exposure Factors Handbook (U.S. EPA, 1997) were then used to derive a weighted Rp value 0.39 for garden produce and 0.5 for forage (U.S. EPA OSW, 2005).

4B2.1.5.2 Plant Surface Loss Coefficient

The U.S. EPA (1990) identified several processes that contributed to the loss of contaminants on vegetative surfaces. The three mechanisms of removal considered included wind removal, water removal and growth dilution. These three mechanisms or processes contribute to the reduction of contaminant that has deposited on vegetative surfaces. The *kp* value is a measure of the amount of contaminant loss due to these three mechanisms. Miller and Hoffman (1983) used the following relationship to relate half-life times to *kp* values.

$$kp = (\ln 2 / t_{1/2}) \times 365 days / year$$

Where:
$t_{1/2}$ = half-life (days)

Miller and Hoffman (1983) reported half-life values of 2.8 to 34 days for a number of different chemicals on vegetative surfaces, which resulted in *kp* values of 7.44 to 90.36 (year^{-1}). As a result, the U.S. EPA (1993), U.S. EPA (1994a) and the U.S. EPA OSW (2005) recommend a default *kp* value of 18, which corresponds to a 14 day half-life.

4B2.1.5.3 Growing Season or Length of Plant Exposure per Year

Belcher and Travis (1989) estimated that forage crops are exposed on average approximately 60 days during the growing season, before harvest. U.S. EPA (1990), U.S. EPA (1993) and the NC DEHNR (1997) recommend a value of 60 days or 0.164 years. Similar assumptions were made for the growing season of garden produce.

4B2.1.5.4 Yield or Standing Crop Biomass or Productivity

The U.S. EPA OSW (2005) recommends using a value of 0.24 kg DW/m^2 for forage and 2.24 kg DW/m^2 for garden produce. Based on a review of recent literature, these values appeared to be the most appropriate. The following equation is used to estimate the forage or crop yield:

$$Yp = \frac{Yh_i}{Ah_i}$$

Where:
Yp = yield (kg/ DW/m2)
Yh_i = harvest yield of the ith crop (kg DW)
Ah_i = area planted to the ith crop (m^2)

4B2.1.5.5 Fraction of Chemical that Adheres to Plant Surfaces

The U.S. EPA OSW (2005) recommends using the chemical class-specific values of 0.2 for anions and 0.6 for cationic compounds. This parameter describes the fraction of wet deposition that would adhere to plant surfaces.

4B2.1.5.6 Empirical Correction Factor

Lipophilic compounds (*i.e.*, those compounds with Log K_{ow} greater than 4) are generally not able to pass through the skin to the inner portions of bulky produce as easily as those compounds which tend to be more water soluble (*i.e.*, with Log K_{ow} less than 4). Therefore the U.S. EPA OSW (2005) recommends using an empirical constant of 0.01 for those compounds considered more lipophilic (i.e., Log K_{ow} greater than 4) and a constant of 1 for those with Log K_{ow} less than 4.

4B2.1.6 The Air-to-Plant Biotransfer Factor for Aboveground Produce

The air-to-plant biotransfer factor (Bv) can be defined as the ratio of chemical in aboveground plant parts to the concentration of chemical in ground-level air (U.S. EPA OSW 2005). According to the U.S. EPA (1995a), root vegetables are protected from this mechanism of uptake. For all organic chemicals, the air-to-plant transfer factors were based on work with azalea leaves by Bacci et al. (1990 and 1992).

The following equation was used to calculate aboveground plant tissue concentrations:

$$P_v = \frac{C_{air} \times B_v \times F_v \times VG_{ag}}{\rho_{air}}$$

Where:

P_v = COPC concentration in plant (mg/kg wet weight)
C_{air} = COPC concentration in air (mg/m^3)
B_v = mass-based air-to-plant biotransfer factor (ug/g dry-weight plant / ug/g air)
F_v = Fraction of chemical in vapour phase
VG_{ag} = Empirical correction factor for aboveground forage (unitless)

Conversion to wet weight (WW):

$$P_v \ (wet\ weight) = P_v \ (dry\ weight) \times (1 - MC)$$

Where:

MC = fraction of plant that is water (0.85; McCrady and Maggard 1993)

Studies based on the Welsch-Pausch et al. (1995) experiments, as by Lorber (1995), suggested a factor of 100 be applied to all biotransfer factors for organics estimated using the Bacci et al. (1992) methodology.

The following equation was derived by Bacci et al. (1992) and is based on the evaluation of 14 different compounds to develop a relationship with K_{ow} and Henry's Law.

$$\log B_{vol} = 1.065 \log K_{ow} - \log\left(\frac{H}{RT}\right) - 1.654$$

Where:

B_{vol} = volumetric air-to-plant biotransfer factor (fresh-weight basis)
log K_{ow} = log of the octanol-water partition coefficient (unitless)

H = Henry's Law constant of the compound (atm m^3/mol)
T = room temperature in Kelvin (293 K)
R = gas constant (8.207E-05 atm m^3/K mol)

The mass based air-to-plant biotransfer factor is calculated with the following equation:

$$B_v = \frac{\rho_{air} \times {B_{vol}}/{RF}}{\left(1 - \int_{water}\right) \times \rho_{forage}}$$

Where:

B_v = mass-based air-to-plant biotransfer factor (ug/g dry-weight plant / ug/g air)
RF = reduction factor (100 for organics; U.S. EPA OSW 2005)
ρ_{air} = density of air 1.19 g/L (Weast 1981)
ρ_{forage} = 770 g/L (McCrady and Maggard 1993) density of forage
f_{wate}r = 0.85 (fraction of forage that is water; McCrady and Maggard 1993)

4B2.1.7 Above and Below Ground Vegetation Concentrations

Contaminants present in soil may be taken up into edible portions of above and belowground plants. As a result, two methods of predicting contaminated concentration in edible plant concentrations have been recommended by the U.S. EPA OSW (2005). These methods are consistent with other U.S. EPA guidance documents (U.S. EPA 1994b; U.S. EPA 1994c; and U.S. EPA 1995b).

4B2.1.7.1 Aboveground Plants

$$\Pr = \left(Cs \times Br_{ag} \right) \times \left(1 - MC\right)$$

Where:

Pr = contaminant concentration in produce as a result of root uptake (mg/kg)
Cs = tilled soil concentration (mg/kg soil)
Br_{ag} = plant-soil bioconcentration factor for aboveground produce (unitless; calculated below for organics)
MC = 0.85 (fraction of forage that is water; McCrady and Maggard 1993)

A substantial amount of empirical data available in the literature demonstrates there is significant uptake of organics into plants. Organic chemicals in soils were reported to be taken up by vegetation (*i.e.*, carrots, tomatoes, potatoes and narcissus) through the roots (Iwata and Gunther 1976; Cocucci et al. 1979; Bacci and Gaggi 1985; Travis and Arms 1988; Schroll and Scheunert 1993). Travis and Arms (1988) reported that uptake of organic chemicals by vegetation is correlated to octanol-water partition coefficients (K_{ow}).

The method of Travis and Arms (1988), as modified by Travis and Blaylock (1992), was used to estimate the bioconcentration of organic chemicals from soil to vegetation *via* root uptake. This method was based on measured data that demonstrated that the bioconcentration factor for an organic chemical in vegetation is inversely proportional to the square root of the octanol-water partition coefficient (K_{ow}). Root uptake of organics has been correlated with K_{ow} and has been shown to decrease as K_{ow} increases (Briggs et al. 1982; in Travis and Blaylock 1992). A geometric mean regression analysis of data for 29 different organic chemicals demonstrated a relationship between bioconcentration factors in vegetation and octanol-water partition coefficients (r = 0.73) (Travis and Arms 1988). The first step of the method of Travis and Arms (1988), as modified by Travis and Blaylock (1992), is to calculate a chemical-specific bioconcentration factor for vegetation. The bioconcentration factor for aboveground vegetation (Br_{ag}) is defined as the ratio of the concentration in the plant (ug of chemical/g of dry plant) to the concentration of the chemical in the soil (ug of chemical/g of dry soil). The Br_{ag} can be calculated for organic chemicals according to the formula:

For organics only:

$$Br_{ag} = 38.73 K_{ow}^{-0.578}$$

4B2.1.8 Belowground Produce

Belowground produce refers to all root-vegetables and therefore concentrations derived using this methodology would only be applied to root-vegetable consumption rates.

$$\mathrm{Pr}_{bg} = \left(Cs \times Br_{rootveg} \times Vg_{root} \right) \times \left(1 - MC\right)$$

Where:

Pr_{bg} = contaminant concentration in belowground produce as a result of root uptake (mg/kg)
Cs = soil concentration (mg/kg soil)
$Br_{rootveg}$ = plant-soil bioconcentration factor for belowground produce (unitless; calculated below for organics only)
Vg_{root} = empirical correction factor for belowground produce (1; unitless)
MC = 0.85 (fraction of forage that is water; McCrady and Maggard, 1993)

Vg_{root} is dependant on the lipophilic nature of the chemical of concern. For compounds with a Log Kow greater than 4, an empirical correction factor of 0.01 was assigned and for compounds with a Log Kow less than 4, a value of 1.0 was applied.

Where the plant-soil bioconcentration factor for belowground produce is as follows:

$$Br_{rootveg} = \frac{RCF}{Kd_s}$$

The root concentration factor (RCF) for organic compounds has been obtained from Briggs et al., 1982.

The following equation estimates a RCF value in fresh weight. The following equation must be adjusted to a dry weight basis using a moisture content of 85 percent in root vegetables (Pennington, 1994). This relationship is recommended by other regulatory documents such as U.S. EPA (1994a).

$$Log\left(RCF - 0.85\right) = 0.77 Log K_{ow} - 1.52$$

The soil-water partitioning coefficient (Kd_s) describes the partitioning of a chemical between soil pore-water and soil particles. For organics, Kd_s has been defined by the following equation:

$$Kd_s = K_{oc} \times f_{oc,s}$$

Where:

K_{oc} = soil organic carbon-water partition coefficient (mL/g)
$f_{oc,s}$ = fraction organic carbon in soil (U.S. EPA OSW 1998)

4B2.1.9 Tissue Concentrations in Livestock and Game

4B2.1.9.1 Predicted Tissue Concentrations

Livestock (i.e., cattle and chickens) and wild game (i.e., deer and ruffed grouse) tissue concentrations were calculated following the U.S. EPA OSW (2005) methodology. For the purpose of estimating tissue residue levels, animals were assumed to be exposed to chemicals through consumption of potentially impacted soil, water and food. Measured background data was used for soil, forage and surface water where possible for the background case.

Estimated soil and forage concentrations were based on a similar methodology to that used for predicting soil and plant concentrations as described previously. Chemical concentrations in drinking water for the livestock and wild game were predicted based on measured surface water concentrations. In addition, atmospheric deposition of the COPCs to soils and subsequent runoff to a small water body (i.e., dugout or lagoon) was incorporated in the estimation of chemical concentration in drinking water. Atmospheric deposition was not included in the predicted COPC concentrations in drinking water for chickens as drinking water is typically supplied via indoor water troughs.

Predicted livestock and wild game tissue concentrations are listed in Table 4E-1 in Appendix 4E. Livestock tissue concentrations were based on maximum predicted air concentrations of the agricultural receptor locations, whereas the maximum predicted air concentrations of the agricultural, residential, public use area, and monitoring receptor locations were used to predict wild game tissue concentrations.

The following equations were used to calculate the total daily dose of a chemical for an animal via the ingestion of soil, food and water, as well as the inhalation of air. Biotransfer factors (BTF) have been included based on the U.S. EPA OSW (2005) to translate the estimated daily dose of a chemical (mg of chemical/day) from the various environmental media to a tissue concentration for each persistent and bioaccumulative COPC. When empirical data are lacking, one of the most widely used approaches is the regression model developed by Travis and Arms (1988), however these regressions are hampered by the limited log K_{ow} range and questions surrounding the validity of the underlying biotransfer data set. New biotransfer models have been developed (RTI 2005) and incorporated within the assessment as recommended by the U.S. EPA OSW (2005). The following equation was developed to predict the transfer rate of chemical intake into fat tissue. The fat tissue concentration is converted to a tissue concentration based on the fat content of the desired tissue (i.e., muscle or milk).

4B2.1.9.2 Determination of Biotransfer Factors

$$\log(BTF) = -0.099 \times \log(K_{ow})^2 + 1.07 \times \log(K_{ow}) - 3.56$$

Where:

BTF = biotransfer factor ([mg/kg-fat] / [mg/day])
K_{ow} = octanol water coefficient

The BTF was adjusted to account for the fat content of milk or muscle. Meat fat content was assumed to The BTF equation is appropriate for organic chemicals lacking empirical biotransfer data and having a log K_{ow} between -0.67 and 8.2.

The BTF was adjusted to account for the amount of fat in the tissue based on the following equation:

$$BTF_a = BTF \times FC \text{ x MF}$$

Where:

BTF_a = adjusted BTF for fat content of tissue ([mg/kg-tissue] / [mg/day])
BTF = biotransfer factor ([mg/kg-fat] / [mg/day])
FC = fat content of tissue (%)
MF = metabolizing factor (0.01, Hofelt et al., 2001)

4B2.1.9.3 Determination of Surface Water Concentration

Surface water concentrations for all scenarios except background (where measured concentrations were used) were calculated using the following formula:

$$Cw = Cs \times \frac{BD}{Pw + (kd \times BD) + (H * Pa)}$$

Where;

Cw = future water concentration (ug/L)
Cs = soil concentration
BD = soil bulk density (1,500, AENV, 2006)
Pw = moisture filled porosity for fine soils (dimensionless) from AENV (2006)
Kd = soil to water partition coefficient from AENV (2006)
H = Henry’s Law Constant (unitless)
Pa = vapour filled porosity for fine soils (dimensionless) from AENV (2006)

4B2.1.9.4 Determination of Game Meat Concentrations

Chemical concentrations in game meat were then predicted based on the following equation:

$$C_{animal} = BTF_a \times \sum \left(C_{Pi} \times P_{Pi} \times F_{Pi} \times FIR \right) + \left(C_{soil} \times SIR \times P_{Soil} \right) + \left(C_{water} \times WIR \right)$$

Where:
C_{animal} = chemical concentration in animal (mg/kg)
BTF_a = adjusted BTF for fat content of tissue ([mg/kg-tissue] / [mg/day])
C_{Pi} = COPC concentration in ith plant food item (mg/kg)
P_{Pi} = proportion of ith plant food item in diet that is contaminated (unitless)
F_{Pi} = fraction of diet consisting of ith plant food item (unitless)
FIR = food ingestion rate (kg/day)
C_{soil} = COPC concentration in soil (mg/kg)
SIR = soil ingestion rate (kg/day)
P_{soil} = proportion of soil in diet that is contaminated (unitless)
C_{water} = COPC concentration in water (calculated below) (mg/L)
WIR = water ingestion rate (L/day)

4B2.2 Calculation of Breast Milk Biotransfer Factor

The potential health effects associated with the ingestion of chemical-impacted breast milk by nursing infants was considered in the current assessment. COPCs with the tendency to bio-accumulate were assessed for the infant's exposure to the mother's milk. The maximum fraction of each COPC expected to bioaccumulate was calculated using the following approach (example given for naphthalene):

$$BM_{BTF} = 2.0E\text{-}07 \times K_{ow} \quad \text{(McKone, 1992)}$$

Where:
BM_{BTF} = breast milk biotransfer factor ([μg/kg milk]/[μg/day intake])
K_{ow} = octanol-water partition coefficient

4B2.2.1 Calculation of Chemical Concentration in Breast Milk

$$CBM = \frac{EXP_{mother} \times BW_{mother} \times BM_{BTF}}{1000}$$

Where:
CBM = chemical concentration in breast milk (ug/g milk)
EXP_{mother} = mother's total daily exposure to chemical via all routes (ug/kg/day)
BW_{mother} = mother's body weight (kg)
BMBTF = breast milk biotransfer factor (ug/kg milk)/(ug/day intake)
1000 = unit conversion factor (g/kg)

4B2.2.2 Air Concentrations

Background air concentrations were included for predicting total exposures to the COPCs, including indoor air concentrations. As described in the main report, existing air concentrations for all discrete receptor locations were predicted in the Air Quality team, and were used to represent background outdoor air concentrations in this assessment. For indoor air, preference was given to background data from the region where possible. In the event that such data was not available, urban Canadian data was applied as necessary.

Acute background air concentrations were not evaluated within this assessment, as the available data represented sampling periods over a number of days. Thus, maximum, median or mean indoor and outdoor air concentrations were evaluated within the chronic assessment only as appropriate.

4B2.3 Drinking Water Concentrations

The concentrations of the COPCs in both treated and untreated drinking water in the area (EPCOR, 2007; Shell, 2007) were determined to be below analytical detection limits. Thus, no reliable data set of measured values exists. As such, drinking water was not evaluated within the HHRA.

4B2.4 Fish Concentrations

4B2.4.1 Background Fish Concentrations

Measured data from the area for both fish tissue and surface water were evaluated to determine the most representative background fish tissue concentrations for the multi-pathway assessment. Surface water concentrations and fish tissue concentrations of the COPCs were all determined to be below analytical detection limits in other assessments completed recently in the area (PCOSI, 2006). As there is no reliable, measured data available, fish consumption was not considered in the HHRA.

4B2.4.2 Predicted Fish Concentrations

As no impacts on water quality or fish health were anticipated in association with the Project, the change in fish concentrations from background were assumed to be zero.

4B2.4.3 Conversion from Dry Weight to Wet Weight

The current methodology estimates vegetation concentrations on a dry weight basis. Since home-grown produce will be consumed on a fresh weight basis, dry weight concentration estimates were converted to a fresh (or wet) weight basis. A moisture content of 85% was used to represent average moisture content of vegetation. The following equation was used to estimate media concentrations on a fresh (or wet) weight basis:

$$\left(Wet\ Weight\ Conc.\right) = \left(Dry\ Weight\ Conc.\right) \times \left(1 - \frac{moisture\ content}{100}\right)$$

4B2.5 Human Receptor Characteristics

4B2.5.1 Receptor Selection

Air quality predictions were available for over 500 receptor locations. Predictions for Edmonton were excluded due to a lack of relevance to the human health assessment. The remaining receptor locations were divided into receptor groups based upon location and potential receptor characteristics.

The receptors that have the highest likelihood of being adversely affected by the COPCs are included in the assessment to represent estimates of reasonable maximum exposure.

The rationale behind this approach is that, if health risks are not identified for highly exposed and susceptible individuals, risks are also likely to be negligible in individuals who received a lower degree of exposure, or who may be less susceptible to the effects of the COPCs. The distinction between the receptor types is necessary, as food consumption patterns and behaviours (e.g., time spent at the site) varies between the groups of people evaluated.

The HHRA for this Project evaluated the potential for adverse health effects to occur in association the Project emissions in individuals who reside in the area 24-hours/day, 7-days/week, 52-weeks/year, as well as those who may work at industrial/commercial locations, or may use public recreational areas within the study area.

Six hypothetical receptor types were included in the HHRA:

- **Agricultural Receptor (AGR):** Includes receptors in the area who live in agricultural areas, and are assumed to obtained 100% of their game, fish, fruit and vegetables from local sources. Agricultural food products such as beef, eggs, poultry and dairy were also included in the assessment for the agricultural receptor, as it is feasible that local products may be consumed on a regular basis It is assumed these receptors live in the area over a lifetime, and are exposed to air, dusts, drinking water, and local foods. All receptor locations that were agricultural in nature within a 4 km radius of the Project were included in this group. In the event that it was not evident whether an active agricultural operation was present at the site, or whether individuals live at the site, it was conservatively assumed that these receptor locations were part of the agricultural group.

- **Residential Receptor (RES):** This group includes receptors who reside in nearby communities. These individuals are assumed to consume some local game meats and garden produce, but the majority of their diet is from non-local sources (e.g., supermarket foods). It is assumed these receptors live in the area over a lifetime, and are exposed to vapours, dusts, drinking water, and local foods.

- **Industrial/Commercial (IND):** Individuals who may work at industrial/commercial sites within the study area, but do not consume local foods on a regular basis over a lifetime (if the workers are local, the assumptions in the agricultural and residential scenarios above would apply). It is also assumed that these receptors are exposed over a lifetime to vapours and dusts.

- **Public Use Area (PUA):** Receptors who visit the area for recreational purposes on an occasional basis during the year. This receptor group includes areas such as parks, campgrounds, etc., within the area. Inhalation exposure is evaluated for this.

- **Monitoring Stations (MON):** Several air quality monitoring stations are within the study area, and have been included in this assessment in order to evaluate the potential for health effects at the monitoring site locations in the future.

- **Fenceline:** Air concentrations at the edge of the North American lease boundary were evaluated to represent a reasonable estimate of maximum concentrations to which transient receptors may be exposed to on a short-term basis.

The agricultural and residential receptor groups both represent individuals who reside in the area over a lifetime, with the only distinctions between the two groups being location (urban vs. farm), and the higher consumption rates. All receptor locations within agricultural and rural areas were included in the agricultural group. Residents of nearby communities with developed residential areas (Bon Accord, Bruderheim, Gibbons, Josephburg, Lamont, Redwater) were included in the residential receptor group.

Industrial locations within the study area incorporated into the assessment included the properties owned by Degussa Canada., North West Upgrading, Providence Grain, Nikoforuk Construction, Provident Energy, Agrium Products, Shell Canada, Value Creations, and Ag-Oil Alberta.

Public Use Areas that were evaluated as part of the assessment included the Bruderheim Natural Area, Astotin Natural Area, Fort Saskatchewan Natural Area, Redwater Natural Area, and Elk Island National Park.

In addition, several monitoring stations (MON) were evaluated. These receptor locations include monitoring stations in various areas (residential, rural and public use areas) including several passive monitoring stations.

A construction worker scenario was not specifically evaluated, given that the HHRA focused on a reasonable maximum exposure that assumed the Project was fully operational. During construction, the Project is not under operation, thus the workers are not exposed to Project emissions. The assessment of the other receptor types (for example, agricultural or residential) involve more conservative exposure estimates, and cover any individual who may live or work within the area (including but not limited to construction workers) given that individuals who consume local water and foods in addition to being exposed to air will have a greater total exposure to the COPCs.

A list of the receptor locations and groups are provided below. The fenceline receptor group was comprised of 327 discrete receptor locations, and the monitoring group consisted of 59 locations. As these groups represent hypothetical receptors, details regarding their specific locations are not detailed below. A list of the detailed receptor locations is provided in Appendix 4B1.

Table 4B-1 Summary of Receptor Groupings for Discrete Receptor Locations

Receptor Group	**Receptor Numbers Included in Group**
Agricultural (AGR)	506, 507, 508, 509, 510, 511, 512, 513, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623
Residential (RES)	484, 485, 486, 487, 488, 489, 553
Industrial/Commercial (IND)	490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 514, 526, 595
Public Use Area (PUA)	501, 502, 503, 504, 505
Monitoring (MON)	425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472 ,473, 474, 475, 476, 477, 478, 479

Receptor Group	Receptor Numbers Included in Group
Fenceline (fenceline)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173,174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230 ,231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243 ,244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254 ,255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273 ,274, 275, 276, 277, 278, 279, 280, 281 ,282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327

4B2.5.2 Agricultural (AGR) Receptor

The agricultural receptor is conservatively assumed to obtained 100% of agricultural foods (beef, dairy, poultry, eggs), fruits and vegetables, game (deer and grouse), and fish from local sources. All consumption rates for the agricultural receptor were obtained or derived from Health Canada (2004a), Health Canada (1994), or O'Connor and Richardson (1997). A summary of the consumption rates and general characteristics of the agricultural receptor are presented below.

Table 4B-2 Summary of Receptor Characteristics for the Agricultural Receptor

Parameter	Unit	Adult	Adolescent	Child	Toddler	Infant	References
Body weight	kg	70.7	59.7	32.9	16.5	8.2	Health Canada,2004
Inhalation rate	m^3/d	15.8	15.8	14.5	9.3	2.1	Health Canada, 2004
Soil ingestion	g/day	0.02	0.02	0.02	0.08	0.02	Health Canada, 2004
Root Vegetables	g/day	188	227	161	105	83	Health Canada, 2004
Leafy Vegetables	g/day	137	120	98	67	72	Health Canada, 2004
Fruit	g/day	46	56	69	40	5	Health Canada, 1994; sum of consumption rates for apples, applesauce, cherries, strawberries, blueberries, jams and honey
Beef	g/day	90	89	53	37	32	Health Canada, 1994; sum of consumption rates for steak, roast and stewing beef, ground beef, pork and lamb
Dairy	g/day	297	590	622	677	546	Health Canada, 1994; sum of consumption rates for whole mil,, 2% milk, skim milk, evaporated milk, cream, ice cream, yogurt, cheese, cottage cheese, processed cheese, butter

Parameter	Unit	Adult	Adolescent	Child	Toddler	Infant	References
Poultry	g/day	21	20	17	13	0	Health Canada, 1994; assumed 100% of chicken consumption rate
Eggs	g/day	32	22	21	24	5	Health Canada, 1994
White-tailed deer	g/day	90	89	53	37	32	Assumed 100% of beef consumption rate (above)
Grouse	g/day	21	20	17	13	0	Assumed 100% of poultry consumption rate (above)
Breast milk	g/day	0	0	0	0	664	O'Connor and Richardson, 1997

Skin surface area and soil loading rates were obtained from Health Canada (2004).

4B2.5.3 Residential (RES) Receptor

Several of the assumptions made for the agricultural receptor were determined to not be as relevant to individuals who do no live on agricultural land and spend most of their time in communities. Food consumption rates were obtained from the same sources as the agricultural receptor, but adjusted to reflect that less locally-sourced food would be consumed and a larger portion of the diet would come from non-local sources (e.g., supermarket items).

The consumption rates and characteristics for the residential receptor are presented below.

Table 4B-3 Summary of Receptor Characteristics for the Residential Receptor

Parameter	Unit	Adult	Adolescent	Child	Toddler	Infant	References
Body weight	kg	70.7	59.7	32.9	16.5	8.2	Health Canada, 2004
Inhalation rate	m^3/d	15.8	15.8	14.5	9.3	2.1	Health Canada, 2004
Soil ingestion	g/day	0.02	0.02	0.02	0.08	0.02	Health Canada, 2004
Root Vegetables	g/day	19	23	16	11	8	Health Canada (2004) adjusted with CCME (1996) factor for proportion of home-grown garden produce consumed
Leafy Vegetables	g/day	14	12	10	7	7	Health Canada (2004) adjusted with CCME (1996) factor for proportion of home-grown garden produce consumed
Fruit	g/day	5	6	7	4	1	Health Canada (1994) Health Canada (2004) adjusted with CCME, 1996 factor for proportion of home-grown garden produce consumed
Beef	g/day	--	--	--	--	--	
Dairy	g/day	--	--	--	--	--	
Poultry	g/day	--	--	--	--	--	
Eggs	g/day	--	--	--	--	--	

Parameter	Unit	Adult	Adolescent	Child	Toddler	Infant	References
White-tailed deer	g/day	45	44	26	18	16	Assumed 50% of beef consumption rate (above) for AGR
Grouse	g/day	11	10	8	7	0	Assumed 50% of poultry consumption rate (above) for AGR
Breast milk	g/day	0	0	0	0	664	O'Connor and Richardson, 1997

4B2.5.4 Industrial (IND) Receptor

The behaviour patterns of workers at the various industrial facilities in the area are likely to be different than those of the long-term residents. Inhalation pathways, and the dermal contact and dust ingestion exposure pathways were assumed to be relevant to this receptor, while the consumption of local foods and water were not.

The body weights, soil ingestion rate, and inhalation rates for the residential receptors (presented above) were applied for the industrial receptors. Skin surface area and soil loading rates were obtained from Health Canada (2004), as both the dermal and oral pathways were evaluated.

4B2.5.5 Public Use Area (PUA) Receptor

The public use area receptor was assessed only in relation to the inhalation pathway, as the behaviour characteristics of this receptor type is such that the duration of time that a person would be in the area would be limited, and their exposure to COPCs via the dermal and oral pathways would be negligible. Thus, receptor characteristics for this receptor related to the oral and dermal contact pathways are not provided as for the other receptor types.

4B2.5.6 Monitoring (MON) Receptor

The monitoring receptor was assessed only in relation to the inhalation pathway. This receptor is hypothetical, as these locations represent monitoring stations in various areas, rather than specific individuals. However, they are of relevance, as existing and future air concentrations of the COPCs are evaluated for these locations. Receptor characteristics for this receptor related to the oral and dermal contact pathways are not provided as for the other receptor types.

4B2.5.7 Fenceline Receptor

The fenceline receptor was assessed only in relation to the inhalation pathway on an acute basis only. This receptor is intended to represent a transient individual who may be present around the North American site boundary on an occasional basis, for a short-duration of time. Residents are not considered to be a part of this group.

4B3 EQUATIONS AND ALGORITHMS USED TO ESTIMATE HUMAN EXPOSURE RATES

The following section identifies the algorithms used to estimate human exposure. Similar methods were used to evaluate all receptors, receptor locations, and COPCs.

4B3.1 Total Exposure from Consumption of Agricultural Foods

4B3.1.1 Consumption of Belowground Produce

$$EVR = \frac{CVR \times AVC \times WP \times RF_{oral} \times FHP}{BW}$$

Where:

EVR = daily exposure from belowground vegetables (ug/kg/day)
CVR = total plant concentration as a result of root uptake (ug/g fresh weight)
AVC = amount of root vegetables consumed per day (g/day)
RF_{oral} = relative bioavailability of compound (%)
FHP = fraction of vegetation that is from home garden (%)
BW = receptor body weight (kg)
WP = washing and food preparation factor (15% reduction, U.S. EPA OSW 1998; 100 - 15 = 85% or 0.85).

4B3.1.2 Consumption of Aboveground Leafy Vegetables

$$EVL = \frac{CVL \times AVL \times WP \times RF_{oral} \times FHP}{BW}$$

Where:

EVL = daily exposure from aboveground leafy vegetables (ug/kg/day)
CVL = total plant concentration (ug/g fresh weight)
AVL = amount of leafy vegetables consumed per day (g/day)
RF_{oral} = relative oral bioavailability of compound (%)
FHP = fraction of vegetation that is from home garden (%)
BW = receptor body weight (kg)
WP = washing and food preparation factor (15% reduction, U.S. EPA OSW 1998; 100 – 15 = 85% or 0.85)

4B3.1.3 Consumption of Fruit/Berries

$$EVF = \frac{CVF \times AVF \times WP \times RF_{oral} \times FHP}{BW}$$

Where:

EVF = daily exposure from fruits (ug/kg/day)
CVF = total fruit concentration (ug/g fresh weight)
AVF = amount of fruit consumed per day (g/day)
RF_{oral} = relative oral bioavailability of compound (%)
FHP = fraction of fruit that is from impacted site (%)
BW = receptor body weight (kg)
WP = washing and food perpetration factor (0% reduction for fruits; U.S. EPA OSW 1998; 100 - 0 = 100% or 1.0).

4B3.1.4 Total Home-grown Produce Exposure

$$EVT = EVL + EVF + EVR$$

Where:
EVT = total exposure from fruits and vegetables (ug/kg/day)

4B3.1.5 Calculation of Human Exposure via Consumption of Game or Fish Tissue

The chemical exposure from consumption of game is shown below (moose is used as an example)

$$Exp_{tissue} = \frac{C_{tissue} \times R_{tissue} \times BIO_{oral}}{BW}$$

Where:
Exp_{tissue} = receptor's daily exposure to chemical (ug/kg/day)
C_{tissue} = chemical concentration in tissue (ug/g fresh weight)
R_{tissue} = amount game tissue consumed (g/day)
BIO_{oral} = relative oral bioavailability of the compound (%)
BW = receptors body weight (kg)

4B3.2 Estimation of Exposure from Air

Direct Air Inhalation

Direct Air Inhalation Exposure on Outdoor days:

$$AirInh_{outdoor} = \frac{AIAct \times RF_{inh} \times cair \times \left(rSAS + rSAW\right)}{BW \times DPY}$$

Where:
$AirInh_{outdoor}$ = inhalation exposure from chemicals in the air during outdoor days (ug/kg/day)
AIAct = amount of air inhaled on outdoor days (m3/day)
cair = site air concentration (ug/m3)
RFInh = relative inhalation bioavailability of the compound (%)
rSAS = outdoor summer days spent (days/year)
rSAW = outdoor winter days spent (days/year)
BW = receptor body weight (kg)
DPY = days per year (365 days/year)

Inhalation Exposure Calculations on Indoor days

$$AirInh_{indoor} = \frac{AIPass \times RF_{inh} \times cair \times \left(rSPS + rSPW\right) \times Inf}{BW \times DPY}$$

Where:

$AirInh_{indoor}$ = inhalation exposure from chemicals in the air during indoor day (ug/kg/day)
AIPass = amount of air inhaled on indoor days (m3/day)
RFInh = relative inhalation bioavailability of the compound (1; unitless)
cair = site air concentration (ug/m3)
rSPS = indoor summer days spent (days)
rSPW = indoor winter days spent (days)
Inf = fraction of indoor air that is from outdoor air (0.75; Hawley 1985)
BW = receptor body weight (kg)
DPY = days per year (365 days/year)

Exposure via Direct Air Inhalation

$$Air_{Total} = AirInh_{indoor} + AirInh_{outdoor}$$

Where:

Air_{Total} = total inhalation exposure from chemical as vapour in air (ug/kg/day)
$AirInh_{outdoor}$ = inhalation exposure from chemicals in the air during outdoor days (ug/kg/day)
$AirInh_{indoo}$r = inhalation exposure from chemicals in the air during indoor day (ug/kg/day)

4B3.3 Calculation of Exposure from Soil/Dust

Assumptions Defining Dust Levels Generated by Soils

Background outside dust levels:	42 ug/m³ (MOEE 1994)
Percent of dust produced from soil:	50% (Hawley 1985)
Percent of outside dust level indoors:	75% (Roberts et al. 1974)

The exposure contributions from chemically impacted soil were considered for three routes of exposure: i) inhalation of re-suspended dusts, ii) incidental ingestion of soil, and iii) dermal contact with skin.

Inhalation Exposure from Dust on Outdoor Summer Days

Contribution from Outside Airborne Dust:

$$EXP_{SIAO} = \frac{AI \times SL \times RF_{inh} \times SODL \times Fd \times SOD}{BW \times DPY}$$

Where:

EXP_{SIAO} = inhalation exposure to chemical from summer outside airborne dust (ug/kg/day)
AI = amount of air inhaled (m^3/day)
SL = concentration of chemical in untilled surficial soil (ug/g)

RF_{inh} = relative inhalation bioavailability (1; unitless)
SODL = background dust level in outside air (g/m^3)
Fd = Fraction of outdoor dust attributable to outdoor soil (50%)
SOD = number of summer days spent outside per year (days/year)
BW = receptor body weight (kg)
DPY = days per year (365 days/year)

Contribution from Indoor Airborne Dust on Summer Days:

$$EXP_{SIAI} = \frac{AI \times SL \times RF_{inh} \times SIDL \times SID}{BW \times DPY}$$

Where:
EXP_{SIAI} = summer inhalation exposure to chemical from summer indoor airborne dust (ug/kg/day)
AI = amount of air inhaled (m^3/day)
SL = concentration of chemical in soil (ug/g)
RF_{inh} = relative inhalation bioavailability (1; unitless)
SIDL = background dust level in indoor air (g/m^3)
Fd = fraction of outdoor dusts attributable to outdoor soil
SID = number of summer days spent indoors (days/year)
BW = receptor body weight (kg)
DPY = days per year (365 days/year)

Inhalation Exposure from Dust on Outdoor Winter Days

It was assumed that 10% of the summer outside dust level was available during the winter months.

Contribution from Outside Airborne Dust:

$$EXP_{WIAO} = \frac{AI \times SL \times RF_{inh} \times WODL \times PWS \times WOD}{BW \times DPY}$$

Where:
EXP_{WIAO} = winter inhalation exposure from outside airborne dust (ug/kg/day)
AI = amount of air inhaled (m^3/day)
SL = concentration of chemical in soil (ug/g)
RF_{inh} = relative inhalation bioavailability (1; unitless)
WODL = background dust level in outside air (g/m^3)
PWS = percentage of winter soil available (10%)
Fd = fraction of outdoor dusts attributable to outdoor soil
WOD = number of winter days spent outside per year (days/years)
BW = receptor body weight (kg)
DPY = days per year (365 days/year)

Contribution from Indoor Airborne Dust on Winter Days:

$$EXP_{WIAI} = \frac{AI \times SL \times RF_{inh} \times WIDL \times PWS \times WID}{BW \times DPY}$$

Where:

EXP_{WIAI} = winter inhalation exposure to chemical from indoor airborne dust (ug/kg/day)
AI = amount of air inhaled (m^3/day)
SL = concentration of chemical in soil (ug/g)
RF_{inh} = relative inhalation bioavailability (1; unitless)
WIDL = background dust level in indoor air (g/m^3)
PWS = percentage of winter soil available (10%)
Fd = fraction of outdoor dust attributable to outdoor soils (50%)
WID = number of winter days spent indoors (days/year)
BW = receptor body weight (kg)
DPY = days per year (365 days/year)

Ingestion of Soil/Dusts

The following provides the equations used to calculate exposures *via* ingestion of soil/dust:

Incidental Outdoor Soil Ingestion during Summer Months

Incidental Outdoor Dust Ingestion during Summer Months

$$EXP_{SGAO} = \frac{AO \times SL \times RF_{oral} \times SOD}{BW \times DPY}$$

Where:

EXP_{SGAO} = exposure from incidental ingestion of outside soil during summer (ug/kg/day)
AO = amount of dust ingested (g/day)
F = fraction of outdoor Soil/Dust Ingestion Rate from outdoor Soil (45%)
SL = concentration of chemical in soil (ug/g)
RF_{oral} = relative oral bioavailability (80%; unitless)
SOD = total number of days spent on the site during the summer (212.92 days/year)
BW = receptor body weight (kg)
DPY = averaging time (365 days)

Incidental Indoor Dust Ingestion during Summer Months

Contribution from Indoor Dust:

$$EXP_{SGAI} = \frac{AO \times F \times SL \times FR_{out} \times RF_{oral} \times SOD}{BW \times DPY}$$

Where:

EXP_{SGAI} = exposure from incidental ingestion of indoor dust during summer (ug/kg/day)
F = fraction of Soil/Dust Ingestion Rate for Indoor Dust (55% for indoors)
AO = amount of soil/dust ingested (g/day)
SL = concentration of chemical in soil (ug/g)

RF_{oral} = relative oral bioavailability (80%; unitless)
FR_{out} = fraction of dust originating from outdoor soil sources (Assumed 100%)
SOD = total number of days spent on the site during the summer (212.92 days/year)
BW = receptor body weight (kg)
DPY = averaging time (365 days)

Incidental Outdoor Soil Ingestion during Winter Months

Contribution from Outside Soil:

$$EXP_{WGAO} = \frac{AO \times F \times SL \times WDF \times F_{oral} \times WOD}{BW \times DPY}$$

Where:
EXP_{WGAO} = exposure from incidental ingestion soil in winter (ug/kg/day)
AO = amount of dust ingested (g/day)
F = fraction of outdoor Soil/Dust Ingestion Rate from outdoor Soil (45%)
SL = concentration of chemical in soil (ug/g)
RF_{oral} = relative oral bioavailability (1; unitless)
WOD = total number of days spent on the site during the winter (152.08 days/year)
WDF = winter soil/dust covering factor (0.10)
BW = receptor body weight (kg)
DPY = averaging time (365 days)

Incidental Indoor Dust Ingestion during Winter Months

Contribution from Indoor Dust:

$$EXP_{WGAI} = \frac{AO \times SL \times WDF \times RF_{oral} \times WOD}{BW \times DPY}$$

Where:
EXP_{WGAI} = exposure from incidental ingestion of indoor dust during winter (ug/kg/day)
AO = amount of soil/dust ingested (g/day)
Fd = fraction of soil/dust ingestion rate from indoor dust (55%)
SL = concentration of chemical in dust (ug/g)
RF_{oral} = relative oral bioavailability (1; unitless)
WOD = total number of days spent on the site (indoors and outdoors) during the winter months (152.08 days/year)
WDF = winter dust covering factor (10%)
BW = receptor body weight (kg)
DPY = averaging time (365 days)

Total Exposure *via* Incidental Ingestion:

$$EXP_{ING} = EXP_{SGAO} + EXP_{WGAO} + EXP_{SGAI} + EXP_{WGAI}$$

Where:
EXP_{ING} = total oral exposure from incidental ingestion of indoor soil/dust ug/kg/day)

EXP_{SGAO} = oral exposure from incidental ingestion of summer outside dust/soil (ug/kg/day)
EXP_{WGAO} = oral exposure from incidental ingestion of outside dust/soil in winter (ug/kg/day)
EXP_{SGAI} = oral exposure from incidental ingestion of inside dust during the summer (ug/kg/day)
EXP_{WGAI} = oral exposure from incidental ingestion of inside dust during winter (ug/kg/day)

Dermal Contact with Soil/Dust

Dermal Exposure from Soil/Dust on Outdoor Summer Days

Contribution from Outside Soil/Dust:

$$EXP_{SDAO} = \frac{[(AS_s \times DAF_B) + (AH \times DAF_H)] \times SL \times AF_{Dermal} \times SOD}{BW \times DPY}$$

Where:
EXP_{SDAO} = dermal exposure to chemical from contact with outside soil/dust in summer (ug/kg/day)
AS_s = area of exposed skin when outside (m^2)
DAF_B = soil/dust adherence factor (g/m^2)
AH = area of exposed hands (m^2)
DAF_H = soil adherence factor hands only (g/m^2/event)
SL = concentration of chemical in soil (ug/g)
AF_{Dermal} = relative dermal bioavailability (unitless)
SOD = number of summer days spent outdoors (106.46 days/year)
BW = receptor body weight (kg)
DPY = days per year (365 days/year)

Contributions from Indoor Soil/Dust:

$$EXP_{SDPI} = \frac{[(AS_s \times DAF_B) + (AH \times DAF_H)] \times SL \times AF_{Dermal} \times SID}{BW \times DPY}$$

Where:
EXP_{SDPI} = dermal exposure to chemical from contact with indoor soil/dust in summer (ug/kg/day)
AS_s = area of exposed skin when indoors (m^2)
DAF_B = soil/dust adherence factor (g/m^2)
AH = area of exposed hands (m^2)
DAF_H = soil adherence factor hands only (g/m^2/event)
SL = concentration of chemical in soil (ug/g)
AF_{Dermal} = relative dermal bioavailability (unitless)
SID = number of days spent indoors (106.46 days/year)
BW = receptor body weight (kg)
DPY = days per year (365 days/year)
0.70 = fraction of dust originating from outdoor soil sources (U.S. EPA 1994a)

Dermal Exposure from Soil/Dust on Outdoor Winter Days

Contribution from Outside Soil/Dust:

$$EXP_{WDAO} = \frac{\left[\left(AS_w \times DAF_B\right) + \left(AH \times DAF_H\right)\right] \times SL \times PWS \times AF_{Dermal} \times WOD}{BW \times DPY}$$

Where:

EXP_{WDAO} = dermal exposure to chemical from contact with outside soil/dust in winter (ug/kg/day)
AS_w = area of exposed skin when indoors (m^2)
DAF_B = soil/dust adherence factor (g/m^2)
AH = area of exposed hands (m^2)
DAF_H = soil adherence factor hands only (g/m^2/event)
SL = concentration of chemical in soil (ug/g)
PWS = percentage of winter soil available (10%)
AF_{Dermal} = relative dermal bioavailability (unitless)
WOD = number of winter days spent outdoors (days/year)
BW = receptor body weight (kg)
DPY = days per year (365 days/year)

Contribution from Indoor Soil/Dust:

$$EXP_{WDPI} = \frac{\left[\left(AS_w \times DAF_B\right) + \left(AH \times DAF_H\right)\right] \times SL \times PWS \times AF_{Dermal} \times WID}{BW \times DPY}$$

Where:

EXP_{WDPI} = dermal exposure to chemical from contact with indoor soil/dust in winter (ug/kg/day)
AS_w = area of exposed skin when indoors (m2)
DAF_B = soil/dust adherence factor (g/m2)
AH = area of exposed hands (m2)
DAF_H = soil adherence factor hands only (g/m2 event)
SL = concentration of chemical in soil (ug/g)
PWS = percentage of winter soil available (10%)
0.70 = fraction of dust originating from outdoor soil sources (U.S. EPA 1994a)
AF_{Dermal} = fraction of chemical absorbed by receptor by dermal contact with soil/dust (unitless)
WID = number of days spent indoors on site (days/year)
BW = receptor body weight (kg)
DPY = days per year (365 days/year)

Total Exposure (dermal)

$$EXP_{DERM} = EXP_{SDAO} + EXP_{SDPI} + EXP_{WDAO} + EXP_{WDPI}$$

Where:

EXP_{DERM} = total dermal exposure to chemical from contact with outside/dust (ug/kg/day)
EXP_{SDAO} = dermal exposure to chemical from contact with summer outside soil/dust (ug/kg/day)

EXP_{SDPI} = dermal exposure to chemical from contact with summer indoor soil/dust (ug/kg/day)
EXP_{WDAO} = dermal exposure to chemical from contact with winter outside soil/dust (ug/kg/day)
EXP_{WDPI} = dermal exposure to chemical from contact with winter indoor soil/dust (ug/kg/day)

4B4 RISK CHARACTERIZATION

4B4.1 Human Risk Characterization

Total exposure was calculated by summing the individual exposures from each media (air, soil, game and vegetation) for all relevant exposure pathways on a chemical and receptor basis. Risk estimates or threshold and non-threshold COPCs were estimated using the equations provided below and the calculated exposure estimates.

Both non-cancer and cancer risks were estimated and presented for appropriate oral, dermal and inhalation exposures.

4B4.2 Calculating Risks for Non-Carcinogens

Oral risks were estimated based on the following equation.

$$RQ = \frac{E_{ORAL} \times RAF}{EL_{ORAL}}$$

Where:
RQ = risk quotient (unitless)
E_{ORAL} = total daily oral exposure from all pathways (ug/kg/day)
RAF = relative absorption factor (80%)
EL_{ORAL} = chemical-specific oral exposure limit (ug/kg/day)

Dermal risks were estimated based on the following equation.

$$RQ = \frac{E_{DERMAL} \times RAF}{EL_{ORAL}}$$

Where:
RQ = risk quotient (unitless)
E_{DERMAL} = total daily dermal exposure from all pathways (ug/kg/day)
RAF = relative absorption factor (0.13 / 0.8 = 0.1625 or 16.255%)
EL_{ORAL} = chemical-specific oral exposure limit (ug/kg/day)

Inhalation risks were calculated based on the following equation.

$$RQ = \frac{EI_{Inhalation} \times RAF}{EL_{Inhalation}}$$

Where:
RQ = risk quotient (unitless)
$EI_{Inhalation}$ = total daily inhalation exposure from all pathways (ug/kg/day)
RAF = relative absorption factor (1.0 / 1.0 = 1.0 or 100%)
$EL_{Inhalation}$ = chemical-specific inhalation exposure limit (ug/kg/day)

Total risk quotient values for all assessed pathways were calculated based on the following equation:

$$RQ_{tot} = RQ_{oral} + RQ_{der} + RQ_{inh}$$

Calculating Risks for Carcinogens

As discussed in the main report, differentiation between lifetime cancer risks (LCR) and incremental lifetime cancer risks (ILCR) has been made in the risk assessment. LCR values describe the estimated number of cancers per 100,000 people to which exposure to the COPC may contribute. There is no acceptable ‘benchmark’ for LCR, and LCR is evaluated in cases where background exposures are included (eg. Background, Baseline, Application and CEA cases).

In contrast, ILCR values were calculated for the Project alone (determined by subtracting the Baseline LCR from the Application LCR), and were compared to the acceptable level of risk of 1 new case per 100,000 people. Thus, the key differences between LCR and ILCR are: whether or not background exposures are included, evaluation of the project alone, and one represents an incidence rate while the other represents the number of cancer cases per 100,000 attributable to the Project.

Carcinogenic risks from oral and dermal exposures (although not for naphthalene) were calculated based on the following equation:

$$LCR = EXP_{Oral+Dermal} \times AMT \times q_1^{*}$$

Where:
LCR = Number of estimated cancer cases per 100,000 population associated with exposure to the COPC
$EXP_{Oral+Dermal}$ = total daily exposure via oral and dermal pathways (ug/kg/day)
q_1* = chemical-specific cancer slope factor for oral (ug/kg bw/day)-1
AMT = receptor specific amortization factor (years exposed / life expectancy (75 years)

Similarly,

$$ILCR = EXP_{Oral+Dermal} \times AMT \times q_1^{*}$$

Carcinogenic risks from inhalation exposures were calculated based on the following equation:

$$LCR = EXP_{inhal} \times AMT \times q_1^{*}$$

Where:

ILCR = incremental lifetime cancer risk
EXP_{inhal} = total daily exposure via inhalation (ug/kg/day)
q_1* = chemical-specific cancer slope factor for inhalation (ug/kg bw/day)-1
AMT = receptor specific amortization factor (years exposed / life expectancy (75 years)

Similarly,

$$ILCR = EXP_{inhal} \times AMT \times q_1^{*}$$

4B5 MODIFICATIONS OF EXPOSURE ESTIMATES BASED ON RELATIVE BIOAVAILABILITY

One of the most important factors in determining exposure of target tissues to chemicals is bioavailability, or the proportion of a chemical dose entering the blood stream (*i.e.*, absorbed dose) following administration *via* a particular route (*i.e.*, oral, inhalation or dermal). Systemic absorption of chemicals can differ according to whether the dose was received *via* the dermal, oral or the inhalation route. Also, the systemic absorption will differ depending on whether the exposure occurs in water, in soil, in food, etc.

It is not considered appropriate to convert exposure estimates to absorbed doses if toxicity values (from recognized agencies) are based on administered doses. However, if an exposure estimate is adjusted for bioavailability and is expressed as an absorbed dose, then it must be compared to an exposure limit that is based on an absorbed dose, not administered dose. Since most exposure limits are based on administered doses, it may not always be appropriate to consider absolute bioavailability (fraction or percentage of an external dose which reaches the systemic circulation) during the assessment of exposure. Therefore relative bioavailability may be determined by comparing the extent of absorption among several routes of exposure, forms of the same chemical, or exposure medium (food, soil, or water).

As a specific example, it is often necessary to consider route-to-route extrapolation when an exposure limit is not available for the exposure route of concern and no other data (such as pharmacokinetics) are available. It is common to assess the risks posed by dermal absorption of a chemical based on the exposure limit established for oral exposure. The systemic dose *via* dermal absorption is scaled to the ‘equivalent’ oral dose by correcting for the bioavailability of dermally-applied chemical relative to an orally-administered dose.

Toxicity information used to derive exposure limits is usually based on the administered dose, the absorbed dose or the internal dose. Incorporating bioavailability is dependant on which form the chemical was introduced to the test organism or toxicity study. For the most part, toxicity studies are based on the chemical given orally in food or water. In addition, these studies will use a form of chemical that is highly bioavailable to promote the most efficient toxic effect to the test organism at a given concentration. For example, in studies involving metal toxicity, the compound is often administered as a very soluble salt in water or food. Differences in the adsorption of chemicals between laboratory organisms and wildlife as well as between different mediums of exposure will invariably exist. The relative absorption factor (RAF) is the variable used to incorporate bioavailability information to exposure assessment (Menzie et al., 2000).

The RAF is used to adjust the absorption of a chemical from an exposure medium to that of the absorption of the chemical used in the toxicity study. The following equation was used to calculate the RAF:

$$RAF = \frac{BA_M}{BA_{EL}}$$

Where:

RAF = relative adsorption factor (unitless)
BA_M = absorption of the chemical form in the exposure medium (%)
BA_{EL} = absorption of the chemical form in the study medium (%)

An RAF can be less than or greater than one. An RAF of one does not indicate that the bioavailability is 100%, but the estimated bioavailability for the chemical in the exposure medium is the same as that used in the toxicity study for developing the toxicity reference value (TRV). In circumstances where the bioavailability is unknown for a particular medium, it is acceptable to conservatively default to an RAF of one. In this case, there is no adjustment of the exposure route relative to the toxicity study. Table 4B-3 provides the bioavailability adjustments that were applied in the HHRA.

Table 4B-3 Bioavailability (BA) Adjustments (%)

Chemical	Type	Inhalation (BA)	Oral (BA)	Dermal (BA)
PAHs				
Anthracene	Route	100	76	13
	Study	100	76	76
Benz(a)anthracene	Route	100	31	13
	Study	100	31	31
Benzo(a)pyrene	Route	100	31	13
	Study	100	31	31
Benzo(e)pyrene	Route	100	31	13
	Study	100	31	31
Benzo(b)fluoranthene	Route	100	31	13
	Study	100	31	31
Benzo(g,h,i)perylene	Route	100	31	13
	Study	100	31	31
Benzo(k)fluoranthene	Route	100	31	13
	Study	100	31	31
Chrysene	Route	100	31	13
	Study	100	31	31
Dibenz(a,h)anthracene	Route	100	31	13
	Study	100	31	31
Fluoranthene	Route	100	31	13
	Study	100	31	31
Fluorene	Route	100	31	13
	Study	100	31	31
Indeno(1,2,3-cd)pyrene	Route	100	31	13
	Study	100	31	31

Chemical	Type	Inhalation (BA)	Oral (BA)	Dermal (BA)
Phenanthrene	Route	100	31	13
	Study	100	31	31
Pyrene	Route	100	31	13
	Study	100	31	31
VOCS				
Naphthalene	Route	100	80	13
	Study	100	80	13

4B6 CANCER RISKS FOR RECEPTORS EXPOSED TO CHEMICALS FROM THE SITE FOR THEIR ENTIRE LIFETIME

The level of risk for the composite receptor was calculated by adding the adjusted exposure ratio (ER) values calculated for each individual life stage (adjusted for duration of exposure) in order to estimate the lifetime cancer risk. The compilation of all five individual life stages (infant, 0.5/75; toddler, 4.5/75; child, 7/75; youth/adolescent, 8/75; adult, 56/75) results in a risk estimate for the composite receptor over a 75-year lifetime.

