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4.0 AIR QUALITY

4.1 Introduction

This section examines air quality in the local and regional study areas. Baseline conditions are examined and air quality changes associated with emissions from the Expansion Project are predicted. Additionally, the cumulative effects of existing, approved and planned industrial sources in the general region are examined. Emissions projections and predicted air quality changes associated with the project are based upon full project production (30 000 b/d) following the completion of the Expansion Project. This assessment is based on a production rate of 10 000 b/d from the Initial Project and 20 000 b/d from the Expansion Project.

4.1.1 Overview

The project will introduce new sources of gaseous emissions to the atmosphere. Human health, wildlife, soils, and waterbodies could be adversely affected by exposure to these emissions. An assessment of existing air quality in the vicinity of the project is provided.

4.1.2 Objectives

The objectives are to:

- define the baseline air quality in the vicinity of the project;
- identify and characterize atmospheric emission sources from existing, approved and proposed regional emission sources;
- predict ambient air quality changes due to the project and other operations in the region; and
- compare the predicted air quality changes to ambient air quality criteria.

These objectives will be achieved by providing historical and predicted information regarding air quality and deposition in the baseline, project and cumulative effects assessment (CEA) cases. The predicted impacts of changes in air quality and/or deposition are discussed in the appropriate sections of this environmental assessment (e.g., surface water quality, vegetation, soil, wildlife, human health).

4.2 Study Area

4.2.1 Spatial Boundaries

The maximum concentrations of substances emitted from the project are expected to occur within a few kilometres of project emission sources. Concentrations will generally decrease steadily with distance from the sources. One exception may be ozone (O_3), which may reach maximum concentration at a distance of tens of kilometres from the source. This is the result of O_3 formation via secondary atmospheric reactions. Additionally, the release of greenhouse gases is dealt with in a national context.

The local and regional study areas for the air assessment are shown in Figure 4.2-1. The size and location were based on several factors:

- the location of major emission sources in the region (primarily oil sands facilities);
- the expected spatial extent of significant project concentration and deposition contours;
- the location of potentially sensitive receptors, including the village of Conklin; and
- the spatial extent of the 0.17 keq/ha/y annual potential acid input (PAI) deposition pattern for the CEA scenario based on the results of a recent oil sands Environmental Impact Assessment (EIA) (EnCana 2007).

The regional study area has a north-south extent of about 409 km and an east-west extent of 212 km (for a total area of about 86 700 km^2). The AQRSA extends from Fort Chipewyan to south of Conklin, and encloses all of the major emissions sources in the Athabasca oil sands and extends eastward about 40 km inside western Saskatchewan.

The air quality local study area (AQLSA) is a 30 km by 30 km square centred on the central processing facility (CPF). The boundary of the AQLSA was chosen to highlight air quality in the immediate area of the project.

4.2.2 Temporal Boundaries

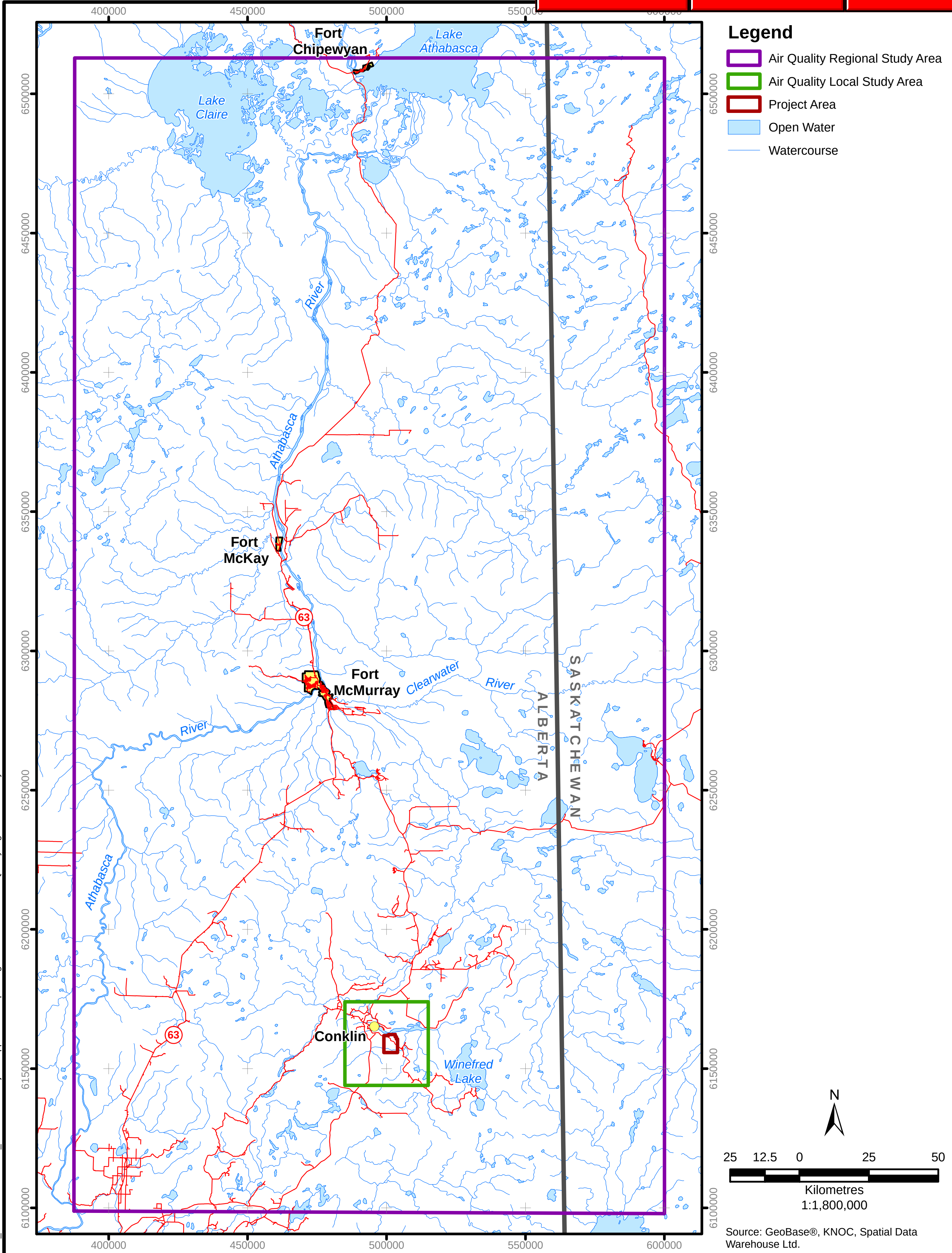
For the project baseline, observations of air quality and meteorology were taken primarily from the years 2002 to 2008. Baseline emissions source parameters were used for regional projects approved and updated as of May 2009.

Predictions of the potential project impacts on air quality, both alone and cumulatively with other regional projects, were made on the assumption that all existing and approved projects will be operating simultaneously at maximum capacity. Specific upset scenarios for the project are dealt with independently.

4.2.3 Terrain

Modern, sophisticated dispersion models take into account specific terrain details in order to more accurately reflect the flow of gas in areas of changing elevations. Topographic elevations for the region were obtained from the Shuttle Radar Topography Mission (SRTM – 3 Arc Second) data downloaded from the United States Geological Survey (USGS) website. The horizontal resolution of these maps is 90 m. The topography in the study area is shown in Figure 4.2-2. Characteristic terrain features in the area include:

- Birch Mountain in the western portion of the study area rises approximately 250 m above the elevation of the project facility and is about 65 km northwest of the AQLSA;
- the Athabasca River valley bisects the AQRSA. Wind directions at monitoring stations near the river are dominated by the valley's orientation;
- Muskeg Mountain, located approximately 60 km to the southwest, rises about 150 m above the elevation of the AQLSA; and
- ground cover varies across the study area and ranges from rolling forest to flat muskeg.



S:\Gis\Projects\CE\KNOC_BlackGold\CE03745_EIA\ArcGIS Projects\Application Report Figures\Section 04 - Air Quality\Fig04.02-01 Study Area.mxd

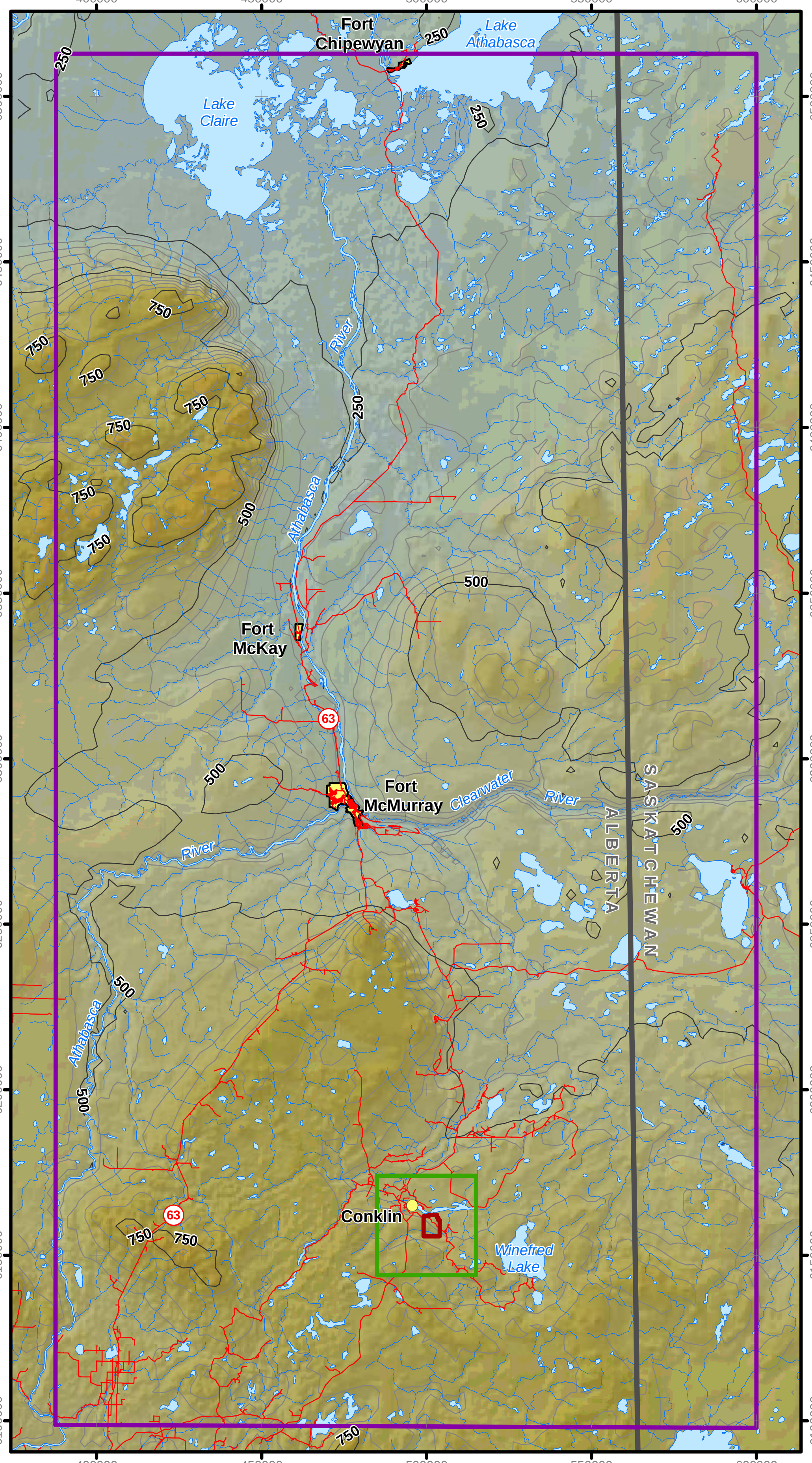
Korea National Oil Corporation

BlackGold Expansion Project

Air Quality Local and Regional Study Areas

DATE: December 2009		Fig04.02-01 Study Areas 09-12-17	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TR	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.2-1



Legend

- Air Quality Regional Study Area
- Air Quality Local Study Area
- Project Area
- Open Water
- Watercourse
- Index Contour (250m interval)

N

25 12.5 0 25 50
Kilometres
1:1,800,000

Source: GeoBase®, KNOC, Spatial Data Warehouse Ltd.

S:\Gis\Projects\CE\KNOC_BlackGold\CE03745_EIA\ArcGIS Projects\Application Report Figures\Section 04 - Air Quality\Fig04.02-02 Topography.mxd

Korea National Oil Corporation

BlackGold Expansion Project

Grid-Averaged Topography of the Air Quality Regional Study Area

DATE: December 2009		Fig04.02-02 Topography 09-12-18	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TR	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.2-2

4.3 Assessment Approach

4.3.1 Issues and Assessment Criteria

The internal scoping exercise conducted by Korea National Oil Corporation (KNOC), based on stakeholder consultation, identified the following key issues for air quality:

- impacts of the project on air quality in the region;
- impacts of air emissions on deposition of acid-forming compounds and nitrogen and appropriate mitigation/monitoring;
- impacts of changes in air quality on human health; and
- production of greenhouse gases (GHGs).

In addition, the Regional Sustainable Development Strategy (RSDS) (AENV 1999a, 1999b) lists high-priority (Category A) issues to be addressed. Table 4.3-1 identifies applicable key issues from the RSDS, their relevance to the project, as well as an indication of to what extent the present document addresses the issues.

Table 4.3-1: Summary of Identified Issues and Their Relevance to the Project

No.	Issue	Relevance to Project EIA
1	Impact of increasing SO_2, NO_x and CO concentrations.	Ambient concentrations are addressed in the air quality impact assessment. Potential effects are addressed in Sections 8.0, 10.0, 11.0, 12.0 and 18.0).
2	Impact of acid and nitrogen deposition.	Acid and nitrogen deposition is examined in the air quality impact assessment and evaluated in Sections 8.0, 10.0, 11.0 and 18.0.
3	Impact of VOC/PAHs concentrations on human health, vegetation and wildlife.	Selected VOC/PAHs concentrations, based on predicted emissions, are addressed in the air quality impact assessment. Potential effects of VOCs and PAHs are discussed in Sections 11.0, 12.0 and 18.0).
4	Meeting ambient air quality and deposition guidelines.	The air quality impact assessment is based upon the comparison of air quality (measured and predicted) to existing guideline levels for both criteria and toxic substances.
5	Cumulative impacts of air pollutants on human health, wildlife, and vegetation.	The project emissions, alone and in combination with emissions from other regional projects, are examined in the air quality impact assessment. Impacts on various receptors are discussed in Sections 8.0, 11.0, 12.0 and 18.0.
6	Impact of ground level O_3 on human health and vegetation.	O_3 concentrations are examined in the air quality impact assessment. Potential effects are discussed in Sections 11.0 and 18.0.
7	Impact of inhalable particulate matter on human health and wildlife.	Concentrations of particulate matter are discussed in the air quality impact assessment. Potential effects are discussed in Sections 12.0 and 18.0.
8	GHGs.	GHG emissions are examined in the air quality impact assessment.
9	Lack of ambient air quality guidelines for some parameters.	Beyond the scope of an EIA.
10	Impact of odours in residential settlements and odours from the project.	Emissions of substances causing odour from the project will be very small, resulting in only very local odour impacts. The impact of upset hydrogen sulphide (H_2S) odour concentration is discussed.
11	Impacts of heavy metal deposition on soil and vegetation, fish, wildlife and/or human health.	The project will burn natural gas for power steam requirements. Heavy metals are not released from this combustion process (Chao *et al.* 1999). Therefore, heavy metals are not evaluated in this assessment.

4.3.2 Air Quality Issues Relating to the Project

The internal scoping exercise identified the following releases as of potential concern for the project: sulphur dioxide (SO_2), gaseous oxides of nitrogen (NO_x), particulate matter (PM), carbon monoxide (CO), volatile organic compound/polycyclic aromatic hydrocarbons (VOC/PAHs), ozone (O_3) and GHG. Emissions of these substances are identified and quantified. The impact of these releases are examined in reference to the issues identified in Table 4.3-2:

Table 4.3-2: Identified Potential Air Issues Associated with Project Emissions

Emission Parameter	Emission Source(s)	Reason for Concern
NO_x	Combustion (natural gas and produced gas).	Exposure at sufficiently high concentration has the potential for adverse effects on human health and vegetation. Can form acidifying compounds through atmospheric reactions that are deposited via wet and dry mechanisms. This deposition can adversely affect soil, vegetation and surface water chemistry.
SO_2	Combustion (natural gas and produced gas).	Exposure at sufficiently high concentration has the potential for adverse effects on human health and vegetation. Can form acidifying compounds through atmospheric reactions that are deposited via wet and dry mechanisms. This deposition can adversely affect soil, vegetation and surface water chemistry.
PM	Combustion (natural gas and produced gas).	Particulate matter, especially that with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$), may impact human health in sufficient concentrations.
VOC	Combustion (natural gas and produced gas). Fugitive emissions (storage tanks).	Comprises a range of compounds, some of which may produce human health impacts in sufficient concentrations.
PAH (polycyclic aromatic hydrocarbons)	Combustion (natural gas and produced gas).	Comprises a range of compounds, some of which may produce human health impacts in sufficient concentrations.
O_3	Secondary reactions involving the NO_x and VOC releases from the project.	In sufficient concentrations, O_3 exposure may adversely affect vegetation and human health.
GHGs	Combustion (natural gas and produced gas).	Overall concerns relating to global climate change.

4.3.3 Air Assessment Criteria

4.3.3.1 Air Emissions Guidelines

Various regulatory and government agencies in Alberta have developed guidelines and criteria intended to restrict emissions to acceptable levels. This section discusses some of the applicable emission criteria.

Emissions from Commercial/Industrial Boilers and Heaters

The Canadian Council of Ministers of the Environment (CCME) has published National Emission Guidelines for Commercial/Industrial Boiler and Heater Sources (CCME 1998). The values set out in this document are frequently referenced by regulatory agencies as targets that need to be achieved for approval and permit compliance. A summary of these guidelines is presented in Table 4.3-3.

Table 4.3-3: Emission Guidelines for Industrial Boilers and Heaters

Parameter	Fuel Type	Emission Limits on Energy Input [g/GJ]	
		10.5 to 105 GJ/h	**>105 GJ/h**
NO_2	Gaseous fuel	26	40
	Distillate oil	40	50
	Residual oil (<0.35% N)	90	90
	Residual oil (> 0.35% N)	110	125
CO	All fuels	125	125

Interim NO_x Emission Guidelines

Alberta Environment (AENV) has published an Interim guideline for NO_x emissions from gas-fired sources specific to the oil sands area North of Fort McMurray (AENV 2007, 2009a, 2009b) but these are not regulatory requirements in the project area at this time. KNOC will consider these proposed guidelines (7.9 g NO_x/GJ) as part of detailed engineering as the project proceeds.

Sulphur Recovery

Energy Resources Conservation Board (ERCB) Interim Directive (ID) 2001-3 (EUB 2001) is based on ERCB Information Letter (IL 88-13; EUB 1988), and includes the recovery of sulphur from sour gas processing plants and new emissions from other types of upstream petroleum operation. Sulphur recovery is required for facilities emitting more than one tonne per day of sulphur.

Recovery of Flared Gases

The EUB Directive 060 provides regulatory requirements and guidelines for flaring, incinerating, and venting in Alberta, as well as procedural information for flare permit applications, dispersion modelling, and the measuring and reporting of flared, incinerated, and vented gas (ERCB 2006).

Fugitive VOC Control

The CCME has developed the Environmental Code of Practice for the Measurement and Control of Fugitive VOC Emissions from Equipment Leaks (CCME 1993). Additionally, ERCB Directive 060 and the associated Best Management Plan for Fugitive Emissions Management (CAPP 2007) provide guidance for the control of VOC releases from leaks. Best practices for testing, monitoring and record keeping are included.

4.3.3.2 Ambient Air Quality Objectives

Ambient objectives have been developed for a variety of regulated substances. Of particular relevance to the project are ambient levels of SO_2, NO_2, CO, oxidants expressed as O_3, particulate matter and benzene. AENV has established a set of Alberta Ambient Air Quality Objectives & Guidelines (AAAQO) (AENV 2009b), and the Canadian government through Environment Canada and the CCME have established Canada-Wide Standards (CWS)

(CCME 1999). Canada has also established four levels of objectives as defined below (Environment Canada 1981, CCME 1999). Table 4.3-4 presents the Alberta and federal air quality objectives for regulated compounds. The objectives are established based on averaging periods ranging from one hour to one year:

- the maximum *desirable* level defines the long-term goal for air quality and provides a basis for an antidegradation policy for the unpolluted parts of the country and for the continuing development of control technology;
- the maximum *acceptable* level is intended to provide adequate protection against adverse effects on soil, water, vegetation, materials, animals, visibility, and personal comfort and well being;
- the maximum *tolerable* level denotes the concentration of an air contaminant that requires abatement without delay to avoid further deterioration to an air quality that endangers the prevailing Canadian lifestyle or, ultimately, to an air quality that poses a substantial risk to public health; and
- the *reference* level is considered to be the lowest level of exposure likely to result in a defined and identifiable but minimal effect. This level is considered as a scientific basis for guidelines, not a part of them.

Table 4.3-4: Alberta and Federal Ambient Air Quality Objectives and Guidelines

	Period	Alberta Objectives		Alberta Guideline	Federal Objectives			
		($\mu g/m^3$)	(ppb)	($\mu g/m^3$)	Desirable ($\mu g/m^3$)	Acceptable ($\mu g/m^3$)	Tolerable ($\mu g/m^3$)	CWS ($\mu g/m^3$)
SO_2	Annual	30	11	–	30	60	–	–
	24-h	150	57	–	150	300	800	–
	1-h	450	172	–	450	900	–	–
H_2S	24-h	4	3	–	–	–	–	–
	1-h	14	10	–	–	–	–	–
NO_2	Annual	60	32	–	60	100	–	–
	24-h	200	106	–	–	200	300	–
	1-h	400	212	–	–	400	1 000	–
CO	8-h	6 000	5 000	–	6 000	15 000	20 000	–
	1-h	15 000	13 000	–	15 000	35 000	–	–
O_3	8-h	–	–	–	–	–	–	130
	1-h	160	82	–	–	–	–	–
Benzene	1-h	30	9	–	–	–	–	–
TSP	Annual[1]	60	–	–	60	70	–	–
	24-h	100	–	–	–	120	400	–
$PM_{2.5}$	24-h	–	–	–	–	–	–	30
	1-h	–	–	80	–	–	–	–

[1] As a geometric mean.

In Alberta, the maximum concentrations in ambient air are currently specified as guidelines for SO_2, H_2S, NO_2, CO, oxidants expressed as O_3 and total suspended particulate (TSP) (AENV 2009b).

$PM_{2.5}$ and O_3 levels were addressed by CCME, and as a result CWS have been adopted and are included in Table 4.3-4. In addition, CCME has adopted the Keeping Clean Areas Clean framework to manage ambient air quality in areas of Alberta currently below the numeric CWS. A series of trigger levels and corresponding actions based on ambient observations have been developed as part of this management framework. As an example, according to AENV (2002), the trigger points and corresponding actions for ambient $PM_{2.5}$ levels are as follows:

- where ambient concentrations are at the lowest levels, baseline monitoring, modelling and forecasting would occur. Results of baseline monitoring would indicate if there is any exceedance of the various trigger levels;
- at the "surveillance trigger" level of 15 µg/m^3, affected stakeholders in areas of concern would undertake pre-planning activities (for example, monitoring, source apportionment modelling, and detailed forecasting);
- between the "planning trigger" of 20 µg/m^3 and the CWS, affected stakeholders will develop and implement a management plan. If this is not done within a certain time frame or by a specified level, AENV will impose a plan; and
- when concentrations of $PM_{2.5}$ exceed the CWS of 30 µg/m^3, AENV will impose a mandatory plan to reduce ambient concentrations to below the CWS within a reasonable amount of time.

Under the framework, the specific threshold levels for surveillance and planning triggers are to be set provincially, and development of regional management plans will take into account naturally occurring background levels.

4.3.3.3 Acid Deposition Criteria

Deposition of acidifying compounds occurs through both wet and dry processes and can result in the long-term accumulation of atmospheric emissions in aquatic and terrestrial ecosystems. The deposition of sulphur and nitrogen compounds to surface water and soil has been associated with potential changes in chemistry, particularly acidity.

The PAI is used as a deposition measure of acidification. For the purposes of this assessment, the calculation of PAI deposition from model predictions is defined as:

$$PAI = \sum (SO_4^{-2}) + \sum (NO_3^-) - \sum (\text{base cations}) + \text{Background PAI}$$

<u>*where*</u>:

$\sum (SO_4^{-2})$	=	total sulphur compound contribution (i.e., SO_2 and SO_4^{-2}) expressed in keq/ha/y
$\sum (NO_3^-)$	=	total nitrogen compound contribution (i.e., NO, NO_2, HNO_3 and NO_3^-) expressed in keq/ha/y
$\sum$ (base cations)	=	primarily calcium (Ca^{+2}) and magnesium (Mg^{+2}) = 0.12 keq/ha/y (Chaikowski 2001)
Background PAI	=	~0.024 to 0.075 keq/ha/y (Cheng 2001)

Critical, target and monitoring loads for management of acid deposition in Alberta have been established by the Clean Air Strategic Alliance (CASA) Target Loading Subgroup (CASA and AENV 1999). These loads were based on predictions generated by the Regional Lagrangian Acid Deposition (RELAD) model and have been accepted by AENV. The RELAD model is applied to grid cells with dimensions of 1 degree latitude by 1 degree longitude and accounts for specific receptor sensitivities. The established management levels are:

- a *monitoring load* of 0.17 keq/ha/y that will trigger monitoring or research action;
- a *target load* of 0.22 keq/ha/y; this is the maximum acceptable deposition that provides long-term protection from adverse ecological consequences to the most sensitive ecosystem components, and is practically achievable; and
- a *critical load* of 0.25 keq/ha/y; this is the maximum acceptable deposition that will not result in chemical changes and long-term harmful effects to the most sensitive ecosystem components.

Any use of these critical, target and monitoring loads uncoupled from RELAD modelling, and the definitions of receptor sensitivity (including the 5% level of protection), in a regional or project-specific application is limited to the use of these values in the identification of areas potentially at risk of becoming acidified. Upon identifying such areas, actions confirming the acidification sensitivity of these areas are to be taken. The provincial acid deposition management framework specifies that an exceedance of a target load at a local scale (e.g., project area) is not to be considered to be an exceedance of an environmental objective. Additionally, any exceedance of the critical, target or monitoring loads predicted by any means other than RELAD modelling (or deposition monitoring) is not to be considered in the provincial management of acid deposition.

The CASA approach is based on the European approach outlined by the World Health Organization (WHO) (WHO 1994). For less sensitive systems, WHO has identified critical loads of 0.5, 1.0 and 1.5 keq/ha/y. This report includes estimates of the areas identified as being above these thresholds, as well as the CASA monitoring, target and critical loads, based on CALPUFF modelling.

4.3.3.4 Nitrogen Deposition Criteria

Nitrogen is the limiting nutrient for growth in many natural ecosystems and the addition of nitrogen via deposition may introduce significant imbalances to natural ecosystems. Certain vegetation such as poor fen/bog vegetation may be most affected by this imbalance. This section outlines the methods used to assess the potential nitrogen deposition as a result of the project and other sources. Established critical loads established in Europe (WHO 2000) are used as reference points. The applicability of these loads has not been evaluated in the oil sands context. A critical load of 0.25 kep/ha/yr of nitrogen has been suggested as an appropriate value for the oil sands region (Vitt *et al*. 2002).

When determining nitrogen deposition from observed data, the deposited nitrogen was scaled by the molecular weights of the deposited species as follows:

$$N = \sum (14/46\ NO_2\ dry) + \sum (14/62\ NO_3^-\ dry) + \sum (14/62\ NO_3^-\ wet) + \sum (14/18\ NH_4\ dry)$$

The CALPUFF model explicitly calculates nitrogen deposition based on chemistry internal to the model. Using either approach, nitrate deposition is accounted for in both acidification and eutrophication calculations.

4.4 Methods

4.4.1 Air Quality Impact Assessment Scenarios

Three scenarios are considered in assessing the impact of the project on ambient air quality:

- the baseline scenario consists of an assessment of air quality from the existing and approved industrial emission sources in the region, as well as estimated emissions from various non-industrial sources including vehicle and recreational emissions. Baseline assessment results reflect the potential cumulative effects on the airshed in the absence of new industrial development. The assessment assumes that all current and approved facilities are operating at their maximum approved levels. As a consequence, the assessment is necessarily conservative in nature;
- the project assessment scenario reflects the emissions from the project in addition to the baseline scenario emissions in the region (i.e., project = baseline + project). The project scenario represents the potential impact on the airshed upon project commencement assuming maximum output from the project. The project contribution to air quality is the difference between the predictions for project and baseline scenarios; and
- the Planned Development scenario includes a cumulative assessment of the existing and approved projects in the region, the project and other planned regional emission sources (planned = baseline + project + announced). As planned projects are in preliminary stages, there is no guarantee that they will be built to the current proposed specifications, if at all. Therefore, the confidence level of the planned development scenario is lower than the previous two scenarios, but it is likely that the assessed emissions in this scenario remain conservative relative to the actual future development.

4.4.2 Dispersion Modelling Methods

The California Meteorological (CALMET) and CALPUFF models were selected for use in the assessment of the potential impact of the project on air quality. These models are described in Scire *et al*. (2000) and Scire and Escoffier-Czaja (2004) and are the models recommended by AENV (2009A) and the United States Environmental Protection Agency (U.S. EPA).

Parameters associated with CALPUFF and CALMET are discussed in more detail in Appendix B1.

4.4.2.1 Model Inputs and Parameters

Other modelling details are as follows:

- receptor grid spacing ranged from 50 m to 10 km over the modelling domain. In areas distant from the project but near to significant emission sources in the region, a denser 2 km grid was used to enhance definition;
- land cover distribution was taken from the land cover map produced by the Canada Centre for Remote Sensing and Canadian Forest Service available from the Natural Resources Canada;
- no upper station was used in modelling. The five-year, 12 km MM5 dataset provided by AENV was used for wind field determination in CALMET runs and also for upper air data readings;
- surface wind data from four Wood Buffalo Environmental Association stations in the area (Fort McMurray, Fort Chipewyan, Fort McKay and Mannix) were used for modelling;
- the regional 1^o by 1^o PAI backgrounds ranging from about 0.024 keq H+/ha/y at the northern boundary of the study area to about 0.075 keq H+/ha/y at the southern boundary are based on RELAD modelling results (Cheng 2001); and
- to account for cation deposition, an average cation background of 0.12 keq/ha/y at Fort McMurray as provided in Chaikowski (2001) was used in PAI predictions.

In addition, discrete receptors were placed at community and recreational receptors in the area. These receptors are listed in Table 4.4-1. Details regarding the receptor grid are provided in Appendix B1.

4.4.2.2 NO to NO_2 Conversion Approach

Although CALPUFF is capable of predicting NO and NO_2 separately in its internal chemistry, these predictions have been shown to overestimate NO_2. The ozone limiting method (OLM) has been shown to produce more accurate results, and is therefore used in this assessment. The OLM assumes that the conversion of NO into NO_2 is limited by the quantity of ambient ozone available for the reaction. The assumption made in the method is that 10% of the produced NO converts to NO_2 in the stack prior to release. The remaining NO is converted to NO_2 only if there is an excess of ozone available. The relationship is therefore:

- $[NO_2] = (0.1)[NO_x] + [O_3]$; or
- $[NO_2] = [NO_x]$, whichever is larger.

Hourly ambient ozone concentrations observed from 2002-2006 at the Fort McKay monitoring station are used. This timeframe coincides with the hourly meteorological data used in modelling.

Table 4.4-1: Location of Community and Recreation Receptors

Receptor ID	Receptor Description	UTM (m E)	UTM (m N)	Elevation (masl)
R01	Trapper's Cabin (SW of Plant)	506970	6153760	605
R02	Camp Site (NW of Plant)	505950	6156430	597
R03	Fish Plant (Winefred Lake)	523500	6146500	594
R04	Cabin (Winefred Lake)	527500	6145000	604
R05	Cabin (NW Kirby Lake)	514000	6148500	637
R06	West Hay Lake	510000	6149500	630
R07	Cabins (North Hay Lake)	510500	6150500	626
R08	Martin's Cabins	504500	6156500	600
R09	Métis Trailer Camp	504500	6157500	594
R10	Conklin	494770	6164890	573
R11	Cabins (NW Christina Lake)	498000	6165000	563
R12	Medicinal Plants	498000	6162000	593
R13	Cabins near Gravel Pit	493500	6170000	557
R14	Cabins	493000	6173000	550
R15	Leismer	497500	6178500	543
R16	East Chard	507500	6188500	483
R17	Pingle	505500	6196000	548
R18	Chard School	515500	6195500	472
R19	Janvier	516270	6197290	467
R20	IR 194B	530000	6160000	600
R21	IR 194A	534000	6197000	477
R22	Fishing Camp (Christina Lake)	513650	6164250	560
R23	Fire Lookout 1	543999	6132500	706
R24	Fire Lookout 2	531400	6200750	513
R25	AltaGas House	514300	6164400	564
R26	MEG Worker’s Camp	518200	6169000	580
R27	Grave Site (Christina Lake)	513650	6164750	562
R28	Grave Site (Winefred Lake)	528000	6159000	601
R29	Grist Lake Lodge 1	534600	6135200	622
R30	Grist Lake South	534250	6135550	611
R31	Winefred Lake Lodge 1	530500	6143500	599
R32	Winefred Lake West	523750	6152300	597
R33	EnCana Camp	512000	6159300	572
R34	Winifred Cabin/Station/Lookout	545500	6132900	713
R35	Campground (Christina Lake)	496700	6164400	568
R36	Wild Rice Operation 1	532100	6142700	602
R37	Wild Rice Operation 2	503100	6166900	561
R38	Fire Lookout Tower	489000	6164000	655
R39	Devenish	488000	6154000	645
R40	Old Cabins and Settlement Area (Wiau Lake)	483500	6136000	658

4.4.2.3 Acid Deposition

CALPUFF was used to estimate the deposition of PAI that would occur for the assessment scenarios where precursor emissions include NO_x and SO_2. The PAI modelling assumed a regional PAI background 0.11 keq H+/ha/y based on regional monitoring, which is more conservative than literature values (Cheng 2001). Cation deposition was 0.10 keq/ha/y calculated from 2006-2008 regional observations (Section 4.5.2).

Note that the use of provincial critical, target and monitoring loads uncoupled from RELAD modelling is limited to the use of these values in the identification of areas potentially at risk of becoming acidified. Upon identifying such areas, actions towards confirming the acidification sensitivity of these areas are to be taken. The provincial acid deposition management framework specifies that an exceedance of a target load at a local scale (e.g., project area) is not to be considered to be an exceedance of an environmental objective. Additionally, any exceedance of the critical, target or monitoring loads predicted by any means other than RELAD modelling (or deposition monitoring) is not to be considered in the provincial management of acid deposition. To allow comparison with RELAD model output, CALPUFF predictions were averaged over one-degree grid cells (Appendix B5).

4.4.2.4 Nitrogen Deposition

Deposition of nitrogen can lead to eutrophication and its calculation includes both wet (removal in precipitation) and dry (direct contact with surface features) processes. In the current approach, nitrate particulate was determined to be deposited by both wet and dry processes and was directly calculated by the dispersion model.

4.4.3 Model Accuracy

Dispersion models are designed to predict concentration and deposition in a manner that accurately reflects reality. They are designed however, to incorporate substantial conservatism in their methods to ensure that potential impacts being modelled are not understated. As with any model or simulation there are limits in the degree to which the model corresponds with actual observations.

4.4.3.1 Model Representativeness and Confidence

The following general comments are made with respect to representative predictions for this project:

- modelling was performed on the basis of anticipated maximum emission rates for the project as well as the maximum approved emission rates for other sources in the area. As such, predictions represent maximum expected concentration and deposition;
- the assessment is based upon a conservative assumption that all approved projects will proceed;
- diffuse area sources (e.g., mines, tailings ponds, non-industrial emissions from population centres, etc.) can be very difficult to parameterize for use in dispersion modelling. Certain parameters must be estimated;

- dispersion model results should be considered reasonably representative in cases where predicted concentrations are within a factor of two of monitoring results and when the maximum concentrations predicted by the model occur under the same meteorological conditions as the monitored maxima; and
- confidence in model predictions is considered reasonable if the maximum predicted concentration for a given area and timeframe is within 10 to 40% of the measured maximum value (U.S. EPA 2003).

4.4.3.2 Model Limitations

As with any prediction model, uncertainty is inherent in CALPUFF. Uncertainties arise due to gaps and errors in various model inputs, including the following:

- lack of surface and upper-air meteorological observations over many sections of the study area;
- discretization of the flow into grid-box averages, which eliminates smaller-scale details;
- uncertainties and discretization of land cover characteristics;
- simplification of emission rates as constant continuous values;
- inaccuracies in source characteristics, including the parameterization of area, line and volume sources into simple shapes; and
- failure to resolve small-scale features surrounding receptors that may influence pollutant behaviour.

Finally, the imperfect state of the science of atmospheric turbulence contributes to errors in accurately simulating the behaviour of the atmosphere and the dispersion of pollutants. The accuracy of the results of dispersion modelling remains heavily dependent on the current understanding of the atmosphere.

Despite these uncertainties, dispersion models remain useful because their results tend to over predict actual conditions (Scire *et al.*, 2000). Such a property is deliberately retained in CALPUFF through the selection of model parameters and in setting of emission parameters during its application.

Near major sources of NO_x and SO_2, and in particular near surface-based sources such as mine pits within the region, predicted concentration and deposition are significantly higher than observed. This is likely the result of the RIVAD/ARM3 chemical transformation algorithms in the model. This limitation has been addressed through the use of the ozone-limited method that more accurately represents the chemical transformation process based on local observations.

All nitrogen deposited to soil or water is assumed to be chemically and/or biologically processed in a manner that leads to acidification of the system. In evaluating the potential effects of nitrogen deposition, it is assumed that all nitrogen deposited to soil or water is chemically and/or biologically processed in a manner that leads to growth (microbial or plant) and potential eutrophication of the system. Thus, nitrogen deposition is accounted for in both acidification and eutrophication calculations, which is conservative.

A great deal of NO_x is transformed into nitric acid during the early life of the plume and that the HNO_3 is then lost to the surface within a few hours (AMEC 2004). The CALPUFF predictions herein assume all available nitrogen is transformed into nitrate particles before being deposited to the surface. Therefore the nitrogen deposition estimates presented are expected to be substantially overstated.

4.4.4 Assessment of Impacts

The evaluation of impacts generally follows the scheme outlined in Section 4.3. This section describes the adaptation and application of this scheme to air quality impacts.

Table 4.4-2 outlines the criteria and definitions used in the assessment as follows:

- *Direction* – Direction refers to a qualitative description of the expected change without regard to its magnitude;
- *Geographic Extent* – Air quality impacts are typically local to the emission source and will tend to decrease distance;
- *Magnitude* – Typically, ambient air quality measurements are viewed as being the same if they are within 10 to 15% of each other; however a more conservative definition has been applied in this assessment in keeping with the concepts and philosophy of the Keeping Clean Areas Clean policy framework. These definitions are consistent with other recent EIAs in the area (Husky 2004, EnCana 2007);
- *Duration* – While emissions will occur for the full duration of the project, changes in air quality will have substantial temporal variability due to the natural variability in meteorology (wind speed, wind direction, temperature etc.) and also short and long-term variability in emissions. In addition, the highest concentrations typically occur for very short durations and there may be infrequent upset conditions.
- *Reversibility* – Air emissions are also considered to be reversible (i.e. emissions cease when project activity ceases);
- *Confidence* – The level of confidence with predicting air quality changes depends on the appropriateness and representativeness of emission rates, the meteorological transport and dispersion parameters, chemical transformation and on the model capability. The confidence rating is based on the assumption that the selected models provide reasonable predictions for air quality assessment purposes given appropriate and representative input data; and
- *Final Impact Rating* – A final rating integrates the individual descriptor ratings and is based on professional judgment. The final rating provided in this section refers to the change in concentration or deposition only and does not account for the receptor response.