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APPENDIX 4B1: DISCRETE RECEPTOR LOCATIONS

Summary of Discrete Receptor Locations, Group, and UTM Coordinates

Receptor Number in HHRA Model	Group	UTM Easting (m)	UTM Northing (m)
1	fenceline	369062	5962945
2	fenceline	369061	5962895
3	fenceline	369059	5962845
4	fenceline	369058	5962795
5	fenceline	369057	5962745
6	fenceline	369055	5962695
7	fenceline	369054	5962645
8	fenceline	369053	5962595
9	fenceline	369051	5962545
10	fenceline	369050	5962495
11	fenceline	369049	5962445
12	fenceline	369048	5962395
13	fenceline	369046	5962345
14	fenceline	369045	5962295
15	fenceline	369044	5962245
16	fenceline	369043	5962195
17	fenceline	369041	5962145
18	fenceline	369040	5962095
19	fenceline	369039	5962045
20	fenceline	369038	5961995
21	fenceline	369037	5961945
22	fenceline	369035	5961895
23	fenceline	369035	5961875
24	fenceline	369006	5961875
25	fenceline	368956	5961877
26	fenceline	368906	5961879
27	fenceline	368856	5961880
28	fenceline	368806	5961882
29	fenceline	368756	5961883
30	fenceline	368706	5961885
31	fenceline	368656	5961886
32	fenceline	368606	5961888
33	fenceline	368556	5961889
34	fenceline	368506	5961891
35	fenceline	368456	5961892
36	fenceline	368406	5961894
37	fenceline	368356	5961895
38	fenceline	368306	5961897
39	fenceline	368256	5961898
40	fenceline	368227	5961899
41	fenceline	368228	5961920
42	fenceline	368229	5961934
43	fenceline	368260	5961952
44	fenceline	368303	5961978
45	fenceline	368345	5962004
46	fenceline	368388	5962030
47	fenceline	368431	5962056
48	fenceline	368474	5962081
49	fenceline	368517	5962107

Receptor Number in HHRA Model	Group	UTM Easting (m)	UTM Northing (m)
50	fenceline	368560	5962133
51	fenceline	368603	5962159
52	fenceline	368645	5962185
53	fenceline	368688	5962210
54	fenceline	368731	5962236
55	fenceline	368774	5962262
56	fenceline	368817	5962288
57	fenceline	368860	5962313
58	fenceline	368902	5962339
59	fenceline	368945	5962365
60	fenceline	368977	5962384
61	fenceline	368970	5962395
62	fenceline	368963	5962405
63	fenceline	368931	5962385
64	fenceline	368888	5962360
65	fenceline	368845	5962334
66	fenceline	368802	5962308
67	fenceline	368759	5962282
68	fenceline	368716	5962257
69	fenceline	368673	5962231
70	fenceline	368672	5962230
71	fenceline	368648	5962273
72	fenceline	368625	5962312
73	fenceline	368621	5962310
74	fenceline	368578	5962285
75	fenceline	368535	5962259
76	fenceline	368492	5962234
77	fenceline	368449	5962208
78	fenceline	368406	5962183
79	fenceline	368400	5962179
80	fenceline	368390	5962138
81	fenceline	368378	5962089
82	fenceline	368375	5962073
83	fenceline	368345	5962056
84	fenceline	368302	5962032
85	fenceline	368258	5962007
86	fenceline	368215	5961982
87	fenceline	368207	5961978
88	fenceline	368205	5961937
89	fenceline	368205	5961919
90	fenceline	368177	5961903
91	fenceline	368134	5961877
92	fenceline	368091	5961852
93	fenceline	368048	5961826
94	fenceline	368005	5961801
95	fenceline	367962	5961775
96	fenceline	367919	5961750
97	fenceline	367876	5961724
98	fenceline	367833	5961699
99	fenceline	367790	5961673
100	fenceline	367747	5961648
101	fenceline	367704	5961622
102	fenceline	367661	5961597
103	fenceline	367618	5961571

Receptor Number in HHRA Model	Group	UTM Easting (m)	UTM Northing (m)
104	fenceline	367575	5961545
105	fenceline	367532	5961520
106	fenceline	367489	5961494
107	fenceline	367446	5961469
108	fenceline	367403	5961443
109	fenceline	367388	5961434
110	fenceline	367387	5961402
111	fenceline	367386	5961352
112	fenceline	367384	5961302
113	fenceline	367382	5961252
114	fenceline	367380	5961202
115	fenceline	367379	5961152
116	fenceline	367377	5961116
117	fenceline	367363	5961117
118	fenceline	367313	5961118
119	fenceline	367263	5961120
120	fenceline	367213	5961122
121	fenceline	367163	5961123
122	fenceline	367113	5961125
123	fenceline	367063	5961127
124	fenceline	367013	5961129
125	fenceline	366963	5961130
126	fenceline	366913	5961132
127	fenceline	366863	5961134
128	fenceline	366816	5961135
129	fenceline	366814	5961134
130	fenceline	366767	5961116
131	fenceline	366720	5961098
132	fenceline	366674	5961080
133	fenceline	366627	5961062
134	fenceline	366581	5961043
135	fenceline	366534	5961025
136	fenceline	366487	5961008
137	fenceline	366441	5960990
138	fenceline	366394	5960972
139	fenceline	366347	5960954
140	fenceline	366301	5960936
141	fenceline	366254	5960918
142	fenceline	366207	5960900
143	fenceline	366161	5960882
144	fenceline	366114	5960864
145	fenceline	366067	5960846
146	fenceline	366021	5960828
147	fenceline	365974	5960811
148	fenceline	365927	5960793
149	fenceline	365880	5960775
150	fenceline	365834	5960757
151	fenceline	365787	5960739
152	fenceline	365740	5960721
153	fenceline	365734	5960719
154	fenceline	365736	5960762
155	fenceline	365737	5960812
156	fenceline	365738	5960862
157	fenceline	365740	5960912

Receptor Number in HHRA Model	Group	UTM Easting (m)	UTM Northing (m)
158	fenceline	365741	5960962
159	fenceline	365743	5961012
160	fenceline	365744	5961062
161	fenceline	365746	5961112
162	fenceline	365747	5961162
163	fenceline	365748	5961212
164	fenceline	365750	5961262
165	fenceline	365751	5961312
166	fenceline	365752	5961362
167	fenceline	365753	5961412
168	fenceline	365755	5961462
169	fenceline	365756	5961512
170	fenceline	365757	5961562
171	fenceline	365759	5961612
172	fenceline	365760	5961662
173	fenceline	365761	5961712
174	fenceline	365762	5961762
175	fenceline	365764	5961812
176	fenceline	365765	5961862
177	fenceline	365766	5961912
178	fenceline	365768	5961962
179	fenceline	365768	5961971
180	fenceline	365809	5961970
181	fenceline	365859	5961968
182	fenceline	365908	5961966
183	fenceline	365958	5961965
184	fenceline	366008	5961963
185	fenceline	366058	5961962
186	fenceline	366108	5961960
187	fenceline	366158	5961959
188	fenceline	366208	5961957
189	fenceline	366258	5961955
190	fenceline	366308	5961954
191	fenceline	366358	5961952
192	fenceline	366408	5961951
193	fenceline	366458	5961949
194	fenceline	366508	5961948
195	fenceline	366558	5961946
196	fenceline	366595	5961945
197	fenceline	366595	5961958
198	fenceline	366597	5962008
199	fenceline	366598	5962058
200	fenceline	366600	5962108
201	fenceline	366601	5962158
202	fenceline	366603	5962208
203	fenceline	366604	5962258
204	fenceline	366605	5962308
205	fenceline	366607	5962358
206	fenceline	366608	5962408
207	fenceline	366610	5962458
208	fenceline	366611	5962508
209	fenceline	366613	5962558
210	fenceline	366614	5962608
211	fenceline	366616	5962658

Receptor Number in HHRA Model	Group	UTM Easting (m)	UTM Northing (m)
212	fenceline	366617	5962708
213	fenceline	366618	5962748
214	fenceline	366628	5962748
215	fenceline	366678	5962746
216	fenceline	366728	5962745
217	fenceline	366778	5962743
218	fenceline	366828	5962742
219	fenceline	366878	5962741
220	fenceline	366928	5962739
221	fenceline	366978	5962738
222	fenceline	367028	5962736
223	fenceline	367078	5962735
224	fenceline	367128	5962733
225	fenceline	367178	5962732
226	fenceline	367228	5962731
227	fenceline	367278	5962729
228	fenceline	367328	5962728
229	fenceline	367378	5962726
230	fenceline	367424	5962725
231	fenceline	367424	5962729
232	fenceline	367426	5962779
233	fenceline	367427	5962829
234	fenceline	367428	5962879
235	fenceline	367430	5962929
236	fenceline	367431	5962979
237	fenceline	367433	5963029
238	fenceline	367434	5963079
239	fenceline	367436	5963129
240	fenceline	367437	5963179
241	fenceline	367438	5963229
242	fenceline	367440	5963279
243	fenceline	367441	5963329
244	fenceline	367443	5963379
245	fenceline	367444	5963429
246	fenceline	367445	5963479
247	fenceline	367447	5963529
248	fenceline	367448	5963579
249	fenceline	367450	5963629
250	fenceline	367451	5963679
251	fenceline	367453	5963729
252	fenceline	367454	5963779
253	fenceline	367456	5963829
254	fenceline	367457	5963878
255	fenceline	367459	5963928
256	fenceline	367460	5963978
257	fenceline	367462	5964028
258	fenceline	367463	5964078
259	fenceline	367465	5964128
260	fenceline	367466	5964178
261	fenceline	367468	5964228
262	fenceline	367469	5964278
263	fenceline	367471	5964328
264	fenceline	367471	5964351
265	fenceline	367499	5964350

Receptor Number in HHRA Model	Group	UTM Easting (m)	UTM Northing (m)
266	fenceline	367549	5964348
267	fenceline	367599	5964347
268	fenceline	367649	5964346
269	fenceline	367699	5964344
270	fenceline	367749	5964343
271	fenceline	367799	5964341
272	fenceline	367849	5964340
273	fenceline	367899	5964339
274	fenceline	367949	5964337
275	fenceline	367999	5964336
276	fenceline	368049	5964334
277	fenceline	368099	5964333
278	fenceline	368149	5964332
279	fenceline	368199	5964330
280	fenceline	368249	5964329
281	fenceline	368278	5964328
282	fenceline	368278	5964308
283	fenceline	368276	5964258
284	fenceline	368274	5964208
285	fenceline	368273	5964158
286	fenceline	368271	5964108
287	fenceline	368269	5964058
288	fenceline	368268	5964008
289	fenceline	368266	5963958
290	fenceline	368264	5963908
291	fenceline	368263	5963858
292	fenceline	368261	5963808
293	fenceline	368259	5963758
294	fenceline	368257	5963708
295	fenceline	368256	5963658
296	fenceline	368254	5963608
297	fenceline	368252	5963558
298	fenceline	368251	5963508
299	fenceline	368251	5963506
300	fenceline	368298	5963504
301	fenceline	368348	5963503
302	fenceline	368398	5963501
303	fenceline	368448	5963500
304	fenceline	368498	5963498
305	fenceline	368548	5963497
306	fenceline	368598	5963495
307	fenceline	368648	5963494
308	fenceline	368698	5963492
309	fenceline	368748	5963491
310	fenceline	368798	5963489
311	fenceline	368848	5963488
312	fenceline	368898	5963486
313	fenceline	368948	5963485
314	fenceline	368998	5963483
315	fenceline	369048	5963482
316	fenceline	369077	5963481
317	fenceline	369076	5963460
318	fenceline	369075	5963410
319	fenceline	369073	5963360

Receptor Number in HHRA Model	Group	UTM Easting (m)	UTM Northing (m)
320	fenceline	369072	5963310
321	fenceline	369071	5963260
322	fenceline	369069	5963210
323	fenceline	369068	5963160
324	fenceline	369066	5963110
325	fenceline	369065	5963060
326	fenceline	369064	5963010
327	fenceline	369062	5962960
426	MON	353232	5952310
427	MON	376056	5958500
428	MON	359833	5958067
429	MON	361891	5968174
430	MON	354826	5954196
431	MON	363073	5962319
432	MON	364935	5963352
433	MON	357139	5953510
434	MON	340475	5967758
435	MON	355804.3	5958149
436	MON	347591.2	5967276
437	MON	354688.1	5960244
438	MON	360878.8	5939796
439	MON	375925.6	5970356
440	MON	361295.7	5980649
441	MON	360697.3	6002572
442	MON	351171.8	5940836
443	MON	383851.1	5995967
444	MON	365162.6	5966771
445	MON	366816.4	5970490
446	MON	370007.3	5966697
447	MON	366611.9	5963581
448	MON	369842.4	5963565
449	MON	373105.3	5962105
450	MON	364845.2	5957949
451	MON	368102.3	5957846
452	MON	373003.3	5957615
453	MON	376282.8	5958384
454	MON	369619.5	5952902
455	MON	376055.4	5950401
456	MON	372711.2	5947789
457	MON	362696.6	5965372
458	MON	356590.3	5959016
459	MON	358451.9	5963805
460	MON	368513.2	5972164
461	MON	371842.8	5974654
462	MON	372141.6	5979614
463	MON	362130.9	5978255
464	MON	361179.8	5964520
465	MON	359687.2	5967081
466	MON	351746.7	5957506
467	MON	336223.4	5958056
468	MON	336842.4	5966913
469	MON	353021.2	5947726
470	MON	353779.9	5970579
471	MON	389763.4	5976129

Receptor Number in HHRA Model	Group	UTM Easting (m)	UTM Northing (m)
472	MON	389551	5966186
473	MON	387702.1	5956521
474	MON	355844	5958173
475	MON	354822.3	5954184
476	MON	359200.8	5953989
477	MON	363112.4	5962284
478	MON	364267.2	5966735
479	MON	376626.5	5949818
484	RES	347140	5967010
485	RES	362040	5979690
486	RES	372290	5963360
487	RES	363650	5953851
488	RES	340889	5967709
489	RES	382356	5957181
490	IND	359660	5967340
491	IND	360538	5968123
492	IND	359505	5965444
493	IND	355265	5968284
494	IND	359570	5965070
495	IND	361366	5970322
496	IND	362330	5968371
497	IND	362120	5962650
498	IND	365860	5965610
499	IND	352645	5974457
500	IND	352421	5974349
501	PUA	367121	5968750
502	PUA	367069	5965875
503	PUA	354582	5955741
504	PUA	371039	5977003
505	PUA	375062	5943202
506	AGR	370275	5960257
507	AGR	369871	5962288
508	AGR	370552	5963564
509	AGR	370087	5963561
510	AGR	366867	5960212
511	AGR	368360	5960315
512	AGR	369188	5960895
513	AGR	369791	5961541
514	IND	368507	5962145
515	AGR	365790	5960355
516	AGR	364939	5961328
517	AGR	364632	5960507
518	AGR	365024	5962425
519	AGR	366546	5962995
520	AGR	365417	5962893
521	AGR	365025	5962997
522	AGR	365116	5963482
523	AGR	369773	5961956
524	AGR	369824	5963113
525	AGR	369832	5964079
526	IND	368343	5964208
527	AGR	369731	5965243
528	AGR	368408	5964719
529	AGR	367030	5963624

Receptor Number in HHRA Model	Group	UTM Easting (m)	UTM Northing (m)
530	AGR	368326	5965508
531	AGR	364457	5960341
532	AGR	364883	5959319
533	AGR	364943	5959893
534	AGR	366566	5959343
535	AGR	368124	5959901
536	AGR	368169	5960050
537	AGR	369773	5960194
538	AGR	368274	5961193
539	AGR	369842	5959053
540	AGR	371151	5959194
541	AGR	371402	5959750
542	AGR	371396	5959205
543	AGR	371728	5960095
544	AGR	371728	5960095
545	AGR	372887	5960078
546	AGR	372967	5960587
547	AGR	373037	5961334
548	AGR	371482	5961462
549	AGR	371440	5962468
550	AGR	373055	5961967
551	AGR	371660	5962466
552	AGR	373113	5962465
553	RES	373233	5963335
554	AGR	365585	5957062
555	AGR	368179	5958462
556	AGR	369689	5958576
557	AGR	368039	5957693
558	AGR	368020	5958047
559	AGR	366630	5958239
560	AGR	368057	5958605
561	AGR	366314	5958425
562	AGR	365291	5957189
563	AGR	363072	5958305
564	AGR	369554	5959301
565	AGR	363936	5960424
566	AGR	371705	5965471
567	AGR	371440	5963472
568	AGR	371517	5964655
569	AGR	371505	5965582
570	AGR	371543	5966013
571	AGR	371705	5965471
572	AGR	371672	5965528
573	AGR	371604	5966213
574	AGR	369963	5967577
575	AGR	370078	5966896
576	AGR	370041	5968315
577	AGR	368338	5965982
578	AGR	367868	5966756
579	AGR	368291	5966578
580	AGR	368345	5966376
581	AGR	369919	5966711
582	AGR	369764	5966800
583	AGR	368311	5967597

Receptor Number in HHRA Model	Group	UTM Easting (m)	UTM Northing (m)
584	AGR	368289	5967882
585	AGR	369376	5961036
586	AGR	369794	5957398
587	AGR	369459	5956792
588	AGR	371361	5957617
589	AGR	371364	5957793
590	AGR	364602	5959099
591	AGR	368197	5959266
592	AGR	367310	5957015
593	AGR	371094	5966951
594	AGR	368884	5966764
595	IND	365627	5960298
596	AGR	364822	5958500
597	AGR	364834	5958621
598	AGR	364794	5958821
599	AGR	363977	5958680
600	AGR	373186	5965469
601	AGR	373178	5960033
602	AGR	371494	5967230
603	AGR	364790	5955647
604	AGR	372986	5959273
605	AGR	366478	5956424
606	AGR	366378	5956387
607	AGR	366489	5956203
608	AGR	366457	5956105
609	AGR	366385	5955931
610	AGR	364726	5955895
611	AGR	372996	5959403
612	AGR	373360	5965477
613	AGR	373147	5965921
614	AGR	371516	5968066
615	AGR	371681	5967326
616	AGR	372809	5966762
617	AGR	373774	5963090
618	AGR	373724	5963133
619	AGR	373733	5963001
620	AGR	373767	5963010
621	AGR	373776	5962963
622	AGR	373755	5962802
623	AGR	372507	5966589
624	Removed – is on lease	366509	5961191
625	Removed is on lease	368320	5963008

TABLE OF CONTENTS

TABLES

4C1 ASSESSMENT OF POTENTIAL CHANGES IN BASELINE MORTALITY AND MORBIDITY RATES FROM PREDICTED PM$_{2.5}$ AIR CONCENTRATIONS

4C1.1 Introduction

Various governmental organizations (U.S. EPA, 2005; WHO, 2005) and academic researchers (Samet., 2000; Cohen., 2004) have investigated and determined the excess risk of mortality and morbidity effects from exposure to daily or short-term changes in ambient PM concentrations. For example, the World Health Organization (WHO) estimates that health risks increase 0.5% for every 10 ug/m^3 increase in daily PM$_{2.5}$ concentrations above 25 ug/m^3 (WHO, 2005). Health Canada's SUM15 method is different from more recent methods and calculates excess health risk when PM$_{2.5}$ air concentrations exceed a daily threshold of 15 ug/m^3 (Health Canada, 1999).

Within the acute inhalation assessment, predicted 98th percentile PM$_{2.5}$ exposures were compared to the Canada Wide Standard (CWS) of 30 ug/m^3 (CCME, 2000). Predicted chronic exposures were compared to the California Air Resource Board's (CARB) standard of 12 ug/m^3 (annual average) (CARB, 2002). In addition to the chronic inhalation assessment using these two exposure limits, an evaluation of potential health effects associated with PM using Health Canada's SUM15 method has been completed (Health Canada, 1999).

4C1.2 Methods

Measured 24-hour PM$_{2.5}$ air concentrations for fifteen selected receptor locations were evaluated for each development case (Baseline, Application, Cumulative and Project). The receptor locations were selected based on proximity to the site and potential variation in wind direction. Time series data for a 365 period was obtained from the Air Quality team for these locations in order to provide a comprehensive SUM15 assessment. The predicted air concentrations in Tables 4C-1 to 4C-4 for the Baseline, Application Cumulative and Project cases are based on the air quality assessment which included all existing and approved industrial sources in the Fort Saskatchewan (including community sources).

Table 4C-1 Summary of Predicted Baseline PM$_{2.5}$ Concentrations

Receptor ID, Location	Annual Average	Median	98th Percentile
R516	3.5	1.9	14.0
R510	3.2	1.7	14.0
R523	3.0	1.6	14.4
R522	3.4	1.7	15.3
R588	3.3	1.8	14.2
R574	2.6	1.1	12.5
R563	3.5	1.6	15.2
R582	2.7	1.2	12.7
R527	2.8	1.3	14.5
R586	3.2	1.7	14.4
R577	2.9	1.3	13.3
R529	3.1	1.6	15.2
R503	4.9	2.4	22.1
R426	7.6	5.1	28.2
R486	2.7	1.4	13.0

Table 4C-2 Summary of Predicted Application $PM_{2.5}$ Concentrations

Receptor ID	Annual Average	Median	98th Percentile
R516	3.7	2.2	15.2
R510	3.5	2.0	15.1
R523	3.5	1.9	15.2
R522	3.6	2.1	16.4
R588	3.5	2.0	15.1
R574	2.7	1.1	13.6
R563	3.6	1.7	15.6
R582	2.8	1.2	13.7
R527	3.0	1.4	15.0
R586	3.3	1.8	14.8
R577	3.1	1.4	14.5
R529	3.6	2.0	16.3
R503	4.9	2.4	22.5
R426	7.7	5.1	28.6
R486	2.9	1.5	13.3

Table 4C-3 Summary of Predicted Cumulative $PM_{2.5}$ Concentrations

Receptor ID	Annual Average	Median	98th Percentile
R516	4.8	2.9	21.3
R510	4.4	2.6	21.5
R523	4.4	2.5	19.6
R522	4.8	2.9	20.8
R588	4.3	2.5	22.0
R574	3.6	1.6	21.3
R563	4.3	2.2	19.1
R582	3.7	1.7	21.2
R527	4.0	1.9	21.0
R586	4.1	2.3	20.9
R577	4.1	2.0	22.3
R529	4.7	2.8	20.9
R503	5.2	2.5	23.4
R426	8.0	5.3	32.9
R486	3.7	1.9	16.7

Table 4C-4 Summary of Predicted Project only $PM_{2.5}$ Concentrations

Receptor ID	Annual Average	Median	98th Percentile
R516	0.2	NA	1.8
R510	0.3	NA	2.7
R523	0.5	NA	2.0
R522	0.3	NA	2.0
R588	0.2	NA	1.4
R574	0.2	NA	1.1
R563	0.1	NA	1.0
R582	0.2	NA	1.1
R527	0.2	NA	1.3
R586	0.2	NA	1.3
R577	0.2	NA	1.7
R529	0.4	NA	2.7
R503	0.1	NA	0.5
R426	0.0	NA	0.5
R486	0.3	NA	1.2

NA: Not applicable – could not determine geometric mean for this data.

4C2 RESULTS OF SUM15 ASSESSMENT

Health risks were calculated using SUM15 methods in combination with predicted $PM_{2.5}$ concentrations, in accordance with Health Canada's Addendum to the Science Assessment Document for Particulate Matter (Health Canada SUM15 method; Health Canada, 1999) at all receptor locations. Health risks were estimated for mortality, respiratory hospital admissions (RHA) and cardiac hospital admissions (CHA).

Information that is required to evaluate the potential health risks of PM includes:

- Cumulative air concentrations of $PM_{2.5}$: the one-year sum (i.e., 364 days) of 24-hour $PM_{2.5}$ concentrations that exceed the Health Canada reference level of 15 ug/m^3 (i.e., ∑ [24-hour $PM_{2.5}$ air concentration – 15 ug/m^3]);
- Relative risk estimates for mortality, RHA and CHA; and
- Baseline mortality, RHA and CHA incidence rates.

Table 4C-5 outlines the cumulative concentrations that were determined for the different receptor locations.

Table 4C-5 Cumulative Daily $PM_{2.5}$ Air Concentrations (ug/m^3) Exceeding Health Canada's Reference Level of 15 ug/m^3

Receptor ID	Baseline	Application	Cumulative	Project only
R516	60.7	67.5	138.9	0.0
R510	54.1	62.5	121.2	0.0
R523	45.5	54.9	120.6	0.0
R522	51.1	60.3	151.6	0.0
R588	55.8	60.9	118.2	0.0
R574	29.4	33.8	96.2	0.0
R563	77.4	82.3	132.3	0.0
R582	32.5	37.7	104.8	0.0
R527	34.2	43.6	114.0	0.0
R586	55.6	59.8	114.9	0.0
R577	38.4	45.4	121.7	0.0
R529	45.5	59.3	142.6	0.0
R503	167.7	170.9	212.8	0.0
R426	377.3	382.9	430.7	0.0
R486	37.0	42.9	88.6	0.0

Health Canada's baseline incidence rates for mortality, CHA and RHA are presented in Tables 4C-6 below.

Table 4C-6 Baseline Incidence Rates and Relative National Risk Estimates

Health Endpoint	Incidence Rate per 1,000,000 Population per Day	Relative Risk per 1 ug/m^3 Change in $PM_{2.5}$	
		Point Estimate	95% Confidence Interval
Mortality	18.4	1.0014	1.001 to 1.0018
Respiratory Hospital Admissions (RHA)	16	1.00074	1.00049 to 1.00099
Cardiovascular Hospital Admissions (CHA)	14.4	1.0007	1.00036 to 1.001

Source: Health Canada 1999

Health Canada uses the information regarding baseline incidence rates of mortality, RHA and CHA to calculate potential health that may be attributable to $PM_{2.5}$ as follows:

$$\text{Cumulative } PM_{2.5} \text{ concentration} \times \text{incidence rate} \times (\text{relative risk } -1) \qquad \text{(Equation 1)}$$

Using Equation 1, risks were estimated for each health endpoint (mortality, RHA and CHA). For example, the predicted change in the daily mortality rate at Receptor Location 486 for the Baseline case that would be attributable to $PM_{2.5}$ was calculated as follows:

$$\text{Change in mortality rate} = 37 \times 18.4 \text{ per } 1{,}000{,}000 \times (1.0014-1) = 0.95 \text{ per } 1{,}000{,}000$$

This calculation illustrates that the cumulative $PM_{2.5}$ concentration of 37 ug/m^3 predicted for the Baseline case at Receptor Location 486 was associated with a predicted increase in the non-accident mortality rate of 0.95 per 1,000,000 people.

The remaining results for mortality, RHA and CHA are outlined in the tables that follow.

Table 4C-7 Mortality (per 1,000,000 people) Attributed to Changes in Daily $PM_{2.5}$

Receptor ID	Baseline	Application	Cumulative	Project
R516	1.6	1.7	3.6	0.0
R510	1.4	1.6	3.1	0.0
R523	1.2	1.4	3.1	0.0
R522	1.3	1.6	3.9	0.0
R588	1.4	1.6	3.0	0.0
R574	0.8	0.9	2.5	0.0
R563	2.0	2.1	3.4	0.0
R582	0.8	1.0	2.7	0.0
R527	0.9	1.1	2.9	0.0
R586	1.4	1.5	3.0	0.0
R577	1.0	1.2	3.1	0.0
R529	1.2	1.5	3.7	0.0
R503	4.3	4.4	5.5	0.0
R426	9.7	9.9	11.1	0.0
R486	1.0	1.1	2.3	0.0

Table 4C-8 Respiratory Hospital Admissions (per 1,000,000 people) Attributed to Changes in Daily $PM_{2.5}$

Receptor ID	Baseline	Application	Cumulative	Project
R516	0.7	0.8	1.6	0.0
R510	0.6	0.7	1.4	0.0
R523	0.5	0.6	1.4	0.0
R522	0.6	0.7	1.8	0.0
R588	0.7	0.7	1.4	0.0
R574	0.3	0.4	1.1	0.0
R563	0.9	1.0	1.6	0.0
R582	0.4	0.4	1.2	0.0
R527	0.4	0.5	1.4	0.0
R586	0.7	0.7	1.4	0.0
R577	0.5	0.5	1.4	0.0
R529	0.5	0.7	1.7	0.0
R503	2.0	2.0	2.5	0.0
R426	4.5	4.5	5.1	0.0
R486	0.4	0.5	1.0	0.0

Table 4C-9 Cardiac Hospital Admissions (Per 1,000,000 People) Attributed To Changes in Daily $PM_{2.5}$

Receptor ID	Baseline	Application	Cumulative	Project
R516	0.6	0.7	1.4	0.0
R510	0.5	0.6	1.2	0.0
R523	0.5	0.6	1.2	0.0
R522	0.5	0.6	1.5	0.0
R588	0.6	0.6	1.2	0.0
R574	0.3	0.3	1.0	0.0
R563	0.8	0.8	1.3	0.0
R582	0.3	0.4	1.1	0.0
R527	0.3	0.4	1.1	0.0
R586	0.6	0.6	1.2	0.0
R577	0.4	0.5	1.2	0.0
R529	0.5	0.6	1.4	0.0
R503	1.7	1.7	2.1	0.0
R426	3.8	3.9	4.3	0.0
R486	0.4	0.4	0.9	0.0

The risk estimates presented are intended to represent the potential increase in mortality, RHA and CHA per 1,000,000 people associated with $PM_{2.5}$ exposure. It is unlikely that health effects attributable to potential $PM_{2.5}$ health effects could be detected at any of the listed receptor locations, considering the size of the population within the study area when compared to a population of 1,000,000.

There appears to be only slight differences between the estimated $PM_{2.5}$ related changes to the baseline and application case mortality and morbidity rates for the selected receptor locations. Sources present in the Baseline Case that are also included in the Application and Cumulative cases appear to contribute the most risk. The PM exposures attributable to the Project alone are not associated with any changes in mortality, RHA or CHA.

4C3 CONCLUSIONS

The SUM15 assessment indicates that incremental changes in mortality and morbidity are expected to be relatively small.

The Project's $PM_{2.5}$ emissions are not expected to increase the baseline mortality and morbidity rates to an appreciable extent.

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APPENDIX 4D: BACKGROUND CONDITIONS

TABLE OF CONTENTS

TABLES

4D1 INTRODUCTION

It is important to give consideration to current exposures associated with existing conditions in relation to human health risk assessment of new projects.

Measured data and modeled data, where appropriate, were used by North American to estimate risks associated with existing conditions for different exposure pathways. Site specific measurements were used when available; in some cases available data were evaluated from other EIAs recently conducted in the area for similar projects (e.g., North West Upgrading, Petro-Canada Oil Sands Inc. Sturgeon Upgrader, Shell Canada Scotford Upgrader Expansion).

This appendix summarizes measured baseline data used for this assessment, and provides an assessment of health risks associated with existing background conditions.

4D1.1 Summary of Measured Data Used in Risk Assessment

4D1.2 Soils

4D1.2.1 Background Soils

A total of six soil samples were collected from within the study area for metals and PAH analysis in June 2007. This data is summarized in Table 4D-1 below, and compared to risk-based soil quality guidelines.

Table 4D-1 Summary of North American Soil Sampling Results

Substance	Detection Limit and Units	Mean (ug/g)	Range (ug/g)	Alberta Tier 1 Soil Guidelines (ug/kg)[1]	Alberta Tier 1 Direct Contact Criteria[2] (ug/kg)	CCME Soil Quality Guidelines (ug/kg)[4]
Metals						
Boron (hot water soluble)	0.1 ug/g	1.5	1.2 - 2.3	2,000	NV	NV
Mercury	0.01 ug/g	0.03	0.01 – 0.07	6,600	6,600	NV
Antimony	0.2 ug/g	0.2*	<0.3 – 0.6	20,000	NV	NV
Arsenic	0.2 ug/g	4.6	2.8 – 6.3	17,000	21,000	12,000
Barium	1 ug/g	189	93 – 287	500,000	NV	500,000
Beryllium	0.1 ug/g	0.48	0.2 – 0.6	5,000	NV	NV
Cadmium	0.01 ug/g	0.43	0.12 – 1.33	1,400	1,400	1,400
Chromium	0.5 ug/g	18.6	8.9 – 21.6	64,000	220,000	64,000
Cobalt	0.1 ug/g	7.2	4.2 – 9.4	20,000	NV	NV
Copper	1 ug/g	90	5 – 24	63,000	1,100,000	63,000
Lead	0.1 ug/g	10.9	4.1 – 27.1	70,000	140,000	70,000
Molybdenum	1 ug/g	0.5*	ND	4,000	NV	NV
Nickel	0.5 ug/g	21.4	8.9 – 28.6	50,000	NV	50,000
Selenium	0.3 ug/g	0.33	< 0.3 – 0.5	1,000	80,000	1,000
Silver	0.1 ug/g	0.14	<0.1 – 0.2	20,000	NV	NV
Thallium	0.05 ug/g	0.16	0.08 – 0.20	1,000	NV	1,000
Tin	1 ug/g	1.7	1-3	5,000	NV	NV
Vanadium	0.1 ug/g	31.4	15.9 – 43.7	130,000	NV	130,000
Zinc	1 ug/g	139.8	38 – 535	200,000	NV	200,000

Substance	Detection Limit and Units	Mean (ug/g)	Range (ug/g)	Alberta Tier 1 Soil Guidelines (ug/kg)[1]	Alberta Tier 1 Direct Contact Criteria[2] (ug/kg)	CCME Soil Quality Guidelines (ug/kg)[4]
Polynuclear Aromatic Hydrocarbons						
Benzo(a)anthracene	0.05 mg/kg dw	0.025	< 0.05	0.22 mg/kg	NV	1,005
Chrysene	0.05 mg/kg dw	0.025	< 0.05	1.3 mg/kg	NV	1,005
Benzo(b)fluoranthene	0.05 mg/kg dw	0.025	< 0.05	1.3 mg/kg	NV	1,005
Benzo(j)fluoranthene3	0.05 mg/kg dw	0.025	< 0.05	1.3 mg/kg	NV	1,005
Benzo(k)fluoranthene	0.05 mg/kg dw	0.025	< 0.05	1.3 mg/kg	NV	1,005
Benzo(a)pyrene	0.05 mg/kg dw	0.025	< 0.05	1.7 mg/kg	NV	1,005
Indeno(1,2,3,cd)pyrene	0.05 mg/kg dw	0.025	< 0.05	NV	NV	1,005
Dibenzo(a,h)anthracene	0.05 mg/kg dw	0.025	< 0.05	0.6	NV	1,005

Notes:

Due to the PAH results being below the detection limit, non-detect results were assumed to be equivalent to one-half the detection limit for comparison against guidelines.

Dw: dry weight.

NV: no value.

1 Lowest value of agricultural and residential land uses selected for fine and coarse soil types.

2 Human Direct Contact Criteria from the Alberta Tier 1 Guidelines.

3 Assumed benzo(k)fluoranthene as a surrogate.

4 The lowest value out of agricultural and residential land use types was selected.

5 Interim remediation criteria not yet replaced by CCME Soil Quality Guidelines.

None of the measured metal or PAH concentrations were above relevant soil quality guidelines. As metals were not included in the air quality inventory, and soil concentrations of metals are below risk-based guidelines, background metals were not quantitatively assessed in the HHRA. However, PAHs were included in the air quality emissions inventory and were quantitatively assessment in the HHRA. For PAHs that were not detected, predictive data based on modeling was used in place of detection limits (please refer to Appendix 4B for information regarding models).

4D1.3 Vegetation

Vegetation sampling was completed by North American in the study area during September 2007. A total of seven samples were collected for chemical analysis of metals and PAHs. The results of this analysis are presented in Table 4D-2.

Table 4D-2 Summary of North American Vegetation Sampling Results 2007

	Range (mg/kg)	Max (mg/kg)
Metals		
Boron (hot water)	3.4 - 19.8	
Chromium VI	<0.2	0.1
Mercury	<0.3	0.15
Antimony	<1 - <4	2
Arsenic	<1 - <4	2
Barium	<10 - 50	50
Beryllium	< 0.4 - <2	1
Cadmium	<0.1 - 0.3	0.3
Chromium	<1 - 1	1
Cobalt	<1 - <4	2
Copper	<5 - 9	9
Lead	<1 - <4	2
Molybdenum	<0.4 - 1.6	1.6
Nickel	<1 - <4	2
Selenium	<0.5 - 0.6	0.6
Silver	<1 - <4	2
Thallium	<0.3 - <1	0.5
Tin	<1 - 5	5
Vanadium	<1 - <4	2
Zinc	15 - 114	114
Polynuclear Aromatic Hydrocarbons		
	Highest Detection Limit (mg/kg)	**Concentration (1/2 detection limit, mg/kg)**
acenaphthene	0.18	0.09
acenaphthylene	0.18	0.09
anthracene	0.18	0.09
benz(a)anthracene	0.18	0.09
benzo(b)fluoranthene	0.18	0.09
benzo(k)fluoranthene	0.18	0.09
benzo(ghi)perylene	0.18	0.09
benzo(a)pyrene	0.18	0.09
benzo(e)pyrene	0.18	0.09
chrysene	0.18	0.09
dibenz(ah)anthracene	0.18	0.09
fluoranthene	0.18	0.09
fluorene	0.18	0.09
indeno(123cd)pyrene	0.18	0.09
2-methylnaphthalene	0.18	0.09
naphthalene	0.18	0.09
phenanthrene	0.18	0.09
pyrene	0.18	0.09

All vegetation samples exhibited non-detect results for metals and PAHs.

Vegetation data from within the area has consistently presented vegetation levels of the PAHs below detection limits (NWU, 2007, PCOSI, 2006). Predictive modeling based on air quality was assumed to be the most appropriate approach for evaluating background risks.

4D1.4 Surface Water

The surface water pathway is applicable to livestock and game animals (consumed by humans) but generally not to humans who obtain their drinking water from groundwater wells in the area.

4D1.4.1 Polycyclic Aromatic Hydrocarbons

Several of the COPCs carried forward into the multi-pathway assessment fall into the PAH group of compounds. Surface water data previously collected in the area was evaluated to collect information regarding measured concentrations. Background surface water analytical results are presented in Table 4D-3.

Table 4D-3 Background Surface Water Concentrations of the COPCs, North Saskatchewan River

COPCs	Detection Limit (mg/L)	½ Detection Limit (mg/L)
Aliphatic C_5-C_8 Group	ND	ND
Aliphatic C_9-C_{16} Group	ND	ND
aliphatic C_{17}-C_{34} group	ND	ND
Anthracene	1.00E-05	5.00E-06
Aromatic C_9-C_{16} Group	ND	ND
Aromatic C_{17}-C_{34} Group	ND	ND
Benzo(a) anthracene	1.00E-05	5.00E-06
Benzo(a) pyrene	1.00E-05	5.00E-06
Benzo(e)pyrene	1.00E-05	5.00E-06
Benzo(b) fluoranthene	1.00E-05	5.00E-06
Benzo(g,h,i) perylene	1.00E-05	5.00E-06
Benzo(k) fluoranthene	1.00E-05	5.00E-06
Biphenyl	ND	ND
Chrysene	1.00E-05	5.00E-06
Dibenzo(a,h) anthracene	1.00E-05	5.00E-06
Fluoranthene	1.00E-05	5.00E-06
Fluorene	1.00E-05	5.00E-06
Indeno(1,2,3-cd) pyrene	1.00E-05	5.00E-06
Naphthalene	1.00E-05	5.00E-06
Phenanthrene	1.00E-05	5.00E-06
Pyrene	1.00E-05	5.00E-06

Notes:

ND : No data available

Source: PCOSI, 2006.

All surface water concentrations were below analytical detection limits, Therefore modelling was used to predict livestock and game tissue concentrations. For the purposes of predicting tissue concentrations, surface water concentrations were predicted based on predicted background air concentrations.

4D1.4.2 Metals

Measured background concentrations of metals in surface water in the North Saskatchewan River at various locations, and predicted water concentrations (1.29 km downstream of the proposed North American outfall) were compared against relevant health-based values from the Canadian Council of Ministers of the Environment, Health Canada Drinking Water Quality Guidelines, and the United States Environmental Protection Agency (Table 4D-4).

Table 4D-4 below compares predicted concentrations to measured concentrations to determine if there is a predicted future impact on water quality. For substances that were determined to have a predicted concentration downstream greater than measured values, the predicted concentrations were compared to drinking water quality guidelines, and U.S. EPA water quality guidelines for both water and fish consumption.

Based upon this screening level risk assessment of surface water quality, no substances were determined to pose a future health risk in association with drinking water consumption.

Table 4D-4 Screening Level Comparison of Measured and Predicted Values Against Water Quality Guidelines

	Measured (mg/L)		**Predicted (mg/L)**		**Predicted (1.29 km)> Measured at Vinca?**	**DWGQ (mg/L)**	**US EPA criteria (water + fish), mg/L**	**Value Derived from Oral RfD**	**Exceed Guidelines?**
	Pakan	**Vinca**	**1.29 km Downstream**	**Full Mixing**					
Aluminum	0.7	0.46	0.0765	0.07	No				
Antimony	0.00018	0.00007	ND	ND	No		0.0056		
Arsenic	0.0008	0.001	0.00001	ND	No		0.000018		
Barium	0.08	0.06	NA	NA	--				
Beryllium	0.0003	0.0003	0.0001	0.0001	No				
Boron	0.033	0.0158	NA	NA	--				
Cadmium	0.0004	0.0004	0.000005	0.000001	No				
Chromium	0.0037	0.002	ND	ND	No				
Cobalt	0.0008	0.0008	ND	ND	No				
Copper	0.0035	0.002	0.001	0.001	No		1.3		
Iron	0.901	0.3	0.1282	0.109	No				
Lead*	0.0024	0.001	0.0009	0.0009	No				
Lithium	0.0085	0.0045	NA	NA	--				
Manganese	0.02	8	NA	NA	--		0.05		
Mercury	0.000042	0.000042	ND	ND	No				
Molybdenum	0.0011	0.001	0.0012	0.0011	Yes	NA		0.23	No
Nickel	0.0054	0.004	0.0019	0.0018	No		0.61		
Selenium	0.0004	0.0003	ND	ND	No		0.17		
Silicon		2.3	NA	NA	--				
Silver	0.0002	0.00001	NA	NA	--				
Strontium	0.4	0.427	NA	NA	--				
Thallium		0.000026	NA	NA	--		0.00024		
Tin	0.001	ND	NA	NA	--				
Titanium	0.016	0.0077	0.0024	0.0023	No				
Uranium	0.0011	0.00055	NA	NA	--				
Vanadium	0.003	0.003	0.00005	ND	No				
Zinc	0.0151	0.007	0.0084	0.008	Yes	5	7.4		No

[1] –A risk-based value was derived by North American based upon the oral Reference Dose for molybdenum of 0.005 mg/kg-day (U.S EPA IRIS, 2007), assuming a body weight of 70 kg and a drinking water ingestion rate of 1.5 L/day from Health Canada 2004. The result is a health risk-based value of about 0.23 mg/L for comparison with the molybdenum concentrations in this assessment.

4D1.5 Groundwater

Groundwater is an important source of drinking water in the Fort Saskatchewan area. Levels of the COPCs in groundwater were not specifically measured in association with this project. However, data is available from other sources that has been used to estimate exposures that residents (agricultural and community) may receive from drinking water.

It was assumed that local residents drink untreated water from private wells. Shell Canada (2007) recently completed groundwater analyses in association with the Shell Scotford Upgrader Expansion. Given the similarities in populations and study areas, these data were assumed in the risk assessment for background conditions (Table 4D-5).

Table 4D-5 Summary of Drinking Water Concentrations for Agricultural Receptor (Shell 2007)

COPC	Detection Limit (ug/L)	Concentration Used in Assessment (ug/L)
Aliphatic C_5-C_8 Group	ND	0
Aliphatic C_9-C_{16} Group	ND	0
Aliphatic C_{17}-C_{34} group	ND	0
Anthracene	0.01	0.005
Aromatic C_9-C_{16} Group	0.04	0.02
Aromatic C_{17}-C_{34} Group	ND	0
Benzo(a)anthracene	0.01	0.005
Benzo(a)pyrene	0.01	0.005
Benzo(e)pyrene*	0.01	0.005
Benzo(b)fluoranthene	0.01	0.005
Benzo(g,h,i)perylene	ND	0.005
Benzo(k)fluoranthene	0.01	0
Biphenyl	ND	0.005
Chrysene	0.01	0
Dibenzo(a,h)anthracene	0.01	0.005
Fluoranthene	0.02	0.01
Fluorene	0.01	0.005
Indeno(1,2,3-cd)pyrene	0.01	0.005
naphthalene	0.04	0.02
Phenanthrene	0.04	0.02
Pyrene	0.02	0.01

ND: not detected, * used benzo(a)pyrene as a surrogate

It was assumed that individuals in local urban communities would have access to treated municipal water. Water quality data were not readily available for Bruderheim or Fort Saskatchewan. Therefore recent water quality data from the City of Edmonton was reviewed (EPCOR 2007) (Table 4D-6).

Table 4D-6 Summary of Municipal Drinking Water Data for Residential Receptor in Local Community

COPC	Detection Limit (ug/L)	Concentration Used in Model (ug/L)
Aliphatic C_5-C_8 Group	ND	ND
Aliphatic C_9-C_{16} Group	ND	ND
Aliphatic C_{17}-C_{34} group	ND	ND
Anthracene	0.1	0.05
Aromatic C_9-C_{16} Group[1]	0.2	0.1
Aromatic C_{17}-C_{34} Group	ND	0
Benzo(a) anthracene	0.1	0.05
Benzo(a) pyrene	0.1	0.05
benzo(e)pyrene[2]	0.1	0.05
Benzo(b) fluoranthene	0.1	0.05
Benzo(g,h,i) perylene	0.2	0.1
Benzo(k) fluoranthene	0.1	0.05
Biphenyl	ND	0
Chrysene	0.1	0.05
Dibenzo(a,h) anthracene	0.5	0.25
Fluoranthene	0.1	0.05
Fluorene	0.1	0.05
Indeno(1,2,3-cd) pyrene	0.1	0.05
Naphthalene	0.1	0.05
Phenanthrene	0.1	0.05
Pyrene	0.1	0.05

Notes:

1 Sum of detection limits for naphthalene and acenaphthene.

2 Assumed benzo(a)pyrene as a surrogate, ND: No data.

Source: EPCOR, 2007.

As all concentrations of the PAHs in the untreated groundwater and treated municipal water were below analytical detection limits, these values were not used in the assessment due to the uncertainty associated with the use of half-detection limits.

4D1.6 Fish

Limited data is available for measured fish tissue concentrations in the Fort Saskatchewan area. A recent investigation as part of the proposed Sturgeon Upgrader Project involved the collection of eight samples of longnose sucker from the Fort Saskatchewan River. These data are presented in Table 4D-7.

Table 4D-7 Background Fish Concentrations, Fort Saskatchewan Area

COPC	Detection Limit (mg/kg ww)	Result
anthracene	0.05	ND
benz(a)anthracene	0.05	ND
benzo(a)pyrene	0.05	ND
benzo(b)fluoranthene	0.05	ND
benzo(ghi)perylene	0.05	ND
benzo(k)fluoranthene	0.05	ND
chrysene	0.05	ND
dibenz(ah)anthracene	0.05	ND
fluoranthene	0.05	ND
fluorene	0.05	ND
indeno(123cd)pyrene	0.05	ND
naphthalene	0.05	ND
perylene	0.05	ND
phenanthrene	0.05	ND
pyrene	0.05	ND

SOURCE: PCOSI, 2006.

Since PAHs in fish were not detected, the fish consumption exposure pathway was not evaluated for background conditions.

4D1.7 Air

4D1.7.1 Outdoor Air Ambient Concentrations

Measured background outdoor air concentrations were not used; rather, existing air concentrations were predicted by the Air Quality team. As part of the Air Quality assessment, Air quality predictions involved a thorough assessment of existing sources of the COPCs within the study area for discrete receptor locations. These background or existing emissions have been included in the air quality prediction for the Baseline, Application and CEA cases and were also generated as a separate data set to permit the evaluation of the potential health effects of existing COPC concentrations.

To ensure that these predictions were adequately representative, the predicted background values were compared with measured air data from various sources (including the Fort Air Partnership for the Fort Saskatchewan area). In the event that the range of air quality predictions for a COPC was below that of previously measured data, a correction factor was applied to the data in the human health risk assessment to ensure that the values were adequately conservative. Table 4D-8 presents a summary of the factors that were used to adjust the Background, Baseline, Application and CEA air quality predictions. COPCs not listed in this table were not adjusted.

Table 4D-8 Summary of Correction Factors Applied to Outdoor Air Quality Data

	1-hour Factor (ug/m^3)	24-hour Factor (ug/m^3)	Annual Factor (ug/m^3)
Acetaldehyde	8.62E+00	1.22E+01	8.77E+00
Aliphatic alcohols	7.28E+01	7.48E+01	9.87E+00
Benzo(a)anthracene	-2.95E-04	-9.00E-05	3.25E-05
Benzo(a)pyrene	3.56E-05	3.75E-05	3.47E-05
Benzo(b)fluoranthene	1.64E-04	1.67E-04	8.87E-05
Benzo(e)pyrene	8.00E-05	8.00E-05	4.70E-05
Benzo(g,h,i)perylene	-1.11E-04	2.32E-05	5.48E-05
Benzo(k)fluoranthene	1.65E-04	1.67E-04	8.87E-05
Dichlorobenzene	1.67E-01	1.68E-01	2.29E-02
Formaldehyde	2.31E+01	2.57E+01	8.58E+00
Hydrogen Sulphide	2.21E+00	2.57E+00	7.74E-01
Isopropylbenzene	4.80E-02	4.80E-02	9.50E-03
Methylene chloride	1.05E+00	1.05E+00	2.20E-01

For the chronic health risk assessment, annual outdoor air concentrations were combined with assumed indoor air concentrations as defined in Section 4D1.7.2. These indoor and outdoor air values were adjusted for the amount of time that each receptor group is likely to spend indoors and outdoors to obtain a realistic estimate of the potential total background exposures to the COPCs (Table 4D-9).

Table 4D-9 Summary of Time Assumed to be Spent Indoors and Outdoors

Receptor Group	Estimated Time Indoors (h/day)	Estimated Time Outdoors (h/day)	References
AGR	19	5	U.S. EPA 1997
RES	22.5	1.5	Health Canada 2004a
IND	8	16	Health Canada 2004a
MON	--	24	Assumed
PUA	--	24	Assumed
Fenceline	--	24	Assumed

4D1.7.2 Indoor Air

Indoor air is a source of background exposures to the COPCs, given that many of them have been measured indoors (e.g., from building materials, household cleaning products). Indoor air exposures are important regarding long-term exposures to the chemicals, and were considered on an annual basis for the chronic assessment only.

Measured indoor air concentrations from Alberta were identified where possible. Alternatively, indoor air concentrations from Canadian or U.S. homes was selected. Average indoor air concentrations were identified as being the most representative of indoor air exposure to which individuals may be exposed to over a lifetime. The values included in the assessment are summarized in the Table 4D-10.

Table 4D-10 Summary of Assumed Indoor Air Concentrations Used in Chronic Assessment

COPC	Value (ug/m^3)	Reference/Comment
1,3-butadiene	2.7E-01	CEPA 2000; mean concentration of 24-hour samples collected from 57 randomly chosen homes in Hamilton, ON during 1993.
2-chloronaphthalene	0.00E+00	NV
2-methylnaphthalene	1.50E+00	ATSDR 2005. Average measured concentration in indoor air in US homes.
Acenaphthene	1.40E-03	AHW 2003. Mean of maximum 7-day integrated indoor air samples collected from 9 residences of Fort Saskatchewan from August – October 2001.
Acetaldehyde	2.60E+01	Gilbert et al. 2005. Mean ambient indoor air concentration from a random survey of 59 homes.
Acrolein	1.30E+00	Gilbert et al. 2005. Mean ambient indoor air concentration from a random survey of 59 homes.
Aliphatic alcohols group	0.00E+00	NV
Aliphatic aldehydes group	0.00E+00	NV
Aliphatic C_{17}-C_{34} group	0.00E+00	NV
Aliphatic C_5-C_8 Group	8.7E+00	Fellin and Otson 1994; Zhu et al. 2005. Mean of 757 indoor air samples of hexane collected from Canadian homes in 1991 and 1992, and a mean of 75 indoor air samples of cyclohexane from Canadian homes in 2005.
Aliphatic C9-C16 group	25E+00	Fellin and Otson 1994; Zhu et al. 2005. Mean of 757 indoor air samples of n-decane collected from Canadian homes in 1991 and 1992
Aliphatic ketones group	2.5E+00	Fellin and Otson 1994. Mean of 757 indoor air samples of methyl ethyl ketone collected from Canadian homes in 1991 and 1992
Ammonia	0.00E+00	NV
Anthracene	0.00E+00	AHW 2003. Mean of maximum 7-day integrated indoor air samples collected from 9 residences of Fort Saskatchewan from August – October 2001.
Aromatic C_{17}-C_{34} group	0.00E+00	NV
Aromatic C_9-C_{16} group	3.5E-03	AHW 2003. Mean of maximum 7-day integrated indoor air samples collected from 9 residences of Fort Saskatchewan from August – October 2001.
Benz(a)anthracene	0.00E+00	AHW 2003. Mean of maximum 7-day integrated indoor air samples collected from 9 residences of Fort Saskatchewan from August – October 2001.
Benzaldehyde	0.00E+00	NV
Benzene	6.40E+00	Fellin and Otson 1994. Mean of 757 indoor air samples collected from Canadian homes in 1991 and 1992
Benzo(a)pyrene	0.00E+00	AHW 2003. Mean of maximum 7-day integrated indoor air samples collected from 9 residences of Fort Saskatchewan from August – October 2001.
Benzo(b)fluoranthene	2.30E-04	AHW 2003. Mean of maximum 7-day integrated indoor air samples collected from 9 residences of Fort Saskatchewan from August – October 2001.
Benzo(e)pyrene	5.70E-05	AHW 2003. Fort Saskatchewan, mean of maximum 7-day integrated outdoor air samples collected from 9 residences of Fort Saskatchewan from August - October 2001.
Benzo(ghi)perylene	6.70E-05	AHW 2003. Fort Saskatchewan, mean of maximum 7-day integrated outdoor air samples collected from 9 residences of Fort Saskatchewan from August - October 2001.
Benzo(k)fluoranthene	2.30E-04	AHW 2003. Fort Saskatchewan, mean of maximum 7-day integrated outdoor air samples collected from 9 residences of Fort Saskatchewan from August - October 2001.
Biphenyl	0.00E+00	NV

COPC	Value (ug/m^3)	Reference/Comment
Chrysene	5.50E-02	AHW 2003. Fort Saskatchewan, mean of maximum 7-day integrated outdoor air samples collected from 9 residences of Fort Saskatchewan from August - October 2001.
COS	0.00E+00	NV
CS2	6.3E-01	ATSDR 1996, CEPA 2000. Mean of indoor air collected in residences of New York City in 1992
Cyclohexane	6.6E+00	Fellin and Otson 1994. Mean of 757 indoor air samples collected from Canadian homes in 1991 and 1992.
Dibenz(ah)anthracene	0.00E+00	AHW 2003. Fort Saskatchewan, mean of maximum 7-day integrated outdoor air samples collected from 9 residences of Fort Saskatchewan from August - October 2001.
Dichlorobenzenes	3.6E+01	Fellin and Otson 1994. Mean of 757 indoor air samples collected from Canadian homes in 1991 and 1992.
Diethanolamine	0.00E+00	NV
Ethylbenzene	6.5E+00	Fellin and Otson 1994. Mean of 757 indoor air samples collected from Canadian homes in 1991 and 1992.
Fluoranthene	4.20E-04	AHW 2003. Fort Saskatchewan, mean of maximum 7-day integrated outdoor air samples collected from 9 residences of Fort Saskatchewan from August - October 2001
Fluorene	2.40E-03	AHW 2003. Fort Saskatchewan, mean of maximum 7-day integrated outdoor air samples collected from 9 residences of Fort Saskatchewan from August - October 2001
Formaldehyde	3.6E+01	CEPA 2001. Mean of pooled data from 5 different Canadian studies (n=151 samples).
H_2S	0.00E+00	Maximum annual average for 3 monitoring stations in the Fort Saskatchewan area from January 2003-April 2006
Hexane	2.1E+00	Fellin and Otson 1994. Mean of indoor 757 air samples taken in Canadian cities in 1991-1992.
Indeno(123cd)pyrene	6.00E-05	AHW 2003. Fort Saskatchewan, mean of maximum 7-day integrated outdoor air samples collected from 9 residences of Fort Saskatchewan from August - October 2001
Isopropylbenzene	0.00E+00	NV
Methylene chloride	1.9E+01	Fellin and Otson 1994. Mean of indoor 757 air samples taken in Canadian cities in 1991-1992.
Naphthalene	1.80E-03	AHW 2003. Fort Saskatchewan, mean of maximum 7-day integrated outdoor air samples collected from 9 residences of Fort Saskatchewan from August - October 2001.
NO_2	0.00E+00	NV
Phenanthrene	7.80E-03	AHW 2003. Fort Saskatchewan, mean of maximum 7-day integrated outdoor air samples collected from 9 residences of Fort Saskatchewan from August - October 2001
PM	0.00E+00	NV
Propylene oxide	0.00E+00	NV
Pyrene	5.00E-04	AHW 2003. Fort Saskatchewan, mean of maximum 7-day integrated outdoor air samples collected from 9 residences of Fort Saskatchewan from August - October 2001
SO_2	0.00E+00	NV
Styrene	7.0E-01	Fellin and Otson 1994. Mean of indoor 757 air samples taken in Canadian cities in 1991-1992
Toluene	1.8E+01	Fellin and Otson 1994. Mean of indoor 757 air samples taken in Canadian cities in 1991-1992
Xylenes	4.1E+00	Fellin and Otson 1994. Mean of indoor 757 air samples taken in Canadian cities in 1991-1992

Indoor and outdoor background exposures were evaluated for all agricultural, residential and industrial receptors. Indoor air exposures are not relevant to fenceline, public use area and monitoring receptors, where exposure to background outdoor concentrations 24-hours/day was assumed. Due to the different behavioural characteristics of the receptors in these groups, different assumptions regarding the duration of time spent indoors and outdoors were applied in the inhalation assessment.

4D2 RISK ASSESSMENT OF BACKGROUND CONDITIONS

4D2.1 Methodology

The potential health effects associated with background conditions are presented below.

Potential health effects associated with the non-carcinogenic COPCs are expressed as Risk Quotients. Potential cancer risks are expressed as Lifetime Cancer Risks (LCR) for the background scenario. Descriptions regarding these terms are provided below.

Risk Quotients were calculated by comparing the predicted levels of exposure for the non-carcinogenic COPCs to their respective exposure limits. RQs were calculated using Equation 1 below:

$$\text{Risk Quotient (RQ)} = \frac{\text{Predicted Exposure (ug/kg or ug/m}^3\text{)}}{\text{Exposure Limit}} \qquad \textit{Equation 1}$$

Interpretation of the RQ values was as follows:

RQ ≤ 1.0 Indicates that the estimated exposure is less than or equal to the exposure limit (i.e., the assumed safe level of exposure). RQs less than one are associated with negligible health risks, even in sensitive individuals given the level of conservatism incorporated in the derivation of the exposure limit and exposure estimate.

RQ > 1.0 Indicates that the exposure estimate exceeds the exposure limit. This suggests an elevated level of risk, the significance of which must be balanced against the high degree of conservatism incorporated into the risk assessment (i.e., the margin of safety is reduced but not removed entirely).

Potential risks from carcinogenic COPCs are expressed as LCRs for the background - the key difference between an LCR estimate and an incremental lifetime cancer risk (ILCR, which was used to evaluate the Project case in the main report) the two is in how they should be interpreted.

Lifetime cancer risks (LCR) simply refer to the number of cancer cases that could potentially result in association with exposures to carcinogens per 100,000 people. There is no clear benchmark for what is an acceptable risk to compare with a calculated LCR, given that the predicted LCRs for these cases not only include background levels (both natural and anthropogenic), but also include emissions from multiple different sources that may impact various environmental media. The overall probability of a person developing cancer in Canada is about 0.4 or 40% (Health Canada, 2004a). This probability could be interpreted as a comparative cancer incidence rate in the population; however, no guidance is provided to this effect. Some individuals may be more susceptible to developing cancer than others, and background exposures alone may exceed reasonably safe exposure levels and may result in the development of cancer in such sensitive individuals (Graham, 1993). Calculation of risk estimates from exposures that include background exposures, and that do not distinguish background risks from potential risks due to other sources, should not be considered as incremental cancer risk. Thus, the LCR is a predicted incidence rate per 100,000 people in a population, but does not readily distinguish an acceptable vs. unacceptable increased cancer risk above background. The LCR values have been calculated according to Equation 2.

$$\text{LCR} = \frac{\text{Background or Predicted Exposure (ug/kg or ug/m}^3\text{)}}{\text{Carcinogenic Exposure Limit}} \qquad \textit{Equation 2}$$

The regulatory benchmark of an acceptable cancer risk of 1 in 100,000 (or 1 in 1,000,000 in some jurisdictions) is policy-based, and its interpretation by various regulatory agencies differs. The generally accepted benchmark of acceptable cancer risk originates from the Delany clause of 1958 (Rosenthal et al. 1992; Mantel and Schneiderman 1975). The concept of essentially negligible cancer risk was also applied in the 1970s for assessing individual animal drug residues in the U.S (Kelley 1991, Graham 1993). U.S. EPA guidance indicates that cancer risks within the range of 10^{-4} to 10^{-6} may be considered acceptable (U.S. EPA 1991).

Therefore, although the basis of the cancer risk benchmark is complex and not always clear, it is apparent that these benchmark values were established to evaluate risks on a “per product” or “per site basis”. Health Canada (2004a) requires that carcinogens be assessed on an incremental basis and mandate an acceptable ILCR of 1 in 100,000. In relation to the current HHRA, it is most appropriate to compare ILCR associated with the Project to the 10^{-5} (1 in 100,000) benchmark as this level of risk is considered acceptable by Alberta Environment and Health Canada. Background and all exposures including background were not compared against these policy-based ILCR criteria. Alternatively, these risks were expressed as LCR.

COPCs with common toxicological endpoints were evaluated as chemical mixtures, assuming additivity in accordance with Health Canada (2004a) guidance. Mixture calculations were completed by summing the RQs for the components of each mixture to calculate an RQ for each type of mixture.

4D2.2 Results

4D2.2.1 Background Inhalation Assessment Results

Background inhalation exposures to COPCs were assessed using predicted air quality values for existing outdoor air, and measured literature-based values for indoor air. As different background outdoor air concentrations were predicted for each receptor group, an assessment of inhalation exposures was completed for each group. Indoor air exposures were only considered to be relevant to the chronic inhalation assessment where individuals were assumed to be exposed on a continual basis over a lifetime, as the potential duration and levels of exposure from indoor air are more variable when assessing on a 24-hour or less basis.

2.2.1.1 Background Acute Inhalation Results

Acute air quality predictions were provided for 1-hour and 24-hour averaging periods. The assessment of each COPC on an acute basis was conducted in association with the averaging period on which the exposure limit was based (Appendix 4A). As described in the methodology section, risk estimates were expressed as Risk Quotients (RQs). Table 4D-11 presents the acute inhalation results for the background assessment.

Table 4D-11 Maximum Background Acute Inhalation RQ Values for All Receptor Groups

		Receptor Group					
COPCs	**Period**	**AGR**	**RES**	**IND**	**PUA**	**MON**	**Fenceline**
1,3-butadiene	1 h	9.9E-04	1.0E-03	8.7E-04	1.3E-03	1.7E-03	8.4E-04
Acetaldehyde	1 h	7.0E-03	7.1E-03	6.6E-03	8.1E-03	9.4E-03	6.5E-03
Acrolein	1 h	**2.0E+00**	**2.1E+00**	**1.8E+00**	**2.7E+00**	**3.5E+00**	**1.7E+00**
Aliphatic alcohols group	1 h	2.4E-02	2.4E-02	2.4E-02	2.4E-02	2.5E-02	2.4E-02
Aliphatic C_5-C_8 Group	1 h	9.3E-04	4.2E-04	6.0E-03	5.4E-04	3.2E-03	5.1E-04
Aliphatic C_9-C_{16} group	1 h	3.0E-03	3.2E-03	5.9E-03	4.1E-03	5.3E-03	2.5E-03
Aliphatic ketones group	1 h	1.5E-04	1.6E-04	1.4E-04	2.1E-04	2.7E-04	1.3E-04
Ammonia	1 h	1.3E-02	7.9E-03	6.1E-02	1.6E-02	5.7E-02	1.0E-02
Aromatic C_9-C_{16} Group	1 h	1.6E-03	1.7E-03	1.5E-03	2.2E-03	2.8E-03	1.4E-03
Benzene	24 h	1.2E-01	8.7E-02	1.6E-01	1.2E-01	1.9E-01	7.7E-02
Carbon disulphide Group	1 h	8.5E-05	4.7E-05	9.0E-05	1.2E-04	4.6E-04	4.0E-05
Cyclohexane	24 h	9.5E-06	6.0E-06	5.5E-05	6.8E-06	4.2E-05	6.3E-06
Dichlorobenzenes	24 h	1.4E-05	1.4E-05	1.4E-05	2.7E-04	1.4E-05	2.1E-04
Ethylbenzene	24 h	4.0E-04	2.1E-04	4.2E-04	6.1E-01	8.6E-04	5.6E-01
Formaldehyde	1 h	5.8E-01	5.8E-01	5.6E-01	3.1E-02	6.6E-01	3.2E-02
H_2S	1 h	3.9E-02	3.5E-02	1.4E-01	1.1E-03	7.6E-02	9.8E-04
Hexane	24 h	1.4E-03	9.2E-04	6.4E-03	5.0E-04	4.4E-03	5.0E-04
Methylene chloride	24 h	5.0E-04	5.0E-04	5.0E-04	2.5E-04	5.0E-04	1.6E-04
Naphthalene	1 h	1.9E-04	2.0E-04	4.6E-04	3.4E-01	3.3E-04	2.5E-01
NO2	1 h	2.5E-01	2.9E-01	3.0E-01	4.4E-01	4.1E-01	2.7E-01
NO_2	24 h	2.9E-01	4.0E-01	4.2E-01	7.4E-01	4.9E-01	4.9E-01
PM	24 h	5.1E-01	6.8E-01	5.5E-01	4.7E-07	**1.1E+00**	2.8E-07
Propylene oxide	1 h	3.8E-07	1.9E-07	5.4E-07	3.7E-01	4.8E-07	2.9E-01
SO_2	10 min	3.4E-01	1.9E-01	**2.4E+00**	2.9E-01	6.9E-01	2.3E-01
SO_2	1 h	2.7E-01	1.5E-01	**1.9E+00**	3.1E-01	5.3E-01	2.7E-01
SO_2	24 h	3.3E-01	1.5E-01	**1.3E+00**	1.5E-04	5.6E-01	1.5E-04
Styrene	1 h	3.9E-04	4.6E-05	6.7E-04	5.3E-04	6.8E-04	3.4E-04
Toluene	1 h	4.0E-04	4.2E-04	5.6E-04	1.3E-03	6.9E-04	8.2E-04
xylenes	1 h	9.7E-04	1.0E-03	2.9E-03	1.3E-03	1.7E-03	8.4E-04

Acrolein, particulate matter, and sulphur dioxide were the only COPCs to exhibit a predicted RQ value greater than 1.0 in association with emissions from existing sources on an acute basis. These potential risks are discussed below.

Acrolein

Acute background acrolein RQ values ranged from 1.7 to 3.5 for all of the different receptor types. These values indicate that existing ambient sources of acrolein result in predicted exceedances the assumed acute exposure limit. Table 4D-12 summarizes the potential short-term effects of acrolein associated with various exposure levels.

Table 4D-12 Potential Acute Effects of Acrolein Exposure

Exposure Concentration (ug/m^3)	Effects	References
70	Odour perception	WHO IPCS 1991
130	Eye irritation	WHO IPCS 1991; Darley et al 1960
340	Nasal irritation	Weber Tschopp et al. 1977
4580	Odour recognition	Sinkuvene 1970
600 – 700	Reduced respiratory rate, coughing, nasal irritation, chest pain, difficult breathing	Kirk et al. 1991; WHO IPCS 1991; Weber-Tschopp et al. 1977
>700	Respiratory and eye irritation, degeneration of respiratory epithelium, edema of tracheal and bronchial mucosa	WHO IPCS 1991
> 5,000	Intolerable to humans	Einhorn 1975, Kirk et al. 1991
>20,000	Lethal	Einhorn 1975, Kirk et al. 1991

The Lowest Observed Adverse Effect Level (LOAEL) identified in the OEHHA (2000) derivation of the acrolein exposure limit was about 138 ug/m^3. based upon the incidence of eye irritation, which is similar to the value of 130 ug/m^3 cited in the table above. The maximum hourly predicted background outdoor air concentrations for acrolein range from 0.5 ug/m^3 to 1 ug/m^3 for the six groups. These exposure levels are over 100 times lower than the LOAEL of 138 µg/m3. Thus the predicted health risks are conservative, and the true risk of experiencing eye irritation in response to acute acrolein exposures as a result of existing sources is likely low.

Particulate Matter

The maximum 24-hour $PM_{2.5}$ air concentration at the monitoring locations exceeded the Canada Wide Standard of 30 ug/m^3. Appendix 4A provides detailed information regarding the potential health effects of $PM_{2.5}$.

The maximum 24-hour background air location was predicted to be 33 ug/m^3. This air concentration is associated with an RQ of 1.1. The maximum air concentrations may be compared against the background levels of PM in other areas in Canada, presented in the Table 4D-13.

Table 4D-13 Ambient $PM_{2.5}$ Concentrations in Canada (2003-2005)

Location	Range in Ambient Air Concentrations^1 (ug/m^3)	Risk Quotient (RQ)^2
Yukon and Northwest Territories	17 to 23	0.57 to 0.77
British Columbia	10 to 34	0.33 to 1.1
Alberta	11 to 22	0.37 to 0.73
Saskatchewan and Manitoba	9 to 15	0.30 to 0.50
Ontario	28 to 34	0.93 to 1.1
Quebec	23 to 40	0.77 to 1.3
Atlantic Canada	10 to 16	0.33 to 0.53

Notes:

1 Averaging times not evident from data source.

2 Risk quotients were calculated using the Health Canada CWS of 30 ug/m^3 (CCME, 2000)

Source: Environment Canada, 2006.

As shown, the maximum background concentration falls within the range reported for other Canadian areas.

Sulphur Dioxide

Sulphur dioxide air concentrations at the industrial receptor locations were associated with RQ values of 2.4 (10 minute), 1.9 (1 h basis) and 1.3 (24 h basis). Sulphur dioxide RQ values for all other receptor groups were less than 1.

In clinical studies (ATSDR 1998; Environment Canada 1987; Linn et al. 1983; UK Dep't of Health, 1995), clear respiratory responses have not been observed in healthy individuals exposed to brief periods of concentrations of SO_2 less than 2000 to 2600 ug/m^3. At a concentration of 1,300 ug/m^3, non-exercising asthmatics displayed a similar lack of respiratory response (Linn et al., 1983; Sheppard et al., 1981). The maximum predicted background SO_2 concentrations for this receptor group are: 1,218 ug/m^3 (10 minute), 851 ug/m^3 (1 h) and 195 (24 h). These levels are within the range of the first row Table 4D-14 below, suggesting that asthmatic or sensitive individuals may experience respiratory difficulties, but that normal individuals are unlikely to experience effects. All three of these predicted concentrations are below the range of 2000-2600 ug/m^3 discussed above.

Table 4D-14 Summary of the Potential Short-term Health Effects of Sulphur Dioxide

Air Concentration (ug/m^3)	**Description of Potential Health Effects**
530 to 1,300	Increased airway resistance and potential bronchoconstriction in asthmatic or sensitive individuals engaged in moderate exercise, but typically no effect on lung function in normal individuals.
1,300 to 2,600	Increased resistance in airways and difficulties breathing may be experienced by normal individuals (in addition to asthmatics and sensitive individuals). Sore throat and the ability to taste and smell SO_2 may also be apparent. Effects in asthmatics and other sensitive individuals may also include wheezing, dyspnea, and bronchoconstriction.
2,600 to 13,000	Odour is detectable. Increased resistance in airways, decreased lung volume, reduced bronchial clearance and evidence of lung irritation (increased macrophages in lung fluid) have been observed at this exposure level. Headache, coughing, throat irritation, nasal congestion, increased salivation may be evident, and some symptoms may persist for several days after exposure. Mucociliary transport in the nasal passages may also be impaired, potentially leading to nasal congestion. Respiratory effects may be more severe in asthmatics and sensitive individuals.
13,000 to 26,000	Increased resistance in airways, decreased respiratory volume, difficulties breathing and lung irritation have been reported at this exposure level. Nasal, throat and eye irritation, nosebleeds, coughing, potentially accompanied by erythema of trachea and bronchi may occur. Respiratory effects may be more severe in asthmatics and sensitive individuals.
26,000 to 130,000	Symptoms of more severe respiratory irritation may appear, such as burning of nose and throat, sneezing, severe airway obstruction, choking, and dyspnea. Exposure may result in damage to airway epithelium that may progress to epithelial hyperplasia, an increased number of secretory goblet cells, and hypertrophy of the sub-mucousal glands. A condition known as Reactive Airway Dysfunction Syndrome (RADS) may arise in the concentration ranges (as well as above) as a result of bronchial epithelial damage. Chronic respiratory effects may develop. Eye irritation, watery eyes, and skin eruptions (rashes) may be evident. Respiratory effects may be more severe in asthmatics and sensitive individuals.

Air Concentration (ug/m^3)	Description of Potential Health Effects
130,000 to 260,000	Symptoms of severe respiratory irritation may occur, such as bronchitis, intolerable irritation of mucous membranes in addition to other effects described above, such as decreased lung capacity and breathing difficulties, runny nose, eye and skin irritation.
>260,000	Immediately dangerous to life and health. Chemical bronchopneumonia and asphyxia have been reported at high levels of exposure. Death may result from severe respiratory depression at concentrations of approximately 2,600,000 ug/m^3.

References: NIOSH (1974); WHO (1979); ATSDR (1998); HSDB (2007); Cal EPA (1999); WHO (2000)

In addition, Alberta Health and Wellness has recently evaluated the potential health effects associated with short-term SO_2 exposures. Based upon a review of human clinical evidence, AHW (2006) concluded that healthy individuals may be exposed to concentrations up to 26,000 $\mu g/m^3$ (10 ppm) with transitory effects on pulmonary function, even under rather extreme conditions involving hyperventilation, mouth-only exposure and heavy exercise.

Thus, it is possible that sensitive individuals may currently experience respiratory difficulties in association with ambient sulphur dioxide exposure at the industrial receptor locations. Healthy individuals are less likely to experience adverse effects.

2.2.1.2 Background Chronic Inhalation Results

Both indoor and outdoor air concentrations were included in the chronic assessment, and different assumptions regarding the time likely to be spent indoors and outdoors by each receptor type were applied. The chronic background inhalation RQ and LCR values for the COPCs are presented in the tables below for the agricultural, residential, industrial, public use area and monitoring receptor groups.

Fenceline receptors were not included in the chronic inhalation assessment, as the purpose of the fenceline group was to evaluate brief, short-term exposures to transient receptors near the North American property boundary.

Table 4D-15 Summary of Background Chronic Inhalation RQ Values for All Receptors

COPC	Period	Receptor Group				
		AGR	RES	IND	PUA	MON
2-chloronaphthalene	annual	5.1E-11	1.2E-11	7.7E-11	1.8E-10	2.8E-10
Acrolein	annual	**5.2E+01**	**6.1E+01**	**4.4E+01**	**2.1E+00**	**3.8E+00**
Aliphatic alcohols group	annual	5.2E-04	1.6E-04	8.3E-04	2.5E-03	2.6E-03
Aliphatic aldehydes group	annual	2.8E-05	9.3E-06	3.6E-05	2.5E-04	5.2E-04
Aliphatic C_{17}-C_{34} group	annual	1.3E-07	4.5E-08	1.7E-07	1.2E-06	2.5E-06
Aliphatic C_5-C_8 Group	annual	4.1E-04	4.5E-04	6.1E-04	1.6E-04	5.0E-04
Aliphatic C_9-C_{16} group	annual	9.9E-02	1.2E-01	8.4E-02	2.5E-03	5.1E-03
Aliphatic ketones group	annual	4.0E-04	4.8E-04	3.4E-04	2.5E-05	5.2E-05
Ammonia	annual	4.6E-03	9.2E-04	2.4E-02	2.4E-02	5.2E-02
Aromatic C_{17}-C_{34} group	annual	1.6E-06	5.4E-07	2.1E-06	1.5E-05	3.0E-05
Aromatic C_9-C_{16} Group	annual	6.5E-03	7.2E-03	5.9E-03	4.6E-03	9.4E-03
Benzaldehyde	annual	1.4E-05	4.6E-06	2.0E-05	1.3E-04	2.6E-04

COPC	**Period**	**Receptor Group**				
		AGR	**RES**	**IND**	**PUA**	**MON**
Biphenyl	annual	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Carbon disulphide Group	annual	5.0E-03	5.9E-03	4.3E-03	1.2E-04	5.2E-04
Cyclohexane	annual	8.7E-04	1.0E-03	7.5E-04	4.8E-06	2.6E-05
Dichlorobenzenes	annual	4.8E-01	5.6E-01	4.0E-01	0.0E+00	0.0E+00
Diethanolamine	annual	0.0E+00	0.0E+00	0.0E+00	1.3E-04	2.7E-04
Ethylbenzene	annual	5.2E-03	6.1E-03	4.4E-03	4.0E-01	4.6E-01
H_2S	annual	8.6E-02	2.5E-02	2.2E-01	9.5E-04	1.9E-03
Hexane	annual	2.6E-03	2.9E-03	3.7E-03	2.4E-05	2.4E-05
Isopropylbenzene	annual	4.9E-06	1.5E-06	7.9E-06	1.1E-02	1.1E-02
Naphthalene	annual	1.4E-03	8.5E-04	8.4E-03	3.7E-01	5.9E-01
NO_2	annual	5.3E-02	1.6E-02	8.5E-02	4.0E-01	6.3E-01
PM	annual	5.9E-02	1.8E-02	1.1E-01	7.5E-06	1.2E-05
SO_2	annual	3.8E-02	6.0E-03	8.3E-02	9.3E-05	2.9E-04
Styrene	annual	6.0E-04	6.6E-04	5.4E-04	1.9E-04	3.8E-04
Toluene	annual	2.9E-03	3.4E-03	2.5E-03	5.4E-03	1.1E-02
Xylenes	annual	3.3E-02	3.9E-02	3.4E-02	1.8E-10	2.8E-10

*Fenceline receptors not evaluated on a chronic basis

Acrolein presented RQ values greater than 1. These findings are discussed further below. All other RQ values were less than 1, suggesting that the risk of long-term effects in association with background exposures to non-carcinogens is negligible.

Acrolein

Acrolein exhibited predicted RQ values of 52 (agricultural), 61 (residential), 44 (industrial), 2.1 (public use area) and 3.8 (monitoring). The agricultural, residential and industrial inhalation exposure assessment included both ambient and indoor air sources of exposure to acrolein, thus have RQ values much higher than the public use area and monitoring groups (assumed to be exposed to outdoor air only). It is possible that sensitive individuals may experience nasal irritation when exposed to the highest predicted background levels of acrolein.

The chronic exposure limit for acrolein is based upon the incidence of non-cancerous nasal lesions in rats from a subchronic study. No long-term studies of the long-term effects of acrolein are available (U.S. EPA, 2003; WHO, 2002; Government of Canada, 2000; WHO IPCS, 1991), thus the true threshold of effects in humans on a long-term basis is unknown. As a result, studies have been based upon acute human or acute and sub-chronic animal exposures. Through the application of uncertainty factors in the derivation of the exposure limit, the effect-threshold for nasal lesions in rats has been adjusted such that the estimated human threshold is about 1,000-times lower than in rats. As such, the true risk of experiencing adverse nasal irritation as a result of current background exposures is likely much less than predicted. Appendix 4A provides additional information regarding the chronic acrolein exposure limit.

The background risk for acrolein for the agricultural, residential and industrial groups is primarily due to the use of an assumed indoor air concentration of 1.3 ug/m^3 in the exposure assessment (obtained from Gilbert et al., 2005). This value is based upon 59 indoor air samples collected from Canadian cities.

The predicted background outdoor air concentration used for all of the receptor groups represented the highest concentrations for those groups in association with existing sources of acrolein in the area.

Table 4D-16 presents a summary of some acrolein indoor air concentrations from various locations, and associated RQ values assuming the same exposure limit of 0.02 ug/m^3 that was used in the chronic assessment.

Table 4D-16 Mean Acrolein Concentrations Measured in Indoor Air and Associated Risk Quotients

Location	Air Concentration (ug/m^3)	Number of Residences Evaluated	Predicted Risk Quotient
Hamilton, Ontario	1.1	11	55
Windsor, Ontario	3.0	29	150
Los Angeles, California	1.2	134	60
Elizabeth, New Jersey	0.96	139	48
Houston, Texas	3.1	125	155
Japan	8.3	1,417	415

The background air concentration for acrolein appears to be within the range of values estimated for other areas in Canada and the world.

Table 4D-17 Summary of Background Inhalation LCR Values for All Receptor Groups*

COPCs	Period	AGR	RES	IND	PUA	MON
1,3-butadiene	annual	7.3E-01	8.5E-01	6.2E-01	1.7E-01	3.4E-01
acetaldehyde	annual	**1.3E+00**	**1.5E+00**	**1.2E+00**	5.4E-01	5.7E-01
benzene	annual	**3.9E+00**	**4.6E+00**	**3.5E+00**	3.1E-01	6.0E-01
benzo(a)pyrene WMM	annual	6.1E-02	1.8E-02	1.1E-01	2.9E-01	2.9E-01
Benzo(a)pyrene IPM-TEQ	annual	4.3E-03	5.1E-03	3.7E-03	2.4E-04	3.2E-04
formaldehyde	annual	**3.9E+01**	**4.5E+01**	**3.5E+01**	**1.2E+01**	**1.2E+01**
methylene chloride	annual	7.9E-01	9.3E-01	6.6E-01	1.1E-02	1.1E-02
propylene oxide	annual	2.1E-06	4.9E-07	3.2E-06	7.5E-06	1.2E-05

*Fenceline receptors not evaluated on a chronic basis

As described in the risk characterization section, LCR values refer to the number of cancer cases that could potentially result from the estimated exposures to these carcinogenic COPCs in a population of 100,000 people. The regulatory benchmark of an acceptable incremental lifetime cancer risk of one in 100,000 is policy-based, and in this assessment has been used to describe incremental risks associated with the Project alone and does not apply to background risks. An acceptable cancer incidence rate for use as a benchmark when evaluating carcinogenic risk associated with background or baseline conditions has yet to be defined by regulatory agencies. Thus, it is important that background cancer risk estimates be interpreted only as tumour incidence per 100,000 individuals.

Acetaldehyde

Acetaldehyde resulted in assumed LCR values of 1.3 (agricultural), 1.5 (residential), and 1.2 (industrial) in association with exposure to background sources.

The exposure limit for acetaldehyde was based on the incidence of nasal tumours (nasal adenocarcinomas and squamous cell carcinomas) in rats (Government of Canada, 2000), as the database associated with the long-term effects of acetaldehyde in humans is limited. The Alberta Cancer Registry (ACB, 2005) report that describes the most recent data for cancer incidence in Alberta notes that 8 cancer cases due to tumours of the nasal cavity were diagnosed per 100,000 people (male and female) in 2003. The total number of cases of cancer diagnosed in Alberta for that year was 12,571 per 100,000, indicating that nasal cavity tumours accounted for about 0.06% of these tumours. The potential contribution of background acetaldehyde exposures, as described in this assessment could contribute 1.2 – 1.5 nasal tumours per 100,000 cases in Alberta. Overall, this tumour type seems to have a relatively low frequency of occurrence within the general population, and potential contributions from background acetaldehyde exposure appear to be minimal.

The assumed exposure level in this assessment for background acetaldehyde represents both background indoor and outdoor exposures, and is dominated by indoor exposure for the agricultural, residential and industrial groups. The indoor air value was obtained from a study of 59 homes (Gilbert et al. 2005) from other parts of Canada, while the outdoor air number was predicted in the air quality assessment using conservative assumptions. It is possible that the exposure levels to which individuals are exposed in both indoor and outdoor air are lower.

Benzene

The critical toxicological effect associated with chronic benzene exposure is cancer, particularly leukemia and other tumours of the hematological system (U.S. EPA, 2007). Based upon the most recently published cancer data from the Alberta Cancer Board (ACB, 2005) for the year 2003, a total of 392 cases attributable to leukemia (men and women combined) out of a total number of cases of all cancers of 12,571 per 100,000 (ACB, 2005). This indicates that in 2003, 3% of cancer diagnoses were associated with leukemia. The LCR values ranging from 3.5 – 4.6 in the table above suggests that background benzene exposures may contribute to the development of about 3.5 – 4.6 cases per 100,000 cases in Alberta as a whole. This further suggests that benzene appears to contribute a relatively small proportion to the overall risk of developing leukemia.

The exposure level in this assessment for background represents both background indoor and outdoor exposures, and is dominated by indoor exposure for the agricultural, residential and industrial groups. The indoor air value was obtained from a study of 59 homes (Gilbert et al. 2005) from other parts of Canada, while the outdoor air number was predicted in the air quality assessment using conservative assumptions. It is possible that the exposure levels to which individuals are exposed in both indoor and outdoor air are lower.

Formaldehyde

Chronic background formaldehyde exposure was associated with predicted LCR values of 39 (agricultural), 45 (residential), 35 (industrial), 12 (public use area), and 12 (monitoring). This suggests that background formaldehyde exposures contributes 12 – 45 cases of cancer per 100,000 people.

Nasopharyngeal tumours are the critical chronic toxicological effect for formaldehyde, although reports of other respiratory tumour types have been noted sporadically (Government of Canada, 2001). The ACB (2005) data for 2003 indicates that a total of 27 new tumours attributable to cancers per 100,000 (males and females combined) of the nasopharynx and nasal cavity were diagnosed. Out of all cases of cancer in 2003 for Alberta, about 0.2% were of the nasopharynx and nasal cavity (27 out of 15,571). Thus, this tumour type appears to be relatively infrequent in Alberta. The estimated LCR values of 12- 45 per 100,000 for background formaldehyde suggests that formaldehyde may contribute to the background cancer incidence rate. However, consideration must be given to the degree of conservatism incorporated into the exposure limit used for the assessment of formaldehyde.

Although formaldehyde is recognized as a human carcinogen (IARC, 2006), the majority of the evidence appears to be from animal studies with exposure levels greater than 7,300 ug/m^3 and from epidemiologic (occupational) case control studies. It is important to recognize that the weight of evidence with respect to the potential for formaldehyde to cause cancer in humans is affected by:

- Differences between rats and humans, such as nasal vs. oronasal breathing patterns, and anatomical differences in relation to dosimetry that may affect the integrity of extrapolating of animal data to humans (Government of Canada, 2001).

- Limited weight of evidence of an association between human cancers and formaldehyde exposure (Hauptmann et al., 2004; Liteplo and Meek, 2003). Health Canada and Environment Canada (Government of Canada, 2001) concluded that although some human case control studies suggest an increased incidence of nasal and nasopharangeal tumours, the findings of these human studies are “less reliable” as a result of limitations in study methodology and design. In contrast to the case studies, larger human cohort studies have not found an association between exposure and nasal cancers (Government of Canada, 2001).

The exposure level in this assessment for background represents both background indoor and outdoor exposures, and is dominated by indoor exposure for the agricultural, residential and industrial groups. The indoor air value was obtained from measurements taken in other parts of Canada (Government of Canada, 2001), while the outdoor air number was predicted in the air quality assessment using conservative assumptions. It is possible that the exposure levels to which individuals are exposed in both indoor and outdoor air are lower.

4D2.2.2 Background Multiple Exposure Pathway Results

The multiple exposure pathway assessment focused on those COPCs that potentially may enter the human food chain. To estimate the exposure to carcinogens that an individual may receive over a lifetime, receptors were evaluated not only by individual life stage but also using a composite receptor where risks were amortized across life stages. As inhalation was assessed separately, the multi-pathway assessment focused on the dermal contact and ingestion pathways (with dust inhalation exposures being considered as oral ingestion exposures).

Potential exposures to persistent/bioaccumulative COPCs were evaluated on a chronic basis for the agricultural, residential and industrial receptors. The multi-pathway model was used to assess potential exposure to these COPCs via various ingestion pathways and the dermal contact pathway, depending on the receptor group. Tables 4D-18 and 4D-19 present the chronic RQ and LCR values.

Table 4D-18 Summary of Background Multi-Pathway RQ Values (Dermal Contact and Ingestion)

COPC	AGR	RES	IND
Aliphatic C_{17}-C_{34}	2.7E-05	8.6E-07	5.5E-07
Aliphatic C_5-C_8	2.4E-09	2.9E-11	2.9E-12
Aliphatic C_9-C_{16}	3.7E-05	8.2E-07	8.6E-07
Aromatic C_{17}-C_{34}	8.9E-04	3.9E-04	3.3E-07
Aromatic C_9-C_{16}	2.5E-05	4.4E-07	2.2E-08
Biphenyl	4.7E-07	2.4E-07	0.0E+00
Naphthalene	1.8E-06	1.8E-07	3.4E-09

NA: not available.

All predicted RQ values were less than 1 for the agricultural, residential and industrial groups, indicating that estimated exposure levels to the non-carcinogenic COPCs did not exceed their respective exposure limits for any of the receptor groups. These results suggest that background exposure to these COPCs through multiple environmental media (i.e., air, water, soil or local country food consumption) are associated with negligible risk of non-carcinogenic health effects.

Table 4D-19 Summary of Background Multi-Pathway LCR Values

COPC	AGR	RES	IND
Benzo(a)pyrene WMM	2.6E-02	1.7E-03	2.3E-04
Benzo(a)pyrene IPM	1.1E-01	7.0E-03	1.3E-03

4D2.2.3 Background Mixture Assessment

As discussed in Appendix 4A, the COPCs were evaluated using unique exposure limits in each the acute and chronic assessments. The COPCs were grouped into chemical mixtures based upon the critical toxicological endpoint(s) upon which their acute and chronic exposure limits were based. For these mixtures, the RQs for the components were summed for every receptor location, and the maximum mixture RQ for each receptor group was evaluated. These maximum values are presented in Table 4D-20 below.

Table 4D-20 Summary of Background Inhalation Mixture RQ and LCR Values for All Receptor Groups

Acute Inhalation Assessment						
Mixture	**Receptor Group**					
	AGR	**RES**	**IND**	**PUA**	**MON**	**Fenceline**
Irritants						
Eye irritants	2.60E+00	2.70E+00	2.40E+00	3.30E+00	4.20E+00	2.30E+00
Nasal irritants	6.00E-01	6.00E-01	5.90E-01	6.40E-01	6.80E-01	5.80E-01
Respiratory irritants	7.10E-01	5.80E-01	3.00E+00	7.30E-01	1.10E+00	6.40E-01
Hepatotoxicants	2.20E-03	2.10E-03	7.50E-03	2.70E-03	4.40E-03	1.80E-03
Nephrotoxicants	2.20E-03	2.10E-03	7.50E-03	2.70E-03	4.40E-03	1.80E-03
Neurotoxicants	7.60E-03	7.70E-03	1.80E-02	9.70E-03	1.20E-02	6.40E-03
Reproductive toxicants	1.30E-03	0.00E+00	1.40E-03	1.70E-03	2.10E-03	1.10E-03

Acute Inhalation Assessment						
Chronic Inhalation Assessment						
Irritants	**AGR**	**RES**	**IND**	**PUA**	**MON**	**Fenceline**
Eye irritants	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
Nasal irritants	5.20E+01	6.20E+01	4.40E+01	2.50E+00	4.20E+00	NA
Respiratory irritants	9.10E-02	2.20E-02	1.70E-01	4.70E-01	7.00E-01	NA
Hepatotoxicants	6.50E-03	7.20E-03	5.90E-03	4.60E-03	9.40E-03	NA
Nephrotoxicants	6.50E-03	7.20E-03	5.90E-03	4.80E-03	9.70E-03	NA
Neurotoxicants	1.40E-01	1.70E-01	1.30E-01	9.30E-03	1.80E-02	NA
Reproductive toxicants	7.00E-03	7.80E-03	6.40E-03	2.70E-03	2.90E-03	NA
Carcinogens(by tumour type						
Leukemia	4.70E+00	5.50E+00	4.10E+00	4.80E-01	9.40E-01	NA
Nasal tumours	4.10E+01	4.60E+01	3.60E+01	1.20E+01	1.30E+01	NA
Lung tumours	8.50E-01	9.50E-01	7.70E-01	3.00E-01	3.10E-01	NA

Several of the predicted acute and chronic RQ values for chemical mixtures were greater than 1.0. These predicted exceedances are discussed below.

Acute Eye Irritants Mixture

The acute eye irritants mixture was associated with maximum mixture RQ values ranging from 2.3 to 4.2, with exceedances reported for all six receptor groups. For all groups, existing ambient acrolein air concentrations are the mixture component associated with the most risk. The highest mixture RQ was predicted for the monitoring group at receptor 496.

Acute Respiratory Irritants Mixture

The acute respiratory irritants mixture was associated with RQ values greater than 1 for only the industrial and monitoring groups. Existing levels of sulphur dioxide were associated with the most risk for both mixtures.

Chronic Nasal Irritants Mixture

The chronic nasal irritants mixture RQ ranged from 2.5 – 4.2 for the receptor groups that did not include indoor air as part of background exposures (public use area, monitoring), and from 44-62 for the receptor groups that included both background outdoor and indoor air (agricultural, residential, industrial).

Acrolein appears to be the mixture component contributing the most risk, with a background RQ of 44-61 (depending on the amount of time estimated to be spent indoors). This background RQ is composed of small background outdoor air RQ and an indoor air RQ of 43 - 61. As such, the RQ values for the background case for the agricultural, residential and industrial groups are all driven by the indoor air background concentration used in this assessment, as opposed to emissions in the area.

Chronic Leukemia Mixture

The background leukemia mixture LCR values were greater than one for the agricultural, residential and industrial air receptors, and not the receptor groups that were assumed to be exposed to only outdoor air. The LCR values for the agricultural, residential, and industrial groups ranged from 4.1 to 5.5.

Of the mixture components, benzene exposure appears to contribute the most risk (LCR of 3.5 – 4.5) with less risk from background 1,3-butadiene (LCR of about 0.7). The background benzene

LCR is composed of an indoor LCR of about 3.3 - 4.6 and outdoor LCR of about 0.2. Thus, it is the background indoor air concentration selected for this assessment that appears to contribute the most risk to this mixture in the background case for receptors that are assumed to spend time indoors.

Chronic Nasal Tumour Mixture

The chronic nasal tumours mixture presented LCR values greater than one for all five receptor types (not including fenceline). The LCR values for receptors that were assumed to be exposed to indoor air (agricultural, residential, and industrial) are much higher than the receptors breathing outdoor air. Thus, existing ambient sources of nasal carcinogens in both indoor and outdoor air contribute to background exposures, and the background tumour incidence rate. The LCR values ranged from 36 to 46 for the receptors that were assumed to be exposed to both indoor and outdoor air. Formaldehyde is the mixture component associated with the most risk for all receptors, with some contribution from acetaldehyde. The LCR associated with indoor formaldehyde levels ranged from 31 – 44, thus the indoor air formaldehyde concentration used in this assessment is associated with the greatest risk.

Existing ambient outdoor sources of formaldehyde and acetaldehyde also contributed the mixture LCR values. Both the public use area and monitoring receptor, which are assumed to be exposed to outdoor air, both presented LCR values of 12-13.

Table 4D-21 below presents a summary of the multi-pathway mixture results for the background case.

Table 4D-21 Summary of Background Multiple Exposure Pathway Chemical Mixture RQ Values (Dermal Contact and Ingestion Only)

COPC	AGR	RES	IND
Hepatotoxicants	8.9E-05	2.4E-06	1.4E-06
Renal Toxicants	9.1E-04	3.9E-04	3.6E-07

All of the multi-pathway values were less than one, indicating that the long-term health risks associated with dermal contact and ingestion exposures to these mixtures are likely negligible.

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Appendix 4E
Multi Media Model - Predicted Tissue Concentrations

Table 4E-1 Predicted Livestock and Game Tissue Concentrations Used in the HHRA [mg/kg-WW]

Chemical	Receptor	Background	Baseline	Application	CEA	Project
Aliphatic C17-C34 Group	Beef	1.5E-03	0.0E+00	9.6E-03	9.6E-03	9.6E-03
Aliphatic C5-C8 Group	Beef	3.8E-07	1.4E-07	1.3E-06	2.9E-06	1.2E-06
Aliphatic C9-C16 group	Beef	8.0E-05	3.1E-05	9.1E-05	2.2E-04	7.1E-05
Anthracene	Beef	6.4E-08	1.5E-11	3.9E-08	3.9E-08	3.9E-08
Aromatic C17-C34 Group	Beef	7.3E-05	1.4E-08	3.9E-05	3.9E-05	3.9E-05
Aromatic C9-C16 Group	Beef	3.3E-05	5.5E-07	2.9E-05	3.6E-05	2.9E-05
Benz(a)anthracene	Beef	2.0E-06	4.5E-09	3.1E-06	3.2E-06	3.1E-06
Benzo(a)pyrene	Beef	9.4E-06	3.6E-09	4.0E-06	4.1E-06	4.0E-06
Benzo(a)pyrene	Beef	9.4E-06	3.6E-09	4.0E-06	4.1E-06	4.0E-06
Benzo(b)fluoranthene	Beef	1.1E-06	2.5E-10	1.8E-07	1.9E-07	1.8E-07
Benzo(e)pyrene	Beef	4.2E-05	6.1E-14	6.1E-14	3.5E-09	0.0E+00
Benzo(ghi)perylene	Beef	1.5E-04	3.2E-08	3.0E-05	3.1E-05	3.0E-05
Benzo(k)fluoranthene	Beef	3.1E-05	7.0E-09	5.2E-06	5.3E-06	5.2E-06
Biphenyl	Beef	0.0E+00	0.0E+00	8.2E-08	8.2E-08	8.2E-08
Chrysene	Beef	1.0E-06	1.3E-09	1.4E-06	1.5E-06	1.4E-06
Dibenz(ah)anthracene	Beef	1.7E-06	7.0E-08	7.7E-05	8.1E-05	7.7E-05
Fluoranthene	Beef	1.1E-06	9.1E-10	6.1E-07	6.3E-07	6.1E-07
Fluorene	Beef	2.4E-08	4.9E-12	1.2E-08	1.3E-08	1.2E-08
Indeno(123cd)pyrene	Beef	3.1E-07	3.2E-09	2.3E-06	2.4E-06	2.3E-06
Naphthalene	Beef	7.6E-07	2.6E-09	6.5E-07	6.7E-07	6.5E-07
Benzo(a)pyrene	Beef	9.4E-06	3.6E-09	4.0E-06	4.1E-06	4.0E-06
Phenanthrene	Beef	3.1E-07	3.7E-10	1.6E-07	1.7E-07	1.6E-07
Pyrene	Beef	6.8E-08	1.0E-09	1.2E-07	1.3E-07	1.2E-07
Aliphatic C17-C34 Group	Chicken	5.3E-05	0.0E+00	3.3E-04	3.3E-04	3.3E-04
Aliphatic C5-C8 Group	Chicken	1.2E-08	4.5E-09	4.2E-08	9.4E-08	4.0E-08
Aliphatic C9-C16 group	Chicken	1.8E-06	6.9E-07	2.0E-06	4.8E-06	1.6E-06
Anthracene	Chicken	8.0E-10	1.9E-13	4.8E-10	4.9E-10	4.8E-10
Aromatic C17-C34 Group	Chicken	7.4E-07	1.5E-10	3.9E-07	3.9E-07	3.9E-07
Aromatic C9-C16 Group	Chicken	4.4E-07	7.3E-09	3.9E-07	4.7E-07	3.8E-07
Benz(a)anthracene	Chicken	2.1E-08	4.8E-11	3.2E-08	3.3E-08	3.2E-08
Benzo(a)pyrene	Chicken	9.9E-08	3.8E-11	4.2E-08	4.3E-08	4.2E-08
Benzo(a)pyrene	Chicken	9.9E-08	3.8E-11	4.2E-08	4.3E-08	4.2E-08
Benzo(b)fluoranthene	Chicken	1.2E-08	2.7E-12	2.0E-09	2.1E-09	2.0E-09
Benzo(e)pyrene	Chicken	4.2E-07	6.1E-16	6.1E-16	3.5E-11	0.0E+00
Benzo(ghi)perylene	Chicken	1.5E-06	3.2E-10	3.0E-07	3.1E-07	3.0E-07
Benzo(k)fluoranthene	Chicken	3.5E-07	7.9E-11	5.8E-08	6.0E-08	5.8E-08
Biphenyl	Chicken	0.0E+00	0.0E+00	8.3E-10	8.3E-10	8.3E-10
Chrysene	Chicken	1.4E-08	1.8E-11	2.0E-08	2.0E-08	2.0E-08
Dibenz(ah)anthracene	Chicken	1.7E-08	7.0E-10	7.8E-07	8.1E-07	7.8E-07
Fluoranthene	Chicken	1.3E-08	1.0E-11	6.9E-09	7.1E-09	6.9E-09
Fluorene	Chicken	2.6E-10	5.4E-14	1.4E-10	1.4E-10	1.4E-10
Indeno(123cd)pyrene	Chicken	3.4E-09	3.4E-11	2.6E-08	2.7E-08	2.6E-08
Naphthalene	Chicken	8.6E-09	2.9E-11	7.3E-09	7.5E-09	7.3E-09
Benzo(a)pyrene	Chicken	9.9E-08	3.8E-11	4.2E-08	4.3E-08	4.2E-08
Phenanthrene	Chicken	3.6E-09	4.2E-12	1.8E-09	1.9E-09	1.8E-09
Pyrene	Chicken	1.4E-09	2.0E-11	2.4E-09	2.6E-09	2.3E-09
Aliphatic C17-C34 Group	Dairy	2.6E-04	0.0E+00	1.6E-03	1.6E-03	1.6E-03
Aliphatic C5-C8 Group	Dairy	1.3E-07	5.0E-08	4.7E-07	1.0E-06	4.4E-07
aliphatic C9-C16 group	Dairy	2.2E-05	8.4E-06	2.4E-05	5.9E-05	1.9E-05
Anthracene	Dairy	2.2E-08	5.3E-12	1.3E-08	1.3E-08	1.3E-08
Aromatic C17-C34 Group	Dairy	2.7E-05	5.2E-09	1.4E-05	1.4E-05	1.4E-05
Aromatic C9-C16 Group	Dairy	1.1E-05	1.9E-07	9.9E-06	1.2E-05	9.8E-06
benz(a)anthracene	Dairy	7.3E-07	1.6E-09	1.1E-06	1.1E-06	1.1E-06
Benzo(a)pyrene	Dairy	3.4E-06	1.3E-09	1.4E-06	1.5E-06	1.4E-06
Benzo(a)pyrene	Dairy	3.4E-06	1.3E-09	1.4E-06	1.5E-06	1.4E-06
Benzo(b)fluoranthene	Dairy	3.9E-07	8.7E-11	6.5E-08	6.6E-08	6.5E-08
Benzo(e)pyrene	Dairy	1.5E-05	2.2E-14	2.2E-14	1.3E-09	0.0E+00

Table 4E-1 Predicted Livestock and Game Tissue Concentrations Used in the HHRA [mg/kg-WW]

Chemical	Receptor	Background	Baseline	Application	CEA	Project
Benzo(ghi)perylene	Dairy	5.3E-05	1.2E-08	1.1E-05	1.1E-05	1.1E-05
Benzo(k)fluoranthene	Dairy	1.1E-05	2.5E-09	1.8E-06	1.9E-06	1.8E-06
biphenyl	Dairy	0.0E+00	0.0E+00	3.0E-08	3.0E-08	3.0E-08
Chrysene	Dairy	3.4E-07	4.3E-10	4.7E-07	4.9E-07	4.7E-07
dibenz(ah)anthracene	Dairy	6.2E-07	2.5E-08	2.8E-05	2.9E-05	2.8E-05
Fluoranthene	Dairy	4.0E-07	3.2E-10	2.2E-07	2.2E-07	2.2E-07
Fluorene	Dairy	8.4E-09	1.7E-12	4.4E-09	4.5E-09	4.4E-09
Indeno(123cd)pyrene	Dairy	1.1E-07	1.1E-09	8.3E-07	8.7E-07	8.3E-07
naphthalene	Dairy	2.7E-07	9.0E-10	2.3E-07	2.4E-07	2.3E-07
Benzo(a)pyrene	Dairy	3.4E-06	1.3E-09	1.4E-06	1.5E-06	1.4E-06
Phenanthrene	Dairy	1.1E-07	1.3E-10	5.6E-08	5.9E-08	5.6E-08
Pyrene	Dairy	1.9E-08	2.9E-10	3.3E-08	3.7E-08	3.3E-08
Aliphatic C17-C34 Group	White-tailed De	1.8E-05	9.3E-11	1.0E-04	1.0E-04	1.0E-04
Aliphatic C5-C8 Group	White-tailed De	2.4E-08	3.2E-08	3.3E-08	9.2E-08	2.7E-08
aliphatic C9-C16 group	White-tailed De	5.1E-06	1.3E-06	1.5E-06	3.8E-05	1.2E-06
Anthracene	White-tailed De	4.8E-08	3.0E-12	4.4E-09	4.4E-09	8.1E-10
Aromatic C17-C34 Group	White-tailed De	3.0E-03	7.1E-05	6.0E-04	1.7E-03	8.6E-07
Aromatic C9-C16 Group	White-tailed De	7.8E-07	1.1E-08	6.1E-07	7.4E-07	6.1E-07
benz(a)anthracene	White-tailed De	1.1E-07	9.9E-11	6.7E-08	6.9E-08	6.7E-08
Benzo(a)pyrene	White-tailed De	5.3E-07	1.5E-10	8.8E-08	9.1E-08	8.8E-08
Benzo(a)pyrene	White-tailed De	5.3E-07	1.5E-10	8.8E-08	9.1E-08	8.8E-08
Benzo(b)fluoranthene	White-tailed De	2.4E-08	6.6E-12	4.0E-09	4.1E-09	4.0E-09
Benzo(e)pyrene	White-tailed De	2.0E-06	3.9E-10	1.8E-07	2.0E-07	0.0E+00
Benzo(ghi)perylene	White-tailed De	3.3E-06	1.1E-09	6.7E-07	6.9E-07	6.7E-07
Benzo(k)fluoranthene	White-tailed De	6.7E-07	1.5E-10	1.1E-07	1.2E-07	1.1E-07
biphenyl	White-tailed De	5.5E-06	1.4E-09	4.8E-07	5.0E-07	1.8E-09
Chrysene	White-tailed De	1.6E-06	1.0E-10	1.3E-07	1.4E-07	2.9E-08
dibenz(ah)anthracene	White-tailed De	5.5E-07	2.9E-09	1.7E-06	1.8E-06	1.7E-06
Fluoranthene	White-tailed De	1.7E-07	6.4E-11	1.4E-08	1.6E-08	1.3E-08
Fluorene	White-tailed De	5.7E-10	2.7E-13	2.7E-10	2.7E-10	2.7E-10
Indeno(123cd)pyrene	White-tailed De	1.6E-08	8.5E-11	3.2E-08	3.5E-08	3.2E-08
naphthalene	White-tailed De	1.3E-06	3.4E-07	3.4E-07	9.7E-06	1.4E-08
Benzo(a)pyrene	White-tailed De	5.3E-07	1.5E-10	8.8E-08	9.1E-08	8.8E-08
Phenanthrene	White-tailed De	7.5E-09	8.0E-12	3.4E-09	3.6E-09	3.4E-09
Pyrene	White-tailed De	5.3E-07	3.3E-11	4.9E-08	4.9E-08	2.0E-09
Aliphatic C17-C34 Group	Eggs	3.0E-05	0.0E+00	1.9E-04	1.9E-04	1.9E-04
Aliphatic C5-C8 Group	Eggs	7.0E-09	2.6E-09	2.4E-08	5.4E-08	2.3E-08
aliphatic C9-C16 group	Eggs	1.0E-06	4.0E-07	1.1E-06	2.8E-06	9.0E-07
Anthracene	Eggs	4.6E-10	1.1E-13	2.8E-10	2.8E-10	2.8E-10
Aromatic C17-C34 Group	Eggs	4.2E-07	8.4E-11	2.2E-07	2.3E-07	2.2E-07
Aromatic C9-C16 Group	Eggs	2.5E-07	4.1E-09	2.2E-07	2.7E-07	2.2E-07
benz(a)anthracene	Eggs	1.2E-08	2.7E-11	1.8E-08	1.9E-08	1.8E-08
Benzo(a)pyrene	Eggs	5.6E-08	2.2E-11	2.4E-08	2.5E-08	2.4E-08
Benzo(a)pyrene	Eggs	5.6E-08	2.2E-11	2.4E-08	2.5E-08	2.4E-08
Benzo(b)fluoranthene	Eggs	6.8E-09	1.5E-12	1.1E-09	1.2E-09	1.1E-09
Benzo(e)pyrene	Eggs	2.4E-07	3.5E-16	3.5E-16	2.0E-11	0.0E+00
Benzo(ghi)perylene	Eggs	8.4E-07	1.8E-10	1.7E-07	1.8E-07	1.7E-07
Benzo(k)fluoranthene	Eggs	2.0E-07	4.5E-11	3.3E-08	3.4E-08	3.3E-08
biphenyl	Eggs	0.0E+00	0.0E+00	4.7E-10	4.7E-10	4.7E-10
Chrysene	Eggs	8.1E-09	1.0E-11	1.1E-08	1.2E-08	1.1E-08
dibenz(ah)anthracene	Eggs	9.8E-09	4.0E-10	4.4E-07	4.6E-07	4.4E-07
Fluoranthene	Eggs	7.3E-09	5.8E-12	4.0E-09	4.0E-09	3.9E-09
Fluorene	Eggs	1.5E-10	3.1E-14	7.9E-11	8.0E-11	7.9E-11
Indeno(123cd)pyrene	Eggs	1.9E-09	2.0E-11	1.5E-08	1.5E-08	1.5E-08
naphthalene	Eggs	4.9E-09	1.6E-11	4.2E-09	4.3E-09	4.2E-09
Benzo(a)pyrene	Eggs	5.6E-08	2.2E-11	2.4E-08	2.5E-08	2.4E-08
Phenanthrene	Eggs	2.1E-09	2.4E-12	1.0E-09	1.1E-09	1.0E-09