Table 4.4-2: Impact Assessment Descriptors as Applied to Ambient Air Quality Changes

Criteria	Air Quality Criteria Definition	
Direction of the Impact	Positive	Measured or estimated impact represents a real or potential increase in abundance, quality or other attribute of the receptor, resource, assessment endpoint or parameter
	Negative	Measured or estimated impact represents a real or potential decrease in abundance, quality or other attribute of the receptor.
	Neutral	There is no impact to quantify; therefore no quantitative assessment (extent, magnitude, duration, etc.) is needed.
Geographic Extent of Impact	Local	Measured or estimated impact occurs only within the boundaries of the LSA.
	Regional	Measured or estimated impact occurs beyond the boundaries of the local study area (LSA), but within the boundaries of the regional study area (RSA).
	Global	Measured or estimated impact occurs beyond the boundaries of the RSA.
Magnitude	Low	The expected emission, ambient concentration, or deposition change is expected to be less than 5%.
	Moderate	The expected emission, ambient concentration or deposition change is expected to be more than 5% but less than or equal to 10%.
	High	The expected emission, ambient concentration or deposition change is greater than 10% or is expected to exceed relevant criteria.
Duration of Impact	Short-term	Predicted impact persists no longer than five years
	Med-term	Predicted impact persists to the end of the operational life of the project
	Long-term	Predicted impact is measurable for more than two years beyond the end of the operational life of the project
Reversible	Yes	Predicted impact is reversible
	No	Predicted impact is irreversible.
Confidence Rating	Poor	Based on incomplete understanding of cause-effect relationships and incomplete data pertinent to study area.
	Moderate	Based on good understanding of cause-effect relationships, but limited by variability over time and/or space.
	High	Based on good understanding of cause-effect relationships and limited variability in data pertinent to study.
Final Impact Rating	Low	Overall rating based on professional judgment taking into account the ratings in each category.
	Moderate	
	High	

4.5 Existing Conditions

4.5.1 Observed Ambient Air Contaminants in the AQRSA

Appendix B3 presents air quality observations in the region. These observations are summarized here to provide context for dispersion modelling results which form the basis of the assessment. WBEA operates a network of 15 meteorological stations, 13 of which collect ambient air quality data. Data for the period 2004-2008 was obtained for these stations. The results of these observations are summarized here, and in Appendix B3. The majority of the maximum values occur in the mining area north of Fort McMurray.

4.5.1.1 Ambient SO_2 Data

A review of the WBEA ambient SO_2 data indicates that:

- maximum 1-hour SO_2 concentrations at seven of the 13 sites exceeded the AENV AAQO of 450 µg/m^3. The maximum 1-hour SO_2 concentrations ranged from 52 µg/m^3 (Fort Chipewyan) to 1 847 µg/m^3 (Mannix);
- all the 1-hour 99.9th percentile values were below the AENV AAQO (450 µg/m^3);
- the maximum 24-hour average SO_2 concentration at one station (Mannix) exceeded the AENV AAQO of 150 µg/m^3;
- all the 24-h 99.9th percentile values were below the AENV AAQO (150 µg/m^3); and
- the period average SO_2 concentrations recorded in 2004-2008 at the 13 stations ranged from 0.8 µg/m^3 to 8.0 µg/m^3, which are all below the annual AENV AAQO of 30 µg/m^3.

4.5.1.2 Ambient NO_2 Data

Ambient NO_2 results indicate that:

- one of the nine stations reported an exceedance of the hourly NO_2 AENV AAQO of 400 µg/m^3. The maximum 1 hour concentrations ranged between 58 µg/m^3 (Fort Chipewyan) and 427 µg/m^3 (Albian Mine);
- the highest 99.9th percentile hourly average NO_2 values ranged from 43 µg/m^3 (Fort Chipewyan) to 154 µg/m^3 (Albian Mine site), which were all below the AENV AAQO;
- 24-hour average NO_2 concentrations ranged from 41 µg/m^3 (Fort Chipewyan) to 156 µg/m^3 (Albian Mine), which were all below the AENV AAQO of 200 µg/m^3; and
- the average NO_2 concentrations recorded in 2004-2008 at the 13 stations ranged from 2 µg/m^3 (Fort Chipewyan) to 27 µg/m^3 (Millennium). All annual average values were below the AENV AAQO of 60 µg/m^3.

4.5.1.3 Ambient $PM_{2.5}$ Data

Ambient $PM_{2.5}$ results indicate that:

- the maximum 24-hour average $PM_{2.5}$ values ranged from 27 µg/m^3 (Horizon) to 96 µg/m^3 (Fort Chipewyan);
- the 98th percentile 24-hour average $PM_{2.5}$ values ranged from 12 µg/m^3 (Fort Chipewyan, Horizon) to 19 µg/m^3 (Albian Mine, Millennium), which were all within the CWS of 30 µg/m^3;
- the 95th percentile 24-hour average values ranged between 6 µg/m^3 (Fort Chipewyan) and 14 µg/m^3 (Millennium); and
- averages for the 2004-2008 period at all stations ranged from 2 µg/m^3 (Fort Chipewyan) to 6 µg/m^3 (Millennium).

4.5.1.4 Ambient O_3 Data

Ambient O_3 results from these stations indicate that:

- the 1-hour maximum O_3 values at three of the six stations exceeded the AENV AAQO of 160 µg/m^3. The maximum O_3 concentrations ranged from 130 µg/m^3 (Fort Chipewyan) to 171 µg/m^3 (Anzac, Athabasca Valley); and
- the CWS (CCME 1999) value of 128 µg/m^3 (65 ppb), based on the 4th highest 8-hour average O_3 concentration, was not exceeded at any of the five stations. The 4th highest 8-hour average concentrations ranged from 105 µg/m^3 (Patricia McInnes) to 117 µg/m^3 (Fort McKay).

4.5.1.5 Ambient CO Data

CO concentration is results indicate that:

- the 1-hour maximum CO concentration was 7 103 µg/m^3, which was well below the AENV AAQO of 15 000 µg/m^3; and
- the 8-hour maximum CO concentration was 1 475 µg/m^3, which was well below the AENV AAQO of 6 000 µg/m^3.

4.5.1.6 Ambient H_2S Data

Ambient H_2S concentration results indicate:

- maximum hourly measured values exceeded the AENV AAQO of 14 µg/m^3 at five of the seven stations. The maximum 1-hour average H_2S concentrations ranged from 4 µg/m^3 (Patricia McInnes) to 127 µg/m^3 (Mildred Lake); and
- the maximum 24-hour average H_2S concentrations ranged from 2 µg/m^3 (Patricia McInnes) to 24 µg/m^3 (Lower Camp, Mildred Lake) and exceeded the AENV AAQO of 4 µg/m^3 at five of the seven stations.

4.5.2 Other Air Quality Observations

Deposition rates of PAI and nitrogen, as well as ambient VOC concentrations, as estimated from continuous WBEA measurements in 2004 to 2008 and from 2002 to 2004 for passive measurements are provided in Appendix B3.

4.5.3 Meteorology Used in Dispersion Modelling

Meteorological input to CALPUFF is generated by the CALMET preprocessor. Input to CALMET came from a five-year (2002 to 2006) meteorological data set for the region provided by Alberta Environment. This meteorological data was the result of MM5 modelling. MM5 is a widely used research and regional forecasting model based on the NCAR-PSU model. MM5 uses global weather observations as its input to generate gridded meteorological data. This data was supplemented with surface data from nearby meteorological monitoring stations including Fort McMurray and Fort Chipewyan. Additional features of the CALMET input include:

- regional terrain variation and spatially varying land-use information, as provided in Figure 4.5-1, to account for deposition; and
- the selection of four seasons to reflect the varying state of the surface cover during the year.

Figure 4.5-2 is a series of wind roses showing the annual frequency of hourly average winds by direction at selected regional monitoring stations. Winds are shown for the 2002-2006 period for the calendar year in line with the period used for modelling. The wind roses show:

- winds are predominantly from the east/west directions at Fort Chipewyan and Fort McMurray, and north/south directions at the Mannix and Fort McKay stations. The wind variability is indicative of channeling effects from the Clearwater and the Athabasca River valleys; and
- winds are generally light in the region. As expected, winds are stronger at the Mannix station. This reflects the fact that Mannix is a 75m wind station as opposed to the standard 10m stations. Wind speeds tend to increase with increasing height above the surface due to reduced frictional interaction between the surface and upper level airflows. Due to frictional effects, the surface winds in open areas can be greater than those over forested areas. Wind speeds vary with location as a result of differences in local site characteristics, regional climatology, site elevation, and the anemometer measurement height.

Wind fields produced by CALMET are influenced by the terrain features in the region. The inferred wind patterns for the project area as determined by CALMET are shown in Figure 4.5-3. It indicates that wind in the vicinity of the project is primarily from the southwest. Details of the approach and the CALMET results are provided in Appendix B1.

While comparisons between observed and predicted winds can provide an indication of the model performance, the comparison should be undertaken with caution since the predicted values will not account for micro-scale terrain and tree canopy influences. Specifically, the predicted values represent the average wind over a 5 km (grid) area, as discussed in more detail in Appendix B1.

4.5.4 Baseline Emissions

Emissions from existing operating facilities in the AQRSA were obtained from facility operators and previously submitted EIAs. This data forms the basis of the model input used in the prediction of baseline air quality. The focus of the obtained data was on projected maximum continuous emissions from the facilities during operation (i.e., not upset conditions).

Table 4.5-1 lists the projects considered in as part of the baseline scenario. There is no guarantee that all of the listed facilities will operate in the future, or that they will be operated at maximum capacity. Therefore, the overall emissions are likely conservative in nature.

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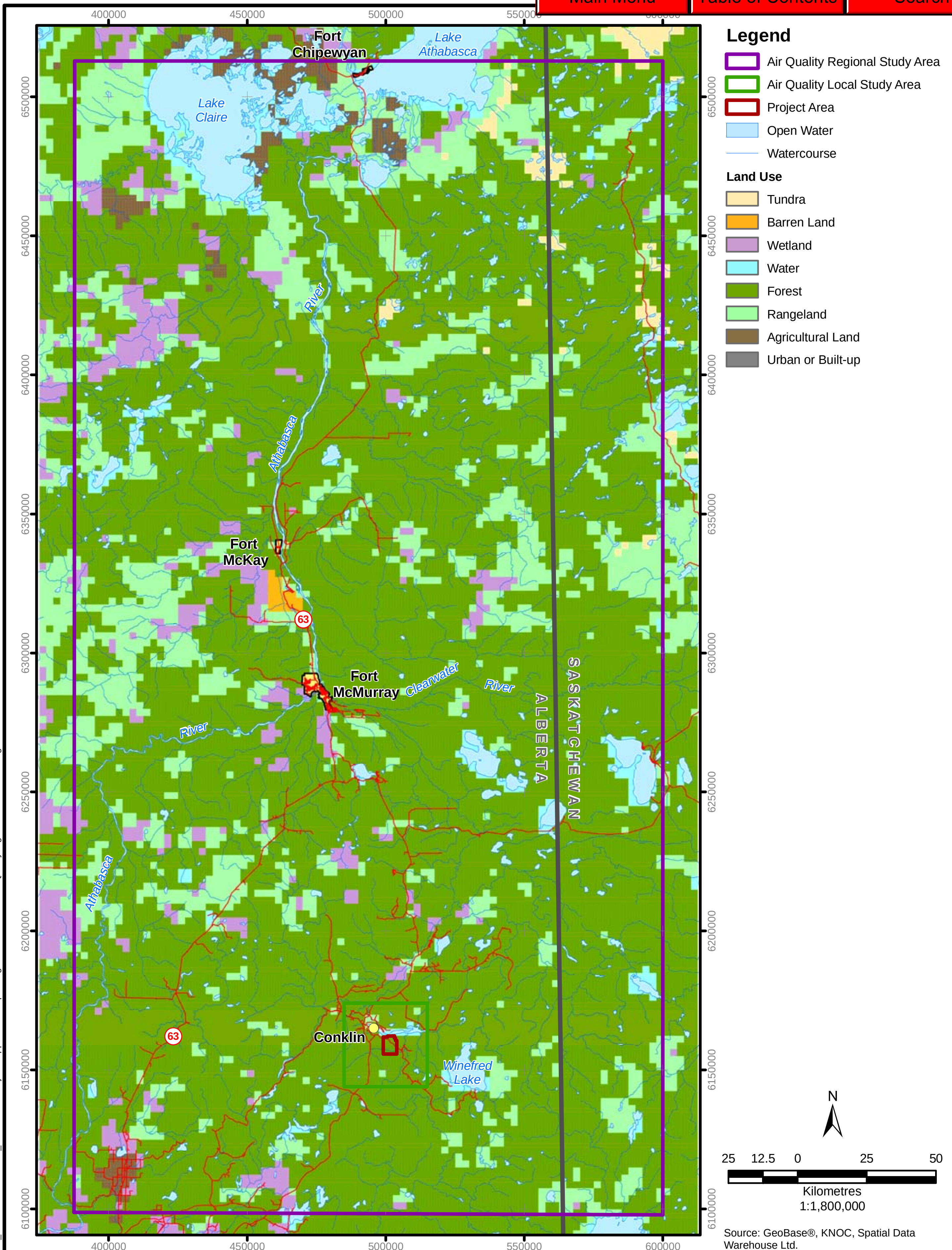

Korea National Oil Corporation

BlackGold Expansion Project

Grid-Averaged Land Use of the Air Quality Regional Study Area

DATE: December 2009	Fig04.05-01 Grid-Averaged LU 09-12-18	**Figure 4.5-1**
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: CF; QA/QC: KW EA DR	DRAWN BY: AMEC; PREPARED BY: AMEC	

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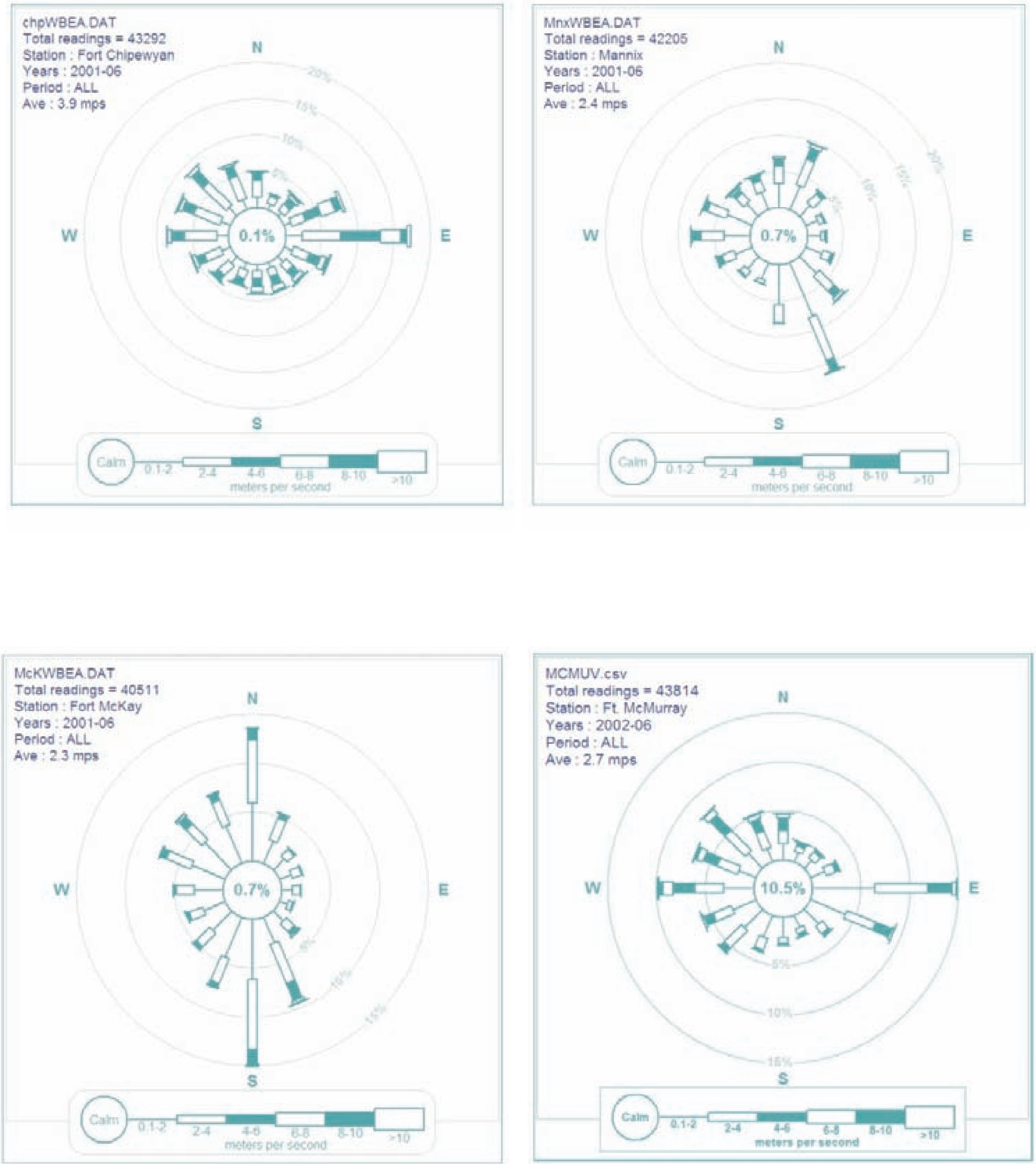

Korea National Oil Corporation

BlackGold Expansion Project

Wind Roses for 2002-2006 at Fort Chipewyan (Top Left), Mannix (Top Right), Fort McKay (Bottom Left and Fort McMurray (Bottom Right)

DATE: December 2009	Fig04.05-02 WindRoses 09-12-14	**Figure 4.5-2**
PROJECT: CE03745/200	DRAWN BY: AMEC	
ANALYST: KW / QA/QC: KW RK DR	PREPARED BY: AMEC	

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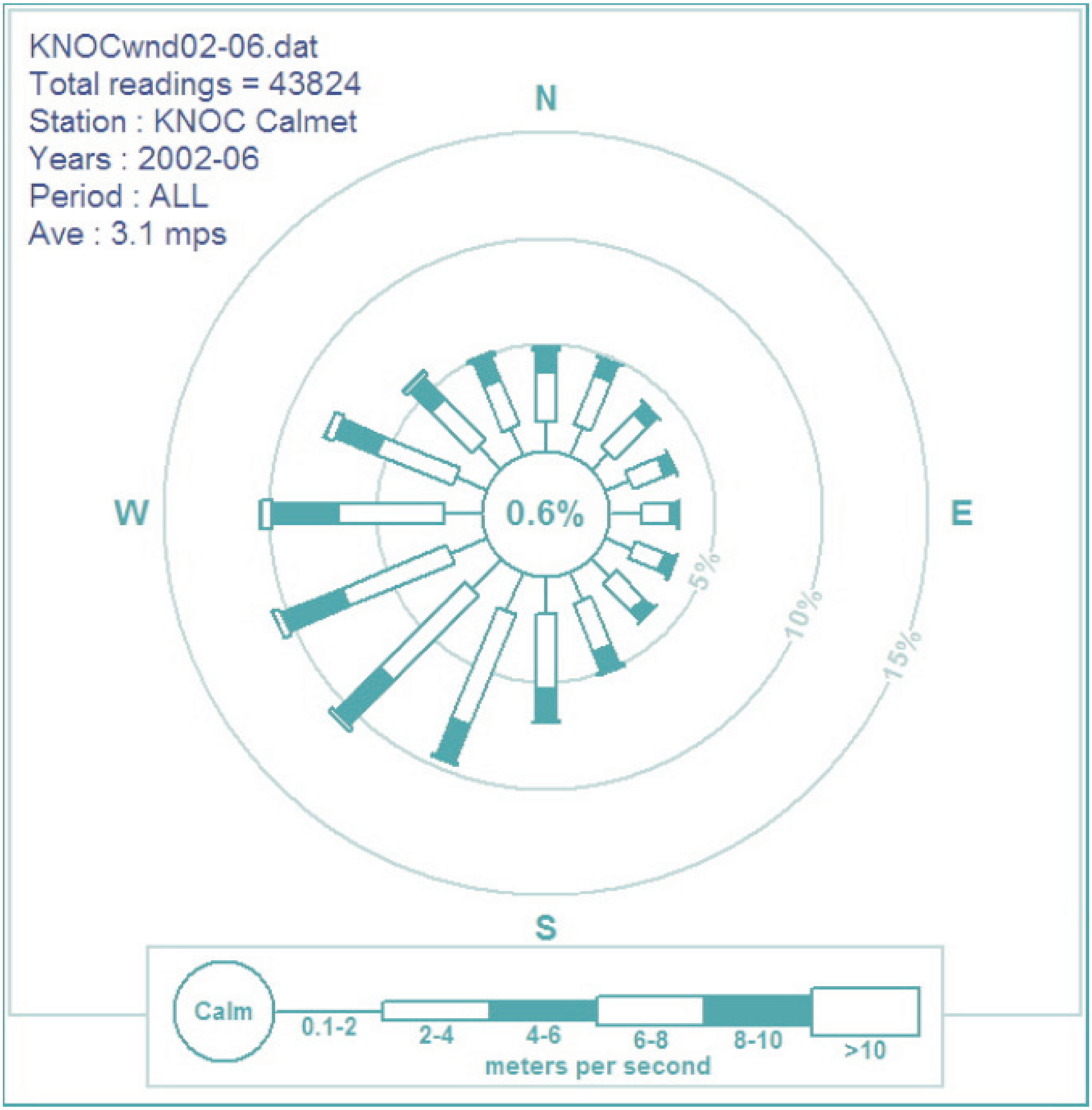

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BlackGold Expansion Project

CALMET Predicted Wind at the Project

DATE: December 2009	Fig04.05-03 WindRose Project 09-12-17	Figure 4.5-3
PROJECT: CE03745/200	DRAWN BY: AMEC	
ANALYST: KW / QA/QC: KW RK DR	PREPARED BY: AMEC	

Table 4.5-1: Project Inclusion List for the Air Quality Assessment

Status	Baseline
Existing and Approved	• Albian Sands Muskeg River Mine & Expansion • Birch Mountain Quarry • CNRL Horizon Oil Sands Project • CNRL Kirby • Connacher Great Divide • ConocoPhilips Surmont • Deer Creek (Total) Joslyn • Devon Jackfish 1 & 2 • EnCana Christina Lake • EnCana Foster Creek Pilot, Phase 1 & 2 • Husky Sunrise • IOL Kearl Lake Mine • JACOS Hangingstone Pilot • MEG Christina Lake Phase 1 & 2 • Northlands Forest Products • OPTI/Nexen Long Lake Phases 1 & 2 • Petro-Canada MacKay River • Petro-Canada/UTS Fort Hills • Shell Jackpine Mine Phase 1 • StatoilHydro Kai Kos Dehseh Demonstration • Suncor Firebag • Suncor Millennium • Suncor Voyageur • Syncrude Aurora North • Syncrude Aurora South • Syncrude Mildred Lake • Whitesands Pilot & May River • Williams Energy Fort McMurray Plant • Gas Production Facilities • Communities

Table 4.5-2 summarizes the emission rates of criteria air contaminants (CACs) and total VOCs for the baseline scenario.