Table 4E-1 Predicted Livestock and Game Tissue Concentrations Used in the HHRA [mg/kg-WW]

Chemical	Receptor	Background	Baseline	Application	CEA	Project
Pyrene	Eggs	7.8E-10	1.1E-11	1.3E-09	1.5E-09	1.3E-09
Aliphatic C17-C34 group	Ruffed_Grouse	1.0E-05	5.4E-11	5.9E-05	5.9E-05	5.9E-05
Aliphatic C5-C8 Group	Ruffed_Grouse	7.4E-09	9.6E-09	1.0E-08	2.8E-08	8.2E-09
aliphatic C9-C16 group	Ruffed_Grouse	1.2E-06	3.2E-07	3.7E-07	9.3E-06	2.9E-07
Anthracene	Ruffed_Grouse	5.6E-09	3.5E-13	5.2E-10	5.2E-10	9.6E-11
Aromatic C17-C34 Group	Ruffed_Grouse	2.9E-04	6.7E-06	5.7E-05	1.6E-04	8.1E-08
Aromatic C9-C16 Group	Ruffed_Grouse	9.7E-08	1.4E-09	7.6E-08	9.3E-08	7.5E-08
benz(a)anthracene	Ruffed_Grouse	1.1E-08	9.7E-12	6.6E-09	6.8E-09	6.6E-09
Benzo(a)pyrene	Ruffed_Grouse	5.2E-08	1.4E-11	8.6E-09	8.9E-09	8.6E-09
Benzo(a)pyrene	Ruffed_Grouse	5.2E-08	1.4E-11	8.6E-09	8.9E-09	8.6E-09
Benzo(b)fluoranthene	Ruffed_Grouse	2.4E-09	6.8E-13	4.1E-10	4.2E-10	4.1E-10
Benzo(e)pyrene	Ruffed_Grouse	1.9E-07	3.6E-11	1.7E-08	1.8E-08	0.0E+00
Benzo(ghi)perylene	Ruffed_Grouse	3.0E-07	1.1E-10	6.3E-08	6.4E-08	6.3E-08
Benzo(k)fluoranthene	Ruffed_Grouse	7.1E-08	1.6E-11	1.2E-08	1.2E-08	1.2E-08
biphenyl	Ruffed_Grouse	5.1E-07	1.3E-10	4.5E-08	4.7E-08	1.7E-10
Chrysene	Ruffed_Grouse	2.1E-07	1.4E-11	1.8E-08	1.8E-08	3.8E-09
dibenz(ah)anthracene	Ruffed_Grouse	5.1E-08	2.7E-10	1.6E-07	1.7E-07	1.6E-07
Fluoranthene	Ruffed_Grouse	1.8E-08	6.8E-12	1.5E-09	1.7E-09	1.4E-09
Fluorene	Ruffed_Grouse	5.9E-11	2.8E-14	2.8E-11	2.8E-11	2.8E-11
Indeno(123cd)pyrene	Ruffed_Grouse	1.7E-09	8.7E-12	3.3E-09	3.6E-09	3.3E-09
naphthalene	Ruffed_Grouse	1.4E-07	3.5E-08	3.6E-08	1.0E-06	1.5E-09
Benzo(a)pyrene	Ruffed_Grouse	5.2E-08	1.4E-11	8.6E-09	8.9E-09	8.6E-09
Phenanthrene	Ruffed_Grouse	8.0E-10	8.5E-13	3.7E-10	3.9E-10	3.6E-10
Pyrene	Ruffed_Grouse	1.1E-07	7.1E-12	1.0E-08	1.1E-08	4.4E-10

Table 4E-2 Plant Concentrations Used to Estimate Livestock and Game Tissue Concentrations [mg/kg-WW]

Chemical	Receptor	Background	Baseline	Application	CEA	Project
Aliphatic C5-C8 Group	Livestock	2.0E-07	7.5E-08	7.0E-07	1.6E-06	6.6E-07
Aliphatic C9-C16 Group	Livestock	2.2E-05	8.5E-06	2.4E-05	5.9E-05	1.9E-05
aliphatic c17-C34 group	Livestock	7.3E-06	0.0E+00	4.6E-05	4.6E-05	4.6E-05
Anthracene	Livestock	2.2E-06	5.2E-10	1.3E-06	1.3E-06	1.3E-06
Aromatic C17-C34 Group	Livestock	2.9E-03	5.7E-07	1.5E-03	1.5E-03	1.5E-03
Aromatic C9-C16 Group	Livestock	1.5E-05	2.5E-07	1.3E-05	1.6E-05	1.3E-05
benz(a)anthracene	Livestock	6.3E-05	1.4E-07	9.6E-05	9.9E-05	9.5E-05
Benzo(a)pyrene	Livestock	3.1E-04	1.2E-07	1.3E-04	1.4E-04	1.3E-04
benzo(e)pyrene	Livestock	2.2E-03	3.2E-12	3.2E-12	1.8E-07	0.0E+00
Benzo(b)fluoranthene	Livestock	3.7E-05	8.3E-09	6.2E-06	6.3E-06	6.2E-06
Benzo(ghi)perylene	Livestock	9.8E-03	2.1E-06	2.0E-03	2.1E-03	2.0E-03
Benzo(k)fluoranthene	Livestock	1.0E-03	2.3E-07	1.7E-04	1.8E-04	1.7E-04
biphenyl	Livestock	0.0E+00	0.0E+00	2.6E-08	2.6E-08	2.6E-08
Chrysene	Livestock	2.7E-05	3.5E-08	3.8E-05	3.9E-05	3.8E-05
dibenz(ah)anthracene	Livestock	7.0E-05	2.9E-06	3.2E-03	3.3E-03	3.2E-03
Fluoranthene	Livestock	3.5E-05	2.8E-08	1.9E-05	1.9E-05	1.9E-05
Fluorene	Livestock	9.9E-07	2.0E-10	5.2E-07	5.2E-07	5.2E-07
Indeno(123cd)pyrene	Livestock	1.3E-05	1.3E-07	9.8E-05	1.0E-04	9.8E-05
naphthalene	Livestock	6.2E-07	2.1E-09	5.3E-07	5.4E-07	5.3E-07
Phenanthrene	Livestock	1.1E-05	1.3E-08	5.6E-06	5.9E-06	5.6E-06
Pyrene	Livestock	1.3E-06	2.0E-08	2.3E-06	2.5E-06	2.3E-06
Aliphatic C5-C8 Group	Wild game	6.0E-07	7.8E-07	8.1E-07	2.3E-06	6.6E-07
Aliphatic C9-C16 Group	Wild game	8.3E-05	2.1E-05	2.4E-05	6.2E-04	1.9E-05
aliphatic c17-C34 group	Wild game	8.2E-06	4.2E-11	4.6E-05	4.6E-05	4.6E-05
Anthracene	Wild game	7.7E-05	4.8E-09	7.1E-06	7.2E-06	1.3E-06
Aromatic C17-C34 Group	Wild game	5.4E+00	1.3E-01	1.1E+00	3.1E+00	1.5E-03
Aromatic C9-C16 Group	Wild game	1.7E-05	2.5E-07	1.3E-05	1.6E-05	1.3E-05
benz(a)anthracene	Wild game	1.6E-04	1.4E-07	9.6E-05	9.9E-05	9.5E-05
Benzo(a)pyrene	Wild game	8.0E-04	2.2E-07	1.3E-04	1.4E-04	1.3E-04
benzo(e)pyrene	Wild game	4.8E-03	9.2E-07	4.4E-04	4.6E-04	0.0E+00
Benzo(b)fluoranthene	Wild game	3.7E-05	1.0E-08	6.2E-06	6.3E-06	6.2E-06
Benzo(ghi)perylene	Wild game	9.8E-03	3.4E-06	2.0E-03	2.1E-03	2.0E-03
Benzo(k)fluoranthene	Wild game	1.0E-03	2.3E-07	1.7E-04	1.8E-04	1.7E-04
biphenyl	Wild game	7.7E-05	2.0E-08	6.8E-06	7.1E-06	2.6E-08
Chrysene	Wild game	2.1E-03	1.4E-07	1.8E-04	1.8E-04	3.8E-05
dibenz(ah)anthracene	Wild game	1.0E-03	5.3E-06	3.2E-03	3.3E-03	3.2E-03
Fluoranthene	Wild game	2.4E-04	9.2E-08	2.0E-05	2.3E-05	1.9E-05
Fluorene	Wild game	1.1E-06	5.1E-10	5.2E-07	5.2E-07	5.2E-07
Indeno(123cd)pyrene	Wild game	3.1E-05	1.6E-07	6.1E-05	6.7E-05	9.8E-05
naphthalene	Wild game	5.0E-05	1.3E-05	1.3E-05	3.7E-04	5.3E-07
Phenanthrene	Wild game	1.2E-05	1.3E-08	5.6E-06	5.9E-06	5.6E-06
Pyrene	Wild game	6.0E-04	3.8E-08	5.5E-05	5.6E-05	2.3E-06

Table 4E-3 Surface Soil Concentrations Used to Estimate Livestock and Game Tissue [mg/kg]

Chemical	Receptor	Background	Baseline	Application	CEA	Project
Aliphatic C5-C8 Group	Livestock	1.3E-06	4.7E-07	4.4E-06	9.9E-06	4.1E-06
Aliphatic C9-C16 Group	Livestock	3.2E-03	1.3E-03	3.6E-03	8.7E-03	2.8E-03
aliphatic c17-C34 group	Livestock	1.2E-01	0.0E+00	7.8E-01	7.8E-01	7.8E-01
Anthracene	Livestock	3.8E-05	9.1E-09	2.3E-05	2.3E-05	2.3E-05
Aromatic C17-C34 Group	Livestock	2.2E-03	4.4E-07	1.2E-03	1.2E-03	1.2E-03
Aromatic C9-C16 Group	Livestock	3.5E-04	5.8E-06	3.1E-04	3.8E-04	3.1E-04
benz(a)anthracene	Livestock	2.4E-04	5.2E-07	3.6E-04	3.7E-04	3.6E-04
Benzo(a)pyrene	Livestock	9.6E-04	3.7E-07	4.1E-04	4.2E-04	4.1E-04
benzo(e)pyrene	Livestock	6.9E-04	1.0E-12	1.0E-12	5.7E-08	0.0E+00
Benzo(b)fluoranthene	Livestock	2.4E-04	5.4E-08	4.0E-05	4.1E-05	4.0E-05
Benzo(ghi)perylene	Livestock	2.7E-03	5.9E-07	5.6E-04	5.7E-04	5.6E-04
Benzo(k)fluoranthene	Livestock	8.2E-03	1.8E-06	1.4E-03	1.4E-03	1.4E-03
biphenyl	Livestock	0.0E+00	0.0E+00	8.5E-10	8.5E-10	8.5E-10
Chrysene	Livestock	8.2E-04	1.0E-06	1.1E-03	1.2E-03	1.1E-03
dibenz(ah)anthracene	Livestock	1.8E-05	7.3E-07	8.1E-04	8.5E-04	8.1E-04
Fluoranthene	Livestock	2.9E-04	2.3E-07	1.6E-04	1.6E-04	1.6E-04
Fluorene	Livestock	7.0E-06	1.4E-09	3.6E-06	3.7E-06	3.6E-06
Indeno(123cd)pyrene	Livestock	7.8E-05	7.9E-07	5.9E-04	6.1E-04	5.9E-04
naphthalene	Livestock	5.1E-06	1.7E-08	4.3E-06	4.4E-06	4.3E-06
Phenanthrene	Livestock	1.1E-04	1.3E-07	5.4E-05	5.7E-05	5.4E-05
Pyrene	Livestock	1.4E-04	2.1E-06	2.5E-04	2.7E-04	2.5E-04
Aliphatic C5-C8 Group	Wild game	3.8E-06	4.9E-06	5.1E-06	1.4E-05	4.1E-06
Aliphatic C9-C16 Group	Wild game	1.2E-02	3.1E-03	3.6E-03	9.1E-02	2.8E-03
aliphatic c17-C34 group	Wild game	1.4E-01	7.2E-07	7.8E-01	7.8E-01	7.8E-01
Anthracene	Wild game	1.3E-03	8.4E-08	1.2E-04	1.2E-04	2.3E-05
Aromatic C17-C34 Group	Wild game	4.2E+00	9.8E-02	8.3E-01	2.4E+00	1.2E-03
Aromatic C9-C16 Group	Wild game	3.9E-04	5.8E-06	3.1E-04	3.8E-04	3.1E-04
benz(a)anthracene	Wild game	5.8E-04	5.2E-07	3.6E-04	3.7E-04	3.6E-04
Benzo(a)pyrene	Wild game	2.5E-03	6.8E-07	4.1E-04	4.2E-04	4.1E-04
benzo(e)pyrene	Wild game	1.5E-03	2.9E-07	1.4E-04	1.5E-04	0.0E+00
Benzo(b)fluoranthene	Wild game	2.4E-04	6.7E-08	4.0E-05	4.1E-05	4.0E-05
Benzo(ghi)perylene	Wild game	2.7E-03	9.5E-07	5.6E-04	5.7E-04	5.6E-04
Benzo(k)fluoranthene	Wild game	8.2E-03	1.8E-06	1.4E-03	1.4E-03	1.4E-03
biphenyl	Wild game	2.5E-06	6.4E-10	2.2E-07	2.3E-07	8.5E-10
Chrysene	Wild game	6.1E-02	4.1E-06	5.3E-03	5.4E-03	1.1E-03
dibenz(ah)anthracene	Wild game	2.6E-04	1.4E-06	8.1E-04	8.5E-04	8.1E-04
Fluoranthene	Wild game	2.0E-03	7.6E-07	1.7E-04	1.9E-04	1.6E-04
Fluorene	Wild game	7.7E-06	3.6E-09	3.6E-06	3.7E-06	3.6E-06
Indeno(123cd)pyrene	Wild game	1.9E-04	9.8E-07	3.7E-04	4.1E-04	5.9E-04
naphthalene	Wild game	4.0E-04	1.0E-04	1.0E-04	3.0E-03	4.3E-06
Phenanthrene	Wild game	1.2E-04	1.3E-07	5.4E-05	5.7E-05	5.4E-05
Pyrene	Wild game	6.4E-02	4.0E-06	5.9E-03	5.9E-03	2.5E-04

Table 4E-4 Soil Concentrations Used to Estimate Livestock and Game Tissue Concentrations [mg/kg]

Chemical	Receptor	Background	Baseline	Application	CEA
Aliphatic C17-C34 Group	Livestock	1.2E-02	0.0E+00	7.8E-02	7.8E-02
Aliphatic C5-C8 Group	Livestock	1.3E-07	4.7E-08	4.4E-07	9.9E-07
aliphatic C9-C16 group	Livestock	3.2E-04	1.3E-04	3.6E-04	8.7E-04
Anthracene	Livestock	3.8E-06	9.1E-10	2.3E-06	2.3E-06
Aromatic C17-C34 Group	Livestock	2.2E-04	4.4E-08	1.2E-04	1.2E-04
Aromatic C9-C16 Group	Livestock	3.5E-05	5.8E-07	3.1E-05	3.8E-05
benz(a)anthracene	Livestock	2.4E-05	5.2E-08	3.6E-05	3.7E-05
Benzo(a)pyrene	Livestock	9.6E-05	3.7E-08	4.1E-05	4.2E-05
Benzo(a)pyrene	Livestock	9.6E-05	3.7E-08	4.1E-05	4.2E-05
Benzo(b)fluoranthene	Livestock	2.4E-05	5.4E-09	4.0E-06	4.1E-06
Benzo(e)pyrene	Livestock	6.9E-05	1.0E-13	1.0E-13	5.7E-09
Benzo(ghi)perylene	Livestock	2.7E-04	5.9E-08	5.6E-05	5.7E-05
Benzo(k)fluoranthene	Livestock	8.2E-04	1.8E-07	1.4E-04	1.4E-04
biphenyl	Livestock	0.0E+00	0.0E+00	8.5E-11	8.5E-11
Chrysene	Livestock	8.2E-05	1.0E-07	1.1E-04	1.2E-04
dibenz(ah)anthracene	Livestock	1.8E-06	7.3E-08	8.1E-05	8.5E-05
Fluoranthene	Livestock	2.9E-05	2.3E-08	1.6E-05	1.6E-05
Fluorene	Livestock	7.0E-07	1.4E-10	3.6E-07	3.7E-07
Indeno(123cd)pyrene	Livestock	7.8E-06	7.9E-08	5.9E-05	6.1E-05
naphthalene	Livestock	5.1E-07	1.7E-09	4.3E-07	4.4E-07
Benzo(a)pyrene	Livestock	9.6E-05	3.7E-08	4.1E-05	4.2E-05
Phenanthrene	Livestock	1.1E-05	1.3E-08	5.4E-06	5.7E-06
Pyrene	Livestock	1.4E-05	2.1E-07	2.5E-05	2.7E-05
Aliphatic C5-C8 Group	Wild game	3.8E-07	4.9E-07	5.1E-07	1.4E-06
Aliphatic C9-C16 Group	Wild game	1.2E-03	3.1E-04	3.6E-04	9.1E-03
aliphatic c17-C34 group	Wild game	1.4E-02	7.2E-08	7.8E-02	7.8E-02
Anthracene	Wild game	1.3E-04	8.4E-09	1.2E-05	1.2E-05
Aromatic C17-C34 Group	Wild game	4.2E-01	9.8E-03	8.3E-02	2.4E-01
Aromatic C9-C16 Group	Wild game	3.9E-05	5.8E-07	3.1E-05	3.8E-05
benz(a)anthracene	Wild game	5.8E-05	5.2E-08	3.6E-05	3.7E-05
Benzo(a)pyrene	Wild game	2.5E-04	6.8E-08	4.1E-05	4.2E-05
benzo(e)pyrene	Wild game	1.5E-04	2.9E-08	1.4E-05	1.5E-05
Benzo(b)fluoranthene	Wild game	2.4E-05	6.7E-09	4.0E-06	4.1E-06
Benzo(ghi)perylene	Wild game	2.7E-04	9.5E-08	5.6E-05	5.7E-05
Benzo(k)fluoranthene	Wild game	8.2E-04	1.8E-07	1.4E-04	1.4E-04
biphenyl	Wild game	2.5E-07	6.4E-11	2.2E-08	2.3E-08
Chrysene	Wild game	6.1E-03	4.1E-07	5.3E-04	5.4E-04
dibenz(ah)anthracene	Wild game	2.6E-05	1.4E-07	8.1E-05	8.5E-05
Fluoranthene	Wild game	2.0E-04	7.6E-08	1.7E-05	1.9E-05
Fluorene	Wild game	7.7E-07	3.6E-10	3.6E-07	3.7E-07
Indeno(123cd)pyrene	Wild game	1.9E-05	9.8E-08	3.7E-05	4.1E-05
naphthalene	Wild game	4.0E-05	1.0E-05	1.0E-05	3.0E-04
Phenanthrene	Wild game	1.2E-05	1.3E-08	5.4E-06	5.7E-06
Pyrene	Wild game	6.4E-03	4.0E-07	5.9E-04	5.9E-04

Table 4E-5 Surface Water Concentrations Used to Estimate Livestock and Game Tissue Concentrations [mg/L]

Chemical	Receptor	Background	Baseline	Application	CEA
Aliphatic C5-C8 Group	Livestock	3.2E-10	1.2E-10	1.1E-09	2.5E-09
Aliphatic C9-C16 Group	Livestock	5.1E-12	2.0E-12	5.7E-12	1.4E-11
aliphatic c17-C34 group	Livestock	1.2E-14	0.0E+00	7.8E-14	7.8E-14
Anthracene	Livestock	8.4E-11	2.0E-14	5.0E-11	5.1E-11
Aromatic C17-C34 Group	Livestock	1.8E-08	3.5E-12	9.3E-09	9.4E-09
Aromatic C9-C16 Group	Livestock	7.0E-08	1.2E-09	6.2E-08	7.5E-08
benz(a)anthracene	Livestock	3.9E-11	8.7E-14	5.9E-11	6.1E-11
Benzo(a)pyrene	Livestock	6.0E-11	2.3E-14	2.6E-11	2.6E-11
benzo(e)pyrene	Livestock	1.7E-09	2.5E-18	2.5E-18	1.4E-13
Benzo(b)fluoranthene	Livestock	2.3E-10	5.1E-14	3.8E-11	3.9E-11
Benzo(ghi)perylene	Livestock	1.7E-09	3.8E-13	3.5E-10	3.6E-10
Benzo(k)fluoranthene	Livestock	4.3E-10	9.7E-14	7.2E-11	7.4E-11
biphenyl	Livestock	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Chrysene	Livestock	1.4E-10	1.7E-13	1.9E-10	2.0E-10
dibenz(ah)anthracene	Livestock	3.1E-13	1.3E-14	1.4E-11	1.5E-11
Fluoranthene	Livestock	2.6E-10	2.1E-13	1.4E-10	1.4E-10
Fluorene	Livestock	3.3E-11	6.8E-15	1.7E-11	1.8E-11
Indeno(123cd)pyrene	Livestock	0.0E+00	0.0E+00	0.0E+00	0.0E+00
naphthalene	Livestock	1.7E-10	5.7E-13	1.4E-10	1.5E-10
Phenanthrene	Livestock	2.9E-10	3.4E-13	1.5E-10	1.5E-10
Pyrene	Livestock	1.5E-10	2.2E-12	2.6E-10	2.8E-10
Aliphatic C5-C8 Group	Wild game	9.5E-10	1.2E-09	1.3E-09	3.6E-09
Aliphatic C9-C16 Group	Wild game	1.9E-11	5.0E-12	5.7E-12	1.4E-10
aliphatic c17-C34 group	Wild game	1.4E-14	7.2E-20	7.8E-14	7.8E-14
Anthracene	Wild game	3.0E-09	1.9E-13	2.7E-10	2.8E-10
Aromatic C17-C34 Group	Wild game	3.3E-05	7.8E-07	6.6E-06	1.9E-05
Aromatic C9-C16 Group	Wild game	7.8E-08	1.2E-09	6.2E-08	7.5E-08
benz(a)anthracene	Wild game	9.7E-11	8.7E-14	5.9E-11	6.1E-11
Benzo(a)pyrene	Wild game	1.5E-10	4.3E-14	2.6E-11	2.6E-11
benzo(e)pyrene	Wild game	3.8E-09	7.2E-13	3.4E-10	3.6E-10
Benzo(b)fluoranthene	Wild game	2.3E-10	6.4E-14	3.8E-11	3.9E-11
Benzo(ghi)perylene	Wild game	1.7E-09	6.0E-13	3.5E-10	3.6E-10
Benzo(k)fluoranthene	Wild game	4.3E-10	9.7E-14	7.2E-11	7.4E-11
biphenyl	Wild game	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Chrysene	Wild game	1.0E-08	6.8E-13	8.8E-10	9.1E-10
dibenz(ah)anthracene	Wild game	4.5E-12	2.3E-14	1.4E-11	1.5E-11
Fluoranthene	Wild game	1.8E-09	6.9E-13	1.5E-10	1.7E-10
Fluorene	Wild game	3.7E-11	1.7E-14	1.7E-11	1.8E-11
Indeno(123cd)pyrene	Wild game	0.0E+00	0.0E+00	0.0E+00	0.0E+00
naphthalene	Wild game	1.3E-08	3.4E-09	3.5E-09	1.0E-07
Phenanthrene	Wild game	3.2E-10	3.4E-13	1.5E-10	1.5E-10
Pyrene	Wild game	6.7E-08	4.2E-12	6.2E-09	6.3E-09

Table 4E-6 Predicted Air Data Used in the Assessment [$\mu g/m^3$]

Chemical	Receptor	Background	Baseline	Application	CEA
Aliphatic C17-C34 Group	Livestock	5.7E-03	0.0E+00	3.6E-02	3.6E-02
Aliphatic C5-C8 Group	Livestock	3.1E+00	1.1E+00	1.1E+01	2.4E+01
Aliphatic C9-C16 group	Livestock	2.7E-01	1.0E-01	3.0E-01	7.2E-01
Anthracene	Livestock	1.1E-04	2.7E-08	6.7E-05	6.8E-05
Aromatic C17-C34 Group	Livestock	1.0E-03	2.0E-07	5.3E-04	5.3E-04
Aromatic C9-C16 Group	Livestock	4.8E-01	7.9E-03	4.2E-01	5.1E-01
Benz(a)anthracene	Livestock	1.4E-05	3.2E-08	2.2E-05	2.2E-05
Benzo(a)pyrene	Livestock	3.5E-05	1.3E-08	1.5E-05	1.5E-05
Benzo(a)pyrene	Livestock	3.5E-05	1.3E-08	1.5E-05	1.5E-05
Benzo(b)fluoranthene	Livestock	8.9E-05	2.0E-08	1.5E-05	1.5E-05
Benzo(e)pyrene	Livestock	4.7E-05	6.9E-14	6.9E-14	3.9E-09
Benzo(ghi)perylene	Livestock	7.3E-05	1.6E-08	1.5E-05	1.5E-05
Benzo(k)fluoranthene	Livestock	8.9E-05	2.0E-08	1.5E-05	1.5E-05
Biphenyl	Livestock	0.0E+00	0.0E+00	3.3E-07	3.3E-07
Chrysene	Livestock	1.6E-05	2.0E-08	2.2E-05	2.3E-05
Dibenz(ah)anthracene	Livestock	3.3E-07	1.3E-08	1.5E-05	1.6E-05
Fluoranthene	Livestock	2.5E-04	2.0E-07	1.4E-04	1.4E-04
Fluorene	Livestock	3.1E-04	6.4E-08	1.6E-04	1.6E-04
Indeno(123cd)pyrene	Livestock	2.0E-06	2.0E-08	1.5E-05	1.6E-05
Naphthalene	Livestock	1.3E-02	4.3E-05	1.1E-02	1.1E-02
Benzo(a)pyrene	Livestock	3.5E-05	1.3E-08	1.5E-05	1.5E-05
Phenanthrene	Livestock	4.5E-04	5.3E-07	2.3E-04	2.4E-04
Pyrene	Livestock	8.7E-06	1.3E-07	1.5E-05	1.7E-05
Aliphatic C5-C8 Group	Wild game	9.1E+00	1.2E+01	1.2E+01	3.4E+01
Aliphatic C9-C16 Group	Wild game	1.0E+00	2.6E-01	3.0E-01	7.5E+00
Aliphatic C17-C34 group	Wild game	6.4E-03	3.3E-08	3.6E-02	3.6E-02
Anthracene	Wild game	3.9E-03	2.5E-07	3.6E-04	3.6E-04
Aromatic C17-C34 Group	Wild game	1.9E+00	4.4E-02	3.7E-01	1.1E+00
Aromatic C9-C16 Group	Wild game	5.4E-01	7.9E-03	4.2E-01	5.1E-01
Benz(a)anthracene	Wild game	3.5E-05	3.2E-08	2.2E-05	2.2E-05
Benzo(a)pyrene	Wild game	8.9E-05	2.5E-08	1.5E-05	1.5E-05
Benzo(e)pyrene	Wild game	1.0E-04	2.0E-08	9.4E-06	1.0E-05
Benzo(b)fluoranthene	Wild game	8.9E-05	2.5E-08	1.5E-05	1.5E-05
Benzo(ghi)perylene	Wild game	7.3E-05	2.5E-08	1.5E-05	1.5E-05
Benzo(k)fluoranthene	Wild game	8.9E-05	2.0E-08	1.5E-05	1.5E-05
Biphenyl	Wild game	9.8E-04	2.5E-07	8.7E-05	9.0E-05
Chrysene	Wild game	1.2E-03	8.0E-08	1.0E-04	1.1E-04
Dibenz(ah)anthracene	Wild game	4.8E-06	2.5E-08	1.5E-05	1.6E-05
Fluoranthene	Wild game	1.7E-03	6.6E-07	1.5E-04	1.6E-04
Fluorene	Wild game	3.5E-04	1.6E-07	1.6E-04	1.6E-04
Indeno(123cd)pyrene	Wild game	4.8E-06	2.5E-08	9.4E-06	1.0E-05
Naphthalene	Wild game	1.0E+00	2.6E-01	2.6E-01	7.5E+00
Phenanthrene	Wild game	5.0E-04	5.3E-07	2.3E-04	2.4E-04
Pyrene	Wild game	3.9E-03	2.5E-07	3.6E-04	3.6E-04

Table 4E-7 Summary of Predicted Tissue Concentrations for Each Receptor, Scenario, and Chemical

								Dietary Concentrations				EDI					
				Soil	Surface Soil	Surface Water	Air	Browse Deposition	Browse Air	Browse Aboveground	Invertebrate Terrestrial	Soil EDI	Browse EDI	Invertebrate EDI	Water EDI	Total EDI Oral	Tissue Concentration
Scenario	**Site**	**Receptor**	**Chemical**	**mg/kg**	**mg/kg**	**mg/L**	**$\mu g/m^3$**	**mg/kg dw**	**mg/kg dw**	**mg/kg dw**	**mg/kg dw**	**mg/day**	**mg/day**	**mg/day**	**mg/day**	**mg/day**	**mg/kg ww**
Baseline	MAX-AGR	Beef	Aliphatic C5-C8 Group	4.73E-08	4.73E-07	1.19E-10	1.15E+00	0.00E+00	4.90E-07	1.15E-08	4.46E-06	2.36E-07	5.91E-06	0.00E+00	4.49E-09	6.15E-06	1.40E-07
Baseline	MAX-AGR	Beef	Aliphatic C9-C16 Group	1.25E-04	1.25E-03	1.99E-12	1.04E-01	0.00E+00	5.60E-05	4.92E-07	5.25E-05	6.26E-04	6.65E-04	0.00E+00	7.52E-11	1.29E-03	3.14E-05
Baseline	MAX-AGR	Beef	aliphatic C17-C34 group	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Baseline	MAX-AGR	Beef	Anthracene	9.07E-10	9.07E-09	2.02E-14	2.67E-08	2.26E-09	1.14E-09	8.80E-11	3.80E-10	4.54E-09	4.11E-08	0.00E+00	7.63E-13	4.56E-08	1.54E-11
Baseline	MAX-AGR	Beef	Aromatic C17-C34 Group	4.40E-08	4.40E-07	3.50E-12	1.98E-07	0.00E+00	3.80E-06	3.32E-10	1.85E-08	2.20E-07	4.48E-05	0.00E+00	1.32E-10	4.50E-05	1.45E-08
Baseline	MAX-AGR	Beef	Aromatic C9-C16 Group	5.81E-07	5.81E-06	1.16E-09	7.94E-03	0.00E+00	1.53E-06	1.24E-07	2.44E-07	2.91E-06	1.95E-05	0.00E+00	4.39E-08	2.24E-05	5.49E-07
Baseline	MAX-AGR	Beef	benz(a)anthracene	5.23E-08	5.23E-07	8.72E-14	3.18E-08	6.95E-07	2.39E-07	1.03E-09	9.40E-09	2.62E-07	1.10E-05	0.00E+00	3.30E-12	1.13E-05	4.50E-09
Baseline	MAX-AGR	Beef	Benzo(a)pyrene	3.67E-08	3.67E-07	2.30E-14	1.34E-08	4.00E-07	3.97E-07	4.84E-10	1.54E-08	1.84E-07	9.40E-06	0.00E+00	8.69E-13	9.58E-06	3.60E-09
Baseline	MAX-AGR	Beef	benzo(e)pyrene	1.01E-13	1.01E-12	2.52E-18	6.90E-14	2.06E-12	1.94E-11	3.91E-16	4.22E-14	5.04E-13	2.53E-10	0.00E+00	9.53E-17	2.53E-10	6.11E-14
Baseline	MAX-AGR	Beef	Benzo(b)fluoranthene	5.37E-09	5.37E-08	5.12E-14	2.01E-08	2.89E-08	2.63E-08	6.00E-11	2.25E-09	2.68E-08	6.50E-07	0.00E+00	1.94E-12	6.77E-07	2.45E-10
Baseline	MAX-AGR	Beef	Benzo(ghi)perylene	5.93E-08	5.93E-07	3.76E-13	1.59E-08	6.34E-07	1.36E-05	1.52E-10	2.49E-08	2.97E-07	1.68E-04	0.00E+00	1.42E-11	1.69E-04	3.21E-08
Baseline	MAX-AGR	Beef	Benzo(k)fluoranthene	1.84E-07	1.84E-06	9.70E-14	2.01E-08	6.18E-07	9.32E-07	2.13E-09	8.83E-08	9.22E-07	1.83E-05	0.00E+00	3.67E-12	1.92E-05	7.00E-09
Baseline	MAX-AGR	Beef	biphenyl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Baseline	MAX-AGR	Beef	Chrysene	1.04E-07	1.04E-06	1.73E-13	2.04E-08	2.21E-07	8.46E-09	2.04E-09	2.48E-08	5.18E-07	2.73E-06	0.00E+00	6.54E-12	3.25E-06	1.30E-09
Baseline	MAX-AGR	Beef	dibenz(ah)anthracene	7.30E-08	7.30E-07	1.26E-14	1.34E-08	5.36E-07	1.85E-05	4.95E-10	3.06E-08	3.65E-07	2.24E-04	0.00E+00	4.76E-13	2.25E-04	6.96E-08
Baseline	MAX-AGR	Beef	Fluoranthene	2.31E-08	2.31E-07	2.10E-13	1.99E-07	6.75E-08	1.18E-07	1.15E-09	9.67E-09	1.15E-07	2.19E-06	0.00E+00	7.94E-12	2.31E-06	9.07E-10
Baseline	MAX-AGR	Beef	Fluorene	1.44E-10	1.44E-09	6.85E-15	6.43E-08	0.00E+00	1.34E-09	2.08E-11	6.03E-11	7.19E-10	1.61E-08	0.00E+00	2.59E-13	1.68E-08	4.92E-12
Baseline	MAX-AGR	Beef	Indeno(123cd)pyrene	7.90E-08	7.90E-07	0.00E+00	2.01E-08	8.45E-07	3.02E-08	4.69E-10	3.79E-08	3.95E-07	1.03E-05	0.00E+00	0.00E+00	1.07E-05	3.15E-09
Baseline	MAX-AGR	Beef	naphthalene	1.70E-09	1.70E-08	5.66E-13	4.26E-05	0.00E+00	1.31E-08	8.14E-10	7.12E-10	8.49E-09	1.63E-07	0.00E+00	2.14E-11	1.72E-07	2.55E-09
Baseline	MAX-AGR	Beef	Phenanthrene	1.26E-08	1.26E-07	3.40E-13	5.28E-07	2.24E-08	6.40E-08	1.22E-09	5.28E-09	6.30E-08	1.03E-06	0.00E+00	1.29E-11	1.09E-06	3.70E-10
Baseline	MAX-AGR	Beef	Pyrene	2.11E-07	2.11E-06	2.22E-12	1.29E-07	3.28E-08	8.72E-08	1.20E-08	8.83E-08	1.05E-06	1.56E-06	0.00E+00	8.39E-11	2.61E-06	1.00E-09
Baseline	MAX-AGR	Chicken	Aliphatic C5-C8 Group	4.73E-08	4.73E-07	1.19E-10	1.15E+00	0.00E+00	4.90E-07	1.15E-08	4.46E-06	1.04E-08	8.03E-08	1.78E-07	3.09E-11	2.69E-07	4.52E-09
Baseline	MAX-AGR	Chicken	Aliphatic C9-C16 Group	1.25E-04	1.25E-03	1.99E-12	1.04E-01	0.00E+00	5.60E-05	4.92E-07	5.25E-05	2.76E-05	9.04E-06	2.10E-06	5.16E-13	3.87E-05	6.93E-07
Baseline	MAX-AGR	chicken	aliphatic C17-C34 group	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Baseline	MAX-AGR	Chicken	Anthracene	9.07E-10	9.07E-09	2.02E-14	2.67E-08	2.26E-09	1.14E-09	8.80E-11	3.80E-10	2.00E-10	5.58E-10	1.52E-11	5.24E-15	7.73E-10	1.93E-13
Baseline	MAX-AGR	Chicken	Aromatic C17-C34 Group	4.40E-08	4.40E-07	3.50E-12	1.98E-07	0.00E+00	3.80E-06	3.32E-10	1.85E-08	9.68E-09	6.09E-07	7.38E-10	9.09E-13	6.19E-07	1.47E-10
Baseline	MAX-AGR	Chicken	Aromatic C9-C16 Group	5.81E-07	5.81E-06	1.16E-09	7.94E-03	0.00E+00	1.53E-06	1.24E-07	2.44E-07	1.28E-07	2.65E-07	9.75E-09	3.02E-10	4.02E-07	7.26E-09
Baseline	MAX-AGR	Chicken	benz(a)anthracene	5.23E-08	5.23E-07	8.72E-14	3.18E-08	6.95E-07	2.39E-07	1.03E-09	9.40E-09	1.15E-08	1.50E-07	3.76E-10	2.27E-14	1.61E-07	4.75E-11
Baseline	MAX-AGR	Chicken	Benzo(a)pyrene	3.67E-08	3.67E-07	2.30E-14	1.34E-08	4.00E-07	3.97E-07	4.84E-10	1.54E-08	8.08E-09	1.28E-07	6.16E-10	5.97E-15	1.36E-07	3.77E-11
Baseline	MAX-AGR	Chicken	benzo(e)pyrene	1.01E-13	1.01E-12	2.52E-18	6.90E-14	2.06E-12	1.94E-11	3.91E-16	4.22E-14	2.22E-14	3.43E-12	1.69E-15	6.55E-19	3.46E-12	6.15E-16
Baseline	MAX-AGR	Chicken	Benzo(b)fluoranthene	5.37E-09	5.37E-08	5.12E-14	2.01E-08	2.89E-08	2.63E-08	6.00E-11	2.25E-09	1.18E-09	8.83E-09	9.00E-11	1.33E-14	1.01E-08	2.69E-12
Baseline	MAX-AGR	Chicken	Benzo(ghi)perylene	5.93E-08	5.93E-07	3.76E-13	1.59E-08	6.34E-07	1.36E-05	1.52E-10	2.49E-08	1.31E-08	2.28E-06	9.95E-10	9.76E-14	2.30E-06	3.23E-10
Baseline	MAX-AGR	Chicken	Benzo(k)fluoranthene	1.84E-07	1.84E-06	9.70E-14	2.01E-08	6.18E-07	9.32E-07	2.13E-09	8.83E-08	4.06E-08	2.48E-07	3.53E-09	2.52E-14	2.92E-07	7.86E-11
Baseline	MAX-AGR	Chicken	biphenyl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Baseline	MAX-AGR	Chicken	Chrysene	1.04E-07	1.04E-06	1.73E-13	2.04E-08	2.21E-07	8.46E-09	2.04E-09	2.48E-08	2.28E-08	3.71E-08	9.93E-10	4.49E-14	6.09E-08	1.79E-11
Baseline	MAX-AGR	Chicken	dibenz(ah)anthracene	7.30E-08	7.30E-07	1.26E-14	1.34E-08	5.36E-07	1.85E-05	4.95E-10	3.06E-08	1.61E-08	3.04E-06	1.22E-09	3.27E-15	3.06E-06	6.99E-10
Baseline	MAX-AGR	Chicken	Fluoranthene	2.31E-08	2.31E-07	2.10E-13	1.99E-07	6.75E-08	1.18E-07	1.15E-09	9.67E-09	5.08E-09	2.98E-08	3.87E-10	5.45E-14	3.53E-08	1.02E-11
Baseline	MAX-AGR	Chicken	Fluorene	1.44E-10	1.44E-09	6.85E-15	6.43E-08	0.00E+00	1.34E-09	2.08E-11	6.03E-11	3.16E-11	2.18E-10	2.41E-12	1.78E-15	2.52E-10	5.44E-14
Baseline	MAX-AGR	Chicken	Indeno(123cd)pyrene	7.90E-08	7.90E-07	0.00E+00	2.01E-08	8.45E-07	3.02E-08	4.69E-10	3.79E-08	1.74E-08	1.40E-07	1.52E-09	0.00E+00	1.59E-07	3.45E-11
Baseline	MAX-AGR	Chicken	naphthalene	1.70E-09	1.70E-08	5.66E-13	4.26E-05	0.00E+00	1.31E-08	8.14E-10	7.12E-10	3.73E-10	2.22E-09	2.85E-11	1.47E-13	2.62E-09	2.87E-11
Baseline	MAX-AGR	Chicken	Phenanthrene	1.26E-08	1.26E-07	3.40E-13	5.28E-07	2.24E-08	6.40E-08	1.22E-09	5.28E-09	2.77E-09	1.40E-08	2.11E-10	8.85E-14	1.70E-08	4.23E-12
Baseline	MAX-AGR	Chicken	Pyrene	2.11E-07	2.11E-06	2.22E-12	1.29E-07	3.28E-08	8.72E-08	1.20E-08	8.83E-08	4.63E-08	2.11E-08	3.53E-09	5.76E-13	7.10E-08	2.01E-11
Baseline	MAX-AGR	Dairy	Aliphatic C5-C8 Group	4.73E-08	4.73E-07	1.19E-10	1.15E+00	0.00E+00	4.90E-07	1.15E-08	4.46E-06	1.89E-07	1.02E-05	0.00E+00	1.35E-08	1.04E-05	4.99E-08
Baseline	MAX-AGR	Dairy	Aliphatic C9-C16 Group	1.25E-04	1.25E-03	1.99E-12	1.04E-01	0.00E+00	5.60E-05	4.92E-07	5.25E-05	5.01E-04	1.15E-03	0.00E+00	2.26E-10	1.65E-03	8.43E-06
Baseline	MAX-AGR	Dairy	aliphatic C17-C34 group	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Baseline	MAX-AGR	Dairy	Anthracene	9.07E-10	9.07E-09	2.02E-14	2.67E-08	2.26E-09	1.14E-09	8.80E-11	3.80E-10	3.63E-09	7.08E-08	0.00E+00	2.29E-12	7.45E-08	5.30E-12
Baseline	MAX-AGR	Dairy	Aromatic C17-C34 Group	4.40E-08	4.40E-07	3.50E-12	1.98E-07	0.00E+00	3.80E-06	3.32E-10	1.85E-08	1.76E-07	7.72E-05	0.00E+00	3.97E-10	7.74E-05	5.25E-09
Baseline	MAX-AGR	Dairy	Aromatic C9-C16 Group	5.81E-07	5.81E-06	1.16E-09	7.94E-03	0.00E+00	1.53E-06	1.24E-07	2.44E-07	2.33E-06	3.36E-05	0.00E+00	1.32E-07	3.60E-05	1.86E-07
Baseline	MAX-AGR	Dairy	benz(a)anthracene	5.23E-08	5.23E-07	8.72E-14	3.18E-08	6.95E-07	2.39E-07	1.03E-09	9.40E-09	2.09E-07	1.90E-05	0.00E+00	9.90E-12	1.92E-05	1.61E-09
Baseline	MAX-AGR	Dairy	Benzo(a)pyrene	3.67E-08	3.67E-07	2.30E-14	1.34E-08	4.00E-07	3.97E-07	4.84E-10	1.54E-08	1.47E-07	1.62E-05	0.00E+00	2.61E-12	1.63E-05	1.29E-09
Baseline	MAX-AGR	Dairy	benzo(e)pyrene	1.01E-13	1.01E-12	2.52E-18	6.90E-14	2.06E-12	1.94E-11	3.91E-16	4.22E-14	4.03E-13	4.36E-10	0.00E+00	2.86E-16	4.36E-10	2.22E-14
Baseline	MAX-AGR	Dairy	Benzo(b)fluoranthene	5.37E-09	5.37E-08	5.12E-14	2.01E-08	2.89E-08	2.63E-08	6.00E-11	2.25E-09	2.15E-08	1.12E-06	0.00E+00	5.82E-12	1.14E-06	8.70E-11
Baseline	MAX-AGR	Dairy	Benzo(ghi)perylene	5.93E-08	5.93E-07	3.76E-13	1.59E-08	6.34E-07	1.36E-05	1.52E-10	2.49E-08	2.37E-07	2.90E-04	0.00E+00	4.27E-11	2.90E-04	1.16E-08
Baseline	MAX-AGR	Dairy	Benzo(k)fluoranthene	1.84E-07	1.84E-06	9.70E-14	2.01E-08	6.18E-07	9.32E-07	2.13E-09	8.83E-08	7.37E-07	3.15E-05	0.00E+00	1.10E-11	3.22E-05	2.48E-09
Baseline	MAX-AGR	Dairy	biphenyl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Baseline	MAX-AGR	Dairy	Chrysene	1.04E-07	1.04E-06	1.73E-13	2.04E-08	2.21E-07	8.46E-09	2.04E-09	2.48E-08	4.15E-07	4.70E-06	0.00E+00	1.96E-11	5.12E-06	4.30E-10
Baseline	MAX-AGR	Dairy	dibenz(ah)anthracene	7.30E-08	7.30E-07	1.26E-14	1.34E-08	5.36E-07	1.85E-05	4.95E-10	3.06E-08	2.92E-07	3.86E-04	0.00E+00	1.43E-12	3.87E-04	2.52E-08
Baseline	MAX-AGR	Dairy	Fluoranthene	2.31E-08	2.31E-07	2.10E-13	1.99E-07	6.75E-08	1.18E-07	1.15E-09	9.67E-09	9.23E-08	3.78E-06	0.00E+00	2.38E-11	3.87E-06	3.20E-10
Baseline	MAX-AGR	Dairy	Fluorene	1.44E-10	1.44E-09	6.85E-15	6.43E-08	0.00E+00	1.34E-09	2.08E-11	6.03E-11	5.75E-10	2.77E-08	0.00E+00	7.78E-13	2.83E-08	1.74E-12
Baseline	MAX-AGR	Dairy	Indeno(123cd)pyrene	7.90E-08	7.90E-07	0.00E+00	2.01E-08	8.45E-07	3.02E-08	4.69E-10	3.79E-08	3.16E-07	1.78E-05	0.00E+00	0.00E+00	1.81E-05	1.12E-09
Baseline	MAX-AGR	Dairy	naphthalene	1.70E-09	1.70E-08	5.66E-13	4.26E-05	0.00E+00	1.31E-08	8.14E-10	7.12E-10	6.79E-09	2.82E-07	0.00E+00	6.43E-11	2.88E-07	9.01E-10
Baseline	MAX-AGR	Dairy	Phenanthrene	1.26E-08	1.26E-07	3.40E-13	5.28E-07	2.24E-08	6.40E-08	1.22E-09	5.28E-09	5.04E-08	1.78E-06	0.00E+00	3.87E-11	1.83E-06	1.30E-10
Baseline	MAX-AGR	Dairy	Pyrene	2.11E-07	2.11E-06	2.22E-12	1.29E-07	3.28E-08	8.72E-08	1.20E-08	8.83E-08	8.42E-07	2.68E-06	0.00E+00	2.52E-10	3.52E-06	2.85E-10
Baseline	MAX-AGR	Eggs	Aliphatic C5-C8 Group	4.73E-08	4.73E-07	1.19E-10	1.15E+00	0.00E+00	4.90E-07	1.15E-08	4.46E-06	1.04E-08	8.03E-08	1.78E-07	3.09E-11	2.69E-07	2.59E-09

Table 4E-7 Summary of Predicted Tissue Concentrations for Each Receptor, Scenario, and Chemical

								Dietary Concentrations				EDI					
								Browse	Browse	Browse	Invertebrate	Soil	Browse	Invertebrate	Water	Total	Tissue
				Soil	Surface Soil	Surface Water	Air	Deposition	Air	Aboveground	Terrestrial	EDI	EDI	EDI	EDI	EDI Oral	Concentration
Scenario	Site	Receptor	Chemical	mg/kg	mg/kg	mg/L	μg/m^3	mg/kg dw	mg/kg dw	mg/kg dw	mg/kg dw	mg/day	mg/day	mg/day	mg/day	mg/day	mg/kg ww
Baseline	MAX-AGR	Eggs	Aliphatic C9-C16 Group	1.25E-04	1.25E-03	1.99E-12	1.04E-01	0.00E+00	5.60E-05	4.92E-07	5.25E-05	2.76E-05	9.04E-06	2.10E-06	5.16E-13	3.87E-05	3.96E-07
Baseline	MAX-AGR	Eggs	aliphatic C17-C34 group	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Baseline	MAX-AGR	Eggs	Anthracene	9.07E-10	9.07E-09	2.02E-14	2.67E-08	2.26E-09	1.14E-09	8.80E-11	3.80E-10	2.00E-10	5.58E-10	1.52E-11	5.24E-15	7.73E-10	1.10E-13
Baseline	MAX-AGR	Eggs	Aromatic C17-C34 Group	4.40E-08	4.40E-07	3.50E-12	1.98E-07	0.00E+00	3.80E-06	3.32E-10	1.85E-08	9.68E-09	6.09E-07	7.38E-10	9.09E-13	6.19E-07	8.39E-11
Baseline	MAX-AGR	Eggs	Aromatic C9-C16 Group	5.81E-07	5.81E-06	1.16E-09	7.94E-03	0.00E+00	1.53E-06	1.24E-07	2.44E-07	1.28E-07	2.65E-07	9.75E-09	3.02E-10	4.02E-07	4.15E-09
Baseline	MAX-AGR	Eggs	benz(a)anthracene	5.23E-08	5.23E-07	8.72E-14	3.18E-08	6.95E-07	2.39E-07	1.03E-09	9.40E-09	1.15E-08	1.50E-07	3.76E-10	2.27E-14	1.61E-07	2.71E-11
Baseline	MAX-AGR	Eggs	Benzo(a)pyrene	3.67E-08	3.67E-07	2.30E-14	1.34E-08	4.00E-07	3.97E-07	4.84E-10	1.54E-08	8.08E-09	1.28E-07	6.16E-10	5.97E-15	1.36E-07	2.16E-11
Baseline	MAX-AGR	Eggs	benzo(e)pyrene	1.01E-13	1.01E-12	2.52E-18	6.90E-14	2.06E-12	1.94E-11	3.91E-16	4.22E-14	2.22E-14	3.43E-12	1.69E-15	6.55E-19	3.46E-12	3.51E-16
Baseline	MAX-AGR	Eggs	Benzo(b)fluoranthene	5.37E-09	5.37E-08	5.12E-14	2.01E-08	2.89E-08	2.63E-08	6.00E-11	2.25E-09	1.18E-09	8.83E-09	9.00E-11	1.33E-14	1.01E-08	1.54E-12
Baseline	MAX-AGR	Eggs	Benzo(ghi)perylene	5.93E-08	5.93E-07	3.76E-13	1.59E-08	6.34E-07	1.36E-05	1.52E-10	2.49E-08	1.31E-08	2.28E-06	9.95E-10	9.76E-14	2.30E-06	1.84E-10
Baseline	MAX-AGR	Eggs	Benzo(k)fluoranthene	1.84E-07	1.84E-06	9.70E-14	2.01E-08	6.18E-07	9.32E-07	2.13E-09	8.83E-08	4.06E-08	2.48E-07	3.53E-09	2.52E-14	2.92E-07	4.49E-11
Baseline	MAX-AGR	Eggs	biphenyl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Baseline	MAX-AGR	Eggs	Chrysene	1.04E-07	1.04E-06	1.73E-13	2.04E-08	2.21E-07	8.46E-09	2.04E-09	2.48E-08	2.28E-08	3.71E-08	9.93E-10	4.49E-14	6.09E-08	1.02E-11
Baseline	MAX-AGR	Eggs	dibenz(ah)anthracene	7.30E-08	7.30E-07	1.26E-14	1.34E-08	5.36E-07	1.85E-05	4.95E-10	3.06E-08	1.61E-08	3.04E-06	1.22E-09	3.27E-15	3.06E-06	3.99E-10
Baseline	MAX-AGR	Eggs	Fluoranthene	2.31E-08	2.31E-07	2.10E-13	1.99E-07	6.75E-08	1.18E-07	1.15E-09	9.67E-09	5.08E-09	2.98E-08	3.87E-10	5.45E-14	3.53E-08	5.83E-12
Baseline	MAX-AGR	Eggs	Fluorene	1.44E-10	1.44E-09	6.85E-15	6.43E-08	0.00E+00	1.34E-09	2.08E-11	6.03E-11	3.16E-11	2.18E-10	2.41E-12	1.78E-15	2.52E-10	3.11E-14
Baseline	MAX-AGR	Eggs	Indeno(123cd)pyrene	7.90E-08	7.90E-07	0.00E+00	2.01E-08	8.45E-07	3.02E-08	4.69E-10	3.79E-08	1.74E-08	1.40E-07	1.52E-09	0.00E+00	1.59E-07	1.97E-11
Baseline	MAX-AGR	Eggs	naphthalene	1.70E-09	1.70E-08	5.66E-13	4.26E-05	0.00E+00	1.31E-08	8.14E-10	7.12E-10	3.73E-10	2.22E-09	2.85E-11	1.47E-13	2.62E-09	1.64E-11
Baseline	MAX-AGR	Eggs	Phenanthrene	1.26E-08	1.26E-07	3.40E-13	5.28E-07	2.24E-08	6.40E-08	1.22E-09	5.28E-09	2.77E-09	1.40E-08	2.11E-10	8.85E-14	1.70E-08	2.42E-12
Baseline	MAX-AGR	Eggs	Pyrene	2.11E-07	2.11E-06	2.22E-12	1.29E-07	3.28E-08	8.72E-08	1.20E-08	8.83E-08	4.63E-08	2.11E-08	3.53E-09	5.76E-13	7.10E-08	1.15E-11
Baseline	MAX	Ruffed_Grouse	Aliphatic C5-C8 Group	4.87E-07	4.87E-06	1.22E-09	1.18E+01	0.00E+00	5.06E-06	1.19E-07	4.60E-05	1.87E-08	1.71E-07	3.80E-07	5.75E-11	5.70E-07	9.58E-09
Baseline	MAX	Ruffed_Grouse	Aliphatic C9-C16 Group	3.14E-04	3.14E-03	4.97E-12	2.60E-01	0.00E+00	1.40E-04	1.23E-06	1.31E-04	1.21E-05	4.67E-06	1.09E-06	2.34E-13	1.78E-05	3.19E-07
Baseline	MAX	Ruffed_Grouse	aliphatic C17-C34 group	7.18E-08	7.18E-07	7.18E-20	3.32E-08	0.00E+00	0.00E+00	2.82E-10	3.01E-08	2.76E-09	9.32E-12	2.49E-10	3.37E-21	3.02E-09	5.40E-11
Baseline	MAX	Ruffed_Grouse	Anthracene	8.39E-09	8.39E-08	1.86E-13	2.47E-07	2.09E-08	1.06E-08	8.14E-10	3.52E-09	3.22E-10	1.07E-09	2.91E-11	8.76E-15	1.42E-09	3.53E-13
Baseline	MAX	Ruffed_Grouse	Aromatic C17-C34 Group	9.76E-03	9.76E-02	7.75E-07	4.39E-02	0.00E+00	8.44E-01	7.36E-05	4.09E-03	3.75E-04	2.79E-02	3.38E-05	3.64E-08	2.83E-02	6.71E-06
Baseline	MAX	Ruffed_Grouse	Aromatic C9-C16 Group	5.81E-07	5.81E-06	1.16E-09	7.94E-03	0.00E+00	1.53E-06	1.24E-07	2.44E-07	2.23E-08	5.47E-08	2.01E-09	5.45E-11	7.91E-08	1.43E-09
Baseline	MAX	Ruffed_Grouse	benz(a)anthracene	5.23E-08	5.23E-07	8.72E-14	3.18E-08	6.95E-07	2.39E-07	1.03E-09	9.40E-09	2.01E-09	3.09E-08	7.77E-11	4.10E-15	3.30E-08	9.71E-12
Baseline	MAX	Ruffed_Grouse	Benzo(a)pyrene	6.84E-08	6.84E-07	4.27E-14	2.49E-08	7.45E-07	7.39E-07	9.01E-10	2.87E-08	2.63E-09	4.91E-08	2.37E-10	2.01E-15	5.19E-08	1.44E-11
Baseline	MAX	Ruffed_Grouse	benzo(e)pyrene	2.88E-08	2.88E-07	7.19E-13	1.97E-08	5.88E-07	5.54E-06	1.12E-10	1.21E-08	1.10E-09	2.02E-07	9.96E-11	3.38E-14	2.04E-07	3.62E-11
Baseline	MAX	Ruffed_Grouse	Benzo(b)fluoranthene	6.67E-09	6.67E-08	6.36E-14	2.49E-08	3.59E-08	3.26E-08	7.45E-11	2.80E-09	2.56E-10	2.27E-09	2.31E-11	2.99E-15	2.55E-09	6.79E-13
Baseline	MAX	Ruffed_Grouse	Benzo(ghi)perylene	9.48E-08	9.48E-07	6.00E-13	2.54E-08	1.01E-06	2.18E-05	2.43E-10	3.98E-08	3.64E-09	7.55E-07	3.29E-10	2.82E-14	7.58E-07	1.06E-10
Baseline	MAX	Ruffed_Grouse	Benzo(k)fluoranthene	1.84E-07	1.84E-06	9.70E-14	2.01E-08	6.18E-07	9.32E-07	2.13E-09	8.83E-08	7.08E-09	5.13E-08	7.30E-10	4.56E-15	5.91E-08	1.59E-11
Baseline	MAX	Ruffed_Grouse	biphenyl	6.42E-11	6.42E-10	0.00E+00	2.48E-07	0.00E+00	1.30E-07	1.78E-12	2.69E-11	2.47E-12	4.30E-09	2.23E-13	0.00E+00	4.30E-09	1.29E-10
Baseline	MAX	Ruffed_Grouse	Chrysene	4.08E-07	4.08E-06	6.80E-13	8.03E-08	8.70E-07	3.33E-08	8.01E-09	9.77E-08	1.57E-08	3.01E-08	8.07E-10	3.19E-14	4.66E-08	1.37E-11
Baseline	MAX	Ruffed_Grouse	dibenz(ah)anthracene	1.36E-07	1.36E-06	2.34E-14	2.49E-08	9.97E-07	3.44E-05	9.20E-10	5.69E-08	5.22E-09	1.17E-06	4.70E-10	1.10E-15	1.18E-06	2.68E-10
Baseline	MAX	Ruffed_Grouse	Fluoranthene	7.59E-08	7.59E-07	6.90E-13	6.57E-07	2.22E-07	3.87E-07	3.79E-09	3.18E-08	2.92E-09	2.03E-08	2.63E-10	3.25E-14	2.35E-08	6.78E-12
Baseline	MAX	Ruffed_Grouse	Fluorene	3.59E-10	3.59E-09	1.71E-14	1.61E-07	0.00E+00	3.35E-09	5.19E-11	1.51E-10	1.38E-11	1.13E-10	1.24E-12	8.04E-16	1.28E-10	2.75E-14
Baseline	MAX	Ruffed_Grouse	Indeno(123cd)pyrene	9.80E-08	9.80E-07	0.00E+00	2.49E-08	1.05E-06	3.74E-08	5.81E-10	4.70E-08	3.77E-09	3.59E-08	3.88E-10	0.00E+00	4.01E-08	8.68E-12
Baseline	MAX	Ruffed_Grouse	naphthalene	1.03E-05	1.03E-04	3.45E-09	2.60E-01	0.00E+00	7.95E-05	4.96E-06	4.34E-06	3.97E-07	2.79E-06	3.58E-08	1.62E-10	3.23E-06	3.53E-08
Baseline	MAX	Ruffed_Grouse	Phenanthrene	1.26E-08	1.26E-07	3.40E-13	5.28E-07	2.24E-08	6.40E-08	1.22E-09	5.28E-09	4.84E-10	2.90E-09	4.37E-11	1.60E-14	3.42E-09	8.53E-13
Baseline	MAX	Ruffed_Grouse	Pyrene	4.02E-07	4.02E-06	4.23E-12	2.47E-07	6.26E-08	1.67E-07	2.29E-08	1.69E-07	1.54E-08	8.33E-09	1.39E-09	1.99E-13	2.52E-08	7.13E-12
Baseline	MAX	White-tailed Deer	Aliphatic C5-C8 Group	4.87E-07	4.87E-06	1.22E-09	1.18E+01	0.00E+00	5.06E-06	1.19E-07	4.60E-05	2.54E-08	1.35E-06	0.00E+00	6.98E-09	1.38E-06	3.16E-08
Baseline	MAX	White-tailed Deer	Aliphatic C9-C16 Group	3.14E-04	3.14E-03	4.97E-12	2.60E-01	0.00E+00	1.40E-04	1.23E-06	1.31E-04	1.64E-05	3.69E-05	0.00E+00	2.83E-11	5.33E-05	1.29E-06
Baseline	MAX	White-tailed Deer	aliphatic C17-C34 group	7.18E-08	7.18E-07	7.18E-20	3.32E-08	0.00E+00	0.00E+00	2.82E-10	3.01E-08	3.75E-09	7.36E-11	0.00E+00	4.09E-19	3.82E-09	9.28E-11
Baseline	MAX	White-tailed Deer	Anthracene	8.39E-09	8.39E-08	1.86E-13	2.47E-07	2.09E-08	1.06E-08	8.14E-10	3.52E-09	4.38E-10	8.42E-09	0.00E+00	1.06E-12	8.86E-09	2.99E-12
Baseline	MAX	White-tailed Deer	Aromatic C17-C34 Group	9.76E-03	9.76E-02	7.75E-07	4.39E-02	0.00E+00	8.44E-01	7.36E-05	4.09E-03	5.09E-04	2.20E-01	0.00E+00	4.42E-06	2.21E-01	7.11E-05
Baseline	MAX	White-tailed Deer	Aromatic C9-C16 Group	5.81E-07	5.81E-06	1.16E-09	7.94E-03	0.00E+00	1.53E-06	1.24E-07	2.44E-07	3.03E-08	4.32E-07	0.00E+00	6.61E-09	4.69E-07	1.15E-08
Baseline	MAX	White-tailed Deer	benz(a)anthracene	5.23E-08	5.23E-07	8.72E-14	3.18E-08	6.95E-07	2.39E-07	1.03E-09	9.40E-09	2.73E-09	2.44E-07	0.00E+00	4.97E-13	2.47E-07	9.85E-11
Baseline	MAX	White-tailed Deer	Benzo(a)pyrene	6.84E-08	6.84E-07	4.27E-14	2.49E-08	7.45E-07	7.39E-07	9.01E-10	2.87E-08	3.57E-09	3.87E-07	0.00E+00	2.44E-13	3.91E-07	1.47E-10
Baseline	MAX	White-tailed Deer	benzo(e)pyrene	2.88E-08	2.88E-07	7.19E-13	1.97E-08	5.88E-07	5.54E-06	1.12E-10	1.21E-08	1.50E-09	1.60E-06	0.00E+00	4.10E-12	1.60E-06	3.86E-10
Baseline	MAX	White-tailed Deer	Benzo(b)fluoranthene	6.67E-09	6.67E-08	6.36E-14	2.49E-08	3.59E-08	3.26E-08	7.45E-11	2.80E-09	3.48E-10	1.79E-08	0.00E+00	3.63E-13	1.82E-08	6.60E-12
Baseline	MAX	White-tailed Deer	Benzo(ghi)perylene	9.48E-08	9.48E-07	6.00E-13	2.54E-08	1.01E-06	2.18E-05	2.43E-10	3.98E-08	4.95E-09	5.96E-06	0.00E+00	3.42E-12	5.96E-06	1.14E-09
Baseline	MAX	White-tailed Deer	Benzo(k)fluoranthene	1.84E-07	1.84E-06	9.70E-14	2.01E-08	6.18E-07	9.32E-07	2.13E-09	8.83E-08	9.62E-09	4.05E-07	0.00E+00	5.53E-13	4.15E-07	1.51E-10
Baseline	MAX	White-tailed Deer	biphenyl	6.42E-11	6.42E-10	0.00E+00	2.48E-07	0.00E+00	1.30E-07	1.78E-12	2.69E-11	3.35E-12	3.40E-08	0.00E+00	0.00E+00	3.40E-08	1.38E-09
Baseline	MAX	White-tailed Deer	Chrysene	4.08E-07	4.08E-06	6.80E-13	8.03E-08	8.70E-07	3.33E-08	8.01E-09	9.77E-08	2.13E-08	2.38E-07	0.00E+00	3.87E-12	2.59E-07	1.03E-10
Baseline	MAX	White-tailed Deer	dibenz(ah)anthracene	1.36E-07	1.36E-06	2.34E-14	2.49E-08	9.97E-07	3.44E-05	9.20E-10	5.69E-08	7.09E-09	9.24E-06	0.00E+00	1.33E-13	9.25E-06	2.86E-09
Baseline	MAX	White-tailed Deer	Fluoranthene	7.59E-08	7.59E-07	6.90E-13	6.57E-07	2.22E-07	3.87E-07	3.79E-09	3.18E-08	3.96E-09	1.60E-07	0.00E+00	3.94E-12	1.64E-07	6.44E-11
Baseline	MAX	White-tailed Deer	Fluorene	3.59E-10	3.59E-09	1.71E-14	1.61E-07	0.00E+00	3.35E-09	5.19E-11	1.51E-10	1.87E-11	8.89E-10	0.00E+00	9.75E-14	9.08E-10	2.66E-13
Baseline	MAX	White-tailed Deer	Indeno(123cd)pyrene	9.80E-08	9.80E-07	0.00E+00	2.49E-08	1.05E-06	3.74E-08	5.81E-10	4.70E-08	5.12E-09	2.84E-07	0.00E+00	0.00E+00	2.89E-07	8.49E-11
Baseline	MAX	White-tailed Deer	naphthalene	1.03E-05	1.03E-04	3.45E-09	2.60E-01	0.00E+00	7.95E-05	4.96E-06	4.34E-06	5.40E-07	2.20E-05	0.00E+00	1.96E-08	2.26E-05	3.36E-07
Baseline	MAX	White-tailed Deer	Phenanthrene	1.26E-08	1.26E-07	3.40E-13	5.28E-07	2.24E-08	6.40E-08	1.22E-09	5.28E-09	6.58E-10	2.29E-08	0.00E+00	1.94E-12	2.35E-08	7.95E-12
Baseline	MAX	White-tailed Deer	Pyrene	4.02E-07	4.02E-06	4.23E-12	2.47E-07	6.26E-08	1.67E-07	2.29E-08	1.69E-07	2.10E-08	6.58E-08	0.00E+00	2.41E-11	8.68E-08	3.34E-11
Application	MAX	Ruffed_Grouse	Aliphatic C5-C8 Group	5.07E-07	5.07E-06	1.27E-09	1.23E+01	0.00E+00	5.25E-06	1.23E-07	4.78E-05	1.95E-08	1.78E-07	3.95E-07	5.98E-11	5.92E-07	9.96E-09
Application	MAX	Ruffed_Grouse	Aliphatic C9-C16 Group	3.62E-04	3.62E-03	5.73E-12	2.99E-01	0.00E+00	1.62E-04	1.42E-06	1.52E-04	1.39E-05	5.39E-06	1.25E-06	2.69E-13	2.05E-05	3.68E-07

Table 4E-7 Summary of Predicted Tissue Concentrations for Each Receptor, Scenario, and Chemical

								Dietary Concentrations				EDI					
								Browse	Browse	Browse	Invertebrate	Soil	Browse	Invertebrate	Water	Total	Tissue
				Soil	Surface Soil	Surface Water	Air	Deposition	Air	Aboveground	Terrestrial	EDI	EDI	EDI	EDI	EDI Oral	Concentration
Scenario	**Site**	**Receptor**	**Chemical**	**mg/kg**	**mg/kg**	**mg/L**	**$\mu g/m^3$**	**mg/kg dw**	**mg/kg dw**	**mg/kg dw**	**mg/kg dw**	**mg/day**	**mg/day**	**mg/day**	**mg/day**	**mg/day**	**mg/kg ww**
Application	MAX	Ruffed_Grouse	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	3.00E-03	1.01E-05	2.70E-04	3.67E-15	3.28E-03	5.87E-05
Application	MAX	Ruffed_Grouse	Anthracene	1.23E-05	1.23E-04	2.73E-10	3.61E-04	3.06E-05	1.55E-05	1.19E-06	5.15E-06	4.72E-07	1.56E-06	4.25E-08	1.28E-11	2.07E-06	5.17E-10
Application	MAX	Ruffed_Grouse	Aromatic C17-C34 Group	8.31E-02	8.31E-01	6.60E-06	3.74E-01	0.00E+00	7.18E+00	6.26E-04	3.48E-02	3.19E-03	2.37E-01	2.88E-04	3.10E-07	2.41E-01	5.72E-05
Application	MAX	Ruffed_Grouse	Aromatic C9-C16 Group	3.11E-05	3.11E-04	6.20E-08	4.24E-01	0.00E+00	8.18E-05	6.61E-06	1.30E-05	1.19E-06	2.92E-06	1.08E-07	2.91E-09	4.23E-06	7.63E-08
Application	MAX	Ruffed_Grouse	benz(a)anthracene	3.56E-05	3.56E-04	5.94E-11	2.16E-05	4.74E-04	1.62E-04	7.00E-07	6.40E-06	1.37E-06	2.10E-05	5.29E-08	2.79E-12	2.25E-05	6.61E-09
Application	MAX	Ruffed_Grouse	Benzo(a)pyrene	4.09E-05	4.09E-04	2.56E-11	1.49E-05	4.46E-04	4.42E-04	5.39E-07	1.72E-05	1.57E-06	2.94E-05	1.42E-07	1.20E-12	3.11E-05	8.61E-09
Application	MAX	Ruffed_Grouse	benzo(e)pyrene	1.37E-05	1.37E-04	3.42E-10	9.38E-06	2.80E-04	2.64E-03	5.31E-08	5.74E-06	5.26E-07	9.64E-05	4.74E-08	1.61E-11	9.69E-05	1.72E-08
Application	MAX	Ruffed_Grouse	Benzo(b)fluoranthene	3.99E-06	3.99E-05	3.81E-11	1.49E-05	2.15E-05	1.95E-05	4.46E-08	1.67E-06	1.53E-07	1.36E-06	1.38E-08	1.79E-12	1.53E-06	4.07E-10
Application	MAX	Ruffed_Grouse	Benzo(ghi)perylene	5.59E-05	5.59E-04	3.54E-10	1.49E-05	5.97E-04	1.28E-02	1.43E-07	2.34E-05	2.15E-06	4.44E-04	1.94E-07	1.66E-11	4.47E-04	6.27E-08
Application	MAX	Ruffed_Grouse	Benzo(k)fluoranthene	1.37E-04	1.37E-03	7.22E-11	1.49E-05	4.60E-04	6.93E-04	1.58E-06	6.57E-05	5.27E-06	3.82E-05	5.43E-07	3.39E-12	4.40E-05	1.18E-08
Application	MAX	Ruffed_Grouse	biphenyl	2.25E-08	2.25E-07	0.00E+00	8.67E-05	0.00E+00	4.55E-05	6.24E-10	9.41E-09	8.63E-10	1.50E-06	7.78E-11	0.00E+00	1.50E-06	4.51E-08
Application	MAX	Ruffed_Grouse	Chrysene	5.29E-04	5.29E-03	8.82E-10	1.04E-04	1.13E-03	4.32E-05	1.04E-05	1.27E-04	2.03E-05	3.91E-05	1.05E-06	4.15E-11	6.05E-05	1.78E-08
Application	MAX	Ruffed_Grouse	dibenz(ah)anthracene	8.13E-05	8.13E-04	1.40E-11	1.49E-05	5.97E-04	2.06E-02	5.51E-07	3.41E-05	3.12E-06	7.00E-04	2.82E-07	6.58E-13	7.04E-04	1.61E-07
Application	MAX	Ruffed_Grouse	Fluoranthene	1.68E-05	1.68E-04	1.53E-10	1.45E-04	4.91E-05	8.56E-05	8.38E-07	7.04E-06	6.45E-07	4.48E-06	5.82E-08	7.18E-12	5.19E-06	1.50E-09
Application	MAX	Ruffed_Grouse	Fluorene	3.64E-07	3.64E-06	1.73E-11	1.63E-04	0.00E+00	3.40E-06	5.26E-08	1.52E-07	1.40E-08	1.14E-07	1.26E-09	8.14E-13	1.29E-07	2.79E-11
Application	MAX	Ruffed_Grouse	Indeno(123cd)pyrene	3.69E-05	3.69E-04	0.00E+00	9.38E-06	3.95E-04	1.41E-05	2.19E-07	1.77E-05	1.42E-06	1.35E-05	1.46E-07	0.00E+00	1.51E-05	3.27E-09
Application	MAX	Ruffed_Grouse	naphthalene	1.05E-05	1.05E-04	3.49E-09	2.63E-01	0.00E+00	8.06E-05	5.02E-06	4.39E-06	4.02E-07	2.83E-06	3.63E-08	1.64E-10	3.27E-06	3.57E-08
Application	MAX	Ruffed_Grouse	Phenanthrene	5.40E-06	5.40E-05	1.46E-10	2.26E-04	9.57E-06	2.74E-05	5.24E-07	2.26E-06	2.07E-07	1.24E-06	1.87E-08	6.86E-12	1.47E-06	3.65E-10
Application	MAX	Ruffed_Grouse	Pyrene	5.88E-04	5.88E-03	6.19E-09	3.61E-04	9.17E-05	2.44E-04	3.35E-05	2.47E-04	2.26E-05	1.22E-05	2.04E-06	2.91E-10	3.68E-05	1.04E-08
Application	MAX	White-tailed Deer	Aliphatic C5-C8 Group	5.07E-07	5.07E-06	1.27E-09	1.23E+01	0.00E+00	5.25E-06	1.23E-07	4.78E-05	2.64E-08	1.40E-06	0.00E+00	7.25E-09	1.44E-06	3.28E-08
Application	MAX	White-tailed Deer	Aliphatic C9-C16 Group	3.62E-04	3.62E-03	5.73E-12	2.99E-01	0.00E+00	1.62E-04	1.42E-06	1.52E-04	1.89E-05	4.25E-05	0.00E+00	3.27E-11	6.14E-05	1.49E-06
Application	MAX	White-tailed Deer	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	4.07E-03	7.99E-05	0.00E+00	4.45E-13	4.15E-03	1.01E-04
Application	MAX	White-tailed Deer	Anthracene	1.23E-05	1.23E-04	2.73E-10	3.61E-04	3.06E-05	1.55E-05	1.19E-06	5.15E-06	6.41E-07	1.23E-05	0.00E+00	1.55E-09	1.30E-05	4.38E-09
Application	MAX	White-tailed Deer	Aromatic C17-C34 Group	8.31E-02	8.31E-01	6.60E-06	3.74E-01	0.00E+00	7.18E+00	6.26E-04	3.48E-02	4.34E-03	1.87E+00	0.00E+00	3.76E-05	1.88E+00	6.05E-04
Application	MAX	White-tailed Deer	Aromatic C9-C16 Group	3.11E-05	3.11E-04	6.20E-08	4.24E-01	0.00E+00	8.18E-05	6.61E-06	1.30E-05	1.62E-06	2.31E-05	0.00E+00	3.53E-07	2.50E-05	6.13E-07
Application	MAX	White-tailed Deer	benz(a)anthracene	3.56E-05	3.56E-04	5.94E-11	2.16E-05	4.74E-04	1.62E-04	7.00E-07	6.40E-06	1.86E-06	1.66E-04	0.00E+00	3.38E-10	1.68E-04	6.71E-08
Application	MAX	White-tailed Deer	Benzo(a)pyrene	4.09E-05	4.09E-04	2.56E-11	1.49E-05	4.46E-04	4.42E-04	5.39E-07	1.72E-05	2.14E-06	2.32E-04	0.00E+00	1.46E-10	2.34E-04	8.79E-08
Application	MAX	White-tailed Deer	benzo(e)pyrene	1.37E-05	1.37E-04	3.42E-10	9.38E-06	2.80E-04	2.64E-03	5.31E-08	5.74E-06	7.14E-07	7.61E-04	0.00E+00	1.95E-09	7.62E-04	1.84E-07
Application	MAX	White-tailed Deer	Benzo(b)fluoranthene	3.99E-06	3.99E-05	3.81E-11	1.49E-05	2.15E-05	1.95E-05	4.46E-08	1.67E-06	2.08E-07	1.07E-05	0.00E+00	2.17E-10	1.09E-05	3.96E-09
Application	MAX	White-tailed Deer	Benzo(ghi)perylene	5.59E-05	5.59E-04	3.54E-10	1.49E-05	5.97E-04	1.28E-02	1.43E-07	2.34E-05	2.92E-06	3.51E-03	0.00E+00	2.02E-09	3.51E-03	6.69E-07
Application	MAX	White-tailed Deer	Benzo(k)fluoranthene	1.37E-04	1.37E-03	7.22E-11	1.49E-05	4.60E-04	6.93E-04	1.58E-06	6.57E-05	7.16E-06	3.01E-04	0.00E+00	4.11E-10	3.08E-04	1.12E-07
Application	MAX	White-tailed Deer	biphenyl	2.25E-08	2.25E-07	0.00E+00	8.67E-05	0.00E+00	4.55E-05	6.24E-10	9.41E-09	1.17E-09	1.19E-05	0.00E+00	0.00E+00	1.19E-05	4.83E-07
Application	MAX	White-tailed Deer	Chrysene	5.29E-04	5.29E-03	8.82E-10	1.04E-04	1.13E-03	4.32E-05	1.04E-05	1.27E-04	2.76E-05	3.09E-04	0.00E+00	5.03E-09	3.36E-04	1.34E-07
Application	MAX	White-tailed Deer	dibenz(ah)anthracene	8.13E-05	8.13E-04	1.40E-11	1.49E-05	5.97E-04	2.06E-02	5.51E-07	3.41E-05	4.24E-06	5.53E-03	0.00E+00	7.99E-11	5.53E-03	1.71E-06
Application	MAX	White-tailed Deer	Fluoranthene	1.68E-05	1.68E-04	1.53E-10	1.45E-04	4.91E-05	8.56E-05	8.38E-07	7.04E-06	8.77E-07	3.54E-05	0.00E+00	8.70E-10	3.63E-05	1.42E-08
Application	MAX	White-tailed Deer	Fluorene	3.64E-07	3.64E-06	1.73E-11	1.63E-04	0.00E+00	3.40E-06	5.26E-08	1.52E-07	1.90E-08	9.00E-07	0.00E+00	9.87E-11	9.20E-07	2.69E-10
Application	MAX	White-tailed Deer	Indeno(123cd)pyrene	3.69E-05	3.69E-04	0.00E+00	9.38E-06	3.95E-04	1.41E-05	2.19E-07	1.77E-05	1.93E-06	1.07E-04	0.00E+00	0.00E+00	1.09E-04	3.20E-08
Application	MAX	White-tailed Deer	naphthalene	1.05E-05	1.05E-04	3.49E-09	2.63E-01	0.00E+00	8.06E-05	5.02E-06	4.39E-06	5.47E-07	2.23E-05	0.00E+00	1.99E-08	2.29E-05	3.40E-07
Application	MAX	White-tailed Deer	Phenanthrene	5.40E-06	5.40E-05	1.46E-10	2.26E-04	9.57E-06	2.74E-05	5.24E-07	2.26E-06	2.82E-07	9.79E-06	0.00E+00	8.31E-10	1.01E-05	3.41E-09
Application	MAX	White-tailed Deer	Pyrene	5.88E-04	5.88E-03	6.19E-09	3.61E-04	9.17E-05	2.44E-04	3.35E-05	2.47E-04	3.07E-05	9.63E-05	0.00E+00	3.53E-08	1.27E-04	4.88E-08
Application	MAX-AGR	Beef	Aliphatic C5-C8 Group	4.42E-07	4.42E-06	1.11E-09	1.07E+01	0.00E+00	4.58E-06	1.07E-07	4.17E-05	2.21E-06	5.53E-05	0.00E+00	4.20E-08	5.75E-05	1.31E-06
Application	MAX-AGR	Beef	Aliphatic C9-C16 Group	3.62E-04	3.62E-03	5.73E-12	2.99E-01	0.00E+00	1.62E-04	1.42E-06	1.52E-04	1.81E-03	1.92E-03	0.00E+00	2.17E-10	3.73E-03	9.05E-05
Application	MAX-AGR	Beef	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	3.90E-01	3.61E-03	0.00E+00	2.95E-12	3.94E-01	9.56E-03
Application	MAX-AGR	Beef	Anthracene	2.27E-06	2.27E-05	5.05E-11	6.68E-05	5.65E-06	2.86E-06	2.20E-07	9.52E-07	1.14E-05	1.03E-04	0.00E+00	1.91E-09	1.14E-04	3.86E-08
Application	MAX-AGR	Beef	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.34E-09	5.29E-04	0.00E+00	1.02E-02	8.86E-07	4.93E-05	5.88E-04	1.20E-01	0.00E+00	3.53E-07	1.20E-01	3.87E-05
Application	MAX-AGR	Beef	Aromatic C9-C16 Group	3.11E-05	3.11E-04	6.20E-08	4.24E-01	0.00E+00	8.18E-05	6.61E-06	1.30E-05	1.55E-04	1.04E-03	0.00E+00	2.35E-06	1.20E-03	2.94E-05
Application	MAX-AGR	Beef	benz(a)anthracene	3.56E-05	3.56E-04	5.94E-11	2.16E-05	4.74E-04	1.62E-04	7.00E-07	6.40E-06	1.78E-04	7.50E-03	0.00E+00	2.25E-09	7.68E-03	3.07E-06
Application	MAX-AGR	Beef	Benzo(a)pyrene	4.09E-05	4.09E-04	2.56E-11	1.49E-05	4.46E-04	4.42E-04	5.39E-07	1.72E-05	2.05E-04	1.05E-02	0.00E+00	9.68E-10	1.07E-02	4.01E-06
Application	MAX-AGR	Beef	benzo(e)pyrene	1.01E-13	1.01E-12	2.52E-18	6.90E-14	2.06E-12	1.94E-11	3.91E-16	4.22E-14	5.04E-13	2.53E-10	0.00E+00	9.53E-17	2.53E-10	6.11E-14
Application	MAX-AGR	Beef	Benzo(b)fluoranthene	3.99E-06	3.99E-05	3.81E-11	1.49E-05	2.15E-05	1.95E-05	4.46E-08	1.67E-06	2.00E-05	4.84E-04	0.00E+00	1.44E-09	5.04E-04	1.82E-07
Application	MAX-AGR	Beef	Benzo(ghi)perylene	5.59E-05	5.59E-04	3.54E-10	1.49E-05	5.97E-04	1.28E-02	1.43E-07	2.34E-05	2.79E-04	1.58E-01	0.00E+00	1.34E-08	1.59E-01	3.02E-05
Application	MAX-AGR	Beef	Benzo(k)fluoranthene	1.37E-04	1.37E-03	7.22E-11	1.49E-05	4.60E-04	6.93E-04	1.58E-06	6.57E-05	6.86E-04	1.36E-02	0.00E+00	2.73E-09	1.43E-02	5.21E-06
Application	MAX-AGR	Beef	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	4.24E-10	2.02E-06	0.00E+00	0.00E+00	2.03E-06	8.25E-08
Application	MAX-AGR	Beef	Chrysene	1.14E-04	1.14E-03	1.90E-10	2.25E-05	2.43E-04	9.30E-06	2.24E-06	2.73E-05	5.70E-04	3.00E-03	0.00E+00	7.19E-09	3.57E-03	1.43E-06
Application	MAX-AGR	Beef	dibenz(ah)anthracene	8.13E-05	8.13E-04	1.40E-11	1.49E-05	5.97E-04	2.06E-02	5.51E-07	3.41E-05	4.06E-04	2.50E-01	0.00E+00	5.30E-10	2.50E-01	7.74E-05
Application	MAX-AGR	Beef	Fluoranthene	1.56E-05	1.56E-04	1.42E-10	1.35E-04	4.58E-05	7.98E-05	7.81E-07	6.56E-06	7.82E-05	1.49E-03	0.00E+00	5.38E-09	1.57E-03	6.15E-07
Application	MAX-AGR	Beef	Fluorene	3.64E-07	3.64E-06	1.73E-11	1.63E-04	0.00E+00	3.40E-06	5.26E-08	1.52E-07	1.82E-06	4.06E-05	0.00E+00	6.55E-10	4.25E-05	1.24E-08
Application	MAX-AGR	Beef	Indeno(123cd)pyrene	5.88E-05	5.88E-04	0.00E+00	1.49E-05	6.29E-04	2.25E-05	3.49E-07	2.82E-05	2.94E-04	7.68E-03	0.00E+00	0.00E+00	7.97E-03	2.34E-06
Application	MAX-AGR	Beef	naphthalene	4.33E-07	4.33E-06	1.44E-10	1.09E-02	0.00E+00	3.33E-06	2.08E-07	1.82E-07	2.17E-06	4.17E-05	0.00E+00	5.47E-09	4.39E-05	6.52E-07
Application	MAX-AGR	Beef	Phenanthrene	5.40E-06	5.40E-05	1.46E-10	2.26E-04	9.57E-06	2.74E-05	5.24E-07	2.26E-06	2.70E-05	4.42E-04	0.00E+00	5.52E-09	4.69E-04	1.59E-07
Application	MAX-AGR	Beef	Pyrene	2.47E-05	2.47E-04	2.60E-10	1.51E-05	3.84E-06	1.02E-05	1.41E-06	1.03E-05	1.23E-04	1.82E-04	0.00E+00	9.83E-09	3.06E-04	1.17E-07
Application	MAX-AGR	Chicken	Aliphatic C5-C8 Group	4.42E-07	4.42E-06	1.11E-09	1.07E+01	0.00E+00	4.58E-06	1.07E-07	4.17E-05	9.73E-08	7.51E-07	1.67E-06	2.89E-10	2.52E-06	4.23E-08
Application	MAX-AGR	Chicken	Aliphatic C9-C16 Group	3.62E-04	3.62E-03	5.73E-12	2.99E-01	0.00E+00	1.62E-04	1.42E-06	1.52E-04	7.96E-05	2.61E-05	6.06E-06	1.49E-12	1.12E-04	2.00E-06
Application	MAX-AGR	Chicken	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	1.72E-02	4.90E-05	1.31E-03	2.03E-14	1.85E-02	3.31E-04

Table 4E-7 Summary of Predicted Tissue Concentrations for Each Receptor, Scenario, and Chemical

								Dietary Concentrations				EDI					
				Soil	Surface Soil	Surface Water	Air	Browse Deposition	Browse Air	Browse Aboveground	Invertebrate Terrestrial	Soil EDI	Browse EDI	Invertebrate EDI	Water EDI	Total EDI Oral	Tissue Concentration
Scenario	**Site**	**Receptor**	**Chemical**	mg/kg	mg/kg	mg/L	$\mu g/m^3$	mg/kg dw	mg/kg dw	mg/kg dw	mg/kg dw	mg/day	mg/day	mg/day	mg/day	mg/day	mg/kg ww
Application	MAX-AGR	Chicken	Anthracene	2.27E-06	2.27E-05	5.05E-11	6.68E-05	5.65E-06	2.86E-06	2.20E-07	9.52E-07	4.99E-07	1.40E-06	3.81E-08	1.31E-11	1.93E-06	4.82E-10
Application	MAX-AGR	Chicken	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.34E-09	5.29E-04	0.00E+00	1.02E-02	8.86E-07	4.93E-05	2.59E-05	1.63E-03	1.97E-06	2.43E-09	1.65E-03	3.92E-07
Application	MAX-AGR	Chicken	Aromatic C9-C16 Group	3.11E-05	3.11E-04	6.20E-08	4.24E-01	0.00E+00	8.18E-05	6.61E-06	1.30E-05	6.84E-06	1.41E-05	5.21E-07	1.61E-08	2.15E-05	3.88E-07
Application	MAX-AGR	Chicken	benz(a)anthracene	3.56E-05	3.56E-04	5.94E-11	2.16E-05	4.74E-04	1.62E-04	7.00E-07	6.40E-06	7.84E-06	1.02E-04	2.56E-07	1.54E-11	1.10E-04	3.24E-08
Application	MAX-AGR	Chicken	Benzo(a)pyrene	4.09E-05	4.09E-04	2.56E-11	1.49E-05	4.46E-04	4.42E-04	5.39E-07	1.72E-05	9.00E-06	1.42E-04	6.86E-07	6.65E-12	1.52E-04	4.20E-08
Application	MAX-AGR	Chicken	benzo(e)pyrene	1.01E-13	1.01E-12	2.52E-18	6.90E-14	2.06E-12	1.94E-11	3.91E-16	4.22E-14	2.22E-14	3.43E-12	1.69E-15	6.55E-19	3.46E-12	6.15E-16
Application	MAX-AGR	Chicken	Benzo(b)fluoranthene	3.99E-06	3.99E-05	3.81E-11	1.49E-05	2.15E-05	1.95E-05	4.46E-08	1.67E-06	8.79E-07	6.57E-06	6.70E-08	9.91E-12	7.52E-06	2.00E-09
Application	MAX-AGR	Chicken	Benzo(ghi)perylene	5.59E-05	5.59E-04	3.54E-10	1.49E-05	5.97E-04	1.28E-02	1.43E-07	2.34E-05	1.23E-05	2.15E-03	9.37E-07	9.19E-11	2.16E-03	3.04E-07
Application	MAX-AGR	Chicken	Benzo(k)fluoranthene	1.37E-04	1.37E-03	7.22E-11	1.49E-05	4.60E-04	6.93E-04	1.58E-06	6.57E-05	3.02E-05	1.85E-04	2.63E-06	1.88E-11	2.17E-04	5.85E-08
Application	MAX-AGR	Chicken	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	1.87E-11	2.75E-08	1.42E-12	0.00E+00	2.75E-08	8.26E-10
Application	MAX-AGR	Chicken	Chrysene	1.14E-04	1.14E-03	1.90E-10	2.25E-05	2.43E-04	9.30E-06	2.24E-06	2.73E-05	2.51E-05	4.08E-05	1.09E-06	4.94E-11	6.69E-05	1.97E-08
Application	MAX-AGR	Chicken	dibenz(ah)anthracene	8.13E-05	8.13E-04	1.40E-11	1.49E-05	5.97E-04	2.06E-02	5.51E-07	3.41E-05	1.79E-05	3.39E-03	1.36E-06	3.64E-12	3.41E-03	7.78E-07
Application	MAX-AGR	Chicken	Fluoranthene	1.56E-05	1.56E-04	1.42E-10	1.35E-04	4.58E-05	7.98E-05	7.81E-07	6.56E-06	3.44E-06	2.02E-05	2.62E-07	3.70E-11	2.39E-05	6.92E-09
Application	MAX-AGR	Chicken	Fluorene	3.64E-07	3.64E-06	1.73E-11	1.63E-04	0.00E+00	3.40E-06	5.26E-08	1.52E-07	8.00E-08	5.52E-07	6.10E-09	4.50E-12	6.38E-07	1.38E-10
Application	MAX-AGR	Chicken	Indeno(123cd)pyrene	5.88E-05	5.88E-04	0.00E+00	1.49E-05	6.29E-04	2.25E-05	3.49E-07	2.82E-05	1.29E-05	1.04E-04	1.13E-06	0.00E+00	1.18E-04	2.56E-08
Application	MAX-AGR	Chicken	naphthalene	4.33E-07	4.33E-06	1.44E-10	1.09E-02	0.00E+00	3.33E-06	2.08E-07	1.82E-07	9.54E-08	5.67E-07	7.27E-09	3.76E-11	6.69E-07	7.32E-09
Application	MAX-AGR	Chicken	Phenanthrene	5.40E-06	5.40E-05	1.46E-10	2.26E-04	9.57E-06	2.74E-05	5.24E-07	2.26E-06	1.19E-06	6.00E-06	9.05E-08	3.79E-11	7.28E-06	1.81E-09
Application	MAX-AGR	Chicken	Pyrene	2.47E-05	2.47E-04	2.60E-10	1.51E-05	3.84E-06	1.02E-05	1.41E-06	1.03E-05	5.43E-06	2.48E-06	4.14E-07	6.75E-11	8.32E-06	2.36E-09
Application	MAX-AGR	Dairy	Aliphatic C5-C8 Group	4.42E-07	4.42E-06	1.11E-09	1.07E+01	0.00E+00	4.58E-06	1.07E-07	4.17E-05	1.77E-06	9.52E-05	0.00E+00	1.26E-07	9.71E-05	4.67E-07
Application	MAX-AGR	Dairy	Aliphatic C9-C16 Group	3.62E-04	3.62E-03	5.73E-12	2.99E-01	0.00E+00	1.62E-04	1.42E-06	1.52E-04	1.45E-03	3.31E-03	0.00E+00	6.51E-10	4.76E-03	2.43E-05
Application	MAX-AGR	Dairy	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	3.12E-01	6.22E-03	0.00E+00	8.86E-12	3.18E-01	1.63E-03
Application	MAX-AGR	Dairy	Anthracene	2.27E-06	2.27E-05	5.05E-11	6.68E-05	5.65E-06	2.86E-06	2.20E-07	9.52E-07	9.08E-06	1.77E-04	0.00E+00	5.73E-09	1.86E-04	1.33E-08
Application	MAX-AGR	Dairy	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.34E-09	5.29E-04	0.00E+00	1.02E-02	8.86E-07	4.93E-05	4.70E-04	2.06E-01	0.00E+00	1.06E-06	2.07E-01	1.40E-05
Application	MAX-AGR	Dairy	Aromatic C9-C16 Group	3.11E-05	3.11E-04	6.20E-08	4.24E-01	0.00E+00	8.18E-05	6.61E-06	1.30E-05	1.24E-04	1.79E-03	0.00E+00	7.04E-06	1.93E-03	9.93E-06
Application	MAX-AGR	Dairy	benz(a)anthracene	3.56E-05	3.56E-04	5.94E-11	2.16E-05	4.74E-04	1.62E-04	7.00E-07	6.40E-06	1.43E-04	1.29E-02	0.00E+00	6.74E-09	1.31E-02	1.10E-06
Application	MAX-AGR	Dairy	Benzo(a)pyrene	4.09E-05	4.09E-04	2.56E-11	1.49E-05	4.46E-04	4.42E-04	5.39E-07	1.72E-05	1.64E-04	1.80E-02	0.00E+00	2.90E-09	1.82E-02	1.44E-06
Application	MAX-AGR	Dairy	benzo(e)pyrene	1.01E-13	1.01E-12	2.52E-18	6.90E-14	2.06E-12	1.94E-11	3.91E-16	4.22E-14	4.03E-13	4.36E-10	0.00E+00	2.86E-16	4.36E-10	2.22E-14
Application	MAX-AGR	Dairy	Benzo(b)fluoranthene	3.99E-06	3.99E-05	3.81E-11	1.49E-05	2.15E-05	1.95E-05	4.46E-08	1.67E-06	1.60E-05	8.34E-04	0.00E+00	4.33E-09	8.50E-04	6.47E-08
Application	MAX-AGR	Dairy	Benzo(ghi)perylene	5.59E-05	5.59E-04	3.54E-10	1.49E-05	5.97E-04	1.28E-02	1.43E-07	2.34E-05	2.23E-04	2.73E-01	0.00E+00	4.01E-08	2.73E-01	1.10E-05
Application	MAX-AGR	Dairy	Benzo(k)fluoranthene	1.37E-04	1.37E-03	7.22E-11	1.49E-05	4.60E-04	6.93E-04	1.58E-06	6.57E-05	5.49E-04	2.34E-02	0.00E+00	8.20E-09	2.40E-02	1.84E-06
Application	MAX-AGR	Dairy	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	3.39E-10	3.49E-06	0.00E+00	0.00E+00	3.49E-06	2.99E-08
Application	MAX-AGR	Dairy	Chrysene	1.14E-04	1.14E-03	1.90E-10	2.25E-05	2.43E-04	9.30E-06	2.24E-06	2.73E-05	4.56E-04	5.17E-03	0.00E+00	2.16E-08	5.63E-03	4.73E-07
Application	MAX-AGR	Dairy	dibenz(ah)anthracene	8.13E-05	8.13E-04	1.40E-11	1.49E-05	5.97E-04	2.06E-02	5.51E-07	3.41E-05	3.25E-04	4.30E-01	0.00E+00	1.59E-09	4.30E-01	2.81E-05
Application	MAX-AGR	Dairy	Fluoranthene	1.56E-05	1.56E-04	1.42E-10	1.35E-04	4.58E-05	7.98E-05	7.81E-07	6.56E-06	6.26E-05	2.57E-03	0.00E+00	1.62E-08	2.63E-03	2.17E-07
Application	MAX-AGR	Dairy	Fluorene	3.64E-07	3.64E-06	1.73E-11	1.63E-04	0.00E+00	3.40E-06	5.26E-08	1.52E-07	1.45E-06	7.00E-05	0.00E+00	1.97E-09	7.15E-05	4.41E-09
Application	MAX-AGR	Dairy	Indeno(123cd)pyrene	5.88E-05	5.88E-04	0.00E+00	1.49E-05	6.29E-04	2.25E-05	3.49E-07	2.82E-05	2.35E-04	1.32E-02	0.00E+00	0.00E+00	1.35E-02	8.33E-07
Application	MAX-AGR	Dairy	naphthalene	4.33E-07	4.33E-06	1.44E-10	1.09E-02	0.00E+00	3.33E-06	2.08E-07	1.82E-07	1.73E-06	7.19E-05	0.00E+00	1.64E-08	7.36E-05	2.30E-07
Application	MAX-AGR	Dairy	Phenanthrene	5.40E-06	5.40E-05	1.46E-10	2.26E-04	9.57E-06	2.74E-05	5.24E-07	2.26E-06	2.16E-05	7.62E-04	0.00E+00	1.66E-08	7.83E-04	5.57E-08
Application	MAX-AGR	Dairy	Pyrene	2.47E-05	2.47E-04	2.60E-10	1.51E-05	3.84E-06	1.02E-05	1.41E-06	1.03E-05	9.87E-05	3.14E-04	0.00E+00	2.95E-08	4.13E-04	3.34E-08
Application	MAX-AGR	Eggs	Aliphatic C5-C8 Group	4.42E-07	4.42E-06	1.11E-09	1.07E+01	0.00E+00	4.58E-06	1.07E-07	4.17E-05	9.73E-08	7.51E-07	1.67E-06	2.89E-10	2.52E-06	2.42E-08
Application	MAX-AGR	Eggs	Aliphatic C9-C16 Group	3.62E-04	3.62E-03	5.73E-12	2.99E-01	0.00E+00	1.62E-04	1.42E-06	1.52E-04	7.96E-05	2.61E-05	6.06E-06	1.49E-12	1.12E-04	1.14E-06
Application	MAX-AGR	Eggs	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	1.72E-02	4.90E-05	1.31E-03	2.03E-14	1.85E-02	1.89E-04
Application	MAX-AGR	Eggs	Anthracene	2.27E-06	2.27E-05	5.05E-11	6.68E-05	5.65E-06	2.86E-06	2.20E-07	9.52E-07	4.99E-07	1.40E-06	3.81E-08	1.31E-11	1.93E-06	2.75E-10
Application	MAX-AGR	Eggs	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.34E-09	5.29E-04	0.00E+00	1.02E-02	8.86E-07	4.93E-05	2.59E-05	1.63E-03	1.97E-06	2.43E-09	1.65E-03	2.24E-07
Application	MAX-AGR	Eggs	Aromatic C9-C16 Group	3.11E-05	3.11E-04	6.20E-08	4.24E-01	0.00E+00	8.18E-05	6.61E-06	1.30E-05	6.84E-06	1.41E-05	5.21E-07	1.61E-08	2.15E-05	2.22E-07
Application	MAX-AGR	Eggs	benz(a)anthracene	3.56E-05	3.56E-04	5.94E-11	2.16E-05	4.74E-04	1.62E-04	7.00E-07	6.40E-06	7.84E-06	1.02E-04	2.56E-07	1.54E-11	1.10E-04	1.85E-08
Application	MAX-AGR	Eggs	Benzo(a)pyrene	4.09E-05	4.09E-04	2.56E-11	1.49E-05	4.46E-04	4.42E-04	5.39E-07	1.72E-05	9.00E-06	1.42E-04	6.86E-07	6.65E-12	1.52E-04	2.40E-08
Application	MAX-AGR	Eggs	benzo(e)pyrene	1.01E-13	1.01E-12	2.52E-18	6.90E-14	2.06E-12	1.94E-11	3.91E-16	4.22E-14	2.22E-14	3.43E-12	1.69E-15	6.55E-19	3.46E-12	3.51E-16
Application	MAX-AGR	Eggs	Benzo(b)fluoranthene	3.99E-06	3.99E-05	3.81E-11	1.49E-05	2.15E-05	1.95E-05	4.46E-08	1.67E-06	8.79E-07	6.57E-06	6.70E-08	9.91E-12	7.52E-06	1.15E-09
Application	MAX-AGR	Eggs	Benzo(ghi)perylene	5.59E-05	5.59E-04	3.54E-10	1.49E-05	5.97E-04	1.28E-02	1.43E-07	2.34E-05	1.23E-05	2.15E-03	9.37E-07	9.19E-11	2.16E-03	1.74E-07
Application	MAX-AGR	Eggs	Benzo(k)fluoranthene	1.37E-04	1.37E-03	7.22E-11	1.49E-05	4.60E-04	6.93E-04	1.58E-06	6.57E-05	3.02E-05	1.85E-04	2.63E-06	1.88E-11	2.17E-04	3.34E-08
Application	MAX-AGR	Eggs	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	1.87E-11	2.75E-08	1.42E-12	0.00E+00	2.75E-08	4.72E-10
Application	MAX-AGR	Eggs	Chrysene	1.14E-04	1.14E-03	1.90E-10	2.25E-05	2.43E-04	9.30E-06	2.24E-06	2.73E-05	2.51E-05	4.08E-05	1.09E-06	4.94E-11	6.69E-05	1.13E-08
Application	MAX-AGR	Eggs	dibenz(ah)anthracene	8.13E-05	8.13E-04	1.40E-11	1.49E-05	5.97E-04	2.06E-02	5.51E-07	3.41E-05	1.79E-05	3.39E-03	1.36E-06	3.64E-12	3.41E-03	4.45E-07
Application	MAX-AGR	Eggs	Fluoranthene	1.56E-05	1.56E-04	1.42E-10	1.35E-04	4.58E-05	7.98E-05	7.81E-07	6.56E-06	3.44E-06	2.02E-05	2.62E-07	3.70E-11	2.39E-05	3.95E-09
Application	MAX-AGR	Eggs	Fluorene	3.64E-07	3.64E-06	1.73E-11	1.63E-04	0.00E+00	3.40E-06	5.26E-08	1.52E-07	8.00E-08	5.52E-07	6.10E-09	4.50E-12	6.38E-07	7.86E-11
Application	MAX-AGR	Eggs	Indeno(123cd)pyrene	5.88E-05	5.88E-04	0.00E+00	1.49E-05	6.29E-04	2.25E-05	3.49E-07	2.82E-05	1.29E-05	1.04E-04	1.13E-06	0.00E+00	1.18E-04	1.46E-08
Application	MAX-AGR	Eggs	naphthalene	4.33E-07	4.33E-06	1.44E-10	1.09E-02	0.00E+00	3.33E-06	2.08E-07	1.82E-07	9.54E-08	5.67E-07	7.27E-09	3.76E-11	6.69E-07	4.18E-09
Application	MAX-AGR	Eggs	Phenanthrene	5.40E-06	5.40E-05	1.46E-10	2.26E-04	9.57E-06	2.74E-05	5.24E-07	2.26E-06	1.19E-06	6.00E-06	9.05E-08	3.79E-11	7.28E-06	1.04E-09
Application	MAX-AGR	Eggs	Pyrene	2.47E-05	2.47E-04	2.60E-10	1.51E-05	3.84E-06	1.02E-05	1.41E-06	1.03E-05	5.43E-06	2.48E-06	4.14E-07	6.75E-11	8.32E-06	1.35E-09
CEA	MAX-AGR	Dairy	Aliphatic C5-C8 Group	9.85E-07	9.85E-06	2.47E-09	2.39E+01	0.00E+00	1.02E-05	2.40E-07	9.29E-05	3.94E-06	2.12E-04	0.00E+00	2.81E-07	2.17E-04	1.04E-06
CEA	MAX-AGR	Dairy	Aliphatic C9-C16 Group	8.73E-04	8.73E-03	1.38E-11	7.22E-01	0.00E+00	3.90E-04	3.43E-06	3.66E-04	3.49E-03	7.99E-03	0.00E+00	1.57E-09	1.15E-02	5.87E-05
CEA	MAX-AGR	Dairy	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	3.12E-01	6.22E-03	0.00E+00	8.86E-12	3.18E-01	1.63E-03
CEA	MAX-AGR	Dairy	Anthracene	2.30E-06	2.30E-05	5.10E-11	6.76E-05	5.72E-06	2.89E-06	2.23E-07	9.63E-07	9.19E-06	1.79E-04	0.00E+00	5.80E-09	1.88E-04	1.34E-08