Table 4.5-2: Summary of Regional Emissions in the AQRSA

Baseline Operation	SO_2 (t/d)	NO_x (t/d)	CO (t/d)	Total VOC (t/d)	$PM_{2.5}$ (t/d)
Albian Sands Muskeg River	0.61	31.81	27.10	26.85	1.64
Birch Mountain Muskeg Valley Quarry	16.81	28.53	14.10	3.03	1.35
CNRL Horizon	16.0	47.45	33.34	73.65	2.31
CNRL Kirby	1.99	2.88	2.45	0.17	0.22
Connacher Great Divide SAGD	0.08	0.49	0.40	0.00	0.04
ConocoPhillips Surmont Pilot & SAGD	0.32	0.80	1.18	0.00	0.08
Deer Creek Joslyn SAGD	0.74	0.51	0.48	0.03	0.04
Devon Jackfish	3.96	4.02	2.72	0.12	0.24
EnCana Christina Lake	6.33	1.89	1.59	0.09	0.09
EnCana Foster Creek	3.00	5.96	7.03	0.00	0.32
Husky Sunrise	1.10	6.68	20.66	0.20	0.00
IOL/Exxon-Mobil Kearl Lake	0.66	42.69	28.60	156.71	1.97
JACOS Hangingstone	0.81	0.68	0.52	0.03	0.02
MEG Christina Lake Phase 1 & 2	1.87	6.48	4.33	0.21	0.37
Northlands Forest Products	0.02	0.19	25.00	1.71	0.19
OPTI/Nexen Long Lake North	18.41	10.90	8.94	0.47	0.78
Petro-Canada MacKay River	1.98	15.48	10.33	0.43	0.82
Petro-Canada/UTS Fort Hills	1.68	26.50	5.14	15.24	0.68
Shell Jackpine Mine Phase 1	0.33	18.27	12.23	17.98	0.85
StatoilHydro Kai Kos Dehseh Leismer Pilot	0.18	1.01	0.61	0.06	0.08
Suncor Baseplant, Millennium, Voyageur	65.18	90.70	54.55	215.52	7.60
Suncor Firebag	7.09	21.18	14.34	0.84	1.65
Syncrude Mildred Lake & Aurora	97.99	91.78	77.62	71.54	6.75
Whitesands Pilot & May River	0.08	0.04	9.23	0.00	0.00
Williams FMM Chemical Plant	0.01	0.02	0.02	0.26	0.01
Community and Highway Emissions	0.03	0.44	2.47	0.00	0.24
Gas Facilities	0.00	43.98	23.03	0.10	0.00
Total Baseline	**247.26**	**501.36**	**388.01**	**585.24**	**28.34**

4.5.5 Estimation of Regional VOC and PAHs Emissions

The emission rates for individual VOCs and PAHs species have not been obtained for all facilities, although total VOC emissions, as well as those for certain species, were available for the majority of facilities and emission sources. For sources where explicitly speciated VOC and PAHs emissions were unavailable, estimates were made using the methodology described in Appendix B4.

4.5.6 Baseline Modelling Results

As required by Alberta Environment modelling guidelines, the highest receptor value of a pollutant at the required rank and averaging period was extracted from results of each modelling year. At each receptor, the maximum among the five modelling years was determined.

A summary of the results representing the highest calculated concentration among all receptors is shown in Tables 4.5.3 to 4.5-6. Exceedances were seen in two pollutants: NO_2 and $PM_{2.5}$ at all averaging times for which standards exist. These exceedances occur in oil sand mining area north of Fort McMurray, where the many industrial and mining sources are located. The nearest predicted exceedance is about 150 km north of the KNOC facility.

4.5.6.1 Sulphur Dioxide

The regional SO_2 emissions on which the assessment was based were 247.26 t/d for the baseline scenario. The predicted concentrations are assessed by comparison with the AENV AAQOs. A summary of the predicted concentrations is shown in Table 4.5-3 and Figures 4.5-4 to 4.5-6. Full results are provided in Appendix B5.

Table 4.5-3: Maximum Predicted SO_2 Concentrations Associated with the Baseline Scenario

Maximum Predicted SO_2 Concentrations	Maximum RSA	Maximum LSA	AAAQO
1-h concentration (µg/m^3)	322	199	450
24-h concentration (µg/m^3)	92	52	150
Annual concentration (µg/m^3)	14	9	30

Notes:
Values that exceed the ambient objective are shown in boldface text.
The values do not include a background value.

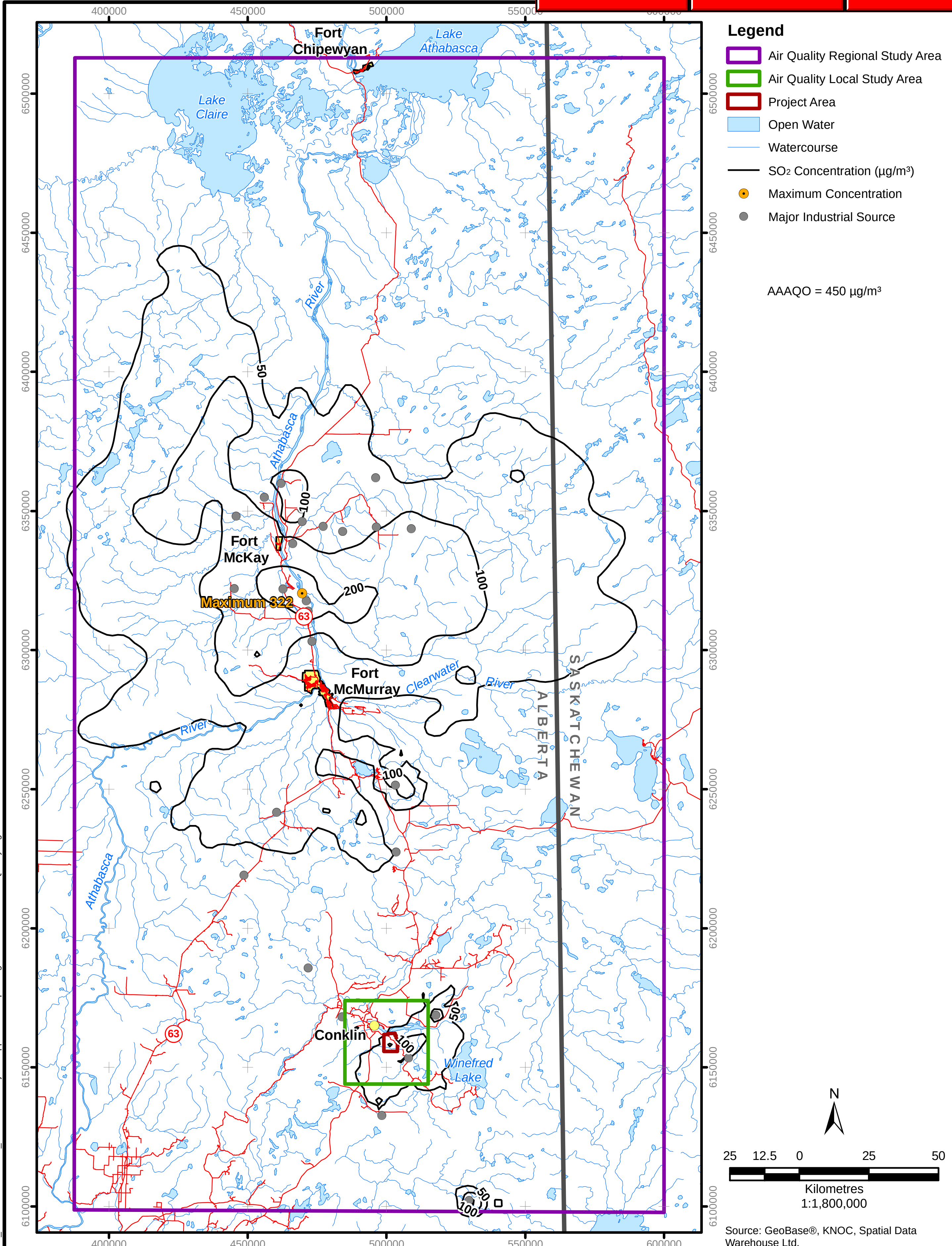
4.5.6.2 Nitrogen Oxides

The assessment was based on total regional NO_x emissions of 501.36 t/d for the baseline scenario. The predicted concentrations are assessed by comparison with the AENV AAQOs for NO_2. A summary of the predicted concentrations is shown in Table 4.5-4 and Figures 4.5-7 to 4.5-9. Full results are provided in Appendix B5.

Table 4.5-4: Maximum Predicted NO_2 Concentrations Associated with the Baseline Scenario

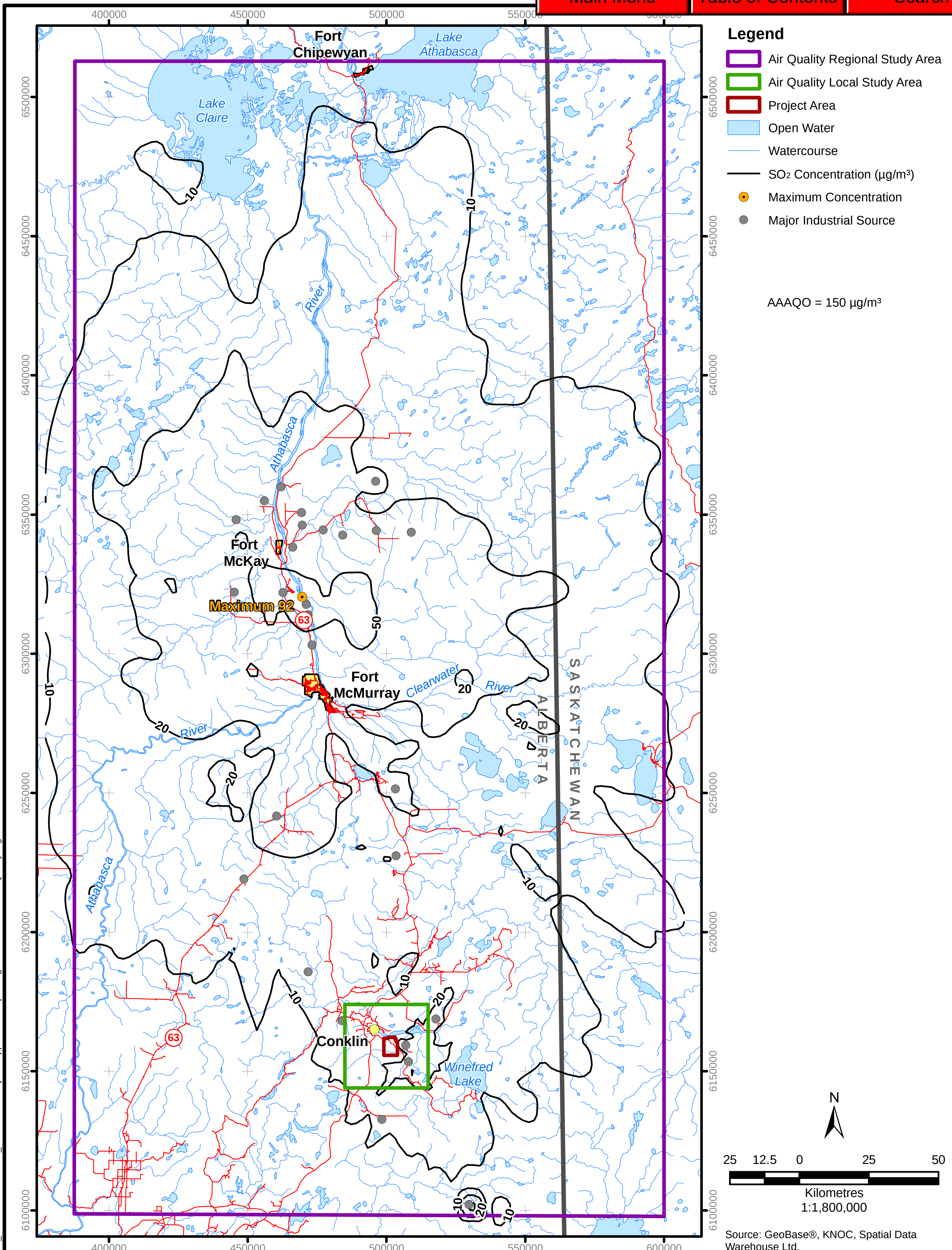
Maximum Predicted NO_2 Concentrations	Maximum RSA	Maximum LSA	AAAQO
1-h concentration (µg/m^3)	**748**	184	400
24-h concentration (µg/m^3)	**279**	32	200
Annual concentration (µg/m^3)	**110**	19	60

Notes:
Values that exceed the ambient objective are shown in boldface text.
The values do not include a background value.



Korea National Oil Corporation **BlackGold Expansion Project**	9th Highest 1-hour SO_2 Concentrations (µg/m³) Baseline Case	DATE: December 2010 PROJECT: CE03745/200 ANALYST: TR QA/QC: KW EA DR	Fig04.05-04 B SO2 1hour 10-03-25 PROJECTION/DATUM: UTM Zone 12 NAD83 DRAWN BY: AMEC PREPARED BY: AMEC

Figure 4.5-4



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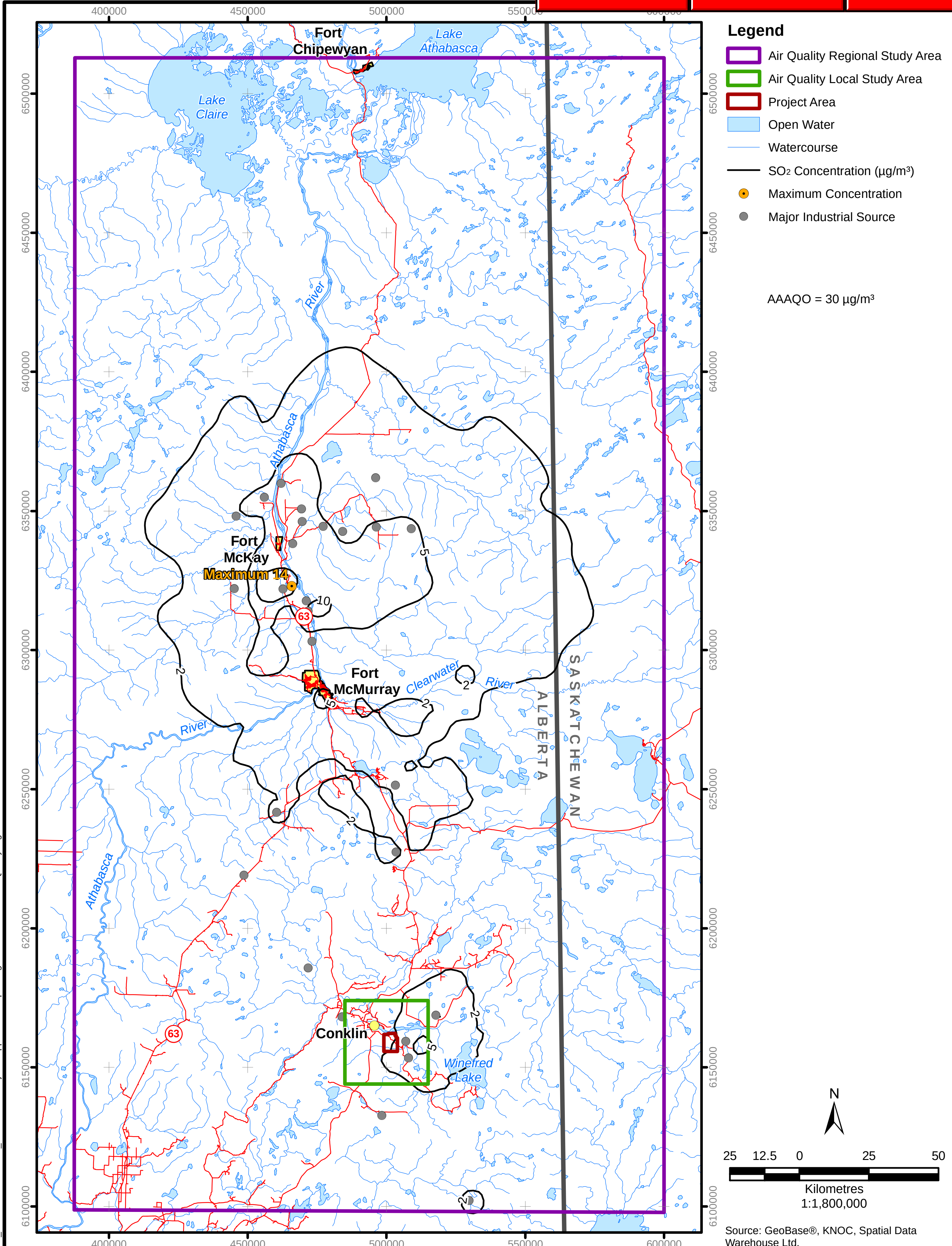
Korea National Oil Corporation

BlackGold Expansion Project

2nd Highest 24-hour SO_2 Concentrations (µg/m³) Baseline Case

DATE: March 2010	Fig04.05-05 B SO2 24hour 10-03-25	
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83	**Figure 4.5-5**
ANALYST: TR / QA/QC: KW EA DR	DRAWN BY: AMEC / PREPARED BY: AMEC	