Table 4E-7 Summary of Predicted Tissue Concentrations for Each Receptor, Scenario, and Chemical

								Dietary Concentrations				EDI					
								Browse	Browse	Browse	Invertebrate	Soil	Browse	Invertebrate	Water	Total	Tissue
				Soil	Surface Soil	Surface Water	Air	Deposition	Air	Aboveground	Terrestrial	EDI	EDI	EDI	EDI	EDI Oral	Concentration
Scenario	Site	Receptor	Chemical	mg/kg	mg/kg	mg/L	μg/m^3	mg/kg dw	mg/kg dw	mg/kg dw	mg/kg dw	mg/day	mg/day	mg/day	mg/day	mg/day	mg/kg ww
CEA	MAX-AGR	Dairy	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.38E-09	5.32E-04	0.00E+00	1.02E-02	8.90E-07	4.95E-05	4.72E-04	2.07E-01	0.00E+00	1.07E-06	2.08E-01	1.41E-05
CEA	MAX-AGR	Dairy	Aromatic C9-C16 Group	3.77E-05	3.77E-04	7.52E-08	5.15E-01	0.00E+00	9.92E-05	8.02E-06	1.58E-05	1.51E-04	2.18E-03	0.00E+00	8.54E-06	2.34E-03	1.20E-05
CEA	MAX-AGR	Dairy	benz(a)anthracene	3.68E-05	3.68E-04	6.14E-11	2.24E-05	4.90E-04	1.68E-04	7.24E-07	6.62E-06	1.47E-04	1.34E-02	0.00E+00	6.97E-09	1.35E-02	1.14E-06
CEA	MAX-AGR	Dairy	Benzo(a)pyrene	4.21E-05	4.21E-04	2.63E-11	1.54E-05	4.59E-04	4.55E-04	5.56E-07	1.77E-05	1.69E-04	1.86E-02	0.00E+00	2.99E-09	1.87E-02	1.48E-06
CEA	MAX-AGR	Dairy	benzo(e)pyrene	5.70E-09	5.70E-08	1.43E-13	3.91E-09	1.17E-07	1.10E-06	2.21E-11	2.39E-09	2.28E-08	2.46E-05	0.00E+00	1.62E-11	2.47E-05	1.25E-09
CEA	MAX-AGR	Dairy	Benzo(b)fluoranthene	4.10E-06	4.10E-05	3.91E-11	1.53E-05	2.21E-05	2.01E-05	4.58E-08	1.72E-06	1.64E-05	8.56E-04	0.00E+00	4.45E-09	8.73E-04	6.65E-08
CEA	MAX-AGR	Dairy	Benzo(ghi)perylene	5.75E-05	5.75E-04	3.64E-10	1.54E-05	6.14E-04	1.32E-02	1.47E-07	2.41E-05	2.30E-04	2.81E-01	0.00E+00	4.13E-08	2.81E-01	1.13E-05
CEA	MAX-AGR	Dairy	Benzo(k)fluoranthene	1.41E-04	1.41E-03	7.41E-11	1.53E-05	4.72E-04	7.12E-04	1.62E-06	6.75E-05	5.63E-04	2.41E-02	0.00E+00	8.42E-09	2.46E-02	1.89E-06
CEA	MAX-AGR	Dairy	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	3.39E-10	3.49E-06	0.00E+00	0.00E+00	3.49E-06	2.99E-08
CEA	MAX-AGR	Dairy	Chrysene	1.18E-04	1.18E-03	1.96E-10	2.32E-05	2.51E-04	9.60E-06	2.31E-06	2.82E-05	4.71E-04	5.34E-03	0.00E+00	2.23E-08	5.81E-03	4.88E-07
CEA	MAX-AGR	Dairy	dibenz(ah)anthracene	8.45E-05	8.45E-04	1.46E-11	1.55E-05	6.21E-04	2.14E-02	5.73E-07	3.54E-05	3.38E-04	4.48E-01	0.00E+00	1.66E-09	4.48E-01	2.92E-05
CEA	MAX-AGR	Dairy	Fluoranthene	1.59E-05	1.59E-04	1.45E-10	1.38E-04	4.67E-05	8.13E-05	7.96E-07	6.69E-06	6.38E-05	2.61E-03	0.00E+00	1.65E-08	2.68E-03	2.21E-07
CEA	MAX-AGR	Dairy	Fluorene	3.69E-07	3.69E-06	1.76E-11	1.65E-04	0.00E+00	3.44E-06	5.33E-08	1.55E-07	1.47E-06	7.10E-05	0.00E+00	1.99E-09	7.25E-05	4.46E-09
CEA	MAX-AGR	Dairy	Indeno(123cd)pyrene	6.14E-05	6.14E-04	0.00E+00	1.56E-05	6.56E-04	2.34E-05	3.64E-07	2.94E-05	2.45E-04	1.38E-02	0.00E+00	0.00E+00	1.41E-02	8.70E-07
CEA	MAX-AGR	Dairy	naphthalene	4.44E-07	4.44E-06	1.48E-10	1.11E-02	0.00E+00	3.41E-06	2.13E-07	1.86E-07	1.78E-06	7.36E-05	0.00E+00	1.68E-08	7.54E-05	2.36E-07
CEA	MAX-AGR	Dairy	Phenanthrene	5.70E-06	5.70E-05	1.54E-10	2.39E-04	1.01E-05	2.90E-05	5.53E-07	2.39E-06	2.28E-05	8.05E-04	0.00E+00	1.75E-08	8.27E-04	5.89E-08
CEA	MAX-AGR	Dairy	Pyrene	2.70E-05	2.70E-04	2.84E-10	1.66E-05	4.20E-06	1.12E-05	1.54E-06	1.13E-05	1.08E-04	3.43E-04	0.00E+00	3.23E-08	4.51E-04	3.65E-08
CEA	MAX-AGR	Eggs	Aliphatic C5-C8 Group	9.85E-07	9.85E-06	2.47E-09	2.39E+01	0.00E+00	1.02E-05	2.40E-07	9.29E-05	2.17E-07	1.67E-06	3.72E-06	6.43E-10	5.61E-06	5.39E-08
CEA	MAX-AGR	Eggs	Aliphatic C9-C16 Group	8.73E-04	8.73E-03	1.38E-11	7.22E-01	0.00E+00	3.90E-04	3.43E-06	3.66E-04	1.92E-04	6.30E-05	1.46E-05	3.60E-12	2.70E-04	2.76E-06
CEA	MAX-AGR	Eggs	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	1.72E-02	4.90E-05	1.31E-03	2.03E-14	1.85E-02	1.89E-04
CEA	MAX-AGR	Eggs	Anthracene	2.30E-06	2.30E-05	5.10E-11	6.76E-05	5.72E-06	2.89E-06	2.23E-07	9.63E-07	5.05E-07	1.41E-06	3.85E-08	1.33E-11	1.96E-06	2.79E-10
CEA	MAX-AGR	Eggs	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.38E-09	5.32E-04	0.00E+00	1.02E-02	8.90E-07	4.95E-05	2.60E-05	1.63E-03	1.98E-06	2.44E-09	1.66E-03	2.25E-07
CEA	MAX-AGR	Eggs	Aromatic C9-C16 Group	3.77E-05	3.77E-04	7.52E-08	5.15E-01	0.00E+00	9.92E-05	8.02E-06	1.58E-05	8.30E-06	1.72E-05	6.32E-07	1.96E-08	2.61E-05	2.69E-07
CEA	MAX-AGR	Eggs	benz(a)anthracene	3.68E-05	3.68E-04	6.14E-11	2.24E-05	4.90E-04	1.68E-04	7.24E-07	6.62E-06	8.11E-06	1.05E-04	2.65E-07	1.60E-11	1.14E-04	1.91E-08
CEA	MAX-AGR	Eggs	Benzo(a)pyrene	4.21E-05	4.21E-04	2.63E-11	1.54E-05	4.59E-04	4.55E-04	5.56E-07	1.77E-05	9.27E-06	1.46E-04	7.07E-07	6.85E-12	1.56E-04	2.47E-08
CEA	MAX-AGR	Eggs	benzo(e)pyrene	5.70E-09	5.70E-08	1.43E-13	3.91E-09	1.17E-07	1.10E-06	2.21E-11	2.39E-09	1.25E-09	1.94E-07	9.56E-11	3.71E-14	1.96E-07	1.99E-11
CEA	MAX-AGR	Eggs	Benzo(b)fluoranthene	4.10E-06	4.10E-05	3.91E-11	1.53E-05	2.21E-05	2.01E-05	4.58E-08	1.72E-06	9.02E-07	6.75E-06	6.88E-08	1.02E-11	7.72E-06	1.18E-09
CEA	MAX-AGR	Eggs	Benzo(ghi)perylene	5.75E-05	5.75E-04	3.64E-10	1.54E-05	6.14E-04	1.32E-02	1.47E-07	2.41E-05	1.26E-05	2.21E-03	9.64E-07	9.46E-11	2.23E-03	1.79E-07
CEA	MAX-AGR	Eggs	Benzo(k)fluoranthene	1.41E-04	1.41E-03	7.41E-11	1.53E-05	4.72E-04	7.12E-04	1.62E-06	6.75E-05	3.10E-05	1.90E-04	2.70E-06	1.93E-11	2.23E-04	3.43E-08
CEA	MAX-AGR	Eggs	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	1.87E-11	2.75E-08	1.42E-12	0.00E+00	2.75E-08	4.72E-10
CEA	MAX-AGR	Eggs	Chrysene	1.18E-04	1.18E-03	1.96E-10	2.32E-05	2.51E-04	9.60E-06	2.31E-06	2.82E-05	2.59E-05	4.21E-05	1.13E-06	5.10E-11	6.91E-05	1.16E-08
CEA	MAX-AGR	Eggs	dibenz(ah)anthracene	8.45E-05	8.45E-04	1.46E-11	1.55E-05	6.21E-04	2.14E-02	5.73E-07	3.54E-05	1.86E-05	3.53E-03	1.42E-06	3.79E-12	3.55E-03	4.63E-07
CEA	MAX-AGR	Eggs	Fluoranthene	1.59E-05	1.59E-04	1.45E-10	1.38E-04	4.67E-05	8.13E-05	7.96E-07	6.69E-06	3.51E-06	2.06E-05	2.67E-07	3.77E-11	2.44E-05	4.03E-09
CEA	MAX-AGR	Eggs	Fluorene	3.69E-07	3.69E-06	1.76E-11	1.65E-04	0.00E+00	3.44E-06	5.33E-08	1.55E-07	8.11E-08	5.59E-07	6.18E-09	4.56E-12	6.47E-07	7.97E-11
CEA	MAX-AGR	Eggs	Indeno(123cd)pyrene	6.14E-05	6.14E-04	0.00E+00	1.56E-05	6.56E-04	2.34E-05	3.64E-07	2.94E-05	1.35E-05	1.09E-04	1.18E-06	0.00E+00	1.24E-04	1.53E-08
CEA	MAX-AGR	Eggs	naphthalene	4.44E-07	4.44E-06	1.48E-10	1.11E-02	0.00E+00	3.41E-06	2.13E-07	1.86E-07	9.76E-08	5.80E-07	7.44E-09	3.85E-11	6.85E-07	4.28E-09
CEA	MAX-AGR	Eggs	Phenanthrene	5.70E-06	5.70E-05	1.54E-10	2.39E-04	1.01E-05	2.90E-05	5.53E-07	2.39E-06	1.25E-06	6.34E-06	9.56E-08	4.01E-11	7.69E-06	1.09E-09
CEA	MAX-AGR	Eggs	Pyrene	2.70E-05	2.70E-04	2.84E-10	1.66E-05	4.20E-06	1.12E-05	1.54E-06	1.13E-05	5.94E-06	2.71E-06	4.53E-07	7.38E-11	9.10E-06	1.47E-09
CEA	MAX	Ruffed_Grouse	Aliphatic C5-C8 Group	1.42E-06	1.42E-05	3.56E-09	3.44E+01	0.00E+00	1.47E-05	3.45E-07	1.34E-04	5.45E-08	4.98E-07	1.10E-06	1.67E-10	1.66E-06	2.79E-08
CEA	MAX	Ruffed_Grouse	Aliphatic C9-C16 Group	9.11E-03	9.11E-02	1.44E-10	7.54E+00	0.00E+00	4.07E-03	3.58E-05	3.82E-03	3.50E-04	1.36E-04	3.16E-05	6.78E-12	5.17E-04	9.26E-06
CEA	MAX	Ruffed_Grouse	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	3.00E-03	1.01E-05	2.70E-04	3.67E-15	3.28E-03	5.87E-05
CEA	MAX	Ruffed_Grouse	Anthracene	1.24E-05	1.24E-04	2.76E-10	3.65E-04	3.09E-05	1.56E-05	1.20E-06	5.20E-06	4.76E-07	1.58E-06	4.30E-08	1.29E-11	2.10E-06	5.22E-10
CEA	MAX	Ruffed_Grouse	Aromatic C17-C34 Group	2.38E-01	2.38E+00	1.89E-05	1.07E+00	0.00E+00	2.06E+01	1.80E-03	1.00E-01	9.16E-03	6.81E-01	8.26E-04	8.90E-07	6.91E-01	1.64E-04
CEA	MAX	Ruffed_Grouse	Aromatic C9-C16 Group	3.77E-05	3.77E-04	7.52E-08	5.15E-01	0.00E+00	9.92E-05	8.02E-06	1.58E-05	1.45E-06	3.55E-06	1.31E-07	3.54E-09	5.13E-06	9.25E-08
CEA	MAX	Ruffed_Grouse	benz(a)anthracene	3.68E-05	3.68E-04	6.14E-11	2.24E-05	4.90E-04	1.68E-04	7.24E-07	6.62E-06	1.42E-06	2.18E-05	5.47E-08	2.89E-12	2.32E-05	6.84E-09
CEA	MAX	Ruffed_Grouse	Benzo(a)pyrene	4.21E-05	4.21E-04	2.63E-11	1.54E-05	4.59E-04	4.55E-04	5.56E-07	1.77E-05	1.62E-06	3.03E-05	1.46E-07	1.24E-12	3.20E-05	8.86E-09
CEA	MAX	Ruffed_Grouse	benzo(e)pyrene	1.45E-05	1.45E-04	3.63E-10	9.96E-06	2.97E-04	2.80E-03	5.64E-08	6.09E-06	5.58E-07	1.02E-04	5.04E-08	1.71E-11	1.03E-04	1.83E-08
CEA	MAX	Ruffed_Grouse	Benzo(b)fluoranthene	4.10E-06	4.10E-05	3.91E-11	1.53E-05	2.21E-05	2.01E-05	4.58E-08	1.72E-06	1.58E-07	1.39E-06	1.42E-08	1.84E-12	1.57E-06	4.18E-10
CEA	MAX	Ruffed_Grouse	Benzo(ghi)perylene	5.75E-05	5.75E-04	3.64E-10	1.54E-05	6.14E-04	1.32E-02	1.47E-07	2.41E-05	2.21E-06	4.57E-04	1.99E-07	1.71E-11	4.60E-04	6.45E-08
CEA	MAX	Ruffed_Grouse	Benzo(k)fluoranthene	1.41E-04	1.41E-03	7.41E-11	1.53E-05	4.72E-04	7.12E-04	1.62E-06	6.75E-05	5.41E-06	3.92E-05	5.58E-07	3.48E-12	4.52E-05	1.21E-08
CEA	MAX	Ruffed_Grouse	biphenyl	2.34E-08	2.34E-07	0.00E+00	9.03E-05	0.00E+00	4.74E-05	6.50E-10	9.81E-09	8.99E-10	1.57E-06	8.10E-11	0.00E+00	1.57E-06	4.70E-08
CEA	MAX	Ruffed_Grouse	Chrysene	5.44E-04	5.44E-03	9.07E-10	1.07E-04	1.16E-03	4.44E-05	1.07E-05	1.30E-04	2.09E-05	4.02E-05	1.08E-06	4.26E-11	6.22E-05	1.83E-08
CEA	MAX	Ruffed_Grouse	dibenz(ah)anthracene	8.45E-05	8.45E-04	1.46E-11	1.55E-05	6.21E-04	2.14E-02	5.73E-07	3.54E-05	3.25E-06	7.29E-04	2.93E-07	6.85E-13	7.32E-04	1.67E-07
CEA	MAX	Ruffed_Grouse	Fluoranthene	1.88E-05	1.88E-04	1.71E-10	1.63E-04	5.50E-05	9.59E-05	9.38E-07	7.88E-06	7.22E-07	5.02E-06	6.51E-08	8.03E-12	5.81E-06	1.68E-09
CEA	MAX	Ruffed_Grouse	Fluorene	3.69E-07	3.69E-06	1.76E-11	1.65E-04	0.00E+00	3.44E-06	5.33E-08	1.55E-07	1.42E-08	1.16E-07	1.28E-09	8.25E-13	1.31E-07	2.83E-11
CEA	MAX	Ruffed_Grouse	Indeno(123cd)pyrene	4.05E-05	4.05E-04	0.00E+00	1.03E-05	4.34E-04	1.55E-05	2.40E-07	1.94E-05	1.56E-06	1.49E-05	1.61E-07	0.00E+00	1.66E-05	3.59E-09
CEA	MAX	Ruffed_Grouse	naphthalene	3.00E-04	3.00E-03	1.00E-07	7.54E+00	0.00E+00	2.31E-03	1.44E-04	1.26E-04	1.15E-05	8.11E-05	1.04E-06	4.70E-09	9.37E-05	1.02E-06
CEA	MAX	Ruffed_Grouse	Phenanthrene	5.70E-06	5.70E-05	1.54E-10	2.39E-04	1.01E-05	2.90E-05	5.53E-07	2.39E-06	2.19E-07	1.31E-06	1.98E-08	7.24E-12	1.55E-06	3.86E-10
CEA	MAX	Ruffed_Grouse	Pyrene	5.94E-04	5.94E-03	6.26E-09	3.65E-04	9.26E-05	2.46E-04	3.39E-05	2.49E-04	2.28E-05	1.23E-05	2.06E-06	2.94E-10	3.72E-05	1.05E-08
CEA	MAX	White-tailed Deer	Aliphatic C5-C8 Group	1.42E-06	1.42E-05	3.56E-09	3.44E+01	0.00E+00	1.47E-05	3.45E-07	1.34E-04	7.40E-08	3.93E-06	0.00E+00	2.03E-08	4.02E-06	9.18E-08
CEA	MAX	White-tailed Deer	Aliphatic C9-C16 Group	9.11E-03	9.11E-02	1.44E-10	7.54E+00	0.00E+00	4.07E-03	3.58E-05	3.82E-03	4.75E-04	1.07E-03	0.00E+00	8.23E-10	1.55E-03	3.76E-05
CEA	MAX	White-tailed Deer	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	4.07E-03	7.99E-05	0.00E+00	4.45E-13	4.15E-03	1.01E-04
CEA	MAX	White-tailed Deer	Anthracene	1.24E-05	1.24E-04	2.76E-10	3.65E-04	3.09E-05	1.56E-05	1.20E-06	5.20E-06	6.47E-07	1.24E-05	0.00E+00	1.57E-09	1.31E-05	4.43E-09
CEA	MAX	White-tailed Deer	Aromatic C17-C34 Group	2.38E-01	2.38E+00	1.89E-05	1.07E+00	0.00E+00	2.06E+01	1.80E-03	1.00E-01	1.24E-02	5.38E+00	0.00E+00	1.08E-04	5.39E+00	1.74E-03

Table 4E-7 Summary of Predicted Tissue Concentrations for Each Receptor, Scenario, and Chemical

								Dietary Concentrations				EDI					
				Soil	Surface Soil	Surface Water	Air	Browse Deposition	Browse Air	Browse Aboveground	Invertebrate Terrestrial	Soil EDI	Browse EDI	Invertebrate EDI	Water EDI	Total EDI Oral	Tissue Concentration
Scenario	Site	Receptor	Chemical	mg/kg	mg/kg	mg/L	μg/m^3	mg/kg dw	mg/kg dw	mg/kg dw	mg/kg dw	mg/day	mg/day	mg/day	mg/day	mg/day	mg/kg ww
CEA	MAX	White-tailed Deer	Aromatic C9-C16 Group	3.77E-05	3.77E-04	7.52E-08	5.15E-01	0.00E+00	9.92E-05	8.02E-06	1.58E-05	1.97E-06	2.80E-05	0.00E+00	4.29E-07	3.04E-05	7.44E-07
CEA	MAX	White-tailed Deer	benz(a)anthracene	3.68E-05	3.68E-04	6.14E-11	2.24E-05	4.90E-04	1.68E-04	7.24E-07	6.62E-06	1.92E-06	1.72E-04	0.00E+00	3.50E-10	1.74E-04	6.94E-08
CEA	MAX	White-tailed Deer	Benzo(a)pyrene	4.21E-05	4.21E-04	2.63E-11	1.54E-05	4.59E-04	4.55E-04	5.56E-07	1.77E-05	2.20E-06	2.39E-04	0.00E+00	1.50E-10	2.41E-04	9.05E-08
CEA	MAX	White-tailed Deer	benzo(e)pyrene	1.45E-05	1.45E-04	3.63E-10	9.96E-06	2.97E-04	2.80E-03	5.64E-08	6.09E-06	7.59E-07	8.08E-04	0.00E+00	2.07E-09	8.09E-04	1.95E-07
CEA	MAX	White-tailed Deer	Benzo(b)fluoranthene	4.10E-06	4.10E-05	3.91E-11	1.53E-05	2.21E-05	2.01E-05	4.58E-08	1.72E-06	2.14E-07	1.10E-05	0.00E+00	2.23E-10	1.12E-05	4.06E-09
CEA	MAX	White-tailed Deer	Benzo(ghi)perylene	5.75E-05	5.75E-04	3.64E-10	1.54E-05	6.14E-04	1.32E-02	1.47E-07	2.41E-05	3.00E-06	3.61E-03	0.00E+00	2.07E-09	3.61E-03	6.88E-07
CEA	MAX	White-tailed Deer	Benzo(k)fluoranthene	1.41E-04	1.41E-03	7.41E-11	1.53E-05	4.72E-04	7.12E-04	1.62E-06	6.75E-05	7.35E-06	3.09E-04	0.00E+00	4.22E-10	3.17E-04	1.16E-07
CEA	MAX	White-tailed Deer	biphenyl	2.34E-08	2.34E-07	0.00E+00	9.03E-05	0.00E+00	4.74E-05	6.50E-10	9.81E-09	1.22E-09	1.24E-05	0.00E+00	0.00E+00	1.24E-05	5.03E-07
CEA	MAX	White-tailed Deer	Chrysene	5.44E-04	5.44E-03	9.07E-10	1.07E-04	1.16E-03	4.44E-05	1.07E-05	1.30E-04	2.84E-05	3.18E-04	0.00E+00	5.17E-09	3.46E-04	1.38E-07
CEA	MAX	White-tailed Deer	dibenz(ah)anthracene	8.45E-05	8.45E-04	1.46E-11	1.55E-05	6.21E-04	2.14E-02	5.73E-07	3.54E-05	4.41E-06	5.75E-03	0.00E+00	8.31E-11	5.76E-03	1.78E-06
CEA	MAX	White-tailed Deer	Fluoranthene	1.88E-05	1.88E-04	1.71E-10	1.63E-04	5.50E-05	9.59E-05	9.38E-07	7.88E-06	9.81E-07	3.96E-05	0.00E+00	9.74E-10	4.06E-05	1.59E-08
CEA	MAX	White-tailed Deer	Fluorene	3.69E-07	3.69E-06	1.76E-11	1.65E-04	0.00E+00	3.44E-06	5.33E-08	1.55E-07	1.92E-08	9.13E-07	0.00E+00	1.00E-10	9.32E-07	2.73E-10
CEA	MAX	White-tailed Deer	Indeno(123cd)pyrene	4.05E-05	4.05E-04	0.00E+00	1.03E-05	4.34E-04	1.55E-05	2.40E-07	1.94E-05	2.12E-06	1.17E-04	0.00E+00	0.00E+00	1.19E-04	3.51E-08
CEA	MAX	White-tailed Deer	naphthalene	3.00E-04	3.00E-03	1.00E-07	7.54E+00	0.00E+00	2.31E-03	1.44E-04	1.26E-04	1.57E-05	6.40E-04	0.00E+00	5.71E-07	6.57E-04	9.75E-06
CEA	MAX	White-tailed Deer	Phenanthrene	5.70E-06	5.70E-05	1.54E-10	2.39E-04	1.01E-05	2.90E-05	5.53E-07	2.39E-06	2.98E-07	1.03E-05	0.00E+00	8.78E-10	1.06E-05	3.60E-09
CEA	MAX	White-tailed Deer	Pyrene	5.94E-04	5.94E-03	6.26E-09	3.65E-04	9.26E-05	2.46E-04	3.39E-05	2.49E-04	3.10E-05	9.73E-05	0.00E+00	3.57E-08	1.28E-04	4.93E-08
CEA	MAX-AGR	Beef	Aliphatic C5-C8 Group	9.85E-07	9.85E-06	2.47E-09	2.39E+01	0.00E+00	1.02E-05	2.40E-07	9.29E-05	4.93E-06	1.23E-04	0.00E+00	9.37E-08	1.28E-04	2.93E-06
CEA	MAX-AGR	Beef	Aliphatic C9-C16 Group	8.73E-04	8.73E-03	1.38E-11	7.22E-01	0.00E+00	3.90E-04	3.43E-06	3.66E-04	4.36E-03	4.63E-03	0.00E+00	5.24E-10	9.00E-03	2.19E-04
CEA	MAX-AGR	Beef	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	3.90E-01	3.61E-03	0.00E+00	2.95E-12	3.94E-01	9.56E-03
CEA	MAX-AGR	Beef	Anthracene	2.30E-06	2.30E-05	5.10E-11	6.76E-05	5.72E-06	2.89E-06	2.23E-07	9.63E-07	1.15E-05	1.04E-04	0.00E+00	1.93E-09	1.16E-04	3.91E-08
CEA	MAX-AGR	Beef	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.38E-09	5.32E-04	0.00E+00	1.02E-02	8.90E-07	4.95E-05	5.90E-04	1.20E-01	0.00E+00	3.55E-07	1.21E-01	3.89E-05
CEA	MAX-AGR	Beef	Aromatic C9-C16 Group	3.77E-05	3.77E-04	7.52E-08	5.15E-01	0.00E+00	9.92E-05	8.02E-06	1.58E-05	1.89E-04	1.26E-03	0.00E+00	2.85E-06	1.45E-03	3.56E-05
CEA	MAX-AGR	Beef	benz(a)anthracene	3.68E-05	3.68E-04	6.14E-11	2.24E-05	4.90E-04	1.68E-04	7.24E-07	6.62E-06	1.84E-04	7.76E-03	0.00E+00	2.32E-09	7.94E-03	3.17E-06
CEA	MAX-AGR	Beef	Benzo(a)pyrene	4.21E-05	4.21E-04	2.63E-11	1.54E-05	4.59E-04	4.55E-04	5.56E-07	1.77E-05	2.11E-04	1.08E-02	0.00E+00	9.97E-10	1.10E-02	4.13E-06
CEA	MAX-AGR	Beef	benzo(e)pyrene	5.70E-09	5.70E-08	1.43E-13	3.91E-09	1.17E-07	1.10E-06	2.21E-11	2.39E-09	2.85E-08	1.43E-05	0.00E+00	5.39E-12	1.43E-05	3.46E-09
CEA	MAX-AGR	Beef	Benzo(b)fluoranthene	4.10E-06	4.10E-05	3.91E-11	1.53E-05	2.21E-05	2.01E-05	4.58E-08	1.72E-06	2.05E-05	4.97E-04	0.00E+00	1.48E-09	5.17E-04	1.87E-07
CEA	MAX-AGR	Beef	Benzo(ghi)perylene	5.75E-05	5.75E-04	3.64E-10	1.54E-05	6.14E-04	1.32E-02	1.47E-07	2.41E-05	2.87E-04	1.63E-01	0.00E+00	1.38E-08	1.63E-01	3.11E-05
CEA	MAX-AGR	Beef	Benzo(k)fluoranthene	1.41E-04	1.41E-03	7.41E-11	1.53E-05	4.72E-04	7.12E-04	1.62E-06	6.75E-05	7.04E-04	1.40E-02	0.00E+00	2.81E-09	1.47E-02	5.35E-06
CEA	MAX-AGR	Beef	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	4.24E-10	2.02E-06	0.00E+00	0.00E+00	2.03E-06	8.25E-08
CEA	MAX-AGR	Beef	Chrysene	1.18E-04	1.18E-03	1.96E-10	2.32E-05	2.51E-04	9.60E-06	2.31E-06	2.82E-05	5.88E-04	3.10E-03	0.00E+00	7.42E-09	3.69E-03	1.47E-06
CEA	MAX-AGR	Beef	dibenz(ah)anthracene	8.45E-05	8.45E-04	1.46E-11	1.55E-05	6.21E-04	2.14E-02	5.73E-07	3.54E-05	4.23E-04	2.60E-01	0.00E+00	5.52E-10	2.60E-01	8.06E-05
CEA	MAX-AGR	Beef	Fluoranthene	1.59E-05	1.59E-04	1.45E-10	1.38E-04	4.67E-05	8.13E-05	7.96E-07	6.69E-06	7.97E-05	1.52E-03	0.00E+00	5.49E-09	1.60E-03	6.27E-07
CEA	MAX-AGR	Beef	Fluorene	3.69E-07	3.69E-06	1.76E-11	1.65E-04	0.00E+00	3.44E-06	5.33E-08	1.55E-07	1.84E-06	4.12E-05	0.00E+00	6.64E-10	4.30E-05	1.26E-08
CEA	MAX-AGR	Beef	Indeno(123cd)pyrene	6.14E-05	6.14E-04	0.00E+00	1.56E-05	6.56E-04	2.34E-05	3.64E-07	2.94E-05	3.07E-04	8.01E-03	0.00E+00	0.00E+00	8.32E-03	2.45E-06
CEA	MAX-AGR	Beef	naphthalene	4.44E-07	4.44E-06	1.48E-10	1.11E-02	0.00E+00	3.41E-06	2.13E-07	1.86E-07	2.22E-06	4.27E-05	0.00E+00	5.60E-09	4.49E-05	6.67E-07
CEA	MAX-AGR	Beef	Phenanthrene	5.70E-06	5.70E-05	1.54E-10	2.39E-04	1.01E-05	2.90E-05	5.53E-07	2.39E-06	2.85E-05	4.67E-04	0.00E+00	5.83E-09	4.95E-04	1.67E-07
CEA	MAX-AGR	Beef	Pyrene	2.70E-05	2.70E-04	2.84E-10	1.66E-05	4.20E-06	1.12E-05	1.54E-06	1.13E-05	1.35E-04	1.99E-04	0.00E+00	1.08E-08	3.34E-04	1.28E-07
CEA	MAX-AGR	Chicken	Aliphatic C5-C8 Group	9.85E-07	9.85E-06	2.47E-09	2.39E+01	0.00E+00	1.02E-05	2.40E-07	9.29E-05	2.17E-07	1.67E-06	3.72E-06	6.43E-10	5.61E-06	9.43E-08
CEA	MAX-AGR	Chicken	Aliphatic C9-C16 Group	8.73E-04	8.73E-03	1.38E-11	7.22E-01	0.00E+00	3.90E-04	3.43E-06	3.66E-04	1.92E-04	6.30E-05	1.46E-05	3.60E-12	2.70E-04	4.83E-06
CEA	MAX-AGR	Chicken	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	1.72E-02	4.90E-05	1.31E-03	2.03E-14	1.85E-02	3.31E-04
CEA	MAX-AGR	Chicken	Anthracene	2.30E-06	2.30E-05	5.10E-11	6.76E-05	5.72E-06	2.89E-06	2.23E-07	9.63E-07	5.05E-07	1.41E-06	3.85E-08	1.33E-11	1.96E-06	4.87E-10
CEA	MAX-AGR	Chicken	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.38E-09	5.32E-04	0.00E+00	1.02E-02	8.90E-07	4.95E-05	2.60E-05	1.63E-03	1.98E-06	2.44E-09	1.66E-03	3.94E-07
CEA	MAX-AGR	Chicken	Aromatic C9-C16 Group	3.77E-05	3.77E-04	7.52E-08	5.15E-01	0.00E+00	9.92E-05	8.02E-06	1.58E-05	8.30E-06	1.72E-05	6.32E-07	1.96E-08	2.61E-05	4.71E-07
CEA	MAX-AGR	Chicken	benz(a)anthracene	3.68E-05	3.68E-04	6.14E-11	2.24E-05	4.90E-04	1.68E-04	7.24E-07	6.62E-06	8.11E-06	1.05E-04	2.65E-07	1.60E-11	1.14E-04	3.35E-08
CEA	MAX-AGR	Chicken	Benzo(a)pyrene	4.21E-05	4.21E-04	2.63E-11	1.54E-05	4.59E-04	4.55E-04	5.56E-07	1.77E-05	9.27E-06	1.46E-04	7.07E-07	6.85E-12	1.56E-04	4.33E-08
CEA	MAX-AGR	Chicken	benzo(e)pyrene	5.70E-09	5.70E-08	1.43E-13	3.91E-09	1.17E-07	1.10E-06	2.21E-11	2.39E-09	1.25E-09	1.94E-07	9.56E-11	3.71E-14	1.96E-07	3.48E-11
CEA	MAX-AGR	Chicken	Benzo(b)fluoranthene	4.10E-06	4.10E-05	3.91E-11	1.53E-05	2.21E-05	2.01E-05	4.58E-08	1.72E-06	9.02E-07	6.75E-06	6.88E-08	1.02E-11	7.72E-06	2.06E-09
CEA	MAX-AGR	Chicken	Benzo(ghi)perylene	5.75E-05	5.75E-04	3.64E-10	1.54E-05	6.14E-04	1.32E-02	1.47E-07	2.41E-05	1.26E-05	2.21E-03	9.64E-07	9.46E-11	2.23E-03	3.12E-07
CEA	MAX-AGR	Chicken	Benzo(k)fluoranthene	1.41E-04	1.41E-03	7.41E-11	1.53E-05	4.72E-04	7.12E-04	1.62E-06	6.75E-05	3.10E-05	1.90E-04	2.70E-06	1.93E-11	2.23E-04	6.00E-08
CEA	MAX-AGR	Chicken	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	1.87E-11	2.75E-08	1.42E-12	0.00E+00	2.75E-08	8.26E-10
CEA	MAX-AGR	Chicken	Chrysene	1.18E-04	1.18E-03	1.96E-10	2.32E-05	2.51E-04	9.60E-06	2.31E-06	2.82E-05	2.59E-05	4.21E-05	1.13E-06	5.10E-11	6.91E-05	2.03E-08
CEA	MAX-AGR	Chicken	dibenz(ah)anthracene	8.45E-05	8.45E-04	1.46E-11	1.55E-05	6.21E-04	2.14E-02	5.73E-07	3.54E-05	1.86E-05	3.53E-03	1.42E-06	3.79E-12	3.55E-03	8.10E-07
CEA	MAX-AGR	Chicken	Fluoranthene	1.59E-05	1.59E-04	1.45E-10	1.38E-04	4.67E-05	8.13E-05	7.96E-07	6.69E-06	3.51E-06	2.06E-05	2.67E-07	3.77E-11	2.44E-05	7.05E-09
CEA	MAX-AGR	Chicken	Fluorene	3.69E-07	3.69E-06	1.76E-11	1.65E-04	0.00E+00	3.44E-06	5.33E-08	1.55E-07	8.11E-08	5.59E-07	6.18E-09	4.56E-12	6.47E-07	1.39E-10
CEA	MAX-AGR	Chicken	Indeno(123cd)pyrene	6.14E-05	6.14E-04	0.00E+00	1.56E-05	6.56E-04	2.34E-05	3.64E-07	2.94E-05	1.35E-05	1.09E-04	1.18E-06	0.00E+00	1.24E-04	2.68E-08
CEA	MAX-AGR	Chicken	naphthalene	4.44E-07	4.44E-06	1.48E-10	1.11E-02	0.00E+00	3.41E-06	2.13E-07	1.86E-07	9.76E-08	5.80E-07	7.44E-09	3.85E-11	6.85E-07	7.50E-09
CEA	MAX-AGR	Chicken	Phenanthrene	5.70E-06	5.70E-05	1.54E-10	2.39E-04	1.01E-05	2.90E-05	5.53E-07	2.39E-06	1.25E-06	6.34E-06	9.56E-08	4.01E-11	7.69E-06	1.92E-09
CEA	MAX-AGR	Chicken	Pyrene	2.70E-05	2.70E-04	2.84E-10	1.66E-05	4.20E-06	1.12E-05	1.54E-06	1.13E-05	5.94E-06	2.71E-06	4.53E-07	7.38E-11	9.10E-06	2.58E-09
Project	MAX-AGR	Beef	Aliphatic C5-C8 Group	4.15E-07	4.15E-06	1.04E-09	1.01E+01	0.00E+00	4.30E-06	1.01E-07	3.91E-05	2.07E-06	5.19E-05	0.00E+00	3.94E-08	5.40E-05	1.23E-06
Project	MAX-AGR	Beef	Aliphatic C9-C16 Group	2.85E-04	2.85E-03	4.51E-12	2.36E-01	0.00E+00	1.27E-04	1.12E-06	1.19E-04	1.42E-03	1.51E-03	0.00E+00	1.71E-10	2.93E-03	7.13E-05
Project	MAX-AGR	Beef	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	3.90E-01	3.61E-03	0.00E+00	2.95E-12	3.94E-01	9.56E-03
Project	MAX-AGR	Beef	Anthracene	2.27E-06	2.27E-05	5.04E-11	6.68E-05	5.65E-06	2.86E-06	2.20E-07	9.52E-07	1.13E-05	1.03E-04	0.00E+00	1.91E-09	1.14E-04	3.86E-08
Project	MAX-AGR	Beef	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.33E-09	5.29E-04	0.00E+00	1.02E-02	8.86E-07	4.93E-05	5.88E-04	1.20E-01	0.00E+00	3.53E-07	1.20E-01	3.87E-05
Project	MAX-AGR	Beef	Aromatic C9-C16 Group	3.07E-05	3.07E-04	6.13E-08	4.20E-01	0.00E+00	8.09E-05	6.54E-06	1.29E-05	1.54E-04	1.03E-03	0.00E+00	2.32E-06	1.19E-03	2.90E-05

Table 4E-7 Summary of Predicted Tissue Concentrations for Each Receptor, Scenario, and Chemical

								Dietary Concentrations				EDI					
								Browse	Browse	Browse	Invertebrate	Soil	Browse	Invertebrate	Water	Total	Tissue
				Soil	Surface Soil	Surface Water	Air	Deposition	Air	Aboveground	Terrestrial	EDI	EDI	EDI	EDI	EDI Oral	Concentration
Scenario	Site	Receptor	Chemical	mg/kg	mg/kg	mg/L	$\mu g/m^3$	mg/kg dw	mg/kg dw	mg/kg dw	mg/kg dw	mg/day	mg/day	mg/day	mg/day	mg/day	mg/kg ww
Project	MAX-AGR	Beef	benz(a)anthracene	3.56E-05	3.56E-04	5.93E-11	2.16E-05	4.73E-04	1.62E-04	6.99E-07	6.40E-06	1.78E-04	7.49E-03	0.00E+00	2.25E-09	7.67E-03	3.06E-06
Project	MAX-AGR	Beef	Benzo(a)pyrene	4.09E-05	4.09E-04	2.56E-11	1.49E-05	4.46E-04	4.42E-04	5.39E-07	1.71E-05	2.04E-04	1.05E-02	0.00E+00	9.67E-10	1.07E-02	4.01E-06
Project	MAX-AGR	Beef	benzo(e)pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Project	MAX-AGR	Beef	Benzo(b)fluoranthene	3.99E-06	3.99E-05	3.81E-11	1.49E-05	2.15E-05	1.95E-05	4.46E-08	1.67E-06	1.99E-05	4.83E-04	0.00E+00	1.44E-09	5.03E-04	1.82E-07
Project	MAX-AGR	Beef	Benzo(ghi)perylene	5.58E-05	5.58E-04	3.53E-10	1.49E-05	5.97E-04	1.28E-02	1.43E-07	2.34E-05	2.79E-04	1.58E-01	0.00E+00	1.34E-08	1.59E-01	3.02E-05
Project	MAX-AGR	Beef	Benzo(k)fluoranthene	1.37E-04	1.37E-03	7.21E-11	1.49E-05	4.59E-04	6.93E-04	1.58E-06	6.57E-05	6.85E-04	1.36E-02	0.00E+00	2.73E-09	1.43E-02	5.20E-06
Project	MAX-AGR	Beef	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	4.24E-10	2.02E-06	0.00E+00	0.00E+00	2.03E-06	8.25E-08
Project	MAX-AGR	Beef	Chrysene	1.14E-04	1.14E-03	1.90E-10	2.24E-05	2.43E-04	9.29E-06	2.24E-06	2.73E-05	5.70E-04	3.00E-03	0.00E+00	7.19E-09	3.57E-03	1.42E-06
Project	MAX-AGR	Beef	dibenz(ah)anthracene	8.12E-05	8.12E-04	1.40E-11	1.49E-05	5.96E-04	2.06E-02	5.50E-07	3.40E-05	4.06E-04	2.49E-01	0.00E+00	5.30E-10	2.50E-01	7.74E-05
Project	MAX-AGR	Beef	Fluoranthene	1.56E-05	1.56E-04	1.42E-10	1.35E-04	4.57E-05	7.97E-05	7.80E-07	6.55E-06	7.82E-05	1.49E-03	0.00E+00	5.38E-09	1.57E-03	6.14E-07
Project	MAX-AGR	Beef	Fluorene	3.64E-07	3.64E-06	1.73E-11	1.63E-04	0.00E+00	3.40E-06	5.26E-08	1.52E-07	1.82E-06	4.06E-05	0.00E+00	6.55E-10	4.24E-05	1.24E-08
Project	MAX-AGR	Beef	Indeno(123cd)pyrene	5.87E-05	5.87E-04	0.00E+00	1.49E-05	6.28E-04	2.24E-05	3.48E-07	2.82E-05	2.94E-04	7.67E-03	0.00E+00	0.00E+00	7.96E-03	2.34E-06
Project	MAX-AGR	Beef	naphthalene	4.32E-07	4.32E-06	1.44E-10	1.09E-02	0.00E+00	3.33E-06	2.07E-07	1.81E-07	2.16E-06	4.16E-05	0.00E+00	5.46E-09	4.38E-05	6.50E-07
Project	MAX-AGR	Beef	Phenanthrene	5.39E-06	5.39E-05	1.46E-10	2.26E-04	9.56E-06	2.74E-05	5.23E-07	2.26E-06	2.69E-05	4.41E-04	0.00E+00	5.51E-09	4.68E-04	1.58E-07
Project	MAX-AGR	Beef	Pyrene	2.45E-05	2.45E-04	2.58E-10	1.51E-05	3.82E-06	1.02E-05	1.40E-06	1.03E-05	1.23E-04	1.81E-04	0.00E+00	9.77E-09	3.04E-04	1.17E-07
Project	MAX-AGR	Chicken	Aliphatic C5-C8 Group	4.15E-07	4.15E-06	1.04E-09	1.01E+01	0.00E+00	4.30E-06	1.01E-07	3.91E-05	9.13E-08	7.04E-07	1.56E-06	2.71E-10	2.36E-06	3.97E-08
Project	MAX-AGR	Chicken	Aliphatic C9-C16 Group	2.85E-04	2.85E-03	4.51E-12	2.36E-01	0.00E+00	1.27E-04	1.12E-06	1.19E-04	6.26E-05	2.05E-05	4.77E-06	1.17E-12	8.79E-05	1.57E-06
Project	MAX-AGR	Chicken	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	1.72E-02	4.90E-05	1.31E-03	2.03E-14	1.85E-02	3.31E-04
Project	MAX-AGR	Chicken	Anthracene	2.27E-06	2.27E-05	5.04E-11	6.68E-05	5.65E-06	2.86E-06	2.20E-07	9.52E-07	4.99E-07	1.40E-06	3.81E-08	1.31E-11	1.93E-06	4.82E-10
Project	MAX-AGR	Chicken	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.33E-09	5.29E-04	0.00E+00	1.02E-02	8.86E-07	4.93E-05	2.59E-05	1.63E-03	1.97E-06	2.43E-09	1.65E-03	3.92E-07
Project	MAX-AGR	Chicken	Aromatic C9-C16 Group	3.07E-05	3.07E-04	6.13E-08	4.20E-01	0.00E+00	8.09E-05	6.54E-06	1.29E-05	6.76E-06	1.40E-05	5.15E-07	1.59E-08	2.13E-05	3.84E-07
Project	MAX-AGR	Chicken	benz(a)anthracene	3.56E-05	3.56E-04	5.93E-11	2.16E-05	4.73E-04	1.62E-04	6.99E-07	6.40E-06	7.83E-06	1.02E-04	2.56E-07	1.54E-11	1.10E-04	3.23E-08
Project	MAX-AGR	Chicken	Benzo(a)pyrene	4.09E-05	4.09E-04	2.56E-11	1.49E-05	4.46E-04	4.42E-04	5.39E-07	1.71E-05	9.00E-06	1.42E-04	6.86E-07	6.65E-12	1.52E-04	4.20E-08
Project	MAX-AGR	Chicken	benzo(e)pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Project	MAX-AGR	Chicken	Benzo(b)fluoranthene	3.99E-06	3.99E-05	3.81E-11	1.49E-05	2.15E-05	1.95E-05	4.46E-08	1.67E-06	8.78E-07	6.57E-06	6.69E-08	9.90E-12	7.51E-06	2.00E-09
Project	MAX-AGR	Chicken	Benzo(ghi)perylene	5.58E-05	5.58E-04	3.53E-10	1.49E-05	5.97E-04	1.28E-02	1.43E-07	2.34E-05	1.23E-05	2.15E-03	9.36E-07	9.18E-11	2.16E-03	3.03E-07
Project	MAX-AGR	Chicken	Benzo(k)fluoranthene	1.37E-04	1.37E-03	7.21E-11	1.49E-05	4.59E-04	6.93E-04	1.58E-06	6.57E-05	3.01E-05	1.85E-04	2.63E-06	1.87E-11	2.17E-04	5.84E-08
Project	MAX-AGR	Chicken	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	1.87E-11	2.75E-08	1.42E-12	0.00E+00	2.75E-08	8.26E-10
Project	MAX-AGR	Chicken	Chrysene	1.14E-04	1.14E-03	1.90E-10	2.24E-05	2.43E-04	9.29E-06	2.24E-06	2.73E-05	2.51E-05	4.07E-05	1.09E-06	4.94E-11	6.69E-05	1.97E-08
Project	MAX-AGR	Chicken	dibenz(ah)anthracene	8.12E-05	8.12E-04	1.40E-11	1.49E-05	5.96E-04	2.06E-02	5.50E-07	3.40E-05	1.79E-05	3.39E-03	1.36E-06	3.64E-12	3.41E-03	7.78E-07
Project	MAX-AGR	Chicken	Fluoranthene	1.56E-05	1.56E-04	1.42E-10	1.35E-04	4.57E-05	7.97E-05	7.80E-07	6.55E-06	3.44E-06	2.02E-05	2.62E-07	3.69E-11	2.39E-05	6.91E-09
Project	MAX-AGR	Chicken	Fluorene	3.64E-07	3.64E-06	1.73E-11	1.63E-04	0.00E+00	3.40E-06	5.26E-08	1.52E-07	8.00E-08	5.52E-07	6.10E-09	4.50E-12	6.38E-07	1.38E-10
Project	MAX-AGR	Chicken	Indeno(123cd)pyrene	5.87E-05	5.87E-04	0.00E+00	1.49E-05	6.28E-04	2.24E-05	3.48E-07	2.82E-05	1.29E-05	1.04E-04	1.13E-06	0.00E+00	1.18E-04	2.56E-08
Project	MAX-AGR	Chicken	naphthalene	4.32E-07	4.32E-06	1.44E-10	1.09E-02	0.00E+00	3.33E-06	2.07E-07	1.81E-07	9.51E-08	5.65E-07	7.25E-09	3.75E-11	6.68E-07	7.31E-09
Project	MAX-AGR	Chicken	Phenanthrene	5.39E-06	5.39E-05	1.46E-10	2.26E-04	9.56E-06	2.74E-05	5.23E-07	2.26E-06	1.19E-06	5.99E-06	9.04E-08	3.79E-11	7.27E-06	1.81E-09
Project	MAX-AGR	Chicken	Pyrene	2.45E-05	2.45E-04	2.58E-10	1.51E-05	3.82E-06	1.02E-05	1.40E-06	1.03E-05	5.40E-06	2.46E-06	4.11E-07	6.71E-11	8.27E-06	2.34E-09
Project	MAX-AGR	Dairy	Aliphatic C5-C8 Group	4.15E-07	4.15E-06	1.04E-09	1.01E+01	0.00E+00	4.30E-06	1.01E-07	3.91E-05	1.66E-06	8.94E-05	0.00E+00	1.18E-07	9.12E-05	4.38E-07
Project	MAX-AGR	Dairy	Aliphatic C9-C16 Group	2.85E-04	2.85E-03	4.51E-12	2.36E-01	0.00E+00	1.27E-04	1.12E-06	1.19E-04	1.14E-03	2.60E-03	0.00E+00	5.12E-10	3.74E-03	1.91E-05
Project	MAX-AGR	Dairy	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	3.12E-01	6.22E-03	0.00E+00	8.86E-12	3.18E-01	1.63E-03
Project	MAX-AGR	Dairy	Anthracene	2.27E-06	2.27E-05	5.04E-11	6.68E-05	5.65E-06	2.86E-06	2.20E-07	9.52E-07	9.08E-06	1.77E-04	0.00E+00	5.73E-09	1.86E-04	1.33E-08
Project	MAX-AGR	Dairy	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.33E-09	5.29E-04	0.00E+00	1.02E-02	8.86E-07	4.93E-05	4.70E-04	2.06E-01	0.00E+00	1.06E-06	2.07E-01	1.40E-05
Project	MAX-AGR	Dairy	Aromatic C9-C16 Group	3.07E-05	3.07E-04	6.13E-08	4.20E-01	0.00E+00	8.09E-05	6.54E-06	1.29E-05	1.23E-04	1.77E-03	0.00E+00	6.96E-06	1.90E-03	9.82E-06
Project	MAX-AGR	Dairy	benz(a)anthracene	3.56E-05	3.56E-04	5.93E-11	2.16E-05	4.73E-04	1.62E-04	6.99E-07	6.40E-06	1.42E-04	1.29E-02	0.00E+00	6.74E-09	1.31E-02	1.10E-06
Project	MAX-AGR	Dairy	Benzo(a)pyrene	4.09E-05	4.09E-04	2.56E-11	1.49E-05	4.46E-04	4.42E-04	5.39E-07	1.71E-05	1.64E-04	1.80E-02	0.00E+00	2.90E-09	1.82E-02	1.44E-06
Project	MAX-AGR	Dairy	benzo(e)pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Project	MAX-AGR	Dairy	Benzo(b)fluoranthene	3.99E-06	3.99E-05	3.81E-11	1.49E-05	2.15E-05	1.95E-05	4.46E-08	1.67E-06	1.60E-05	8.33E-04	0.00E+00	4.32E-09	8.49E-04	6.47E-08
Project	MAX-AGR	Dairy	Benzo(ghi)perylene	5.58E-05	5.58E-04	3.53E-10	1.49E-05	5.97E-04	1.28E-02	1.43E-07	2.34E-05	2.23E-04	2.73E-01	0.00E+00	4.01E-08	2.73E-01	1.09E-05
Project	MAX-AGR	Dairy	Benzo(k)fluoranthene	1.37E-04	1.37E-03	7.21E-11	1.49E-05	4.59E-04	6.93E-04	1.58E-06	6.57E-05	5.48E-04	2.34E-02	0.00E+00	8.19E-09	2.40E-02	1.84E-06
Project	MAX-AGR	Dairy	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	3.39E-10	3.49E-06	0.00E+00	0.00E+00	3.49E-06	2.99E-08
Project	MAX-AGR	Dairy	Chrysene	1.14E-04	1.14E-03	1.90E-10	2.24E-05	2.43E-04	9.29E-06	2.24E-06	2.73E-05	4.56E-04	5.17E-03	0.00E+00	2.16E-08	5.62E-03	4.73E-07
Project	MAX-AGR	Dairy	dibenz(ah)anthracene	8.12E-05	8.12E-04	1.40E-11	1.49E-05	5.96E-04	2.06E-02	5.50E-07	3.40E-05	3.25E-04	4.30E-01	0.00E+00	1.59E-09	4.30E-01	2.81E-05
Project	MAX-AGR	Dairy	Fluoranthene	1.56E-05	1.56E-04	1.42E-10	1.35E-04	4.57E-05	7.97E-05	7.80E-07	6.55E-06	6.25E-05	2.56E-03	0.00E+00	1.61E-08	2.63E-03	2.17E-07
Project	MAX-AGR	Dairy	Fluorene	3.64E-07	3.64E-06	1.73E-11	1.63E-04	0.00E+00	3.40E-06	5.26E-08	1.52E-07	1.45E-06	7.00E-05	0.00E+00	1.97E-09	7.15E-05	4.40E-09
Project	MAX-AGR	Dairy	Indeno(123cd)pyrene	5.87E-05	5.87E-04	0.00E+00	1.49E-05	6.28E-04	2.24E-05	3.48E-07	2.82E-05	2.35E-04	1.32E-02	0.00E+00	0.00E+00	1.35E-02	8.33E-07
Project	MAX-AGR	Dairy	naphthalene	4.32E-07	4.32E-06	1.44E-10	1.09E-02	0.00E+00	3.33E-06	2.07E-07	1.81E-07	1.73E-06	7.17E-05	0.00E+00	1.64E-08	7.35E-05	2.30E-07
Project	MAX-AGR	Dairy	Phenanthrene	5.39E-06	5.39E-05	1.46E-10	2.26E-04	9.56E-06	2.74E-05	5.23E-07	2.26E-06	2.16E-05	7.60E-04	0.00E+00	1.65E-08	7.82E-04	5.57E-08
Project	MAX-AGR	Dairy	Pyrene	2.45E-05	2.45E-04	2.58E-10	1.51E-05	3.82E-06	1.02E-05	1.40E-06	1.03E-05	9.81E-05	3.12E-04	0.00E+00	2.93E-08	4.10E-04	3.32E-08
Project	MAX-AGR	Eggs	Aliphatic C5-C8 Group	4.15E-07	4.15E-06	1.04E-09	1.01E+01	0.00E+00	4.30E-06	1.01E-07	3.91E-05	9.13E-08	7.04E-07	1.56E-06	2.71E-10	2.36E-06	2.27E-08
Project	MAX-AGR	Eggs	Aliphatic C9-C16 Group	2.85E-04	2.85E-03	4.51E-12	2.36E-01	0.00E+00	1.27E-04	1.12E-06	1.19E-04	6.26E-05	2.05E-05	4.77E-06	1.17E-12	8.79E-05	8.99E-07
Project	MAX-AGR	Eggs	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	1.72E-02	4.90E-05	1.31E-03	2.03E-14	1.85E-02	1.89E-04
Project	MAX-AGR	Eggs	Anthracene	2.27E-06	2.27E-05	5.04E-11	6.68E-05	5.65E-06	2.86E-06	2.20E-07	9.52E-07	4.99E-07	1.40E-06	3.81E-08	1.31E-11	1.93E-06	2.75E-10
Project	MAX-AGR	Eggs	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.33E-09	5.29E-04	0.00E+00	1.02E-02	8.86E-07	4.93E-05	2.59E-05	1.63E-03	1.97E-06	2.43E-09	1.65E-03	2.24E-07
Project	MAX-AGR	Eggs	Aromatic C9-C16 Group	3.07E-05	3.07E-04	6.13E-08	4.20E-01	0.00E+00	8.09E-05	6.54E-06	1.29E-05	6.76E-06	1.40E-05	5.15E-07	1.59E-08	2.13E-05	2.19E-07
Project	MAX-AGR	Eggs	benz(a)anthracene	3.56E-05	3.56E-04	5.93E-11	2.16E-05	4.73E-04	1.62E-04	6.99E-07	6.40E-06	7.83E-06	1.02E-04	2.56E-07	1.54E-11	1.10E-04	1.85E-08

Table 4E-7 Summary of Predicted Tissue Concentrations for Each Receptor, Scenario, and Chemical

								Dietary Concentrations				EDI					
				Soil	Surface Soil	Surface Water	Air	Browse Deposition	Browse Air	Browse Aboveground	Invertebrate Terrestrial	Soil EDI	Browse EDI	Invertebrate EDI	Water EDI	Total EDI Oral	Tissue Concentration
Scenario	**Site**	**Receptor**	**Chemical**	**mg/kg**	**mg/kg**	**mg/L**	**$\mu g/m^3$**	**mg/kg dw**	**mg/kg dw**	**mg/kg dw**	**mg/kg dw**	**mg/day**	**mg/day**	**mg/day**	**mg/day**	**mg/day**	**mg/kg ww**
Project	MAX-AGR	Eggs	Benzo(a)pyrene	4.09E-05	4.09E-04	2.56E-11	1.49E-05	4.46E-04	4.42E-04	5.39E-07	1.71E-05	9.00E-06	1.42E-04	6.86E-07	6.65E-12	1.52E-04	2.40E-08
Project	MAX-AGR	Eggs	benzo(e)pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Project	MAX-AGR	Eggs	Benzo(b)fluoranthene	3.99E-06	3.99E-05	3.81E-11	1.49E-05	2.15E-05	1.95E-05	4.46E-08	1.67E-06	8.78E-07	6.57E-06	6.69E-08	9.90E-12	7.51E-06	1.14E-09
Project	MAX-AGR	Eggs	Benzo(ghi)perylene	5.58E-05	5.58E-04	3.53E-10	1.49E-05	5.97E-04	1.28E-02	1.43E-07	2.34E-05	1.23E-05	2.15E-03	9.36E-07	9.18E-11	2.16E-03	1.73E-07
Project	MAX-AGR	Eggs	Benzo(k)fluoranthene	1.37E-04	1.37E-03	7.21E-11	1.49E-05	4.59E-04	6.93E-04	1.58E-06	6.57E-05	3.01E-05	1.85E-04	2.63E-06	1.87E-11	2.17E-04	3.34E-08
Project	MAX-AGR	Eggs	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	1.87E-11	2.75E-08	1.42E-12	0.00E+00	2.75E-08	4.72E-10
Project	MAX-AGR	Eggs	Chrysene	1.14E-04	1.14E-03	1.90E-10	2.24E-05	2.43E-04	9.29E-06	2.24E-06	2.73E-05	2.51E-05	4.07E-05	1.09E-06	4.94E-11	6.69E-05	1.12E-08
Project	MAX-AGR	Eggs	dibenz(ah)anthracene	8.12E-05	8.12E-04	1.40E-11	1.49E-05	5.96E-04	2.06E-02	5.50E-07	3.40E-05	1.79E-05	3.39E-03	1.36E-06	3.64E-12	3.41E-03	4.44E-07
Project	MAX-AGR	Eggs	Fluoranthene	1.56E-05	1.56E-04	1.42E-10	1.35E-04	4.57E-05	7.97E-05	7.80E-07	6.55E-06	3.44E-06	2.02E-05	2.62E-07	3.69E-11	2.39E-05	3.95E-09
Project	MAX-AGR	Eggs	Fluorene	3.64E-07	3.64E-06	1.73E-11	1.63E-04	0.00E+00	3.40E-06	5.26E-08	1.52E-07	8.00E-08	5.52E-07	6.10E-09	4.50E-12	6.38E-07	7.86E-11
Project	MAX-AGR	Eggs	Indeno(123cd)pyrene	5.87E-05	5.87E-04	0.00E+00	1.49E-05	6.28E-04	2.24E-05	3.48E-07	2.82E-05	1.29E-05	1.04E-04	1.13E-06	0.00E+00	1.18E-04	1.46E-08
Project	MAX-AGR	Eggs	naphthalene	4.32E-07	4.32E-06	1.44E-10	1.09E-02	0.00E+00	3.33E-06	2.07E-07	1.81E-07	9.51E-08	5.65E-07	7.25E-09	3.75E-11	6.68E-07	4.17E-09
Project	MAX-AGR	Eggs	Phenanthrene	5.39E-06	5.39E-05	1.46E-10	2.26E-04	9.56E-06	2.74E-05	5.23E-07	2.26E-06	1.19E-06	5.99E-06	9.04E-08	3.79E-11	7.27E-06	1.03E-09
Project	MAX-AGR	Eggs	Pyrene	2.45E-05	2.45E-04	2.58E-10	1.51E-05	3.82E-06	1.02E-05	1.40E-06	1.03E-05	5.40E-06	2.46E-06	4.11E-07	6.71E-11	8.27E-06	1.34E-09
Project	MAX	Ruffed_Grouse	Aliphatic C5-C8 Group	4.15E-07	4.15E-06	1.04E-09	1.01E+01	0.00E+00	4.30E-06	1.01E-07	3.91E-05	1.59E-08	1.46E-07	3.23E-07	4.90E-11	4.85E-07	8.15E-09
Project	MAX	Ruffed_Grouse	Aliphatic C9-C16 Group	2.85E-04	2.85E-03	4.51E-12	2.36E-01	0.00E+00	1.27E-04	1.12E-06	1.19E-04	1.09E-05	4.24E-06	9.86E-07	2.12E-13	1.62E-05	2.89E-07
Project	MAX	Ruffed_Grouse	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	3.00E-03	1.01E-05	2.70E-04	3.67E-15	3.28E-03	5.87E-05
Project	MAX	Ruffed_Grouse	Anthracene	2.27E-06	2.27E-05	5.04E-11	6.68E-05	5.65E-06	2.86E-06	2.20E-07	9.52E-07	8.72E-08	2.89E-07	7.86E-09	2.37E-12	3.84E-07	9.56E-11
Project	MAX	Ruffed_Grouse	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.33E-09	5.29E-04	0.00E+00	1.02E-02	8.86E-07	4.93E-05	4.52E-06	3.36E-04	4.07E-07	4.39E-10	3.41E-04	8.08E-08
Project	MAX	Ruffed_Grouse	Aromatic C9-C16 Group	3.07E-05	3.07E-04	6.13E-08	4.20E-01	0.00E+00	8.09E-05	6.54E-06	1.29E-05	1.18E-06	2.89E-06	1.06E-07	2.88E-09	4.18E-06	7.54E-08
Project	MAX	Ruffed_Grouse	benz(a)anthracene	3.56E-05	3.56E-04	5.93E-11	2.16E-05	4.73E-04	1.62E-04	6.99E-07	6.40E-06	1.37E-06	2.10E-05	5.29E-08	2.79E-12	2.24E-05	6.60E-09
Project	MAX	Ruffed_Grouse	Benzo(a)pyrene	4.09E-05	4.09E-04	2.56E-11	1.49E-05	4.46E-04	4.42E-04	5.39E-07	1.71E-05	1.57E-06	2.94E-05	1.42E-07	1.20E-12	3.11E-05	8.60E-09
Project	MAX	Ruffed_Grouse	benzo(e)pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Project	MAX	Ruffed_Grouse	Benzo(b)fluoranthene	3.99E-06	3.99E-05	3.81E-11	1.49E-05	2.15E-05	1.95E-05	4.46E-08	1.67E-06	1.53E-07	1.36E-06	1.38E-08	1.79E-12	1.52E-06	4.06E-10
Project	MAX	Ruffed_Grouse	Benzo(ghi)perylene	5.58E-05	5.58E-04	3.53E-10	1.49E-05	5.97E-04	1.28E-02	1.43E-07	2.34E-05	2.14E-06	4.44E-04	1.93E-07	1.66E-11	4.46E-04	6.26E-08
Project	MAX	Ruffed_Grouse	Benzo(k)fluoranthene	1.37E-04	1.37E-03	7.21E-11	1.49E-05	4.59E-04	6.93E-04	1.58E-06	6.57E-05	5.26E-06	3.81E-05	5.43E-07	3.39E-12	4.39E-05	1.18E-08
Project	MAX	Ruffed_Grouse	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	3.26E-12	5.68E-09	2.94E-13	0.00E+00	5.69E-09	1.71E-10
Project	MAX	Ruffed_Grouse	Chrysene	1.14E-04	1.14E-03	1.90E-10	2.24E-05	2.43E-04	9.29E-06	2.24E-06	2.73E-05	4.38E-06	8.42E-06	2.26E-07	8.92E-12	1.30E-05	3.83E-09
Project	MAX	Ruffed_Grouse	dibenz(ah)anthracene	8.12E-05	8.12E-04	1.40E-11	1.49E-05	5.96E-04	2.06E-02	5.50E-07	3.40E-05	3.12E-06	7.00E-04	2.81E-07	6.58E-13	7.03E-04	1.61E-07
Project	MAX	Ruffed_Grouse	Fluoranthene	1.56E-05	1.56E-04	1.42E-10	1.35E-04	4.57E-05	7.97E-05	7.80E-07	6.55E-06	6.01E-07	4.17E-06	5.42E-08	6.68E-12	4.83E-06	1.40E-09
Project	MAX	Ruffed_Grouse	Fluorene	3.64E-07	3.64E-06	1.73E-11	1.63E-04	0.00E+00	3.40E-06	5.26E-08	1.52E-07	1.40E-08	1.14E-07	1.26E-09	8.14E-13	1.29E-07	2.79E-11
Project	MAX	Ruffed_Grouse	Indeno(123cd)pyrene	3.69E-05	3.69E-04	0.00E+00	9.37E-06	3.94E-04	1.41E-05	2.19E-07	1.77E-05	1.42E-06	1.35E-05	1.46E-07	0.00E+00	1.51E-05	3.27E-09
Project	MAX	Ruffed_Grouse	naphthalene	4.32E-07	4.32E-06	1.44E-10	1.09E-02	0.00E+00	3.33E-06	2.07E-07	1.81E-07	1.66E-08	1.17E-07	1.50E-09	6.78E-12	1.35E-07	1.48E-09
Project	MAX	Ruffed_Grouse	Phenanthrene	5.39E-06	5.39E-05	1.46E-10	2.26E-04	9.56E-06	2.74E-05	5.23E-07	2.26E-06	2.07E-07	1.24E-06	1.87E-08	6.84E-12	1.46E-06	3.65E-10
Project	MAX	Ruffed_Grouse	Pyrene	2.45E-05	2.45E-04	2.58E-10	1.51E-05	3.82E-06	1.02E-05	1.40E-06	1.03E-05	9.43E-07	5.08E-07	8.50E-08	1.21E-11	1.54E-06	4.35E-10
Project	MAX	White-tailed Deer	Aliphatic C5-C8 Group	4.15E-07	4.15E-06	1.04E-09	1.01E+01	0.00E+00	4.30E-06	1.01E-07	3.91E-05	2.17E-08	1.15E-06	0.00E+00	5.94E-09	1.18E-06	2.69E-08
Project	MAX	White-tailed Deer	Aliphatic C9-C16 Group	2.85E-04	2.85E-03	4.51E-12	2.36E-01	0.00E+00	1.27E-04	1.12E-06	1.19E-04	1.49E-05	3.35E-05	0.00E+00	2.57E-11	4.83E-05	1.17E-06
Project	MAX	White-tailed Deer	aliphatic C17-C34 group	7.80E-02	7.80E-01	7.80E-14	3.60E-02	0.00E+00	0.00E+00	3.06E-04	3.27E-02	4.07E-03	7.99E-05	0.00E+00	4.45E-13	4.15E-03	1.01E-04
Project	MAX	White-tailed Deer	Anthracene	2.27E-06	2.27E-05	5.04E-11	6.68E-05	5.65E-06	2.86E-06	2.20E-07	9.52E-07	1.18E-07	2.28E-06	0.00E+00	2.87E-10	2.40E-06	8.10E-10
Project	MAX	White-tailed Deer	Aromatic C17-C34 Group	1.18E-04	1.18E-03	9.33E-09	5.29E-04	0.00E+00	1.02E-02	8.86E-07	4.93E-05	6.13E-06	2.65E-03	0.00E+00	5.32E-08	2.66E-03	8.56E-07
Project	MAX	White-tailed Deer	Aromatic C9-C16 Group	3.07E-05	3.07E-04	6.13E-08	4.20E-01	0.00E+00	8.09E-05	6.54E-06	1.29E-05	1.60E-06	2.28E-05	0.00E+00	3.49E-07	2.48E-05	6.06E-07
Project	MAX	White-tailed Deer	benz(a)anthracene	3.56E-05	3.56E-04	5.93E-11	2.16E-05	4.73E-04	1.62E-04	6.99E-07	6.40E-06	1.86E-06	1.66E-04	0.00E+00	3.38E-10	1.68E-04	6.70E-08
Project	MAX	White-tailed Deer	Benzo(a)pyrene	4.09E-05	4.09E-04	2.56E-11	1.49E-05	4.46E-04	4.42E-04	5.39E-07	1.71E-05	2.13E-06	2.32E-04	0.00E+00	1.46E-10	2.34E-04	8.79E-08
Project	MAX	White-tailed Deer	benzo(e)pyrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Project	MAX	White-tailed Deer	Benzo(b)fluoranthene	3.99E-06	3.99E-05	3.81E-11	1.49E-05	2.15E-05	1.95E-05	4.46E-08	1.67E-06	2.08E-07	1.07E-05	0.00E+00	2.17E-10	1.09E-05	3.95E-09
Project	MAX	White-tailed Deer	Benzo(ghi)perylene	5.58E-05	5.58E-04	3.53E-10	1.49E-05	5.97E-04	1.28E-02	1.43E-07	2.34E-05	2.91E-06	3.51E-03	0.00E+00	2.01E-09	3.51E-03	6.68E-07
Project	MAX	White-tailed Deer	Benzo(k)fluoranthene	1.37E-04	1.37E-03	7.21E-11	1.49E-05	4.59E-04	6.93E-04	1.58E-06	6.57E-05	7.15E-06	3.01E-04	0.00E+00	4.11E-10	3.08E-04	1.12E-07
Project	MAX	White-tailed Deer	biphenyl	8.49E-11	8.49E-10	0.00E+00	3.28E-07	0.00E+00	1.72E-07	2.36E-12	3.56E-11	4.43E-12	4.49E-08	0.00E+00	0.00E+00	4.49E-08	1.83E-09
Project	MAX	White-tailed Deer	Chrysene	1.14E-04	1.14E-03	1.90E-10	2.24E-05	2.43E-04	9.29E-06	2.24E-06	2.73E-05	5.95E-06	6.65E-05	0.00E+00	1.08E-09	7.24E-05	2.89E-08
Project	MAX	White-tailed Deer	dibenz(ah)anthracene	8.12E-05	8.12E-04	1.40E-11	1.49E-05	5.96E-04	2.06E-02	5.50E-07	3.40E-05	4.24E-06	5.53E-03	0.00E+00	7.98E-11	5.53E-03	1.71E-06
Project	MAX	White-tailed Deer	Fluoranthene	1.56E-05	1.56E-04	1.42E-10	1.35E-04	4.57E-05	7.97E-05	7.80E-07	6.55E-06	8.16E-07	3.29E-05	0.00E+00	8.10E-10	3.38E-05	1.32E-08
Project	MAX	White-tailed Deer	Fluorene	3.64E-07	3.64E-06	1.73E-11	1.63E-04	0.00E+00	3.40E-06	5.26E-08	1.52E-07	1.90E-08	9.00E-07	0.00E+00	9.87E-11	9.19E-07	2.69E-10
Project	MAX	White-tailed Deer	Indeno(123cd)pyrene	3.69E-05	3.69E-04	0.00E+00	9.37E-06	3.94E-04	1.41E-05	2.19E-07	1.77E-05	1.93E-06	1.07E-04	0.00E+00	0.00E+00	1.09E-04	3.19E-08
Project	MAX	White-tailed Deer	naphthalene	4.32E-07	4.32E-06	1.44E-10	1.09E-02	0.00E+00	3.33E-06	2.07E-07	1.81E-07	2.26E-08	9.22E-07	0.00E+00	8.22E-10	9.46E-07	1.40E-08
Project	MAX	White-tailed Deer	Phenanthrene	5.39E-06	5.39E-05	1.46E-10	2.26E-04	9.56E-06	2.74E-05	5.23E-07	2.26E-06	2.81E-07	9.78E-06	0.00E+00	8.30E-10	1.01E-05	3.40E-09
Project	MAX	White-tailed Deer	Pyrene	2.45E-05	2.45E-04	2.58E-10	1.51E-05	3.82E-06	1.02E-05	1.40E-06	1.03E-05	1.28E-06	4.01E-06	0.00E+00	1.47E-09	5.30E-06	2.04E-09
Background	MAX-AGR	Beef	Aliphatic C5-C8 Group	1.28E-07	1.28E-06	3.20E-10	3.09E+00	0.00E+00	1.32E-06	3.10E-08	1.20E-05	6.38E-07	1.60E-05	0.00E+00	1.21E-08	1.66E-05	3.79E-07
Background	MAX-AGR	Beef	Aliphatic C9-C16 Group	3.21E-04	3.21E-03	5.08E-12	2.65E-01	0.00E+00	1.43E-04	1.26E-06	1.34E-04	1.60E-03	1.70E-03	0.00E+00	1.92E-10	3.31E-03	8.03E-05
Background	MAX-AGR	Beef	aliphatic C17-C34 group	1.24E-02	1.24E-01	1.24E-14	5.72E-03	0.00E+00	0.00E+00	4.86E-05	5.19E-03	6.19E-02	5.72E-04	0.00E+00	4.68E-13	6.24E-02	1.52E-03
Background	MAX-AGR	Beef	Anthracene	3.78E-06	3.78E-05	8.39E-11	1.11E-04	9.40E-06	4.75E-06	3.66E-07	1.58E-06	1.89E-05	1.71E-04	0.00E+00	3.18E-09	1.90E-04	6.42E-08
Background	MAX-AGR	Beef	Aromatic C17-C34 Group	2.22E-04	2.22E-03	1.77E-08	1.00E-03	0.00E+00	1.92E-02	1.68E-06	9.32E-05	1.11E-03	2.26E-01	0.00E+00	6.68E-07	2.28E-01	7.32E-05
Background	MAX-AGR	Beef	Aromatic C9-C16 Group	3.51E-05	3.51E-04	7.00E-08	4.79E-01	0.00E+00	9.23E-05	7.46E-06	1.47E-05	1.75E-04	1.18E-03	0.00E+00	2.65E-06	1.35E-03	3.31E-05
Background	MAX-AGR	Beef	benz(a)anthracene	2.36E-05	2.36E-04	3.94E-11	1.44E-05	3.14E-04	1.08E-04	4.65E-07	4.25E-06	1.18E-04	4.98E-03	0.00E+00	1.49E-09	5.10E-03	2.03E-06

Table 4E-7 Summary of Predicted Tissue Concentrations for Each Receptor, Scenario, and Chemical

								Dietary Concentrations				EDI					
								Browse	Browse	Browse	Invertebrate	Soil	Browse	Invertebrate	Water	Total	Tissue
				Soil	Surface Soil	Surface Water	Air	Deposition	Air	Aboveground	Terrestrial	EDI	EDI	EDI	EDI	EDI Oral	Concentration
Scenario	**Site**	**Receptor**	**Chemical**	**mg/kg**	**mg/kg**	**mg/L**	**$\mu g/m^3$**	**mg/kg dw**	**mg/kg dw**	**mg/kg dw**	**mg/kg dw**	**mg/day**	**mg/day**	**mg/day**	**mg/day**	**mg/day**	**mg/kg ww**
Background	MAX-AGR	Beef	Benzo(a)pyrene	9.63E-05	9.63E-04	6.02E-11	3.51E-05	1.05E-03	1.04E-03	1.27E-06	4.04E-05	4.81E-04	2.46E-02	0.00E+00	2.28E-09	2.51E-02	9.43E-06
Background	MAX-AGR	Beef	benzo(e)pyrene	6.86E-05	6.86E-04	1.71E-09	4.70E-05	1.40E-03	1.32E-02	2.66E-07	2.88E-05	3.43E-04	1.72E-01	0.00E+00	6.49E-08	1.72E-01	4.16E-05
Background	MAX-AGR	Beef	Benzo(b)fluoranthene	2.38E-05	2.38E-04	2.27E-10	8.91E-05	1.28E-04	1.17E-04	2.66E-07	9.99E-06	1.19E-04	2.89E-03	0.00E+00	8.61E-09	3.01E-03	1.09E-06
Background	MAX-AGR	Beef	Benzo(ghi)perylene	2.72E-04	2.72E-03	1.72E-09	7.26E-05	2.90E-03	6.25E-02	6.97E-07	1.14E-04	1.36E-03	7.70E-01	0.00E+00	6.51E-08	7.71E-01	1.47E-04
Background	MAX-AGR	Beef	Benzo(k)fluoranthene	8.18E-04	8.18E-03	4.31E-10	8.91E-05	2.74E-03	4.14E-03	9.44E-06	3.92E-04	4.09E-03	8.11E-02	0.00E+00	1.63E-08	8.52E-02	3.11E-05
Background	MAX-AGR	Beef	biphenyl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Background	MAX-AGR	Beef	Chrysene	8.16E-05	8.16E-04	1.36E-10	1.61E-05	1.74E-04	6.66E-06	1.60E-06	1.95E-05	4.08E-04	2.15E-03	0.00E+00	5.15E-09	2.56E-03	1.02E-06
Background	MAX-AGR	Beef	dibenz(ah)anthracene	1.79E-06	1.79E-05	3.09E-13	3.29E-07	1.32E-05	4.54E-04	1.21E-08	7.51E-07	8.96E-06	5.50E-03	0.00E+00	1.17E-11	5.51E-03	1.71E-06
Background	MAX-AGR	Beef	Fluoranthene	2.90E-05	2.90E-04	2.64E-10	2.51E-04	8.49E-05	1.48E-04	1.45E-06	1.22E-05	1.45E-04	2.76E-03	0.00E+00	9.98E-09	2.91E-03	1.14E-06
Background	MAX-AGR	Beef	Fluorene	6.96E-07	6.96E-06	3.31E-11	3.11E-04	0.00E+00	6.50E-06	1.01E-07	2.92E-07	3.48E-06	7.78E-05	0.00E+00	1.25E-09	8.13E-05	2.38E-08
Background	MAX-AGR	Beef	Indeno(123cd)pyrene	7.76E-06	7.76E-05	0.00E+00	1.97E-06	8.30E-05	2.97E-06	4.61E-08	3.72E-06	3.88E-05	1.01E-03	0.00E+00	0.00E+00	1.05E-03	3.09E-07
Background	MAX-AGR	Beef	naphthalene	5.07E-07	5.07E-06	1.69E-10	1.27E-02	0.00E+00	3.90E-06	2.43E-07	2.12E-07	2.53E-06	4.87E-05	0.00E+00	6.39E-09	5.13E-05	7.61E-07
Background	MAX-AGR	Beef	Phenanthrene	1.07E-05	1.07E-04	2.90E-10	4.49E-04	1.90E-05	5.44E-05	1.04E-06	4.49E-06	5.36E-05	8.77E-04	0.00E+00	1.10E-08	9.31E-04	3.15E-07
Background	MAX-AGR	Beef	Pyrene	1.42E-05	1.42E-04	1.50E-10	8.74E-06	2.22E-06	5.90E-06	8.11E-07	5.97E-06	7.12E-05	1.05E-04	0.00E+00	5.67E-09	1.76E-04	6.78E-08
Background	MAX-AGR	Chicken	Aliphatic C5-C8 Group	1.28E-07	1.28E-06	3.20E-10	3.09E+00	0.00E+00	1.32E-06	3.10E-08	1.20E-05	2.81E-08	2.17E-07	4.81E-07	8.33E-11	7.26E-07	1.22E-08
Background	MAX-AGR	Chicken	Aliphatic C9-C16 Group	3.21E-04	3.21E-03	5.08E-12	2.65E-01	0.00E+00	1.43E-04	1.26E-06	1.34E-04	7.05E-05	2.31E-05	5.38E-06	1.32E-12	9.90E-05	1.77E-06
Background	MAX-AGR	Chicken	aliphatic C17-C34 group	1.24E-02	1.24E-01	1.24E-14	5.72E-03	0.00E+00	0.00E+00	4.86E-05	5.19E-03	2.72E-03	7.77E-06	2.07E-04	3.22E-15	2.94E-03	5.26E-05
Background	MAX-AGR	Chicken	Anthracene	3.78E-06	3.78E-05	8.39E-11	1.11E-04	9.40E-06	4.75E-06	3.66E-07	1.58E-06	8.31E-07	2.32E-06	6.33E-08	2.18E-11	3.22E-06	8.01E-10
Background	MAX-AGR	Chicken	Aromatic C17-C34 Group	2.22E-04	2.22E-03	1.77E-08	1.00E-03	0.00E+00	1.92E-02	1.68E-06	9.32E-05	4.89E-05	3.08E-03	3.73E-06	4.59E-09	3.13E-03	7.42E-07
Background	MAX-AGR	Chicken	Aromatic C9-C16 Group	3.51E-05	3.51E-04	7.00E-08	4.79E-01	0.00E+00	9.23E-05	7.46E-06	1.47E-05	7.71E-06	1.60E-05	5.88E-07	1.82E-08	2.43E-05	4.38E-07
Background	MAX-AGR	Chicken	benz(a)anthracene	2.36E-05	2.36E-04	3.94E-11	1.44E-05	3.14E-04	1.08E-04	4.65E-07	4.25E-06	5.20E-06	6.76E-05	1.70E-07	1.02E-11	7.30E-05	2.15E-08
Background	MAX-AGR	Chicken	Benzo(a)pyrene	9.63E-05	9.63E-04	6.02E-11	3.51E-05	1.05E-03	1.04E-03	1.27E-06	4.04E-05	2.12E-05	3.34E-04	1.61E-06	1.56E-11	3.57E-04	9.89E-08
Background	MAX-AGR	Chicken	benzo(e)pyrene	6.86E-05	6.86E-04	1.71E-09	4.70E-05	1.40E-03	1.32E-02	2.66E-07	2.88E-05	1.51E-05	2.34E-03	1.15E-06	4.46E-10	2.35E-03	4.19E-07
Background	MAX-AGR	Chicken	Benzo(b)fluoranthene	2.38E-05	2.38E-04	2.27E-10	8.91E-05	1.28E-04	1.17E-04	2.66E-07	9.99E-06	5.24E-06	3.92E-05	4.00E-07	5.91E-11	4.49E-05	1.20E-08
Background	MAX-AGR	Chicken	Benzo(ghi)perylene	2.72E-04	2.72E-03	1.72E-09	7.26E-05	2.90E-03	6.25E-02	6.97E-07	1.14E-04	5.97E-05	1.05E-02	4.56E-06	4.47E-10	1.05E-02	1.48E-06
Background	MAX-AGR	Chicken	Benzo(k)fluoranthene	8.18E-04	8.18E-03	4.31E-10	8.91E-05	2.74E-03	4.14E-03	9.44E-06	3.92E-04	1.80E-04	1.10E-03	1.57E-05	1.12E-10	1.30E-03	3.49E-07
Background	MAX-AGR	Chicken	biphenyl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Background	MAX-AGR	Chicken	Chrysene	8.16E-05	8.16E-04	1.36E-10	1.61E-05	1.74E-04	6.66E-06	1.60E-06	1.95E-05	1.79E-05	2.92E-05	7.82E-07	3.53E-11	4.79E-05	1.41E-08
Background	MAX-AGR	Chicken	dibenz(ah)anthracene	1.79E-06	1.79E-05	3.09E-13	3.29E-07	1.32E-05	4.54E-04	1.21E-08	7.51E-07	3.94E-07	7.47E-05	3.00E-08	8.03E-14	7.52E-05	1.72E-08
Background	MAX-AGR	Chicken	Fluoranthene	2.90E-05	2.90E-04	2.64E-10	2.51E-04	8.49E-05	1.48E-04	1.45E-06	1.22E-05	6.38E-06	3.75E-05	4.87E-07	6.86E-11	4.44E-05	1.28E-08
Background	MAX-AGR	Chicken	Fluorene	6.96E-07	6.96E-06	3.31E-11	3.11E-04	0.00E+00	6.50E-06	1.01E-07	2.92E-07	1.53E-07	1.06E-06	1.17E-08	8.62E-12	1.22E-06	2.63E-10
Background	MAX-AGR	Chicken	Indeno(123cd)pyrene	7.76E-06	7.76E-05	0.00E+00	1.97E-06	8.30E-05	2.97E-06	4.61E-08	3.72E-06	1.71E-06	1.38E-05	1.49E-07	0.00E+00	1.56E-05	3.38E-09
Background	MAX-AGR	Chicken	naphthalene	5.07E-07	5.07E-06	1.69E-10	1.27E-02	0.00E+00	3.90E-06	2.43E-07	2.12E-07	1.11E-07	6.62E-07	8.50E-09	4.39E-11	7.82E-07	8.56E-09
Background	MAX-AGR	Chicken	Phenanthrene	1.07E-05	1.07E-04	2.90E-10	4.49E-04	1.90E-05	5.44E-05	1.04E-06	4.49E-06	2.36E-06	1.19E-05	1.80E-07	7.53E-11	1.45E-05	3.60E-09
Background	MAX-AGR	Chicken	Pyrene	1.42E-05	1.42E-04	1.50E-10	8.74E-06	2.22E-06	5.90E-06	8.11E-07	5.97E-06	3.13E-06	1.43E-06	2.39E-07	3.90E-11	4.80E-06	1.36E-09
Background	MAX-AGR	Dairy	Aliphatic C5-C8 Group	1.28E-07	1.28E-06	3.20E-10	3.09E+00	0.00E+00	1.32E-06	3.10E-08	1.20E-05	5.10E-07	2.75E-05	0.00E+00	3.64E-08	2.80E-05	1.35E-07
Background	MAX-AGR	Dairy	Aliphatic C9-C16 Group	3.21E-04	3.21E-03	5.08E-12	2.65E-01	0.00E+00	1.43E-04	1.26E-06	1.34E-04	1.28E-03	2.93E-03	0.00E+00	5.77E-10	4.22E-03	2.16E-05
Background	MAX-AGR	Dairy	aliphatic C17-C34 group	1.24E-02	1.24E-01	1.24E-14	5.72E-03	0.00E+00	0.00E+00	4.86E-05	5.19E-03	4.95E-02	9.86E-04	0.00E+00	1.40E-12	5.05E-02	2.58E-04
Background	MAX-AGR	Dairy	Anthracene	3.78E-06	3.78E-05	8.39E-11	1.11E-04	9.40E-06	4.75E-06	3.66E-07	1.58E-06	1.51E-05	2.95E-04	0.00E+00	9.53E-09	3.10E-04	2.21E-08
Background	MAX-AGR	Dairy	Aromatic C17-C34 Group	2.22E-04	2.22E-03	1.77E-08	1.00E-03	0.00E+00	1.92E-02	1.68E-06	9.32E-05	8.89E-04	3.90E-01	0.00E+00	2.01E-06	3.91E-01	2.65E-05
Background	MAX-AGR	Dairy	Aromatic C9-C16 Group	3.51E-05	3.51E-04	7.00E-08	4.79E-01	0.00E+00	9.23E-05	7.46E-06	1.47E-05	1.40E-04	2.02E-03	0.00E+00	7.95E-06	2.17E-03	1.12E-05
Background	MAX-AGR	Dairy	benz(a)anthracene	2.36E-05	2.36E-04	3.94E-11	1.44E-05	3.14E-04	1.08E-04	4.65E-07	4.25E-06	9.46E-05	8.58E-03	0.00E+00	4.48E-09	8.67E-03	7.29E-07
Background	MAX-AGR	Dairy	Benzo(a)pyrene	9.63E-05	9.63E-04	6.02E-11	3.51E-05	1.05E-03	1.04E-03	1.27E-06	4.04E-05	3.85E-04	4.24E-02	0.00E+00	6.83E-09	4.28E-02	3.39E-06
Background	MAX-AGR	Dairy	benzo(e)pyrene	6.86E-05	6.86E-04	1.71E-09	4.70E-05	1.40E-03	1.32E-02	2.66E-07	2.88E-05	2.74E-04	2.97E-01	0.00E+00	1.95E-07	2.97E-01	1.51E-05
Background	MAX-AGR	Dairy	Benzo(b)fluoranthene	2.38E-05	2.38E-04	2.27E-10	8.91E-05	1.28E-04	1.17E-04	2.66E-07	9.99E-06	9.53E-05	4.97E-03	0.00E+00	2.58E-08	5.07E-03	3.86E-07
Background	MAX-AGR	Dairy	Benzo(ghi)perylene	2.72E-04	2.72E-03	1.72E-09	7.26E-05	2.90E-03	6.25E-02	6.97E-07	1.14E-04	1.09E-03	1.33E+00	0.00E+00	1.95E-07	1.33E+00	5.32E-05
Background	MAX-AGR	Dairy	Benzo(k)fluoranthene	8.18E-04	8.18E-03	4.31E-10	8.91E-05	2.74E-03	4.14E-03	9.44E-06	3.92E-04	3.27E-03	1.40E-01	0.00E+00	4.89E-08	1.43E-01	1.10E-05
Background	MAX-AGR	Dairy	biphenyl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Background	MAX-AGR	Dairy	Chrysene	8.16E-05	8.16E-04	1.36E-10	1.61E-05	1.74E-04	6.66E-06	1.60E-06	1.95E-05	3.26E-04	3.70E-03	0.00E+00	1.54E-08	4.03E-03	3.39E-07
Background	MAX-AGR	Dairy	dibenz(ah)anthracene	1.79E-06	1.79E-05	3.09E-13	3.29E-07	1.32E-05	4.54E-04	1.21E-08	7.51E-07	7.16E-06	9.48E-03	0.00E+00	3.51E-11	9.49E-03	6.19E-07
Background	MAX-AGR	Dairy	Fluoranthene	2.90E-05	2.90E-04	2.64E-10	2.51E-04	8.49E-05	1.48E-04	1.45E-06	1.22E-05	1.16E-04	4.76E-03	0.00E+00	3.00E-08	4.87E-03	4.03E-07
Background	MAX-AGR	Dairy	Fluorene	6.96E-07	6.96E-06	3.31E-11	3.11E-04	0.00E+00	6.50E-06	1.01E-07	2.92E-07	2.78E-06	1.34E-04	0.00E+00	3.76E-09	1.37E-04	8.43E-09
Background	MAX-AGR	Dairy	Indeno(123cd)pyrene	7.76E-06	7.76E-05	0.00E+00	1.97E-06	8.30E-05	2.97E-06	4.61E-08	3.72E-06	3.11E-05	1.75E-03	0.00E+00	0.00E+00	1.78E-03	1.10E-07
Background	MAX-AGR	Dairy	naphthalene	5.07E-07	5.07E-06	1.69E-10	1.27E-02	0.00E+00	3.90E-06	2.43E-07	2.12E-07	2.03E-06	8.40E-05	0.00E+00	1.92E-08	8.61E-05	2.69E-07
Background	MAX-AGR	Dairy	Phenanthrene	1.07E-05	1.07E-04	2.90E-10	4.49E-04	1.90E-05	5.44E-05	1.04E-06	4.49E-06	4.28E-05	1.51E-03	0.00E+00	3.29E-08	1.55E-03	1.11E-07
Background	MAX-AGR	Dairy	Pyrene	1.42E-05	1.42E-04	1.50E-10	8.74E-06	2.22E-06	5.90E-06	8.11E-07	5.97E-06	5.69E-05	1.81E-04	0.00E+00	1.70E-08	2.38E-04	1.93E-08
Background	MAX-AGR	Eggs	Aliphatic C5-C8 Group	1.28E-07	1.28E-06	3.20E-10	3.09E+00	0.00E+00	1.32E-06	3.10E-08	1.20E-05	2.81E-08	2.17E-07	4.81E-07	8.33E-11	7.26E-07	6.98E-09
Background	MAX-AGR	Eggs	Aliphatic C9-C16 Group	3.21E-04	3.21E-03	5.08E-12	2.65E-01	0.00E+00	1.43E-04	1.26E-06	1.34E-04	7.05E-05	2.31E-05	5.38E-06	1.32E-12	9.90E-05	1.01E-06
Background	MAX-AGR	Eggs	aliphatic C17-C34 group	1.24E-02	1.24E-01	1.24E-14	5.72E-03	0.00E+00	0.00E+00	4.86E-05	5.19E-03	2.72E-03	7.77E-06	2.07E-04	3.22E-15	2.94E-03	3.00E-05
Background	MAX-AGR	Eggs	Anthracene	3.78E-06	3.78E-05	8.39E-11	1.11E-04	9.40E-06	4.75E-06	3.66E-07	1.58E-06	8.31E-07	2.32E-06	6.33E-08	2.18E-11	3.22E-06	4.58E-10
Background	MAX-AGR	Eggs	Aromatic C17-C34 Group	2.22E-04	2.22E-03	1.77E-08	1.00E-03	0.00E+00	1.92E-02	1.68E-06	9.32E-05	4.89E-05	3.08E-03	3.73E-06	4.59E-09	3.13E-03	4.24E-07
Background	MAX-AGR	Eggs	Aromatic C9-C16 Group	3.51E-05	3.51E-04	7.00E-08	4.79E-01	0.00E+00	9.23E-05	7.46E-06	1.47E-05	7.71E-06	1.60E-05	5.88E-07	1.82E-08	2.43E-05	2.50E-07
Background	MAX-AGR	Eggs	benz(a)anthracene	2.36E-05	2.36E-04	3.94E-11	1.44E-05	3.14E-04	1.08E-04	4.65E-07	4.25E-06	5.20E-06	6.76E-05	1.70E-07	1.02E-11	7.30E-05	1.23E-08
Background	MAX-AGR	Eggs	Benzo(a)pyrene	9.63E-05	9.63E-04	6.02E-11	3.51E-05	1.05E-03	1.04E-03	1.27E-06	4.04E-05	2.12E-05	3.34E-04	1.61E-06	1.56E-11	3.57E-04	5.65E-08

Table 4E-7 Summary of Predicted Tissue Concentrations for Each Receptor, Scenario, and Chemical

								Dietary Concentrations				EDI					
				Soil	Surface Soil	Surface Water	Air	Browse Deposition	Browse Air	Browse Aboveground	Invertebrate Terrestrial	Soil EDI	Browse EDI	Invertebrate EDI	Water EDI	Total EDI Oral	Tissue Concentration
Scenario	**Site**	**Receptor**	**Chemical**	**mg/kg**	**mg/kg**	**mg/L**	**$\mu g/m^3$**	**mg/kg dw**	**mg/kg dw**	**mg/kg dw**	**mg/kg dw**	**mg/day**	**mg/day**	**mg/day**	**mg/day**	**mg/day**	**mg/kg ww**
Background	MAX-AGR	Eggs	benzo(e)pyrene	6.86E-05	6.86E-04	1.71E-09	4.70E-05	1.40E-03	1.32E-02	2.66E-07	2.88E-05	1.51E-05	2.34E-03	1.15E-06	4.46E-10	2.35E-03	2.39E-07
Background	MAX-AGR	Eggs	Benzo(b)fluoranthene	2.38E-05	2.38E-04	2.27E-10	8.91E-05	1.28E-04	1.17E-04	2.66E-07	9.99E-06	5.24E-06	3.92E-05	4.00E-07	5.91E-11	4.49E-05	6.83E-09
Background	MAX-AGR	Eggs	Benzo(ghi)perylene	2.72E-04	2.72E-03	1.72E-09	7.26E-05	2.90E-03	6.25E-02	6.97E-07	1.14E-04	5.97E-05	1.05E-02	4.56E-06	4.47E-10	1.05E-02	8.44E-07
Background	MAX-AGR	Eggs	Benzo(k)fluoranthene	8.18E-04	8.18E-03	4.31E-10	8.91E-05	2.74E-03	4.14E-03	9.44E-06	3.92E-04	1.80E-04	1.10E-03	1.57E-05	1.12E-10	1.30E-03	1.99E-07
Background	MAX-AGR	Eggs	biphenyl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Background	MAX-AGR	Eggs	Chrysene	8.16E-05	8.16E-04	1.36E-10	1.61E-05	1.74E-04	6.66E-06	1.60E-06	1.95E-05	1.79E-05	2.92E-05	7.82E-07	3.53E-11	4.79E-05	8.05E-09
Background	MAX-AGR	Eggs	dibenz(ah)anthracene	1.79E-06	1.79E-05	3.09E-13	3.29E-07	1.32E-05	4.54E-04	1.21E-08	7.51E-07	3.94E-07	7.47E-05	3.00E-08	8.03E-14	7.52E-05	9.80E-09
Background	MAX-AGR	Eggs	Fluoranthene	2.90E-05	2.90E-04	2.64E-10	2.51E-04	8.49E-05	1.48E-04	1.45E-06	1.22E-05	6.38E-06	3.75E-05	4.87E-07	6.86E-11	4.44E-05	7.33E-09
Background	MAX-AGR	Eggs	Fluorene	6.96E-07	6.96E-06	3.31E-11	3.11E-04	0.00E+00	6.50E-06	1.01E-07	2.92E-07	1.53E-07	1.06E-06	1.17E-08	8.62E-12	1.22E-06	1.51E-10
Background	MAX-AGR	Eggs	Indeno(123cd)pyrene	7.76E-06	7.76E-05	0.00E+00	1.97E-06	8.30E-05	2.97E-06	4.61E-08	3.72E-06	1.71E-06	1.38E-05	1.49E-07	0.00E+00	1.56E-05	1.93E-09
Background	MAX-AGR	Eggs	naphthalene	5.07E-07	5.07E-06	1.69E-10	1.27E-02	0.00E+00	3.90E-06	2.43E-07	2.12E-07	1.11E-07	6.62E-07	8.50E-09	4.39E-11	7.82E-07	4.89E-09
Background	MAX-AGR	Eggs	Phenanthrene	1.07E-05	1.07E-04	2.90E-10	4.49E-04	1.90E-05	5.44E-05	1.04E-06	4.49E-06	2.36E-06	1.19E-05	1.80E-07	7.53E-11	1.45E-05	2.06E-09
Background	MAX-AGR	Eggs	Pyrene	1.42E-05	1.42E-04	1.50E-10	8.74E-06	2.22E-06	5.90E-06	8.11E-07	5.97E-06	3.13E-06	1.43E-06	2.39E-07	3.90E-11	4.80E-06	7.77E-10
Background	MAX	Ruffed_Grouse	Aliphatic C5-C8 Group	3.78E-07	3.78E-06	9.48E-10	9.15E+00	0.00E+00	3.92E-06	9.18E-08	3.56E-05	1.45E-08	1.32E-07	2.94E-07	4.46E-11	4.41E-07	7.42E-09
Background	MAX	Ruffed_Grouse	Aliphatic C9-C16 Group	1.23E-03	1.23E-02	1.95E-11	1.02E+00	0.00E+00	5.49E-04	4.82E-06	5.15E-04	4.72E-05	1.83E-05	4.26E-06	9.15E-13	6.98E-05	1.25E-06
Background	MAX	Ruffed_Grouse	aliphatic C17-C34 group	1.39E-02	1.39E-01	1.39E-14	6.42E-03	0.00E+00	0.00E+00	5.46E-05	5.83E-03	5.34E-04	1.80E-06	4.82E-05	6.53E-16	5.84E-04	1.05E-05
Background	MAX	Ruffed_Grouse	Anthracene	1.33E-04	1.33E-03	2.96E-09	3.92E-03	3.32E-04	1.68E-04	1.29E-05	5.59E-05	5.12E-06	1.69E-05	4.62E-07	1.39E-10	2.25E-05	5.61E-09
Background	MAX	Ruffed_Grouse	Aromatic C17-C34 Group	4.16E-01	4.16E+00	3.31E-05	1.87E+00	0.00E+00	3.60E+01	3.14E-03	1.74E-01	1.60E-02	1.19E+00	1.44E-03	1.55E-06	1.21E+00	2.86E-04
Background	MAX	Ruffed_Grouse	Aromatic C9-C16 Group	3.93E-05	3.93E-04	7.85E-08	5.37E-01	0.00E+00	1.04E-04	8.37E-06	1.65E-05	1.51E-06	3.70E-06	1.36E-07	3.69E-09	5.35E-06	9.65E-08
Background	MAX	Ruffed_Grouse	benz(a)anthracene	5.82E-05	5.82E-04	9.71E-11	3.54E-05	7.74E-04	2.66E-04	1.14E-06	1.05E-05	2.24E-06	3.44E-05	8.65E-08	4.56E-12	3.67E-05	1.08E-08
Background	MAX	Ruffed_Grouse	Benzo(a)pyrene	2.45E-04	2.45E-03	1.53E-10	8.95E-05	2.67E-03	2.65E-03	3.23E-06	1.03E-04	9.43E-06	1.76E-04	8.50E-07	7.21E-12	1.86E-04	5.16E-08
Background	MAX	Ruffed_Grouse	benzo(e)pyrene	1.50E-04	1.50E-03	3.75E-09	1.03E-04	3.07E-03	2.89E-02	5.82E-07	6.29E-05	5.77E-06	1.06E-03	5.20E-07	1.76E-10	1.06E-03	1.89E-07
Background	MAX	Ruffed_Grouse	Benzo(b)fluoranthene	2.39E-05	2.39E-04	2.28E-10	8.95E-05	1.29E-04	1.17E-04	2.67E-07	1.00E-05	9.19E-07	8.13E-06	8.29E-08	1.07E-11	9.13E-06	2.44E-09
Background	MAX	Ruffed_Grouse	Benzo(ghi)perylene	2.72E-04	2.72E-03	1.72E-09	7.26E-05	2.90E-03	6.25E-02	6.97E-07	1.14E-04	1.04E-05	2.16E-03	9.41E-07	8.08E-11	2.17E-03	3.05E-07
Background	MAX	Ruffed_Grouse	Benzo(k)fluoranthene	8.18E-04	8.18E-03	4.31E-10	8.91E-05	2.74E-03	4.14E-03	9.44E-06	3.92E-04	3.14E-05	2.28E-04	3.24E-06	2.02E-11	2.62E-04	7.05E-08
Background	MAX	Ruffed_Grouse	biphenyl	2.54E-07	2.54E-06	0.00E+00	9.79E-04	0.00E+00	5.14E-04	7.04E-09	1.06E-07	9.75E-09	1.70E-05	8.79E-10	0.00E+00	1.70E-05	5.10E-07
Background	MAX	Ruffed_Grouse	Chrysene	6.12E-03	6.12E-02	1.02E-08	1.21E-03	1.31E-02	4.99E-04	1.20E-04	1.47E-03	2.35E-04	4.52E-04	1.21E-05	4.80E-10	7.00E-04	2.06E-07
Background	MAX	Ruffed_Grouse	dibenz(ah)anthracene	2.59E-05	2.59E-04	4.46E-12	4.75E-06	1.90E-04	6.55E-03	1.75E-07	1.08E-05	9.94E-07	2.23E-04	8.96E-08	2.10E-13	2.24E-04	5.11E-08
Background	MAX	Ruffed_Grouse	Fluoranthene	1.99E-04	1.99E-03	1.81E-09	1.72E-03	5.83E-04	1.01E-03	9.93E-06	8.35E-05	7.65E-06	5.31E-05	6.90E-07	8.50E-11	6.15E-05	1.78E-08
Background	MAX	Ruffed_Grouse	Fluorene	7.74E-07	7.74E-06	3.69E-11	3.46E-04	0.00E+00	7.23E-06	1.12E-07	3.25E-07	2.98E-08	2.43E-07	2.68E-09	1.73E-12	2.75E-07	5.94E-11
Background	MAX	Ruffed_Grouse	Indeno(123cd)pyrene	1.87E-05	1.87E-04	0.00E+00	4.75E-06	2.00E-04	7.14E-06	1.11E-07	8.96E-06	7.18E-07	6.85E-06	7.40E-08	0.00E+00	7.64E-06	1.66E-09
Background	MAX	Ruffed_Grouse	naphthalene	4.05E-05	4.05E-04	1.35E-08	1.02E+00	0.00E+00	3.11E-04	1.94E-05	1.70E-05	1.56E-06	1.09E-05	1.40E-07	6.34E-10	1.26E-05	1.38E-07
Background	MAX	Ruffed_Grouse	Phenanthrene	1.18E-05	1.18E-04	3.19E-10	4.96E-04	2.10E-05	6.01E-05	1.15E-06	4.96E-06	4.54E-07	2.72E-06	4.10E-08	1.50E-11	3.21E-06	8.00E-10
Background	MAX	Ruffed_Grouse	Pyrene	6.39E-03	6.39E-02	6.73E-08	3.92E-03	9.96E-04	2.65E-03	3.64E-04	2.68E-03	2.46E-04	1.32E-04	2.21E-05	3.16E-09	4.00E-04	1.13E-07
Background	MAX	White-tailed Deer	Aliphatic C5-C8 Group	3.78E-07	3.78E-06	9.48E-10	9.15E+00	0.00E+00	3.92E-06	9.18E-08	3.56E-05	1.97E-08	1.05E-06	0.00E+00	5.41E-09	1.07E-06	2.44E-08
Background	MAX	White-tailed Deer	Aliphatic C9-C16 Group	1.23E-03	1.23E-02	1.95E-11	1.02E+00	0.00E+00	5.49E-04	4.82E-06	5.15E-04	6.41E-05	1.45E-04	0.00E+00	1.11E-10	2.09E-04	5.07E-06
Background	MAX	White-tailed Deer	Aliphatic C17-C34 group	1.39E-02	1.39E-01	1.39E-14	6.42E-03	0.00E+00	0.00E+00	5.46E-05	5.83E-03	7.26E-04	1.42E-05	0.00E+00	7.92E-14	7.40E-04	1.80E-05
Background	MAX	White-tailed Deer	Anthracene	1.33E-04	1.33E-03	2.96E-09	3.92E-03	3.32E-04	1.68E-04	1.29E-05	5.59E-05	6.96E-06	1.34E-04	0.00E+00	1.69E-08	1.41E-04	4.76E-08
Background	MAX	White-tailed Deer	Aromatic C17-C34 Group	4.16E-01	4.16E+00	3.31E-05	1.87E+00	0.00E+00	3.60E+01	3.14E-03	1.74E-01	2.17E-02	9.39E+00	0.00E+00	1.88E-04	9.41E+00	3.03E-03
Background	MAX	White-tailed Deer	Aromatic C9-C16 Group	3.93E-05	3.93E-04	7.85E-08	5.37E-01	0.00E+00	1.04E-04	8.37E-06	1.65E-05	2.05E-06	2.92E-05	0.00E+00	4.47E-07	3.17E-05	7.76E-07
Background	MAX	White-tailed Deer	benz(a)anthracene	5.82E-05	5.82E-04	9.71E-11	3.54E-05	7.74E-04	2.66E-04	1.14E-06	1.05E-05	3.04E-06	2.72E-04	0.00E+00	5.53E-10	2.75E-04	1.10E-07
Background	MAX	White-tailed Deer	Benzo(a)pyrene	2.45E-04	2.45E-03	1.53E-10	8.95E-05	2.67E-03	2.65E-03	3.23E-06	1.03E-04	1.28E-05	1.39E-03	0.00E+00	8.74E-10	1.40E-03	5.27E-07
Background	MAX	White-tailed Deer	benzo(e)pyrene	1.50E-04	1.50E-03	3.75E-09	1.03E-04	3.07E-03	2.89E-02	5.82E-07	6.29E-05	7.83E-06	8.34E-03	0.00E+00	2.14E-08	8.35E-03	2.02E-06
Background	MAX	White-tailed Deer	Benzo(b)fluoranthene	2.39E-05	2.39E-04	2.28E-10	8.95E-05	1.29E-04	1.17E-04	2.67E-07	1.00E-05	1.25E-06	6.42E-05	0.00E+00	1.30E-09	6.55E-05	2.37E-08
Background	MAX	White-tailed Deer	Benzo(ghi)perylene	2.72E-04	2.72E-03	1.72E-09	7.26E-05	2.90E-03	6.25E-02	6.97E-07	1.14E-04	1.42E-05	1.71E-02	0.00E+00	9.80E-09	1.71E-02	3.25E-06
Background	MAX	White-tailed Deer	Benzo(k)fluoranthene	8.18E-04	8.18E-03	4.31E-10	8.91E-05	2.74E-03	4.14E-03	9.44E-06	3.92E-04	4.27E-05	1.80E-03	0.00E+00	2.45E-09	1.84E-03	6.71E-07
Background	MAX	White-tailed Deer	biphenyl	2.54E-07	2.54E-06	0.00E+00	9.79E-04	0.00E+00	5.14E-04	7.04E-09	1.06E-07	1.32E-08	1.34E-04	0.00E+00	0.00E+00	1.34E-04	5.46E-06
Background	MAX	White-tailed Deer	Chrysene	6.12E-03	6.12E-02	1.02E-08	1.21E-03	1.31E-02	4.99E-04	1.20E-04	1.47E-03	3.20E-04	3.57E-03	0.00E+00	5.82E-08	3.89E-03	1.55E-06
Background	MAX	White-tailed Deer	dibenz(ah)anthracene	2.59E-05	2.59E-04	4.46E-12	4.75E-06	1.90E-04	6.55E-03	1.75E-07	1.08E-05	1.35E-06	1.76E-03	0.00E+00	2.54E-11	1.76E-03	5.46E-07
Background	MAX	White-tailed Deer	Fluoranthene	1.99E-04	1.99E-03	1.81E-09	1.72E-03	5.83E-04	1.01E-03	9.93E-06	8.35E-05	1.04E-05	4.20E-04	0.00E+00	1.03E-08	4.30E-04	1.69E-07
Background	MAX	White-tailed Deer	Fluorene	7.74E-07	7.74E-06	3.69E-11	3.46E-04	0.00E+00	7.23E-06	1.12E-07	3.25E-07	4.04E-08	1.92E-06	0.00E+00	2.10E-10	1.96E-06	5.73E-10
Background	MAX	White-tailed Deer	Indeno(123cd)pyrene	1.87E-05	1.87E-04	0.00E+00	4.75E-06	2.00E-04	7.14E-06	1.11E-07	8.96E-06	9.76E-07	5.41E-05	0.00E+00	0.00E+00	5.51E-05	1.62E-08
Background	MAX	White-tailed Deer	naphthalene	4.05E-05	4.05E-04	1.35E-08	1.02E+00	0.00E+00	3.11E-04	1.94E-05	1.70E-05	2.11E-06	8.64E-05	0.00E+00	7.69E-08	8.85E-05	1.31E-06
Background	MAX	White-tailed Deer	Phenanthrene	1.18E-05	1.18E-04	3.19E-10	4.96E-04	2.10E-05	6.01E-05	1.15E-06	4.96E-06	6.17E-07	2.14E-05	0.00E+00	1.82E-09	2.21E-05	7.46E-09
Background	MAX	White-tailed Deer	Pyrene	6.39E-03	6.39E-02	6.73E-08	3.92E-03	9.96E-04	2.65E-03	3.64E-04	2.68E-03	3.34E-04	1.05E-03	0.00E+00	3.83E-07	1.38E-03	5.30E-07