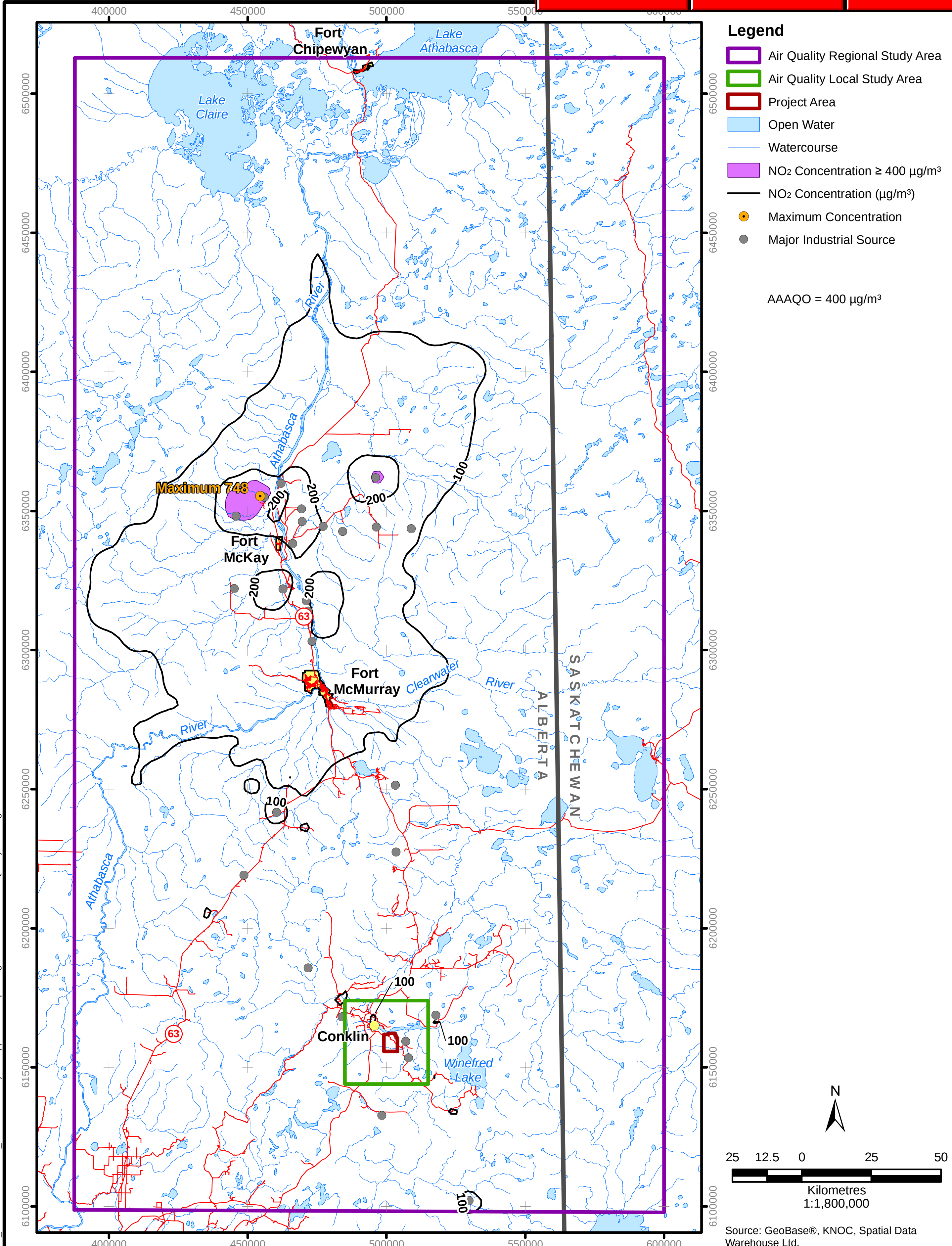


Korea National Oil Corporation

BlackGold Expansion Project

Annual Average SO_2 Concentrations (µg/m³) Baseline Case

DATE: March 2010	Fig04.05-06 B SO2 Annual 10-03-25	**Figure 4.5-6**
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TR; QA/QC: KW EA DR	DRAWN BY: AMEC; PREPARED BY: AMEC	

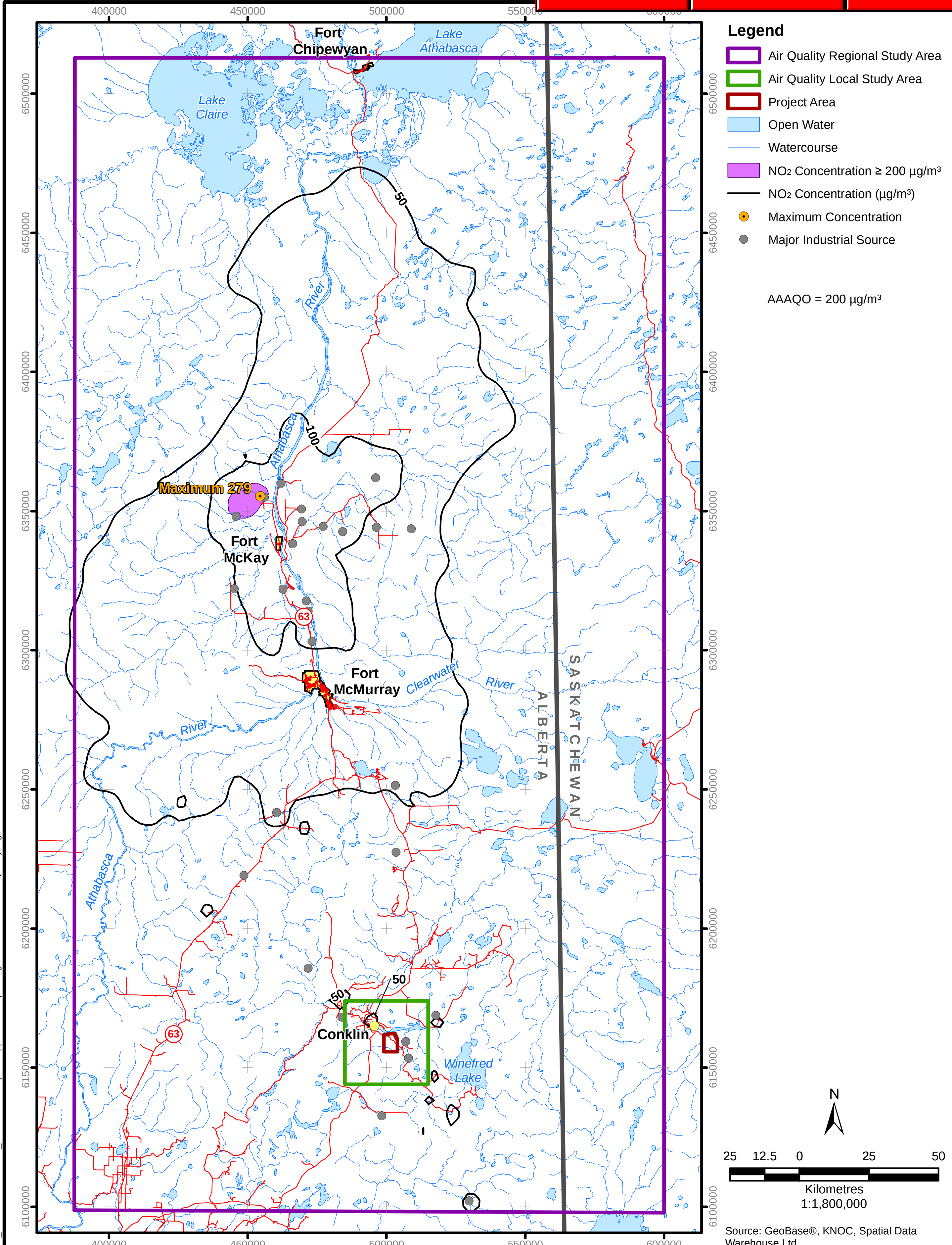


Korea National Oil Corporation

BlackGold Expansion Project

9th Highest 1-hour NO_2 Concentrations (µg/m³) Baseline Case

DATE: March 2010		Fig04.05-07 B NO2 1hour 10-03-31	Figure 4.5-7
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC



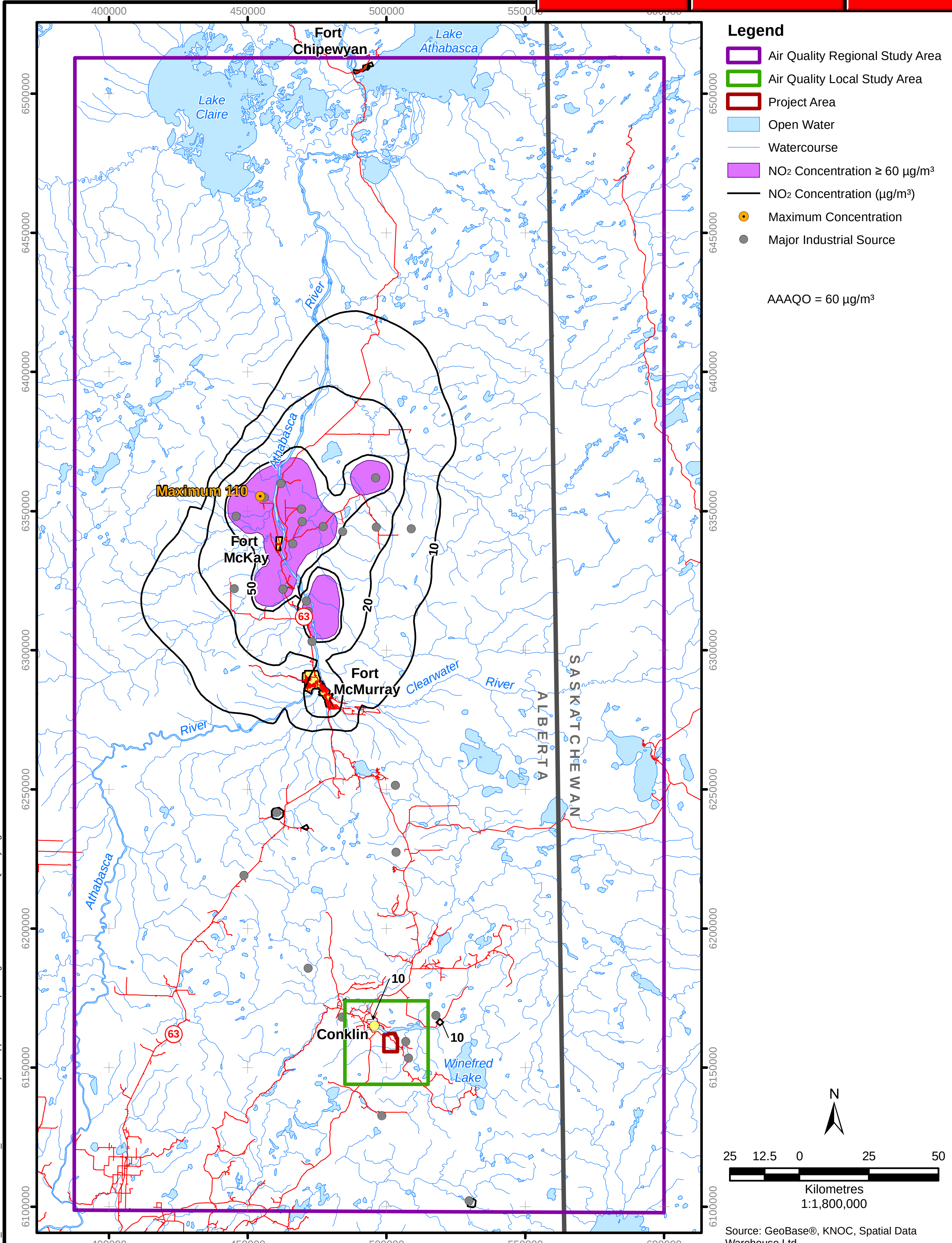
Korea National Oil Corporation

BlackGold Expansion Project

2nd Highest 24-hour NO_2 Concentrations (µg/m³) Baseline Case

DATE: March 2010		Fig04.05-08 B NO2 24hour 10-03-31	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.5-8



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Korea National Oil Corporation

BlackGold Expansion Project

Annual Average NO_2 Concentrations (µg/m³) Baseline Case

DATE: March 2010	Fig04.05-09 B NO2 Annual 10-03-31		Figure 4.5-9
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83		
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

4.5.6.3 Particulate Matter

For the impact assessment, total regional emissions of $PM_{2.5}$ emissions were estimated to be 28.34 t/d for the baseline scenario. Secondary $PM_{2.5}$ particulate after combustion (nitrates and sulphates) is generated within the CALPUFF model.

The predicted concentrations are assessed by comparison with the corresponding AAQG/CWS. The results include the sum of primary $PM_{2.5}$ and the secondary formation of sulphate and nitrate. A summary of the predicted concentrations is shown in Table 4.5-5 and Figures 4.5-10 to 4.5-11. Full results are provided in Appendix B5.

Table 4.5-5: Maximum Predicted $PM_{2.5}$ Concentrations Associated with the Baseline Scenario

Maximum Predicted $PM_{2.5}$ Concentrations	Maximum RSA	Maximum LSA	AAAQO
1-h concentration (µg/m^3)	**560**	6	80
24-h concentration (µg/m^3)	**164**	2	30

Notes:
Values that exceed the ambient objective are shown in boldface text.
The values do not include a background value.

4.5.6.4 Carbon Monoxide

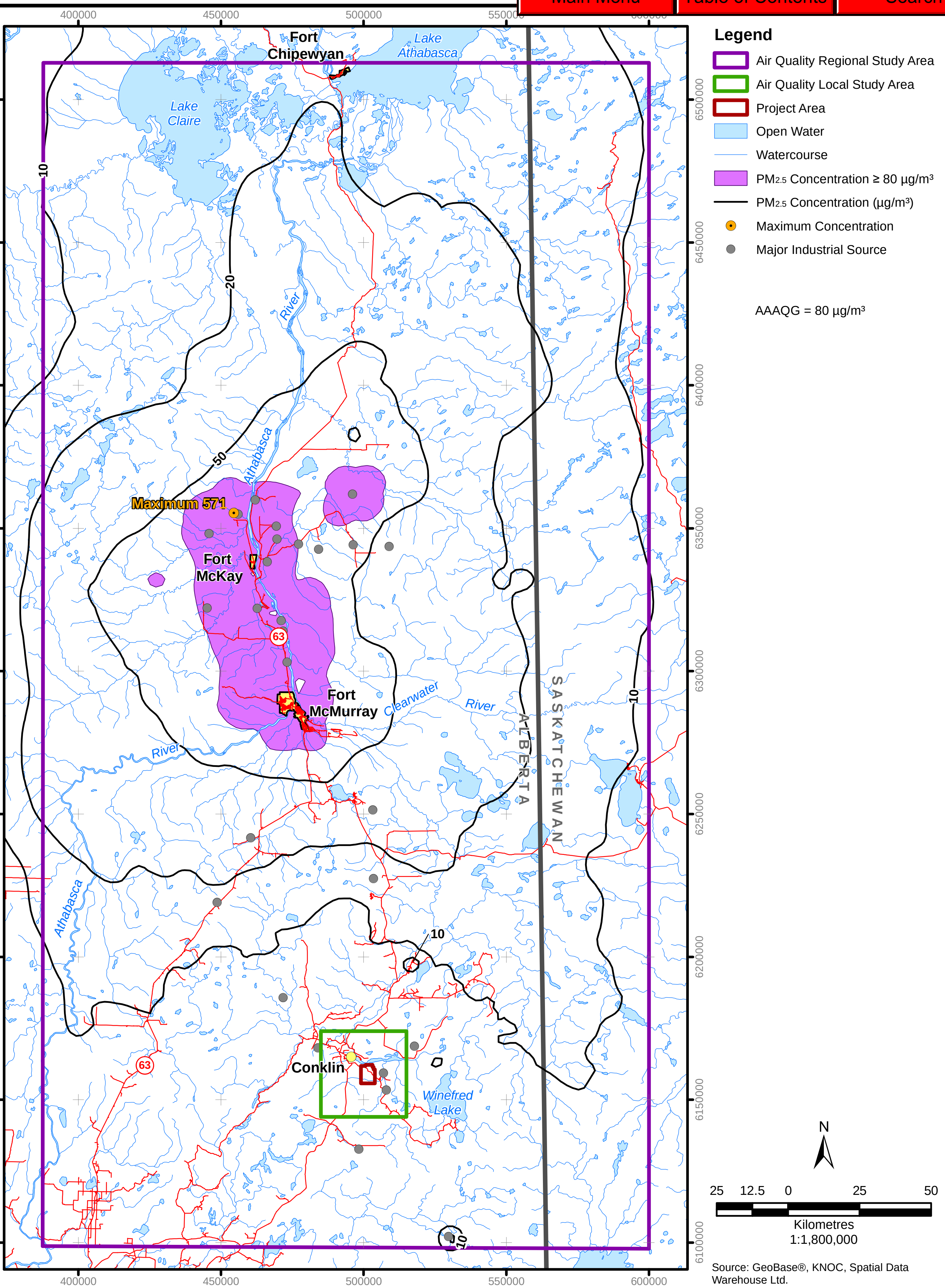
The CALPUFF model was used to estimate the concentration of CO that would occur for the baseline scenario. Total regional emissions for the baseline were 388.01 t/d.

Table 4.5-6 and Figures 4.5-12 to 4.5-13 summarize the CO modelling results. Full results are provided in Appendix B5.

Table 4.5-6: Maximum Predicted CO Concentrations Associated with the Baseline Scenario

Maximum Predicted CO Concentrations	Maximum RSA	Maximum LSA	AAAQO
1-h concentration (µg/m^3)	5 556	1 136	15 000
8-h concentration (µg/m^3)	3403	762	6 000

Notes:
Values that exceed the ambient objective are shown in boldface text.
The values do not include a background value.



Source: GeoBase®, KNOC, Spatial Data Warehouse Ltd.

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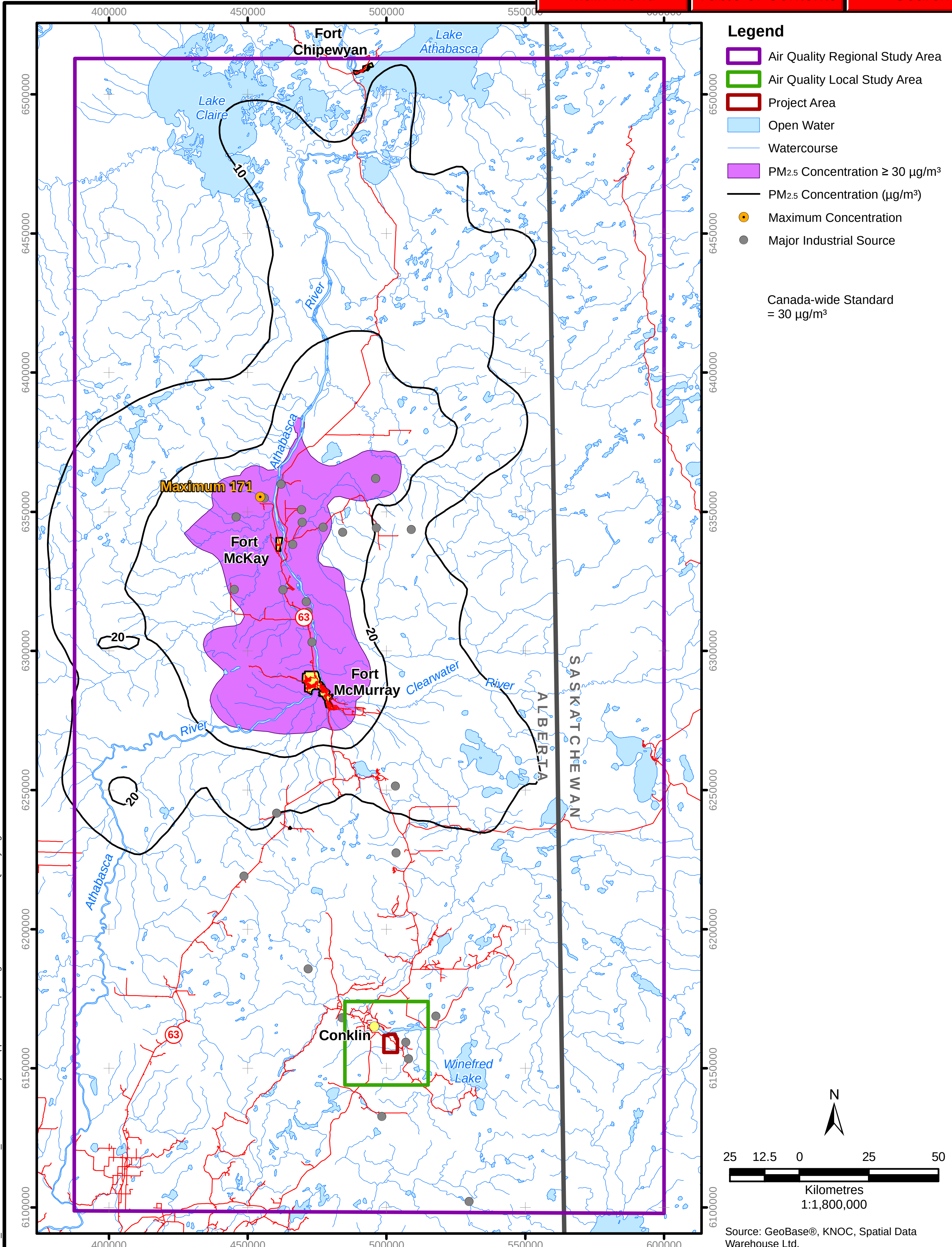
Korea National Oil Corporation

BlackGold Expansion Project

9th Highest 1-hour $PM_{2.5}$ Concentrations (µg/m³) Baseline Case

DATE: March 2010	Fig04.05-10 B PM25 1hour 10-03-31		**Figure 4.5-10**
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83		
ANALYST: TM; QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC	