Table 4E-8 Receptor Exposure Variables

Receptor	Variable	Abbreviation	Value	Units	Reference
Beef	BW	BW_Beef	3.93E+02	kg	RTI 2005 (based on conversion in Table 2; percent feed intake rate per body weight (PFIR) = 0.03)
Chicken	BW	BW_Chicken		kg	Not required have because have the IRf
Dairy	BW	BW_Dairy	6.77E+02	kg	RTI 2005 (based on conversion in Table 2; percent feed intake rate per body weight (PFIR) = 0.03)
Eggs	BW	BW_Eggs		kg	Not required have because have the IRf
Ruffed_Grouse	BW	BW_Ruffed_Grouse	7.02E-01	kg	U.S. EPA 1993
White-tailed Deer	BW	BW_White-tailed Deer	5.65E+01	kg	Sample and Suter II 1994
Beef	IR_f	IRf_Beef	1.18E+01	kg dry weight/day	U.S. EPA OSW 2005 (based on beef cattle)
Chicken	IR_f	IRf_Chicken	2.00E-01	kg dry weight/day	U.S. EPA OSW 2005
Dairy	IR_f	IRf_Dairy	2.03E+01	kg dry weight/day	U.S. EPA OSW 2005 (based on dairy cattle)
Eggs	IR_f	IRf_Eggs	2.00E-01	kg dry weight/day	U.S. EPA OSW 2005 (assumed equal to chicken)
Ruffed_Grouse	IR_f	IRf_Ruffed_Grouse	4.13E-02	kg dry weight/day	P. 3-5, eq'n: 3-5 (U.S. EPA 1993)
White-tailed Deer	IR_f	IRf_White-tailed Deer	2.61E-01	kg dry weight/day	Based on 1.74 kg wet weight/day (Sample and Suter II 1994) and moisture content of 85% (Suter et al 2000)
Beef	IR_s	IRs_Beef	5.00E-01	kg/day	U.S. EPA OSW 2005 (based on beef cattle)
Chicken	IR_s	IRs_Chicken	2.20E-02	kg/day	U.S. EPA OSW 2005
Dairy	IR_s	IRs_Dairy	4.00E-01	kg/day	U.S. EPA OSW 2005 (based on dairy cattle)
Eggs	IR_s	IRs_Eggs	2.20E-02	kg/day	U.S. EPA OSW 2005 (needs to be equal to chicken)
Ruffed_Grouse	IR_s	IRs_Ruffed_Grouse	3.84E-03	kg/day	9.3% of food ingestion rate (based on Wild turkey from Suter et al 2000)
White-tailed Deer	IR_s	IRs_White-tailed Deer	5.22E-03	kg/day	<2%; Suter et al 2000
Beef	WIR	WIR_Beef	3.79E+01	L/day	Government of Alberta 2000 (based on feeders)
Chicken	WIR	WIR_Chicken	2.60E-01	L/day	Government of Alberta 2000 (based on breeder chickens)
Dairy	WIR	WIR_Dairy	1.14E+02	L/day	Government of Alberta 2000 (based on milking cow)
Eggs	WIR	WIR_Eggs	2.60E-01	L/day	Government of Alberta 2000 (based on breeder chickens)
Ruffed_Grouse	WIR	WIR_Ruffed_Grouse	4.70E-02	L/day	U.S. EPA 1993 (allometric equation and BW of 0.7 kg)
White-tailed Deer	WIR	WIR_White-tailed Deer	5.70E+00	L/day	B.C. MELP 1996 (based on mule deer)

BW = Body Weight

IRs = Ingestion rate soil

IRf = Ingestion rate food

WIR = Water ingestion rate

Table 4E-9 Receptor Dietary Composition [Media % of Diet]

Receptor	Media	Abbreviation	Value
Beef	Browse	Beef_Browse	100%
Beef	Invertebrate	Beef_Invertebrate	0%
Dairy	Browse	Dairy_Browse	100%
Dairy	Invertebrate	Dairy_Invertebrate	0%
Chicken	Browse	Chicken_Browse	80%
Chicken	Invertebrate	Chicken_Invertebrate	20%
Eggs	Browse	Eggs_Browse	80%
Eggs	Invertebrate	Eggs_Invertebrate	20%
White-tailed Deer	Browse	White-tailed Deer_Browse	100%
White-tailed Deer	Invertebrate	White-tailed Deer_Invertebrate	0%
Ruffed_Grouse	Browse	Ruffed_Grouse_Browse	80%
Ruffed_Grouse	Invertebrate	Ruffed_Grouse_Invertebrate	20%

Table 4E-10 Vapour Pressure [mmHg]

Chemical	**Value**	**VP[atm]**	**VP[Pa]**	**VP[kPa]**	**Reference**
Aliphatic C5-C8 Group	4.79E+01	6.30E-02	6.38E+03	6.38E+00	CCME 2000
Aliphatic C9-C16 Group	3.65E-02	4.80E-05	4.86E+00	4.86E-03	CCME 2000
Aliphatic C17-C34 group	8.36E-04	1.10E-06	1.11E-01	1.11E-04	TPHCWG 1997 (cited in CCME 2000)
Anthracene	2.70E-06	3.55E-09	3.60E-04	3.60E-07	US EPA OSW 2005
Aromatic C9-C16 Group	3.65E-02	4.80E-05	4.86E+00	4.86E-03	CCME 2000
Aromatic C17-C34 Group	3.34E-07	4.40E-10	4.46E-05	4.46E-08	CCME 2000
Benz(a)anthracene	1.10E-07	1.45E-10	1.47E-05	1.47E-08	US EPA OSW 2005
Benzo(a)pyrene	5.50E-09	7.24E-12	7.34E-07	7.34E-10	US EPA OSW 2005
Benzo(e)pyrene	6.60E-08	8.68E-11	8.80E-06	8.80E-09	Mackay et al 1992; mean of values
Benzo(b)fluoranthene	5.00E-07	6.58E-10	6.67E-05	6.67E-08	US EPA OSW 2005
Benzo(ghi)perylene	9.98E-11	1.31E-13	1.33E-08	1.33E-11	Mackay et al 1992
Benzo(k)fluoranthene	2.00E-09	2.63E-12	2.66E-07	2.66E-10	US EPA OSW 2005
Biphenyl	2.33E-02	3.06E-05	3.10E+00	3.10E-03	Mackay et al 1992; mean of values
Chrysene	6.20E-09	8.16E-12	8.27E-07	8.27E-10	US EPA OSW 2005
Dibenz(ah)anthracene	1.00E-10	1.32E-13	1.34E-08	1.34E-11	US EPA OSW 2005
Fluoranthene	7.83E-06	1.03E-08	1.04E-03	1.04E-06	US EPA OSW 2005
Fluorene	6.30E-04	8.29E-07	8.40E-02	8.40E-05	US EPA OSW 2005
Indeno(123cd)pyrene	1.00E-10	1.32E-13	1.34E-08	1.34E-11	US EPA OSW 2005
Naphthalene	8.51E-02	1.12E-04	1.13E+01	1.13E-02	US EPA OSW 2005
Phenanthrene	1.10E-04	1.45E-07	1.47E-02	1.47E-05	US EPA OSW 2005
Pyrene	4.60E-06	6.05E-09	6.13E-04	6.13E-07	US EPA OSW 2005

Table 4E-11 Solubility [mg/L] or [ppm]

Chemical	**Value**	**S[kg/m^3]**	**Reference**
Aliphatic C5-C8 Group	5.40E+00	5.40E-03	CCME 2000
Aliphatic C9-C16 Group	7.60E-04	7.60E-07	CCME 2000
Aliphatic C17-C34 group	2.50E-06	2.50E-09	TPHCWG 1997 (cited in CCME 2000)
Anthracene	4.30E-02	4.30E-05	US EPA OSW 2005
Aromatic C9-C16 Group	5.80E+00	5.80E-03	CCME 2000
Aromatic C17-C34 Group	6.60E-03	6.60E-06	TPHCWG 1997 (cited in CCME 2000)
Benz(a)anthracene	9.40E-03	9.40E-06	US EPA OSW 2005
Benzo(a)pyrene	1.60E-03	1.60E-06	US EPA OSW 2005
Benzo(e)pyrene	5.00E-03	5.00E-06	Mackay et al 1992; mean of values
Benzo(b)fluoranthene	1.50E-03	1.50E-06	US EPA OSW 2005
Benzo(ghi)perylene	2.60E-04	2.60E-07	Mackay et al 1992
Benzo(k)fluoranthene	8.00E-04	8.00E-07	US EPA OSW 2005
Biphenyl	9.50E+00	9.50E-03	Mackay et al 1992; mean of values
Chrysene	6.30E-03	6.30E-06	US EPA OSW 2005
Dibenz(ah)anthracene	2.50E-03	2.50E-06	US EPA OSW 2005
Fluoranthene	2.10E-01	2.10E-04	US EPA OSW 2005
Fluorene	2.00E+00	2.00E-03	US EPA OSW 2005
Indeno(123cd)pyrene	2.20E-05	2.20E-08	US EPA OSW 2005
Naphthalene	3.10E+01	3.10E-02	US EPA OSW 2006
Phenanthrene	1.10E+00	1.10E-03	US EPA OSW 2005
Pyrene	1.40E+00	1.40E-03	US EPA OSW 2005

Table 4E-12 Koc [(μg/g) / (μg/mL)] or [L/kg]

Chemical	**Value**	**Log(Koc)**	**Reference**
Aliphatic C5-C8 Group	3.98E+03	3.60E+00	CCME 2000
Aliphatic C9-C16 Group	6.31E+08	8.80E+00	CCME 2000
Aliphatic C17-C34 group	1.00E+13	1.30E+01	CCME 2000
Anthracene	2.35E+04	4.37E+00	US EPA OSW 2005
Aromatic C9-C16 Group	5.01E+03	3.70E+00	CCME 2000
Aromatic C17-C34 Group	1.26E+05	5.10E+00	CCME 2000
Benz(a)anthracene	3.58E+05	5.55E+00	US EPA OSW 2005
Benzo(a)pyrene	9.69E+05	5.99E+00	US EPA OSW 2005
Benzo(e)pyrene	4.00E+05	5.60E+00	Mackay et al 1992; mean of values
Benzo(b)fluoranthene	1.05E+06	6.02E+00	US EPA OSW 2005
Benzo(ghi)perylene	1.58E+06	6.20E+00	Mackay et al 1992
Benzo(k)fluoranthene	9.92E+05	6.00E+00	US EPA OSW 2005
Biphenyl	6.90E+03	3.84E+00	Mackay et al 1992; mean of values
Chrysene	4.01E+05	5.60E+00	US EPA OSW 2005
Dibenz(ah)anthracene	1.79E+06	6.25E+00	US EPA OSW 2005
Fluoranthene	4.91E+04	4.69E+00	US EPA OSW 2005
Fluorene	7.71E+03	3.89E+00	US EPA OSW 2005
Indeno(123cd)pyrene	3.08E+06	6.49E+00	US EPA OSW 2005
Naphthalene	1.19E+03	3.08E+00	US EPA OSW 2005
Phenanthrene	2.65E+04	4.42E+00	US EPA OSW 2005
Pyrene	6.80E+04	4.83E+00	US EPA OSW 2005

Table 4E-13 Kow

Chemical	**Value**	**Log(Kow)**	**Reference**
Aliphatic C5-C8 Group	6.46E+03	3.81E+00	CCME 2000
Aliphatic C9-C16 Group	8.13E+06	6.91E+00	CCME 2000
Aliphatic C17-C34 group	8.13E+06	6.91E+00	Assumed equal to Aliphatic C9-C16 due to lack of information
Anthracene	3.16E+04	4.50E+00	US EPA OSW 2005
Aromatic C9-C16 Group	8.13E+03	3.91E+00	CCME 2000
Aromatic C17-C34 Group	2.63E+06	6.42E+00	Mackay et al 1992 (based on 3-methylcholanthrene)
Benz(a)anthracene	5.01E+05	5.70E+00	US EPA OSW 2005
Benzo(a)pyrene	1.00E+06	6.00E+00	US EPA OSW 2005
Benzo(e)pyrene	8.30E+06	6.90E+00	Mackay et al. 1992; mean of values
Benzo(b)fluoranthene	1.33E+06	6.12E+00	US EPA OSW 2005
Benzo(ghi)perylene	1.70E+07	7.23E+00	Mackay et al 1992
Benzo(k)fluoranthene	1.26E+06	6.10E+00	US EPA OSW 2005
Biphenyl	2.75E+05	5.44E+00	Mackay et al. 1992; mean of values
Chrysene	5.01E+05	5.70E+00	US EPA OSW 2005
Dibenz(ah)anthracene	3.16E+06	6.50E+00	US EPA OSW 2005
Fluoranthene	1.00E+05	5.00E+00	US EPA OSW 2005
Fluorene	1.58E+04	4.20E+00	US EPA OSW 2005
Indeno(123cd)pyrene	3.98E+06	6.60E+00	US EPA OSW 2005
Naphthalene	2.00E+03	3.30E+00	US EPA OSW 2005
Phenanthrene	3.16E+04	4.50E+00	US EPA OSW 2005
Pyrene	7.94E+04	4.90E+00	US EPA OSW 2005

Table 4E-14 Soil to water partition coefficient [L/kg]

Chemical	Kd	Comment/Reference
Aliphatic C5-C8 Group	3.98E+01	Calculated; US EPA 2005
Aliphatic C9-C16 Group	6.31E+06	Calculated; US EPA 2005
Aliphatic C17-C34 group	1.00E+11	Calculated; US EPA 2005
Anthracene	4.50E+03	US EPA 2005
Aromatic C9-C16 Group	5.01E+01	Calculated; US EPA 2005
Aromatic C17-C34 Group	1.26E+03	Calculated; US EPA 2005
Benz(a)anthracene	6.00E+04	US EPA 2005
Benzo(a)pyrene	1.60E+05	US EPA 2005
Benzo(e)pyrene	4.00E+03	Calculated; US EPA 2005
Benzo(b)fluoranthene	1.05E+04	US EPA 2005
Benzo(ghi)perylene	1.58E+04	Calculated; US EPA 2005
Benzo(k)fluoranthene	1.90E+05	US EPA 2005
Chrysene	6.00E+04	US EPA 2005
Dibenz(ah)anthracene	5.80E+05	US EPA 2005
Fluoranthene	1.10E+04	US EPA 2005
Fluorene	2.10E+03	US EPA 2005
Indeno(1,2,3cd)pyrene	5.30E+05	US EPA 2005
Naphthalene	3.00E+02	US EPA 2005
Phenanthrene	3.70E+03	US EPA 2005
Pyrene	9.50E+03	US EPA 2005

Calculated Kd = Koc x foc

foc(g/g) = 0.01

Table 4E-15 Fraction of Chemical in the Vapour Phase

Chemical	**Value**	**Reference**
Aliphatic C5-C8 Group	100.00%	Assumed
Aliphatic C9-C16 Group	100.00%	Assumed
Aliphatic C17-C34 group	100.00%	Assumed
Anthracene	99.80%	US EPA OSW 2005
Aromatic C9-C16 Group	100.00%	Assumed
Aromatic C17-C34 Group	100.00%	Assumed
Benz(a)anthracene	48.30%	US EPA OSW 2005
Benzo(a)pyrene	29.40%	US EPA OSW 2005
Benzo(e)pyrene	29.40%	Assumed benzo(a)pyrene as a surrogate
Benzo(b)fluoranthene	96.60%	US EPA OSW 2005
Benzo(ghi)perylene	5.50%	Assumed = dibenzo(a,h)anthracene
Benzo(k)fluoranthene	27.30%	US EPA OSW 2005
Biphenyl	100.00%	Assumed
Chrysene	74.40%	US EPA OSW 2005
Dibenz(ah)anthracene	5.50%	US EPA OSW 2005
Fluoranthene	99.20%	US EPA OSW 2005
Fluorene	100.00%	US EPA OSW 2005
Indeno(123cd)pyrene	0.50%	US EPA OSW 2005
Naphthalene	100.00%	US EPA OSW 2005
Phenanthrene	99.90%	US EPA OSW 2005
Pyrene	99.40%	US EPA OSW 2005

Table 4E-16 Chemical Group

Chemical	Group
Aliphatic C5-C8 Group	VOC
Aliphatic C9-C16 Group	VOC
Aliphatic C17-C34 group	VOC
Anthracene	PAH
Aromatic C9-C16 Group	VOC
Aromatic C17-C34 Group	PAH
Benz(a)anthracene	PAH
Benzo(a)pyrene	PAH
Benzo(e)pyrene	PAH
Benzo(b)fluoranthene	PAH
Benzo(ghi)perylene	PAH
Benzo(k)fluoranthene	PAH
Biphenyl	VOC
Chrysene	PAH
Dibenz(ah)anthracene	PAH
Fluoranthene	PAH
Fluorene	PAH
Indeno(123cd)pyrene	PAH
Naphthalene	PAH
Phenanthrene	PAH
Pyrene	PAH

Table 4E-17 Vegetation Adjustment Factor [Unitless]

Chemical	Value	Log(Kow)	Reference
Aliphatic C5-C8 Group	1.00	3.81	US EPA OSW 2005
Aliphatic C9-C16 Group	1.00	6.91	US EPA OSW 2005
Aliphatic C17-C34 group	1.00	6.91	Assumed equal to aliphatic c9-C16
Anthracene	1.00	4.50	US EPA OSW 2005
Aromatic C9-C16 Group	1.00	3.91	US EPA OSW 2005
Aromatic C17-C34 Group	1.00	6.42	US EPA OSW 2005
Benz(a)anthracene	1.00	5.70	US EPA OSW 2005
Benzo(a)pyrene	1.00	6.00	US EPA OSW 2005
Benzo(e)pyrene	1.00	6.92	
Benzo(b)fluoranthene	1.00	6.12	US EPA OSW 2005
Benzo(ghi)perylene	1.00	7.23	US EPA OSW 2005
Benzo(k)fluoranthene	1.00	6.10	US EPA OSW 2005
Biphenyl	1.00	5.44	
Chrysene	1.00	5.70	US EPA OSW 2005
Dibenz(ah)anthracene	1.00	6.50	US EPA OSW 2005
Fluoranthene	1.00	5.00	US EPA OSW 2005
Fluorene	1.00	4.20	US EPA OSW 2005
Indeno(123cd)pyrene	1.00	6.60	US EPA OSW 2005
Naphthalene	1.00	3.30	
Phenanthrene	1.00	4.50	US EPA OSW 2005
Pyrene	1.00	4.90	US EPA OSW 2005

Table 4E-18 Deposition Velocities [m/s]

Chemical	Wet	Dry	Reference Wet	Reference Dry
Aliphatic C5-C8 Group	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Aliphatic C9-C16 Group	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Aliphatic C17-C34 group	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Anthracene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Aromatic C9-C16 Group	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Aromatic C17-C34 Group	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Benz(a)anthracene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Benzo(a)pyrene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Benzo(e)pyrene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Benzo(b)fluoranthene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Benzo(ghi)perylene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Benzo(k)fluoranthene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Biphenyl	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Chrysene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Dibenz(ah)anthracene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Fluoranthene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Fluorene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Indeno(123cd)pyrene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Naphthalene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Phenanthrene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Pyrene	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000
Total PAH group	4.00E-03	1.00E-02	MacKay 1991	Extrapolation from Wesley and Hicks 2000

Table 4E-19 Soil Loss Constant (k_s) [yr^{-1}]

Chemical	Value	Half-life [Days]	Reference
Aliphatic C5-C8 Group	3.56E-01	7.12E+02	CCME 2000
Aliphatic C9-C16 Group	1.45E-01	1.75E+03	CCME 2000
Aliphatic C17-C34 group	1.45E-01	1.75E+03	Assumed equal to Aliphatic C9-C16
Anthracene	5.50E-01	4.60E+02	US EPA OSW 2005
Aromatic C9-C16 Group	1.45E-01	1.75E+03	CCME 2000
Aromatic C17-C34 Group	1.81E-01	1.40E+03	Mackay et al 1992 (based on 3-methylcholanthrene)
Benz(a)anthracene	3.70E-01	6.84E+02	US EPA OSW 2005
Benzo(a)pyrene	4.80E-01	5.27E+02	US EPA OSW 2005
Benzo(e)pyrene	4.80E-01	5.27E+02	Assumed benzo(a)pyrene as a surrogate
Benzo(b)fluoranthene	4.10E-01	6.17E+02	US EPA OSW 2005
Benzo(ghi)perylene	3.89E-01	6.50E+02	Mackay et al 1992
Benzo(k)fluoranthene	1.20E-01	2.11E+03	US EPA OSW 2005
Biphenyl	2.58E+00	9.80E+01	HSDB 2007; used most conservative value available
Chrysene	2.51E-01	1.01E+03	US EPA OSW 2005
Dibenz(ah)anthracene	2.70E-01	9.38E+02	US EPA OSW 2005
Fluoranthene	5.70E-01	4.44E+02	US EPA OSW 2005
Fluorene	4.22E+00	6.00E+01	US EPA OSW 2005
Indeno(123cd)pyrene	3.50E-01	7.23E+02	US EPA OSW 2005
Naphthalene	5.27E+00	4.80E+01	US EPA OSW 2005
Phenanthrene	1.26E+00	2.01E+02	US EPA OSW 2005
Pyrene	1.30E-01	1.95E+03	US EPA OSW 2005

Table 4E-20 Henry's Constant [atm m^3 / mol]

Chemical	Value	H [Pa m^3/mol]	Unitless	Reference
Aliphatic C5-C8 Group	1.20E+00	1.22E+05	4.92E+01	CCME 2000
Aliphatic C9-C16 Group	1.90E+00	1.93E+05	7.81E+01	CCME 2000
Aliphatic c17-C34 group	1.18E+02	1.20E+07	4.84E+03	CCME 2000
Anthracene	6.50E-05	6.59E+00	2.67E-03	US EPA OSW 2005
Aromatic C9-C16 Group	3.40E-03	3.45E+02	1.40E-01	CCME 2000
Aromatic C17-C34 Group	1.61E-05	1.63E+00	6.60E-04	CCME 2000
Benz(a)anthracene	3.40E-06	3.45E-01	1.40E-04	US EPA OSW 2005
Benzo(a)pyrene	1.10E-06	1.11E-01	4.49E-05	US EPA OSW 2005
Benzo(e)pyrene	1.10E-06	1.11E-01	4.51E-05	Assumed benzo(a)pyrene as a surrogate
Benzo(b)fluoranthene	1.11E-04	1.12E+01	4.53E-03	US EPA OSW 2005
Benzo(ghi)perylene	1.44E-07	1.46E-02	5.91E-06	Mackay et al 1992
Benzo(k)fluoranthene	8.30E-07	8.41E-02	3.40E-05	US EPA OSW 2005
Biphenyl	5.33E-05	5.40E+00	2.19E-03	Mackay et al 1992; mean of values
Chrysene	9.50E-05	9.63E+00	3.90E-03	US EPA OSW 2005
Dibenz(ah)anthracene	1.50E-08	1.52E-03	6.15E-07	US EPA OSW 2005
Fluoranthene	1.60E-05	1.62E+00	6.56E-04	US EPA OSW 2005
Fluorene	6.40E-05	6.48E+00	2.62E-03	US EPA OSW 2005
Indeno(123cd)pyrene	1.60E-06	1.62E-01	6.56E-05	US EPA OSW 2005
Naphthalene	4.80E-04	4.86E+01	1.97E-02	US EPA OSW 2005
Perylene	4.34E-06	4.40E-01	1.78E-04	Mackay et al 1992
Phenanthrene	2.30E-05	2.33E+00	9.43E-04	US EPA OSW 2005
Pyrene	1.10E-05	1.11E+00	4.49E-04	US EPA OSW 2005

Table 4E-21 Surface Water Half-life [yrs^{-1}]

Chemical	**Value**[a]	**Reference**
Aliphatic C5-C8 Group	1.41	Mackay et al 1992 (based on cyclohexane)
Aliphatic C9-C16 Group	1.63	HSDB 2007 (based on nonane)
Aliphatic C17-C34 group		
Anthracene	48.65	Mackay et al 1992
Aromatic C9-C16 Group	1.26	Mackay et al 1992 (based on fluoranthene)
Aromatic C17-C34 Group	3.72	Mackay et al 1992 (based on chrysene)
Benz(a)anthracene	19.46	Assumed equal to benzo(a)pyrene
Benzo(a)pyrene	19.46	Mackay et al 1992
Benzo(e)pyrene	19.46	Assumed equal to benzo(a)pyrene
Benzo(b)fluoranthene	8.43	Mackay et al 1992
Benzo(ghi)perylene	19.46	Assumed equal to benzo(a)pyrene
Benzo(k)fluoranthene	12.05	Mackay et al 1992
Biphenyl	169.00	Mackay et al 1992
Chrysene	3.72	Mackay et al 1992
Dibenz(ah)anthracene	7.67	Mackay et al 1992
Fluoranthene	1.26	Mackay et al 1992
Fluorene	4.22	Mackay et al 1992
Indeno(123cd)pyrene	19.46	Assumed equal to benzo(a)pyrene
Naphthalene	84.00	Mackay et al 1992
Perylene	19.46	Assumed equal to benzo(a)pyrene
Phenanthrene	3.67	Mackay et al 1992
Pyrene	42.88	Mackay et al 1992

A) Half-life [yrs^{-1}] = ln(2) / (Half-life [days] / 365 [days/year])

Table 4E-22 Percent of Exposure Derived from Impacted Area

Receptor	Value	Comment
Beef	100%	Assumed
Dairy	100%	Assumed
Chicken	100%	Assumed
Eggs	100%	Assumed
White-tailed Deer	100%	Assumed
Ruffed_Grouse	100%	Assumed

Table 4E-23 Water Content in Wildlife Food [%]

Receptor	Value	Reference
Browse	85%	U.S. EPA 1993; pg. 4-13
Invertebrate	71%	U.S. EPA 1993; pg. 4-13

Table 4E-24 Equation Variables Plant Concentration Due to Direct Deposition

Variable	Value	Units	Reference
Empirical Constant - (y)	2.88	Unitless	U.S. EPA OSW 1999; Table B-3-1
Yield or Standing Biomass (Yp)	0.246	kg DW/m^2	U.S. EPA OSW 1999; Table B-3-1
Plant Surface Loss Coefficient - (kp)	18	yr^{-1}	U.S. EPA OSW 1999; Table B-3-1
Period of Browse Exposure - (Tp)	0.16	yr	U.S. EPA OSW 1999
Fraction of COPC in Vapour Phase	NA	Chemical Specific	
Deposition Velocity	NA	Chemical Specific	

Table 4E-25 Time Period of Deposition [years]

Variable	Value	Comment
Time	75	Life of facility

Table 4E-26 Soil Properties

Variable	Value	Units
Surface Soil Mixing Depth = Depth1	0.02	m
Soil Mixing Depth for Plants = Depth2	0.2	m
Soil Bulk Density	1500	kg/m^3

Table 4E-27 Gas Constants

Variable	Value	Units
Universal Gas Constant (R)	8.21E-05	atm m^3 / mol
Temperature (T)	288	Kelvin
R x T	2.36E-02	Kelvin atm m^3 / mol

Table 4E-28 Literature Derived Regression Models and Bio-Concentration Factors from Soil to Selected Media [DW Basis]

Media	Chemical	Abrevation	BCF	Reference
Browse	Aliphatic C5-C8 Group	Browse_Aliphatic C5-C8 Group	2.43E-01	Travis and Arms 1988
Browse	Aliphatic C9-C16 Group	Browse_Aliphatic C9-C16 Group	3.93E-03	Travis and Arms 1988
Browse	Aliphatic C17-C34 group	Browse_Aliphatic C17-C34 group	3.93E-03	Travis and Arms 1988
Browse	Anthracene	Browse_Anthracene	9.71E-02	Travis and Arms 1988
Browse	Aromatic C9-C16 Group	Browse_Aromatic C9-C16 Group	2.13E-01	Travis and Arms 1988
Browse	Aromatic C17-C34 Group	Browse_Aromatic C17-C34 Group	7.54E-03	Travis and Arms 1988
Browse	Benz(a)anthracene	Browse_Benz(a)anthracene	1.97E-02	Travis and Arms 1988
Browse	Benzo(a)pyrene	Browse_Benzo(a)pyrene	1.32E-02	Travis and Arms 1988
Browse	Benzo(e)pyrene	Browse_Benzo(e)pyrene	3.88E-03	Travis and Arms 1988
Browse	Benzo(b)fluoranthene	Browse_Benzo(b)fluoranthene	1.12E-02	Travis and Arms 1988
Browse	Benzo(ghi)perylene	Browse_Benzo(ghi)perylene	2.56E-03	Travis and Arms 1988
Browse	Benzo(k)fluoranthene	Browse_Benzo(k)fluoranthene	1.15E-02	Travis and Arms 1988
Browse	Biphenyl	Browse_Biphenyl	2.78E-02	Travis and Arms 1988
Browse	Chrysene	Browse_Chrysene	1.97E-02	Travis and Arms 1988
Browse	Dibenz(ah)anthracene	Browse_Dibenz(ah)anthracene	6.78E-03	Travis and Arms 1989
Browse	Fluoranthene	Browse_Fluoranthene	4.99E-02	Travis and Arms 1990
Browse	Fluorene	Browse_Fluorene	1.45E-01	Travis and Arms 1990
Browse	Indeno(123cd)pyrene	Browse_Indeno(123cd)pyrene	5.93E-03	Travis and Arms 1992
Browse	Naphthalene	Browse_Naphthalene	4.79E-01	Travis and Arms 1988
Browse	Phenanthrene	Browse_Phenanthrene	9.71E-02	Travis and Arms 1998
Browse	Pyrene	Browse_Pyrene	5.70E-02	Travis and Arms 1999
Invertebrate	Aliphatic C5-C8 Group	Invertebrate_Aliphatic C5-C8 Group	9.43E+01	Southworth et al 1978
Invertebrate	Aliphatic C9-C16 Group	Invertebrate_Aliphatic C9-C16 Group	4.19E-01	Assumed = benzo(a)pyrene
Invertebrate	Aliphatic C17-C34 group	Invertebrate_Aliphatic C17-C34 group	4.19E-01	Assumed = benzo(a)pyrene
Invertebrate	Anthracene	Invertebrate_Anthracene	4.19E-01	Assumed = benzo(a)pyrene
Invertebrate	Aromatic C9-C16 Group	Invertebrate_Aromatic C9-C16 Group	4.19E-01	Assumed = benzo(a)pyrene
Invertebrate	Aromatic C17-C34 Group	Invertebrate_Aromatic C17-C34 Group	4.19E-01	Assumed = benzo(a)pyrene
Invertebrate	Benz(a)anthracene	Invertebrate_Benz(a)anthracene	1.80E-01	U.S. EPA OSW 1999; Converted to dry weight by multiplying value by 5.99
Invertebrate	Benzo(a)pyrene	Invertebrate_Benzo(a)pyrene	4.19E-01	U.S. EPA OSW 1999; Converted to dry weight by multiplying value by 5.99
Invertebrate	Benzo(e)pyrene	Invertebrate_Benzo(e)pyrene	4.19E-01	Assumed = benzo(a)pyrene
Invertebrate	Benzo(b)fluoranthene	Invertebrate_Benzo(b)fluoranthene	4.19E-01	U.S. EPA OSW 1999; Converted to dry weight by multiplying value by 5.99
Invertebrate	Benzo(ghi)perylene	Invertebrate_Benzo(ghi)perylene	4.19E-01	Assumed = benzo(a)pyrene
Invertebrate	Benzo(k)fluoranthene	Invertebrate_Benzo(k)fluoranthene	4.79E-01	U.S. EPA OSW 1999; Converted to dry weight by multiplying value by 5.99
Invertebrate	Biphenyl	Invertebrate_Biphenyl	4.19E-01	Assumed = benzo(a)pyrene
Invertebrate	Chrysene	Invertebrate_Chrysene	2.40E-01	U.S. EPA OSW 1999; Converted to dry weight by multiplying value by 5.99
Invertebrate	Dibenz(ah)anthracene	Invertebrate_Dibenz(ah)anthracene	4.19E-01	U.S. EPA OSW 1999; Converted to dry weight by multiplying value by 5.99
Invertebrate	Fluoranthene	Invertebrate_Fluoranthene	4.19E-01	Assumed = benzo(a)pyrene
Invertebrate	Fluorene	Invertebrate_Fluorene	4.19E-01	Assumed = benzo(a)pyrene
Invertebrate	Indeno(123cd)pyrene	Invertebrate_Indeno(123cd)pyrene	4.79E-01	U.S. EPA OSW 1999; Converted to dry weight by multiplying value by 5.99
Invertebrate	Naphthalene	Invertebrate_Naphthalene	4.19E-01	Assumed equal to B(a)P
Invertebrate	Phenanthrene	Invertebrate_Phenanthrene	4.19E-01	Assumed = benzo(a)pyrene
Invertebrate	Pyrene	Invertebrate_Pyrene	4.19E-01	Assumed = benzo(a)pyrene

Predicted Linear Uptake Factors:

UF Soil - Plant [dry weight] = logBCF = 1.588 - 0.578log(Kow); Travis and Arms 1988

UF Soil - Invertebrate [dry weight] = logBCF = 1.146 - 0.819log(Kow); Southworth et al 1978

Table 4E-29 Fat Content

Receptor	%	Reference/Comment
Beef	0.19	U.S. EPA OSW 2005
Dairy	0.04	U.S. EPA OSW 2005
Chicken	0.14	U.S. EPA OSW 2005
Eggs	0.08	U.S. EPA OSW 2005
White-tailed Deer	0.19	U.S. EPA OSW 2005; assumed equal to beef
Ruffed_Grouse	0.14	U.S. EPA OSW 2005; assumed equal to chicken

Table 4E-30 Metabolism Factor

Chemical	Value	Reference
Aliphatic C5-C8 Group	1.00	Assumed
Aliphatic C9-C16 Group	1.00	Assumed
Aliphatic C17-C34 group	1.00	Assumed
Anthracene	0.01	Hofelt et al 2001
Aromatic C9-C16 Group	1.00	Assumed
Aromatic C17-C34 Group	0.01	Assumed similar to PAHs
Benz(a)anthracene	0.01	Hofelt et al 2001
Benzo(a)pyrene	0.01	Hofelt et al 2001
Benzo(e)pyrene	0.01	Assumed BaP
Benzo(b)fluoranthene	0.01	Hofelt et al 2001
Benzo(ghi)perylene	0.01	Hofelt et al 2001
Benzo(k)fluoranthene	0.01	Hofelt et al 2001
Biphenyl	1.00	Assumed
Chrysene	0.01	Hofelt et al 2001
Dibenz(ah)anthracene	0.01	Hofelt et al 2001
Fluoranthene	0.01	Hofelt et al 2001
Fluorene	0.01	Hofelt et al 2001
Indeno(123cd)pyrene	0.01	Hofelt et al 2001
Naphthalene	1.00	Assumed
Perylene	1.00	Assumed
Phenanthrene	0.01	Hofelt et al 2001
Pyrene	0.01	Hofelt et al 2001

Table 4E-31 Bio Transfer Factors [day/kg FW]

Media	**Chemical**	**Abbreviation**	**Value**	**Comment**
Beef	Aliphatic C5-C8 Group	Beef_Aliphatic C5-C8 Group	2.28E-02	U.S. EPA OSW 2005
Beef	Aliphatic C9-C16 Group	Beef_Aliphatic C9-C16 Group	2.43E-02	U.S. EPA OSW 2005
Beef	Aliphatic C17-C34 group	Beef_Aliphatic C17-C34 group	2.43E-02	U.S. EPA OSW 2005
Beef	Anthracene	Beef_Anthracene	3.38E-04	U.S. EPA OSW 2005
Beef	Aromatic C9-C16 Group	Beef_Aromatic C9-C16 Group	2.45E-02	U.S. EPA OSW 2005
Beef	Aromatic C17-C34 Group	Beef_Aromatic C17-C34 Group	3.22E-04	U.S. EPA OSW 2005
Beef	Benz(a)anthracene	Beef_Benz(a)anthracene	3.99E-04	U.S. EPA OSW 2005
Beef	Benzo(a)pyrene	Beef_Benzo(a)pyrene	3.76E-04	U.S. EPA OSW 2005
Beef	Benzo(e)pyrene	Beef_Benzo(e)pyrene	2.41E-04	U.S. EPA OSW 2005
Beef	Benzo(b)fluoranthene	Beef_Benzo(b)fluoranthene	3.62E-04	U.S. EPA OSW 2005
Beef	Benzo(ghi)perylene	Beef_Benzo(ghi)perylene	1.90E-04	U.S. EPA OSW 2005
Beef	Benzo(k)fluoranthene	Beef_Benzo(k)fluoranthene	3.65E-04	U.S. EPA OSW 2005
Beef	Biphenyl	Beef_Biphenyl	4.07E-02	U.S. EPA OSW 2005
Beef	Chrysene	Beef_Chrysene	3.99E-04	U.S. EPA OSW 2005
Beef	Dibenz(ah)anthracene	Beef_Dibenz(ah)anthracene	3.10E-04	U.S. EPA OSW 2005
Beef	Fluoranthene	Beef_Fluoranthene	3.92E-04	U.S. EPA OSW 2005
Beef	Fluorene	Beef_Fluorene	2.93E-04	U.S. EPA OSW 2005
Beef	Indeno(123cd)pyrene	Beef_Indeno(123cd)pyrene	2.94E-04	U.S. EPA OSW 2005
Beef	Naphthalene	Beef_Naphthalene	1.48E-02	U.S. EPA OSW 2005
Beef	Phenanthrene	Beef_Phenanthrene	3.38E-04	U.S. EPA OSW 2005
Beef	Pyrene	Beef_Pyrene	3.84E-04	U.S. EPA OSW 2005
Chicken	Aliphatic C5-C8 Group	Chicken_Aliphatic C5-C8 Group	1.68E-02	U.S. EPA OSW 2005
Chicken	Aliphatic C9-C16 Group	Chicken_Aliphatic C9-C16 Group	1.79E-02	U.S. EPA OSW 2005
Chicken	Aliphatic C17-C34 group	Chicken_Aliphatic C17-C34 group	1.79E-02	U.S. EPA OSW 2005
Chicken	Anthracene	Chicken_Anthracene	2.49E-04	U.S. EPA OSW 2005
Chicken	Aromatic C9-C16 Group	Chicken_Aromatic C9-C16 Group	1.80E-02	U.S. EPA OSW 2005
Chicken	Aromatic C17-C34 Group	Chicken_Aromatic C17-C34 Group	2.37E-04	U.S. EPA OSW 2005
Chicken	Benz(a)anthracene	Chicken_Benz(a)anthracene	2.94E-04	U.S. EPA OSW 2005
Chicken	Benzo(a)pyrene	Chicken_Benzo(a)pyrene	2.77E-04	U.S. EPA OSW 2005
Chicken	Benzo(e)pyrene	Chicken_Benzo(e)pyrene	1.78E-04	U.S. EPA OSW 2005
Chicken	Benzo(b)fluoranthene	Chicken_Benzo(b)fluoranthene	2.67E-04	U.S. EPA OSW 2005
Chicken	Benzo(ghi)perylene	Chicken_Benzo(ghi)perylene	1.40E-04	U.S. EPA OSW 2005
Chicken	Benzo(k)fluoranthene	Chicken_Benzo(k)fluoranthene	2.69E-04	U.S. EPA OSW 2005
Chicken	Biphenyl	Chicken_Biphenyl	3.00E-02	U.S. EPA OSW 2005
Chicken	Chrysene	Chicken_Chrysene	2.94E-04	U.S. EPA OSW 2005
Chicken	Dibenz(ah)anthracene	Chicken_Dibenz(ah)anthracene	2.28E-04	U.S. EPA OSW 2005
Chicken	Fluoranthene	Chicken_Fluoranthene	2.89E-04	U.S. EPA OSW 2005
Chicken	Fluorene	Chicken_Fluorene	2.16E-04	U.S. EPA OSW 2005
Chicken	Indeno(123cd)pyrene	Chicken_Indeno(123cd)pyrene	2.17E-04	U.S. EPA OSW 2005

Table 4E-31 Bio Transfer Factors [day/kg FW]

Media	**Chemical**	**Abbreviation**	**Value**	**Comment**
Chicken	Naphthalene	Chicken_Naphthalene	1.09E-02	U.S. EPA OSW 2005
Chicken	Phenanthrene	Chicken_Phenanthrene	2.49E-04	U.S. EPA OSW 2005
Chicken	Pyrene	Chicken_Pyrene	2.83E-04	U.S. EPA OSW 2005
Dairy	Aliphatic C5-C8 Group	Dairy_Aliphatic C5-C8 Group	4.80E-03	U.S. EPA OSW 2005
Dairy	Aliphatic C9-C16 Group	Dairy_Aliphatic C9-C16 Group	5.11E-03	U.S. EPA OSW 2005
Dairy	Aliphatic C17-C34 group	Dairy_Aliphatic C17-C34 group	5.11E-03	U.S. EPA OSW 2005
Dairy	Anthracene	Dairy_Anthracene	7.12E-05	U.S. EPA OSW 2005
Dairy	Aromatic C9-C16 Group	Dairy_Aromatic C9-C16 Group	5.16E-03	U.S. EPA OSW 2005
Dairy	Aromatic C17-C34 Group	Dairy_Aromatic C17-C34 Group	6.78E-05	U.S. EPA OSW 2005
Dairy	Benz(a)anthracene	Dairy_Benz(a)anthracene	8.41E-05	U.S. EPA OSW 2005
Dairy	Benzo(a)pyrene	Dairy_Benzo(a)pyrene	7.91E-05	U.S. EPA OSW 2005
Dairy	Benzo(e)pyrene	Dairy_Benzo(e)pyrene	5.08E-05	U.S. EPA OSW 2005
Dairy	Benzo(b)fluoranthene	Dairy_Benzo(b)fluoranthene	7.62E-05	U.S. EPA OSW 2005
Dairy	Benzo(ghi)perylene	Dairy_Benzo(ghi)perylene	4.01E-05	U.S. EPA OSW 2005
Dairy	Benzo(k)fluoranthene	Dairy_Benzo(k)fluoranthene	7.68E-05	U.S. EPA OSW 2005
Dairy	Biphenyl	Dairy_Biphenyl	8.57E-03	U.S. EPA OSW 2005
Dairy	Chrysene	Dairy_Chrysene	8.41E-05	U.S. EPA OSW 2005
Dairy	Dibenz(ah)anthracene	Dairy_Dibenz(ah)anthracene	6.52E-05	U.S. EPA OSW 2005
Dairy	Fluoranthene	Dairy_Fluoranthene	8.26E-05	U.S. EPA OSW 2005
Dairy	Fluorene	Dairy_Fluorene	6.16E-05	U.S. EPA OSW 2005
Dairy	Indeno(123cd)pyrene	Dairy_Indeno(123cd)pyrene	6.19E-05	U.S. EPA OSW 2005
Dairy	Naphthalene	Dairy_Naphthalene	3.13E-03	U.S. EPA OSW 2005
Dairy	Phenanthrene	Dairy_Phenanthrene	7.12E-05	U.S. EPA OSW 2005
Dairy	Pyrene	Dairy_Pyrene	8.09E-05	U.S. EPA OSW 2005
Eggs	Aliphatic C5-C8 Group	Eggs_Aliphatic C5-C8 Group	9.61E-03	U.S. EPA OSW 2005
Eggs	Aliphatic C9-C16 Group	Eggs_Aliphatic C9-C16 Group	1.02E-02	U.S. EPA OSW 2005
Eggs	Aliphatic C17-C34 group	Eggs_Aliphatic C17-C34 group	1.02E-02	U.S. EPA OSW 2005
Eggs	Anthracene	Eggs_Anthracene	1.42E-04	U.S. EPA OSW 2005
Eggs	Aromatic C9-C16 Group	Eggs_Aromatic C9-C16 Group	1.03E-02	U.S. EPA OSW 2005
Eggs	Aromatic C17-C34 Group	Eggs_Aromatic C17-C34 Group	1.36E-04	U.S. EPA OSW 2005
Eggs	Benz(a)anthracene	Eggs_Benz(a)anthracene	1.68E-04	U.S. EPA OSW 2005
Eggs	Benzo(a)pyrene	Eggs_Benzo(a)pyrene	1.58E-04	U.S. EPA OSW 2005
Eggs	Benzo(e)pyrene	Eggs_Benzo(e)pyrene	1.02E-04	U.S. EPA OSW 2005
Eggs	Benzo(b)fluoranthene	Eggs_Benzo(b)fluoranthene	1.52E-04	U.S. EPA OSW 2005
Eggs	Benzo(ghi)perylene	Eggs_Benzo(ghi)perylene	8.02E-05	U.S. EPA OSW 2005
Eggs	Benzo(k)fluoranthene	Eggs_Benzo(k)fluoranthene	1.54E-04	U.S. EPA OSW 2005
Eggs	Biphenyl	Eggs_Biphenyl	1.71E-02	U.S. EPA OSW 2005
Eggs	Chrysene	Eggs_Chrysene	1.68E-04	U.S. EPA OSW 2005
Eggs	Dibenz(ah)anthracene	Eggs_Dibenz(ah)anthracene	1.30E-04	U.S. EPA OSW 2005

Table 4E-31 Bio Transfer Factors [day/kg FW]

Media	Chemical	Abbreviation	Value	Comment
Eggs	Fluoranthene	Eggs_Fluoranthene	1.65E-04	U.S. EPA OSW 2005
Eggs	Fluorene	Eggs_Fluorene	1.23E-04	U.S. EPA OSW 2005
Eggs	Indeno(123cd)pyrene	Eggs_Indeno(123cd)pyrene	1.24E-04	U.S. EPA OSW 2005
Eggs	Naphthalene	Eggs_Naphthalene	6.25E-03	U.S. EPA OSW 2005
Eggs	Phenanthrene	Eggs_Phenanthrene	1.42E-04	U.S. EPA OSW 2005
Eggs	Pyrene	Eggs_Pyrene	1.62E-04	U.S. EPA OSW 2005
Ruffed_Grouse	Aliphatic C5-C8 Group	Ruffed_Grouse_Aliphatic C5-C8 Group	1.68E-02	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Aliphatic C9-C16 Group	Ruffed_Grouse_Aliphatic C9-C16 Group	1.79E-02	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Aliphatic C17-C34 group	Ruffed_Grouse_Aliphatic C17-C34 group	1.79E-02	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Anthracene	Ruffed_Grouse_Anthracene	2.49E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Aromatic C9-C16 Group	Ruffed_Grouse_Aromatic C9-C16 Group	1.80E-02	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Aromatic C17-C34 Group	Ruffed_Grouse_Aromatic C17-C34 Group	2.37E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Benz(a)anthracene	Ruffed_Grouse_Benz(a)anthracene	2.94E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Benzo(a)pyrene	Ruffed_Grouse_Benzo(a)pyrene	2.77E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Benzo(e)pyrene	Ruffed_Grouse_Benzo(e)pyrene	1.78E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Benzo(b)fluoranthene	Ruffed_Grouse_Benzo(b)fluoranthene	2.67E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Benzo(ghi)perylene	Ruffed_Grouse_Benzo(ghi)perylene	1.40E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Benzo(k)fluoranthene	Ruffed_Grouse_Benzo(k)fluoranthene	2.69E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Biphenyl	Ruffed_Grouse_Biphenyl	3.00E-02	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Chrysene	Ruffed_Grouse_Chrysene	2.94E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Dibenz(ah)anthracene	Ruffed_Grouse_Dibenz(ah)anthracene	2.28E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Fluoranthene	Ruffed_Grouse_Fluoranthene	2.89E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Fluorene	Ruffed_Grouse_Fluorene	2.16E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Indeno(123cd)pyrene	Ruffed_Grouse_Indeno(123cd)pyrene	2.17E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Naphthalene	Ruffed_Grouse_Naphthalene	1.09E-02	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Phenanthrene	Ruffed_Grouse_Phenanthrene	2.49E-04	U.S. EPA OSW 2005 Assumed = chicken
Ruffed_Grouse	Pyrene	Ruffed_Grouse_Pyrene	2.83E-04	U.S. EPA OSW 2005 Assumed = chicken
White-tailed Deer	Aliphatic C5-C8 Group	White-tailed Deer_Aliphatic C5-C8 Group	2.28E-02	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Aliphatic C9-C16 Group	White-tailed Deer_Aliphatic C9-C16 Group	2.43E-02	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Aliphatic C17-C34 group	White-tailed Deer_Aliphatic C17-C34 group	2.43E-02	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Anthracene	White-tailed Deer_Anthracene	3.38E-04	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Aromatic C9-C16 Group	White-tailed Deer_Aromatic C9-C16 Group	2.45E-02	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Aromatic C17-C34 Group	White-tailed Deer_Aromatic C17-C34 Group	3.22E-04	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Benz(a)anthracene	White-tailed Deer_Benz(a)anthracene	3.99E-04	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Benzo(a)pyrene	White-tailed Deer_Benzo(a)pyrene	3.76E-04	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Benzo(e)pyrene	White-tailed Deer_Benzo(e)pyrene	2.41E-04	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Benzo(b)fluoranthene	White-tailed Deer_Benzo(b)fluoranthene	3.62E-04	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Benzo(ghi)perylene	White-tailed Deer_Benzo(ghi)perylene	1.90E-04	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Benzo(k)fluoranthene	White-tailed Deer_Benzo(k)fluoranthene	3.65E-04	U.S. EPA OSW 2005 Assumed = beef

Table 4E-31 Bio Transfer Factors [day/kg FW]

Media	**Chemical**	**Abbreviation**	**Value**	**Comment**
White-tailed Deer	Biphenyl	White-tailed Deer_Biphenyl	4.07E-02	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Chrysene	White-tailed Deer_Chrysene	3.99E-04	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Dibenz(ah)anthracene	White-tailed Deer_Dibenz(ah)anthracene	3.10E-04	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Fluoranthene	White-tailed Deer_Fluoranthene	3.92E-04	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Fluorene	White-tailed Deer_Fluorene	2.93E-04	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Indeno(123cd)pyrene	White-tailed Deer_Indeno(123cd)pyrene	2.94E-04	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Naphthalene	White-tailed Deer_Naphthalene	1.48E-02	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Phenanthrene	White-tailed Deer_Phenanthrene	3.38E-04	U.S. EPA OSW 2005 Assumed = beef
White-tailed Deer	Pyrene	White-tailed Deer_Pyrene	3.84E-04	U.S. EPA OSW 2005 Assumed = beef

log(BTF) [day/kg FW] = {-0.099 x Log(Kow)^2 + 1.07 x LOG(Kow) - 3.56} x Fat Content of Tissue x Metabolism Factor

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