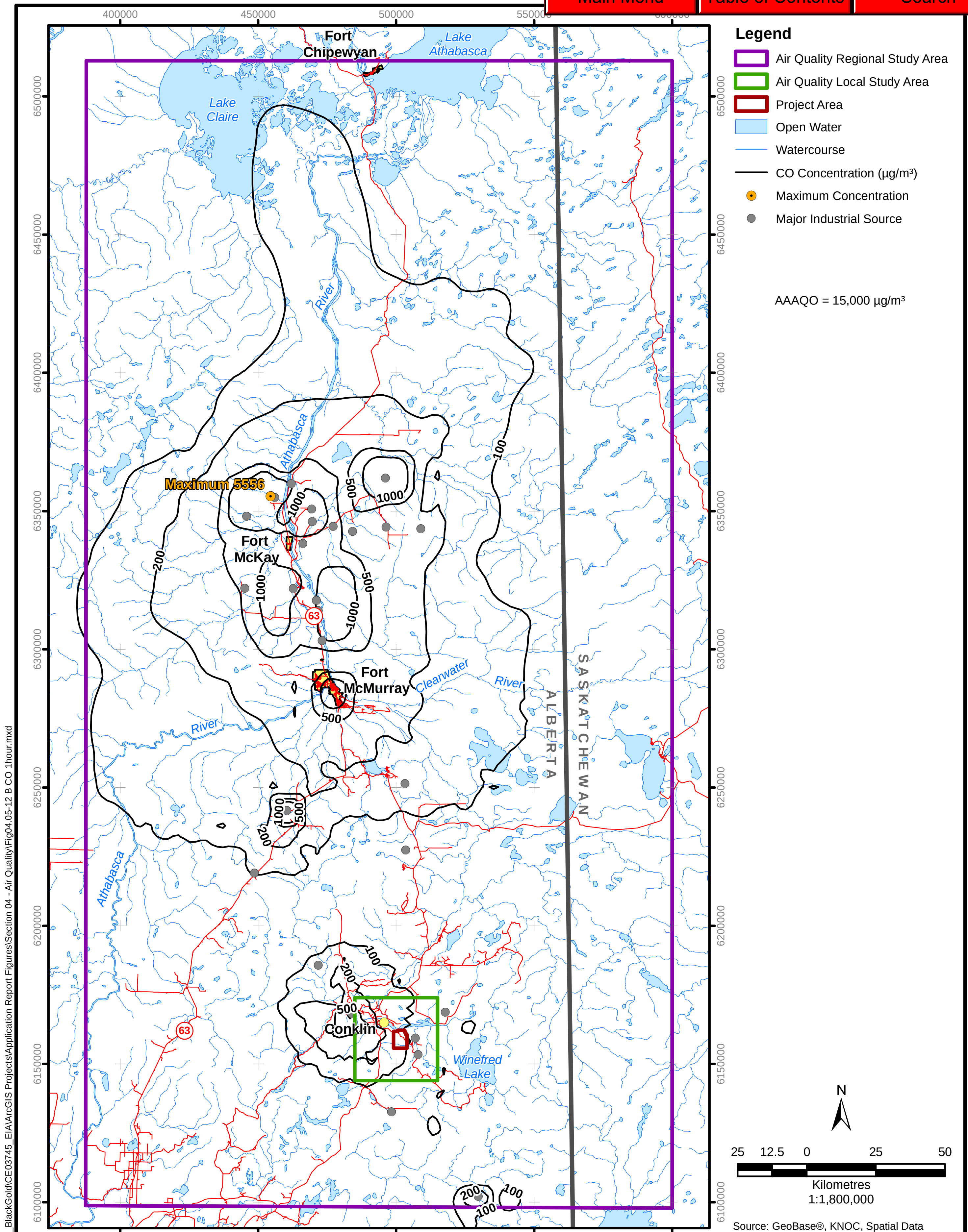
Korea National Oil Corporation

BlackGold Expansion Project

2nd Highest 24-hour $PM_{2.5}$ Concentrations (µg/m³) Baseline Case

DATE: March 2010	Fig04.05-11 B PM25 24hour 10-03-31	
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM / QA/QC: KW EA DR	DRAWN BY: AMEC / PREPARED BY: AMEC	

Figure 4.5-11



Korea National Oil Corporation

BlackGold Expansion Project

9th Highest 1-hour CO Concentrations (µg/m³) Baseline Case

DATE: March 2010	Fig04.05-12 B CO 1hour 10-03-31	
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83	**Figure 4.5-12**
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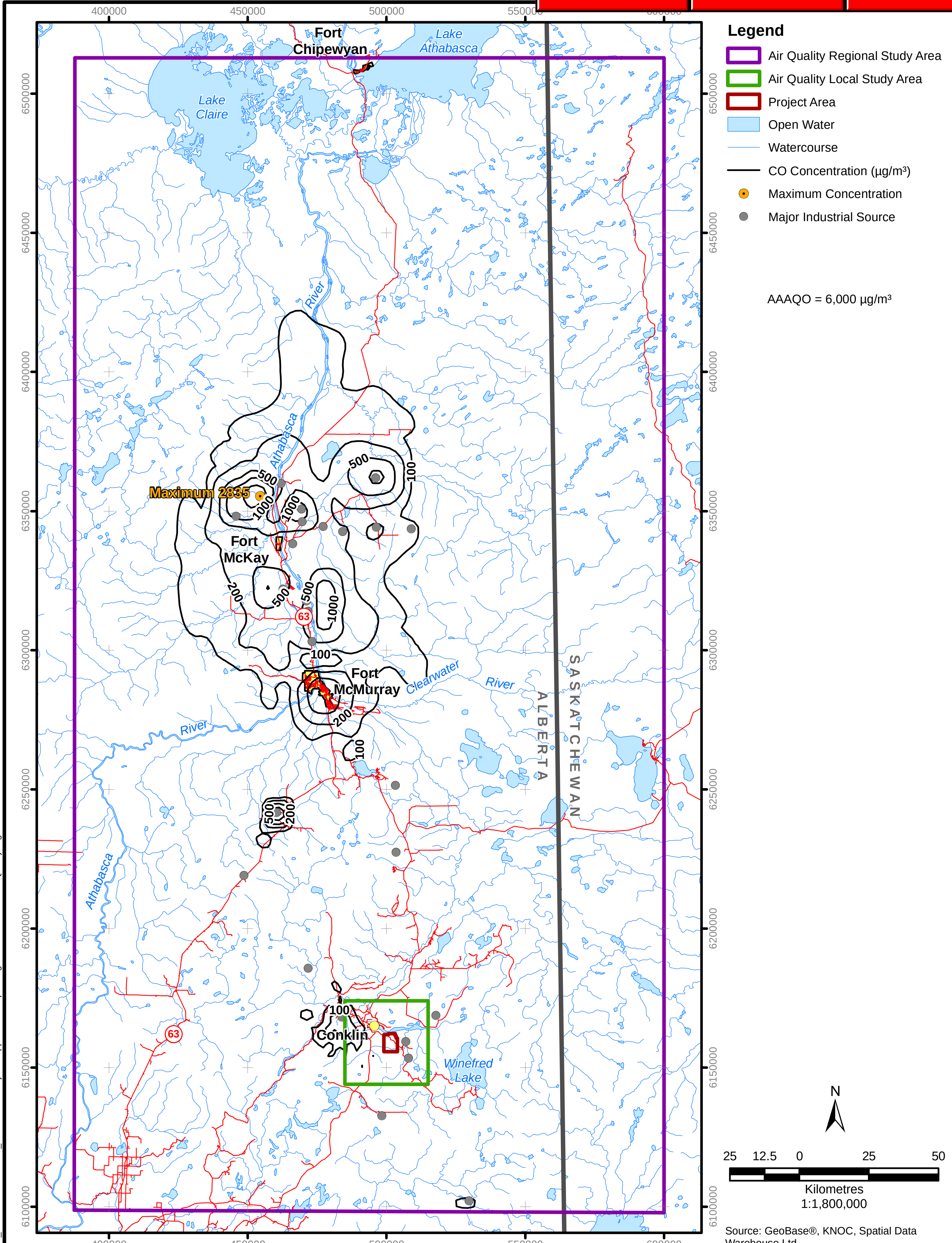

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Korea National Oil Corporation

BlackGold Expansion Project

2nd Highest 8-hour CO Concentrations (µg/m³) Baseline Case

DATE: March 2010		Fig04.05-13 B CO 8hour 10-03-31	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.5-13

4.5.6.5 Acid Deposition

Table 4.5-7 and Figure 4.5-14 provide a summary of the baseline modelling information for acid deposition. CALPUFF predictions are above the provincial critical load (0.25 keq H+/ha/y) in three grid cells (see Appendix B5) in the AQRSA for the baseline scenario. Because these results are determined using CALPUFF, not RELAD which has been run by AENV, they cannot be considered as being comparable to an environmental objective that was determined using RELAD. Therefore, these results are limited to the identification of areas potentially at risk of becoming acidified. Further details are provided in Appendix B5.

Table 4.5-7: Maximum Predicted PAI Associated with the Baseline Scenario

Maximum Predicted PAI	Maximum RSA	Maximum LSA	Critical Loads (1° by 1° Scale)
Sulphate (keq H^+/ha/y)	2.43	1.11	–
Nitrate (keq H^+/ha/y)	12.30	0.29	–
PAI (no background) (keq H^+/ha/y)	13.12	0.58	0.25 to 1.00
PAI (with background) (keq H^+/ha/y)	13.13	0.59	0.25 to 1.00

Notes:

The sulphate and nitrate values do not include background.
Regional background PAI is based on ambient monitoring in the region (Section 4.4).
The maximum sulphate and nitrate are not additive since they occur at different locations.
Monitoring Loads include low, moderate and sensitive receptors (CASA and AENV 1999).

The effects of acid deposition to lakes are assessed in Section 8.0 and to soils in Section 10.0.

4.5.6.6 Nitrogen Deposition

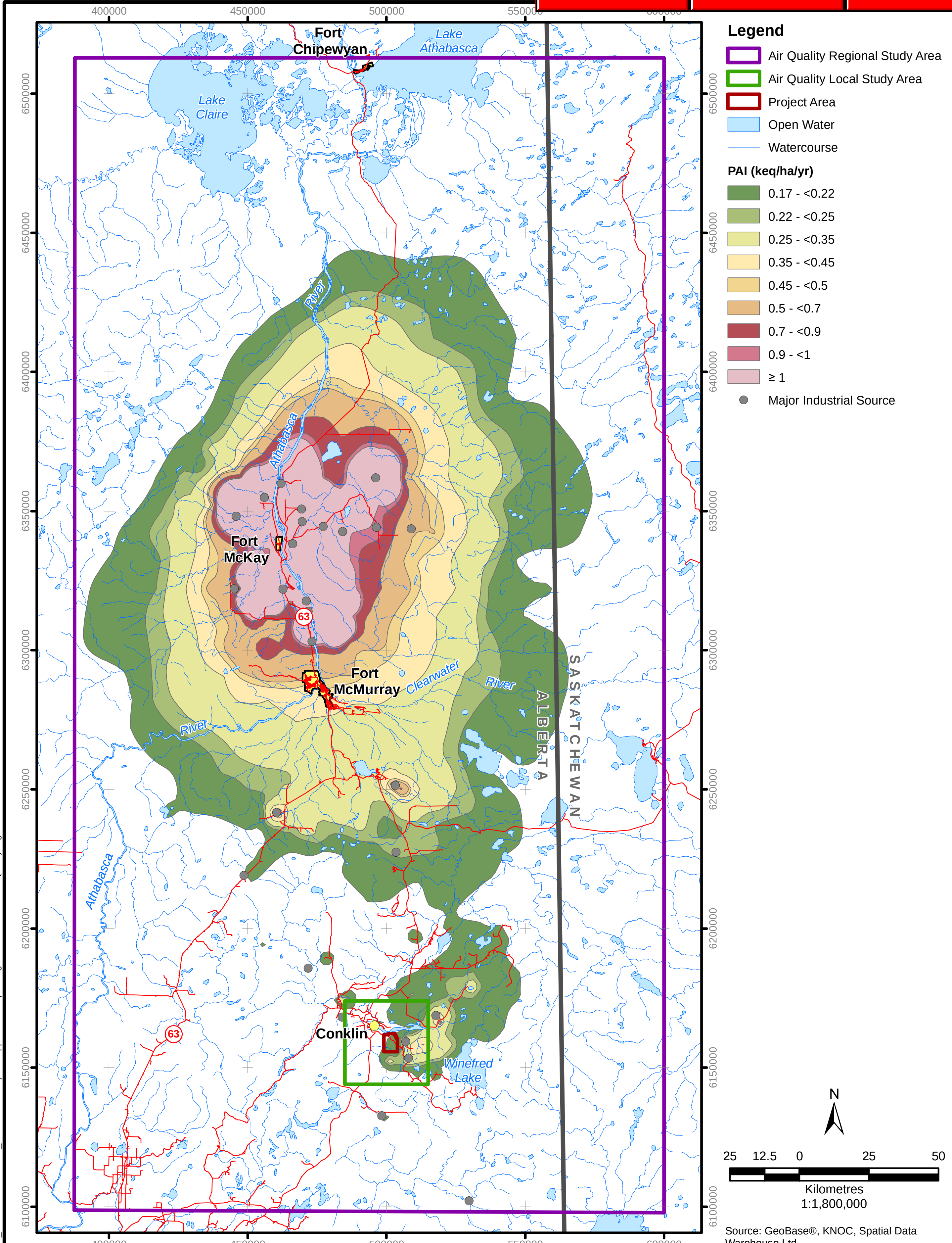
Table 4.5-8 and Figure 4.5-15 provide the model results for nitrogen deposition in the baseline scenario and compare the results to representative critical loads. Further details are provided in Appendix B5.

Table 4.5-8: Maximum Predicted Nitrogen Deposition Associated with the Baseline Scenario

Maximum Predicted Nitrogen Deposition	Maximum RSA	Maximum LSA	Critical Loads (1° by 1° Scale)
Nitrogen Deposition (kg/ha/y)	172	4	5 to 20

Notes:
The sulphate and nitrate values do not include background.
Regional background PAI is based on ambient monitoring in the region (Section 4.4)
The maximum sulphate and nitrate are not additive since they occur at different locations.
Critical loads depend on land use and vegetation (WHO 2000).

The estimates of N deposition are extreme predictions, in that all available nitrogen is assumed to contribute fully to acid deposition, eutrophication and O_3 production simultaneously.



Korea National Oil Corporation

BlackGold Expansion Project

PAI (keq/ha/yr)
Baseline Case

DATE:	Fig04.05-14 PAI Baseline 10-03-25	
March 2010		
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.5-14

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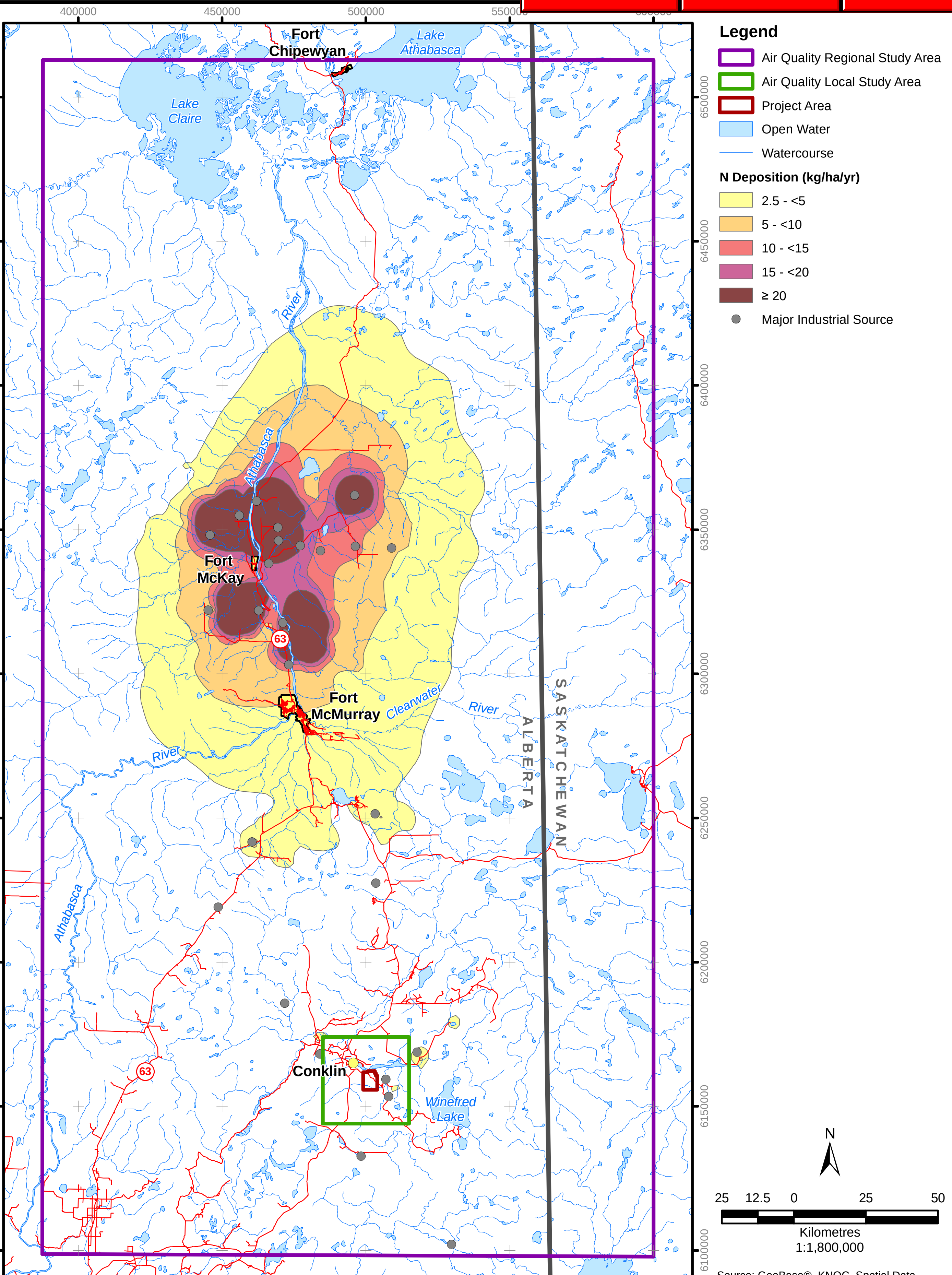

Source: GeoBase®, KNOC, Spatial Data Warehouse Ltd.

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BlackGold Expansion Project

Nitrogen Deposition (kg/ha/yr)
Baseline Case

DATE: March 2010		Fig04.05-15 N Baseline 10-03-25	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.5-15

4.5.6.7 Ozone

There is a potential for the photochemical production of ground-level O_3 from emissions of anthropogenic NO_x, anthropogenic VOC, and biogenic VOC compounds. The potential is greatest during summer periods characterized by high ambient temperatures and stagnant weather conditions (i.e., low wind speeds). The potential is considered to be greatest when temperatures are above 30°C but O_3 was observed to be formed in oil sands plumes at lower temperatures (AMEC 2004). The potential for photochemical production of ground-level O_3 exists for a relatively small number of hours each year.

Photochemical models can be used to predict the secondary formation of O_3 based on precursor emissions and meteorological conditions. These models, in particular CALGRID, have been applied to the Athabasca oil sands region (Syncrude 1998) to determine the potential for O_3 formation due to the developments proposed for the region. The modelling was conducted for summer periods with the highest potential for photochemical production, when regional biogenic VOC emissions were assumed to be 1 087 t/d. The results (based on Davies and Fellin 1999) show an increasing trend in O_3 concentration with increasing emissions (Table 4.5-9).

Table 4.5-9: CALGRID Predictions of Maximum O_3 Concentration

NO_x Emission (t/d)	Anthropogenic VOC Emissions (t/d)	Maximum Predicted O_3 (ppb)
3.7	0	65
74	172	92
111	212	104
222	435	111

4.5.6.8 Volatile Organic Compounds and Polycyclic Aromatic Hydrocarbons Concentrations

Predictions of the impact of VOC and PAHs emissions at community and recreational locations near the project are presented here and provide input data for the Human Health Risk Assessment (Section 18.0). The chemical compounds assessed in the section have been identified as those emitted by the project that may potentially have a deleterious effect on human health if present in air in sufficient concentrations. As such, these compounds were modelled to determine the maximum hourly, daily and annual concentration at community and recreation receptors located near the proposed project. The VOCs and PAHs assessed, including groupings of compounds, are listed in Table 4.5-10.

Table 4.5-10: VOCs and PAHs Considered in Assessment

Chemical Name		
Benzene	3-Methylcholanthrene	Chrysene
Napthalene	7,12-Dimethylbenz(a)anthracene	Dibenzo(a,h)anthracene
Toluene	Acenapthalene	Dichlorobenzene
Xylenes	Acenaphthylene	Fluoranthene
Aliphatics	Acetaldehyde	Fluorene
Aromatics	Acrolein	Formaldehyde
RSC	Anthracene	Indeno(1,2,3-cd)pyrene
Thiophenes	Benzo(a)anthracene	n-hexane
Mercaptans	Benzo(a)pyrene	n-pentane
Ethyl Benzene	Benzo(b)fluoranthene	Phenanthrene
1,3-Butadiene	Benzo(k)fluoranthene	Pyrene
2-Methyl Napthalene	Benzo(g,h,i)perylene	

Since VOC emissions of community, transportation and industrial sources were all incorporated into the modelling, no additional ambient background concentrations for VOC species were added. Natural VOC emissions (or resulting concentrations) were not included.

4.6 Potential Impacts and Mitigative Measures

4.6.1 Project Emissions

4.6.1.1 Introduction

This section addresses the potential impacts of the project at full production capacity including 10,000 b/d from the Initial Project and 20,000 b/d from the Expansion Project. Facility emissions will interact with emissions from other existing and approved sources in the AQLSA and AQRSA.

4.6.1.2 Mitigative Measures

KNOC's engineering design estimates were applied to identify and quantify emissions from the project. Emission sources are classified as combustion sources and fugitive plant sources.

4.6.1.3 Combustion Sources

The SO_2 emitted from the project will vary with produced gas flow rate and H_2S content. Other combustion products such as NO_X, CO, VOC and $PM_{2.5}$ are less dependent on the fuel composition and are more dependent on the combustion process. Relative to the use of other fossil fuels (e.g., oil or coal), natural gas is a clean burning fuel. Continuously operating combustion sources at the proposed plant include:

- four steam generator boilers;
- two glycol heaters; and
- two flare pilots.

During upset conditions, a flare stack will be used to dispose of unwanted gas streams. Upset flaring will be infrequent and short in duration. An emergency generator will be used to provide electrical power during periods of power outages.

The following design features were used to reduce combustion emissions from the proposed facility:

- the centralization of emissions from the field to the plant will result in lower impact compared to that from scattered sources (e.g., individual well pad flares) due to greater dispersion potential associated with central plant emission points;
- the combustion of produced gas in the boilers, rather than a flare, offers the advantage of more reliable and complete combustion, reducing the opportunity for the formation of incomplete combustion products;
- the use of produced gas in the boilers replaces natural gas that would otherwise be required; and
- the steam boilers will use low NO_x burners. KNOC will ensure that the proposed boilers will meet the NO_x emission levels specified in CCME (1998).

Combustion emissions are proportional to the amount of fuel gas used. KNOC is taking a number of steps to efficiently use fuel and implement technologies to reduce emissions. These steps include the following:

- steam generators will be designed to operate at a high efficiency (i.e., above 84% on a high heating value basis); and
- steam lines will be insulated to minimize heat losses associated with the transport of steam to the pads.

4.6.1.4 Fugitive Sources

Fugitive hydrocarbon emissions can result from various connection leaks (i.e., valve packing and pipe flanges), venting associated with maintenance activities or venting associated with short-duration outages of vapour-recovery compressors. The following specific items will be installed:

- a plant vapour recovery system for the facility tankage; and
- partial redundancy in compressors for the plant vapour recovery system to minimize emissions in the event of a compressor upset.

Table 4.6-1 provides the estimated potential fugitive hydrocarbon emissions for the project.

Table 4.6-1: KNOC Project Estimated Fugitive Emissions

Facility Component	CO_2 (t/d)	CH_4 (t/d)	VOC (t/d)	THC (t/d)
Central Plant	0.007	0.753	0.015	0.768

Notes:

CO_2 = Carbon Dioxide.
CH_4 = Methane.
VOC = Volatile Organic Compounds (propane and all heavier hydrocarbons).
THC = Total Hydrocarbon (all hydrocarbons; i.e*.,* VOC plus methane and ethane).

4.6.1.5 Results

Table 4.6-2 provides the estimated project emissions and compares AQRSA and AQLSA emission totals for the baseline and the application assessment scenarios. The change values provided in the table represent the increases due to the addition of the project relative to the baseline scenario. The following are noted:

- in the AQRSA, the project contribution to emissions is in the 0.0 to 0.4% range relative to the baseline, depending on the compound; and
- in the AQLSA, the project contribution to emissions is in the 1.6 to 15.6% range relative to the baseline, depending on the compound.

Table 4.6-2: Study Area Emission Changes Due to the Project

Scenario	SO_2	NO_x	CO	VOC	$PM_{2.5}$
Project					
Project Only (t/d)	1.00	1.24	0.91	0.04	0.13
RSA					
Baseline (t/d)	247.62	505.96	414.14	585.24	30.85
Application (t/d)	248.62	507.20	415.05	585.28	30.98
Increase Due to Project (%)	0.4	0.2	0.2	0.0	0.3
LSA					
Baseline (t/d)	10.29	8.63	5.84	2.44	3.82
Application (t/d)	11.29	9.87	6.75	2.48	3.95
Increase Due to Project (%)	9.7	14.3	15.6	1.6	3.4

4.6.2 Project Impacts

4.6.2.1 Introduction

The addition of the project will increase emissions within the AQLSA and AQRSA, leading to an increase in ground-level concentrations. The comparison of the predicted baseline and application scenario concentrations shows the project contribution to SO_2, NO_2 and $PM_{2.5}$ concentrations and PAI. The maximum predicted concentrations associated with the application scenario are shown in Table 4.6-3.

Table 4.6-3: Maximum Predicted SO_2, NO_2, $PM_{2.5}$ and CO Concentrations, and PAI and Nitrogen Deposition Values Associated with the Application Scenario

Maximum Predicted Concentrations	Maximum RSA	Maximum LSA	AAAQO
SO_2			
1-h concentration ($\mu g/m^3$)	322	199	450
24-h concentration ($\mu g/m^3$)	92	53	150
Annual concentration ($\mu g/m^3$)	13.6	9.3	30
NO_2			
1-h concentration ($\mu g/m^3$)	**748**	184	400
24-h concentration ($\mu g/m^3$)	**279**	111	200
Annual concentration ($\mu g/m^3$)	**109.7**	18.7	60
$PM_{2.5}$			
1-h concentration ($\mu g/m^3$)	**560**	5.9	80
24-h concentration ($\mu g/m^3$)	**164**	2.2	30
CO			
1-h concentration ($\mu g/m^3$)	5556	1136	15 000
8-h concentration ($\mu g/m^3$)	2835	468	6 000

Notes:
Values that exceed the ambient objective are shown in boldface text.
The values do not include a background value.

Maximum Predicted PAI (small-scale grid)	Maximum RSA	Maximum LSA	Critical Loads (1° by 1° scale)
Sulphate (keq H^+/ha/yr)	2.43	1.12	–
Nitrate (keq H^+/ha/yr)	12.31	0.29	–
PAI (no background) (keq H^+/ha/yr)	13.12	0.58	0.25 to 1.00
PAI (with background) (keq H^+/ha/yr)	13.13	0.59	0.25 to 1.00

Notes:
The sulphate and nitrate values do not include a background value.
The background PAI is based on the Alberta Environment (Cheng 2001) predicted deposition contours.
The maximum sulphate and nitrate values are not additive, since they may occur at different locations.
The PAI critical loads (as defined by CASA and AENV 1999) include low, moderate and sensitive receptors

Maximum Predicted Nitrogen Deposition (small-scale grid)	Maximum RSA	Maximum LSA	Critical Loads (1° by 1° scale)
Nitrogen Deposition (kg/ha/yr)	172	4	5 to 20

Notes:
Values do not include background.
Critical loads depend on land use and vegetation (WHO 2000).

4.6.3 Sulphur Dioxide Emissions and Impacts

4.6.3.1 Introduction

SO_2 emissions due to the project result from the combustion of produced gas, which contains H_2S. Maximum ambient SO_2 concentration patterns are evaluated for the three averaging periods associated with the ambient air quality objectives (1-h, 24-h and annual).

4.6.3.2 Results

<u>SO_2 Concentrations Due to Routine Project Operations</u>

A comparison of Baseline and Application scenario predictions is presented in Table 4.6-4 and as contours for the three respective averaging periods (Figures 4.6-1 to 4.6-3). The maximum predicted SO_2 concentrations do not exceed the corresponding ambient air quality guidelines in the AQLSA or the AQRSA.

Table 4.6-4: Maximum SO_2 Concentrations Due to the Project

Scenario	RSA			LSA		
	1-h	24-h	Annual	1-h	24-h	Annual
Baseline ($\mu g/m^3$)	322	92	13.6	199	52.5	9.2
Application ($\mu g/m^3$)	322	92	13.6	199	52.7	9.3
Increase Due to Project (%)	<1	<1	<1	<1	<1	+1.7
Objective ($\mu g/m^3$)	450	150	30	450	150	30

Notes:
The values do not include a background value.

The maximum predicted SO_2 concentrations for both scenarios do not exceed the 1-h, 24-h or annual average ambient air quality objectives in the AQRSA or AQLSA. For the maximum predicted concentrations in the AQRSA, the project contribution to these maxima is minimal (i.e., 1% or less). In the AQLSA, the project contribution increases the maximum by up to 1.7% for the annual average SO_2 concentration.

The concentration contour plots for the three averaging periods for the application scenario are shown in the following figures:

- Figure 4.6-1 shows the maximum *1-h average SO_2* concentrations for the application scenario. The differences between the predicted baseline and application concentrations external to the AQLSA are minimal. Within the AQLSA, there are slight changes due to the addition of the project SO_2 emissions.

- Figure 4.6-2 shows the maximum *24-h average SO_2* concentrations for the application scenario. The differences between the predicted baseline and application concentrations external to the AQLSA are minimal. Within the AQLSA, there are slight changes due to the addition of the project SO_2 emissions.

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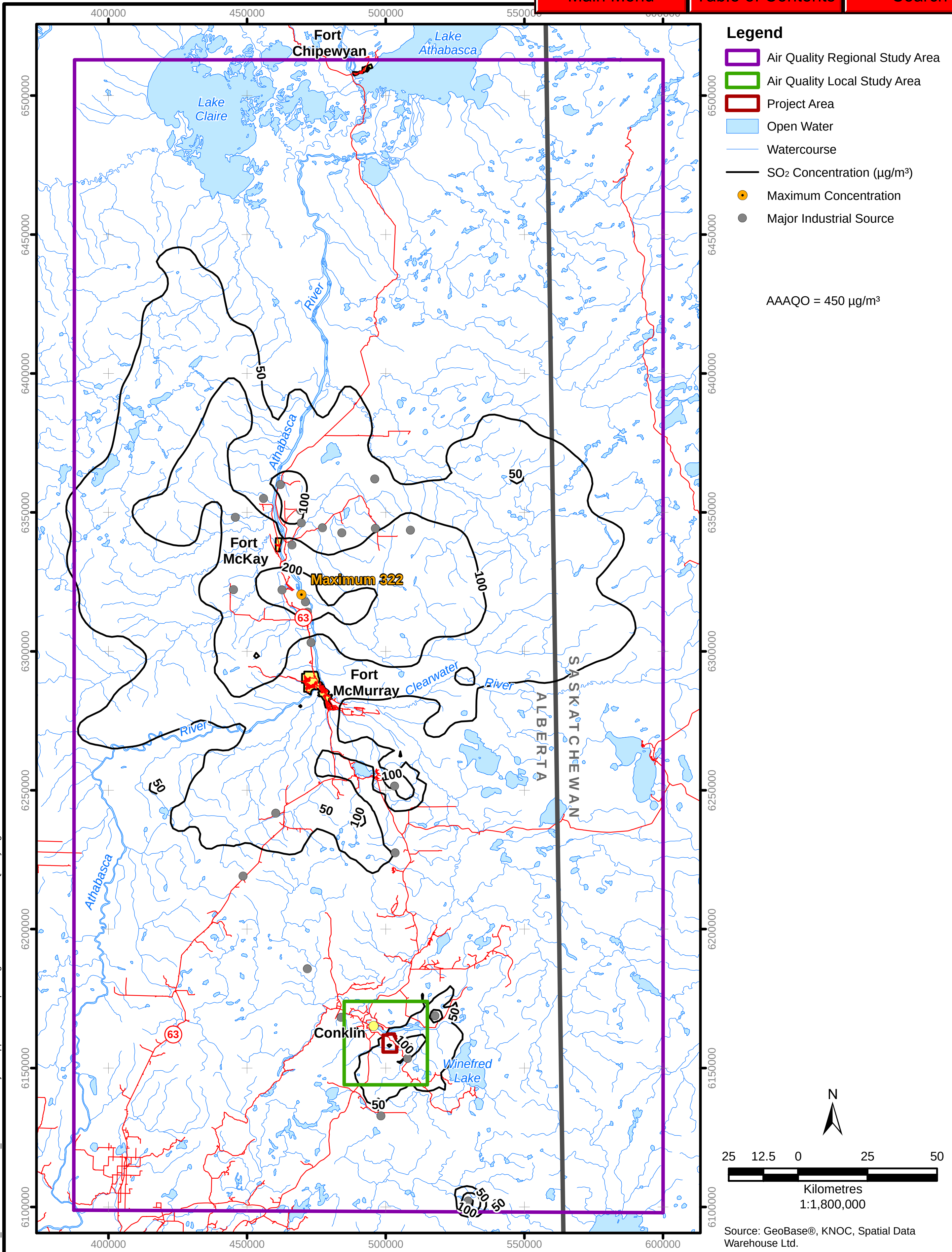

Korea National Oil Corporation

BlackGold Expansion Project

9th Highest 1-hour SO_2 Concentrations (µg/m³) Application Case

DATE: March 2010		Fig04.06-01 AC SO2 1hour 10-03-02	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: CF	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.6-1

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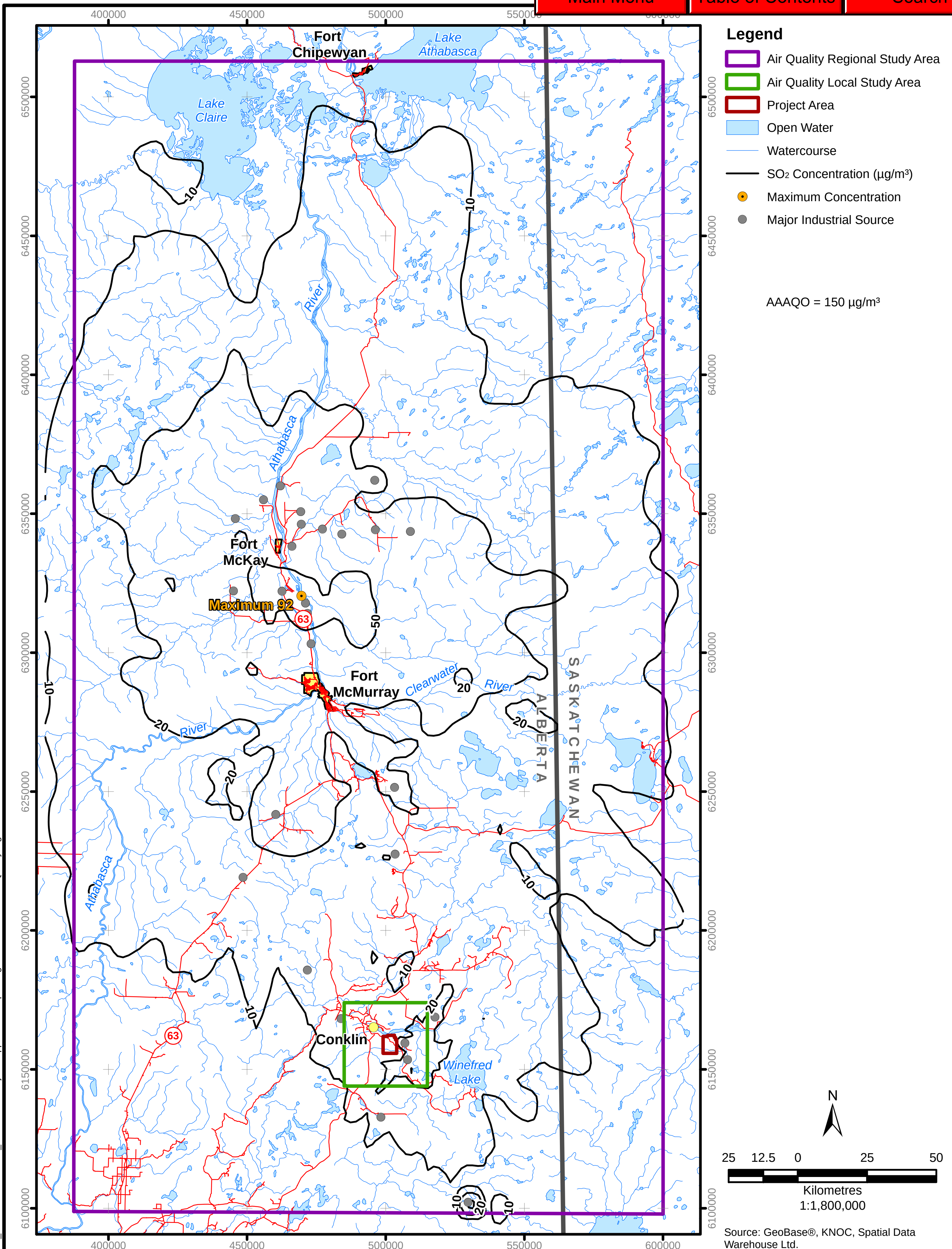

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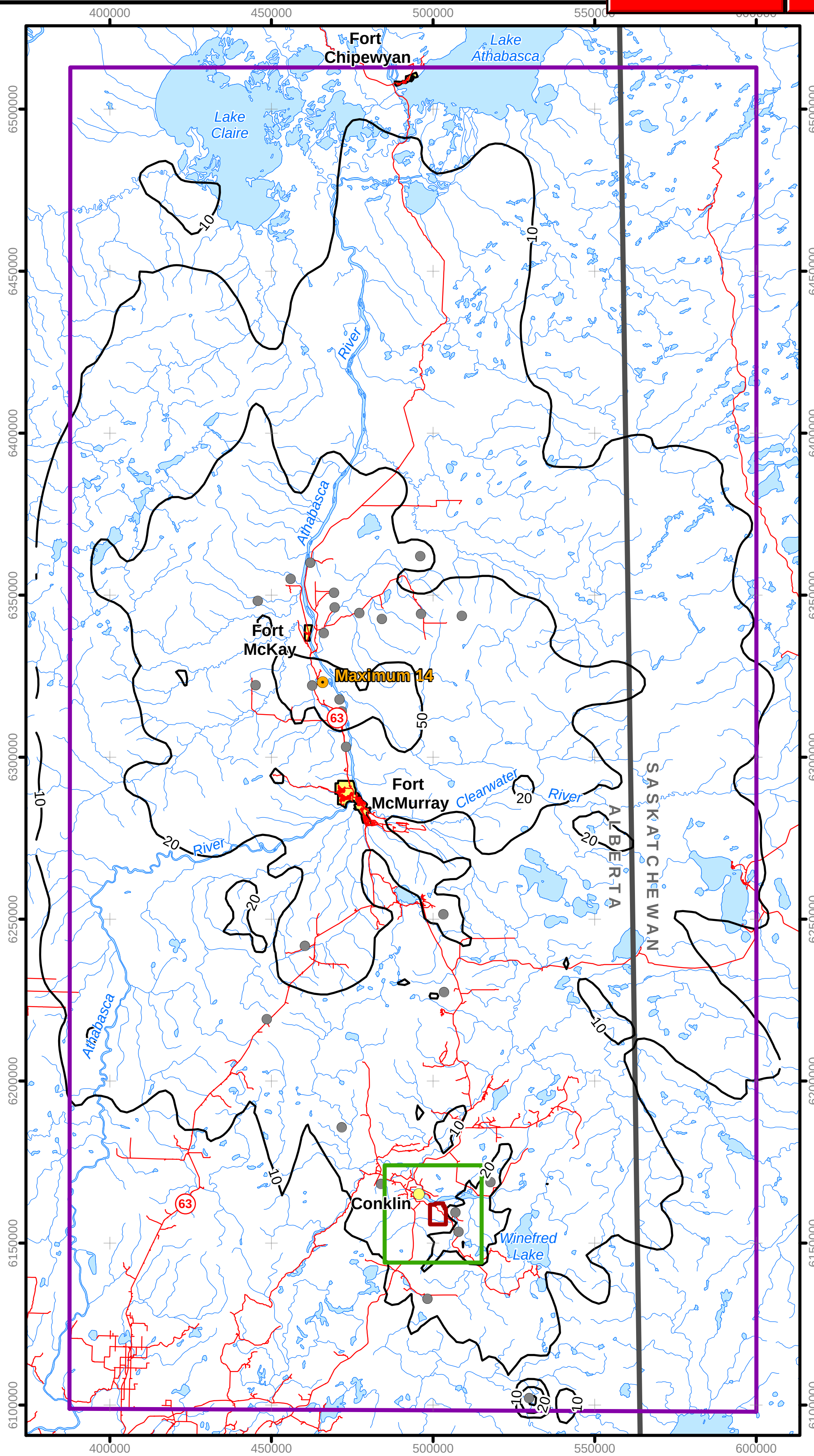
Korea National Oil Corporation

BlackGold Expansion Project

2nd Highest 24-hour SO_2 Concentrations (µg/m³) Application Case

DATE: March 2010		Fig04.06-02 AC SO2 24hour 10-02-25	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TR	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.6-2



Legend

- Air Quality Regional Study Area
- Air Quality Local Study Area
- Project Area
- Open Water
- Watercourse
- SO_2 Concentration (µg/m³)
- Maximum Concentration
- Major Industrial Source

AAAQO = 30 µg/m³

N

25 12.5 0 25 50

Kilometres

1:1,800,000

Source: GeoBase®, KNOC, Spatial Data Warehouse Ltd.

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Korea National Oil Corporation

BlackGold Expansion Project

Annual Average SO_2 Concentrations (µg/m³) Application Case

DATE: March 2010		Fig04.06-03 AC SO2 Annual 10-03-02	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.6-3

- Figure 4.6-3 shows the *annual average SO_2* concentrations for the application scenario. The differences between the predicted baseline and application concentrations external to the AQLSA are minimal. Within the AQLSA, there are changes due to the addition of the project SO_2 emissions.

The maximum 1-h, 24-h and annual average AQRSA concentration patterns for the baseline scenario are virtually identical to their respective application scenario patterns, indicating the small contribution of the project. In the AQLSA, the effect of the project is discernable; however, the maximum predicted SO_2 concentrations due to the application emissions remain below the AAAQOs.

SO_2 Concentrations Due to Project Upset Flaring

There are two possible scenarios under which an upset flaring event may occur:

- flaring of gas vented from vapour recovery in the event of VRU failure; and
- steam generator shutdown where the produced gas is diverted to the flare.

The second case results in significantly larger emissions than the first case and has therefore been modelled in order to assess the worst-case upset conditions.

Emission parameters required to model the impact of the project emergency flare were determined using the ERCB Flare Calculation Spreadsheet Version 3.0. Input parameters and pseudo-parameters generated by the spreadsheet are shown in Table 4.6-5. All other model input parameters were kept at their default values.

Table 4.6-5: Inputs and Pseudo-parameters for Flare Modelling

	Value
Input Parameter	
Gas Flow Rate	0.0538 m^3/s
Stack Height	36.6 m
Stack Diameter	0.4 m
Flare Stack UTM Easting	500.830 km
Flare Stack UTM Northing	6159.314 km
CH_4 Fraction	0.60988
C_2H_6 Fraction	0.0059
C_3H_8 Fraction	0.0029
C_4H_{10} Fraction	0.0026
C_5+ Fraction	0.0015
H_2S Fraction	0.0098
Pseudo-parameter	
Exit Velocity	0.4 m/s
Stack Height	38.4 m
Stack Diameter	3.14 m
SO_2 Emission Rate	1.4 g/s

These input parameters were used in the CALPUFF model using the same setup used in the air quality assessment for routine project operations.

The predicted 9th highest 1-hour SO_2 concentration arising from emergency flare emissions is 25.5 µg/m³, below the guideline value of 450 µg/m³. Concentrations at other averaging periods were not predicted as emergency flaring is not expected to occur frequently and will last for no more than a few hours per occurrence. The flaring of produced gas will not increase facility SO_2 emissions; however, the location of the emissions will change from the generator stacks to the flare stack.

Overall SO_2 Results

Table 4.6-6 provides the impact ratings for ambient SO_2 concentration changes due to the project.

Table 4.6-6: Impact Ratings for Ambient SO_2 Concentration Changes Due to the Project

Impact Attribute	Rating	Comment
Direction	Negative	Predicted ambient SO_2 concentrations within the LSA and RSA increase.
Geographic Extent	Regional	Changes are limited to the RSA.
Magnitude	Low	In the RSA, the changes are less than 1% for all averaging periods.
	Low	In the LSA, the changes are less than 1% for 1-hour and 24-hour averaging periods and less than 2% for the annual average.
Temporal	Infrequent	Ambient SO_2 concentrations due to flaring.
	Short-term	Hourly and daily average SO_2 concentrations will vary due to meteorological variations. High concentration events tend to be infrequent and of limited duration due to meteorological variability.
	Long-term	Annual values represent a continuous exposure for the 25-year life of the project.
Confidence	High	The model and associated input parameters are sufficiently well understood.
Final Rating	Low	In the RSA.
	Low	In the LSA.

Project emissions of SO_2 increase the maximum predicted annual concentration in the AQLSA by approximately 1.7% (i.e., from 9.2 to 9.3 $\mu g/m^3$). The effect of the project over other averaging periods is predicted to be less than 1%.The addition of project emissions does not result in any exceedances of ambient air quality objectives. The project is therefore predicted to have a low effect on the maximum SO_2 concentrations in the AQLSA.

4.6.4 Nitrogen Oxide Emissions and Impacts

4.6.4.1 Introduction

NO_x emissions due to the project result from the combustion of natural gas and produced gas. Maximum ambient nitrogen dioxide (NO_2) concentration patterns are predicted for the three averaging periods associated with the ambient air quality objectives (1-h, 24-h and annual).

4.6.4.2 Results

Application scenario NO_2 concentration predictions for each averaging period are presented in Table 4.6-7 and Figures 4.6-4 to 4.6-6. The maximum predicted NO_2 concentrations are less than the AAAQO in the AQLSA, but greater than objective values in the AQRSA. Comparison of the Baseline and Application scenarios illustrates the contribution of the project. For both the AQRSA and the AQLSA, the project contribution to the maxima is less than 1% for all averaging periods.

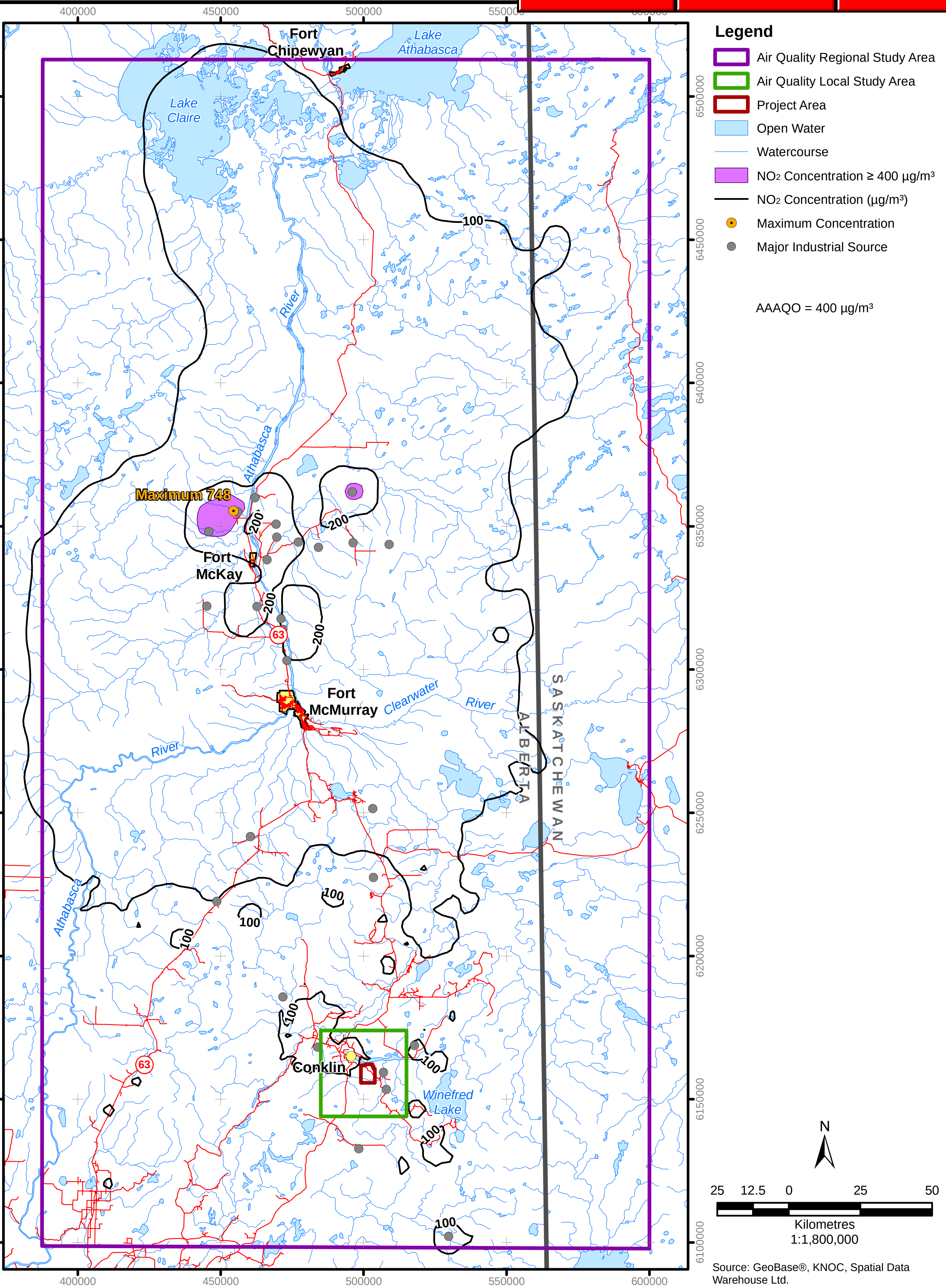
Table 4.6-7: Maximum NO_2 Concentration Changes Due to the Project

Scenario	**RSA**			**LSA**		
	1-h	**24-h**	**Annual**	**1-h**	**24-h**	**Annual**
Baseline ($\mu g/m^3$)	**748**	**279**	**110**	184	111	18.7
Application ($\mu g/m^3$)	**748**	**279**	**110**	184	111	18.7
Increase Due to Project (%)	<1	<1	<1	<1	<1	<1
Objective	400	200	60	400	200	60

Notes:
Values that exceed the ambient objective are shown in boldface text.
The values do not include a background value.

The concentration contour plots for the different averaging periods and the application scenario are shown in the following figures:

- Figure 4.6-4 shows the maximum *1-h average NO_2* concentrations for the application scenario. The differences between the predicted baseline and application concentrations are minimal.
- Figure 4.6-5 shows the maximum *24-h average NO_2* concentrations for the application scenario. The differences between the predicted baseline and application concentrations are minimal.
- Figure 4.6-6 shows the *annual average NO_2* concentrations for the application scenario. The differences between the predicted baseline and application concentrations are minimal.



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Korea National Oil Corporation

BlackGold Expansion Project

9th Highest 1-hour
NO_2 Concentrations (µg/m³)
Application Case

DATE: March 2010		Fig04.06-04 AC NO2 1hour 10-02-31	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.6-4

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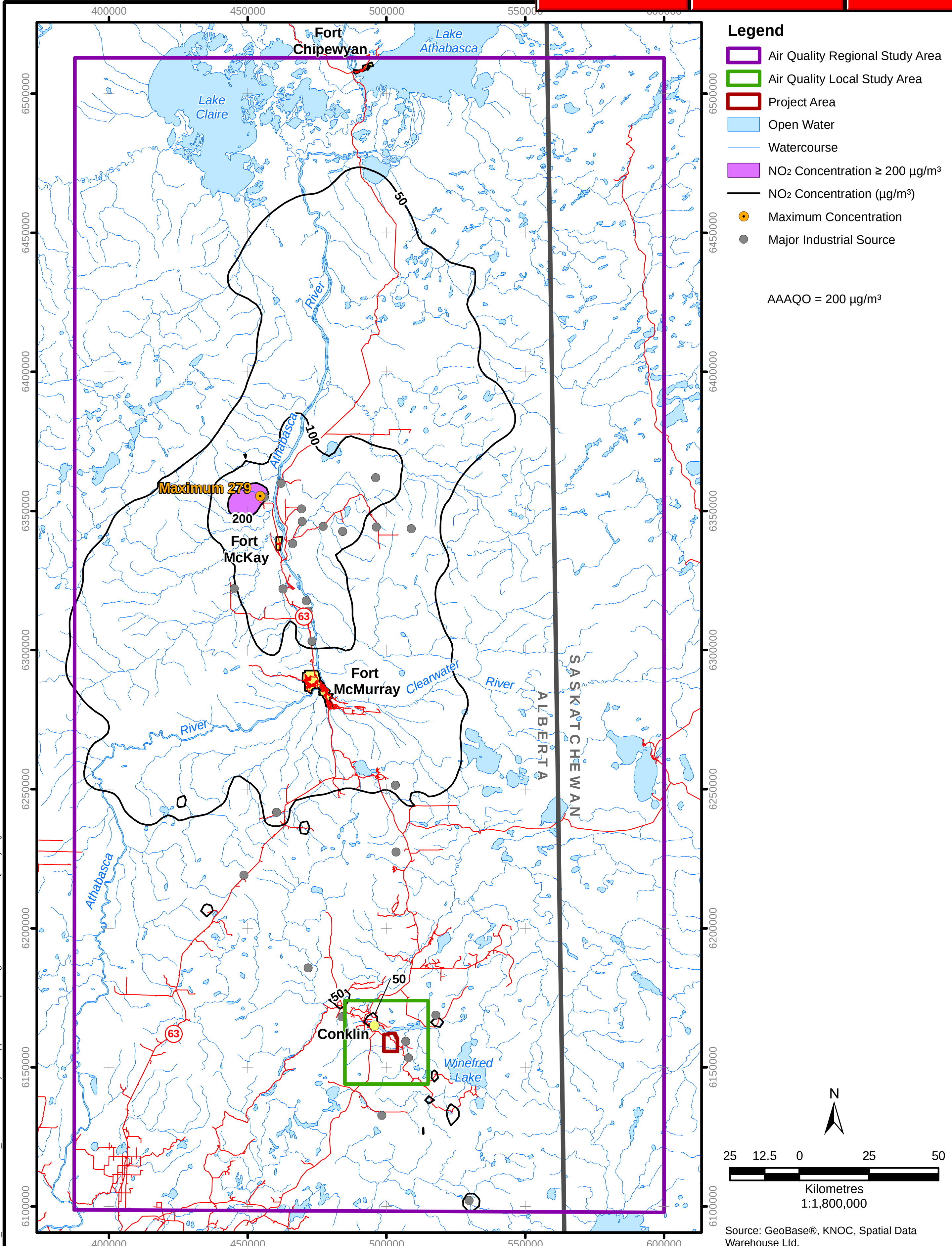
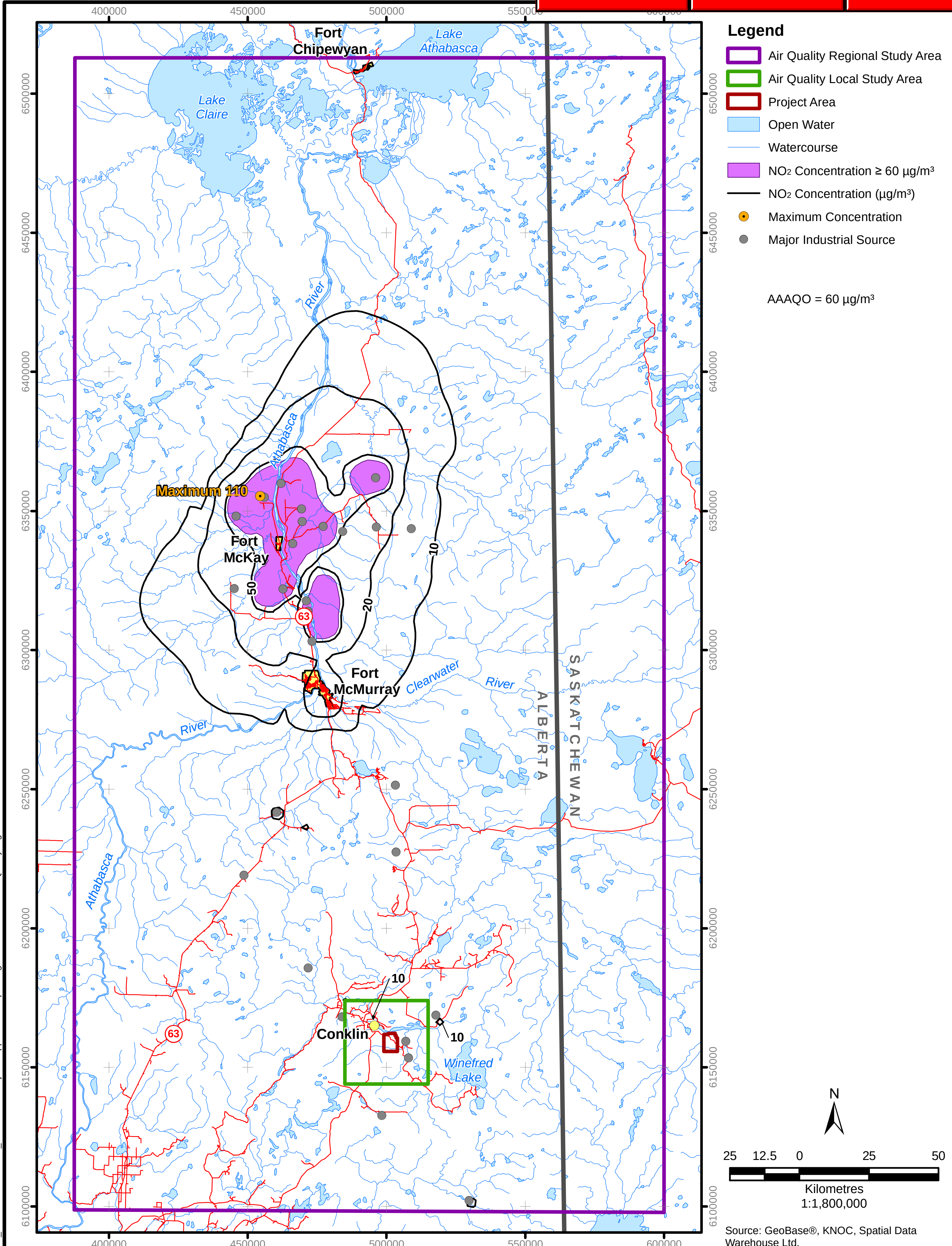


Korea National Oil Corporation

BlackGold Expansion Project

2nd Highest 24-hour NO_2 Concentrations (µg/m³) Application Case

DATE: March 2010		Fig04.06-05 AC NO2 24hour. 10-02-31	**Figure 4.6-5**
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC



Korea National Oil Corporation

BlackGold Expansion Project

Annual Average NO_2 Concentrations (µg/m³) Application Case

DATE: March 2010	Fig04.06-06 AC NO2 Annual 10-03-31	**Figure 4.6-6**
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM / QA/QC: KW EA DR	DRAWN BY: AMEC / PREPARED BY: AMEC	

The maximum 1-h, 24-h and annual average concentration patterns for the baseline scenario are virtually identical to those for the application scenario, indicating the small contribution of the project.

Table 4.6-8 provides the impact ratings for ambient NO_2 concentration changes due to the project.

Table 4.6-8: Impact Ratings for Ambient NO_2 Concentration Changes Due to the Project

Impact Attribute	Rating	Comment
Direction	Negative	Predicted ambient NO_2 concentrations within the LSA and RSA increase.
Geographic Extent	Regional	These emission changes occur in the LSA and RSA.
Magnitude	Low	In the RSA, the change is less than 1%. Maximum values are predicted to exceed the ambient air quality objectives for all averaging periods.
	Low	In the LSA, the change is less than 1%. Maximum values remain below the ambient air quality objectives for all averaging periods.
Temporal	Infrequent	Ambient NO_2 concentrations due to upset flaring and the emergency generator.
	Short-term	Hourly and daily average NO_2 concentrations will vary due to meteorological variations. High concentration events tend to be infrequent and of limited duration due to meteorological variability.
	Long-term	Annual values represent a continuous exposure.
Confidence	High	The model and associated input parameters are sufficiently well understood.
Final Rating	Low	In the RSA.
	Low	In the LSA.

The effects of the project NO_x emissions are predicted to be minimal outside the AQLSA. In the AQLSA, ambient NO_2 exposures near the project are predicted to slightly increase. The maximum NO_2 concentrations in the vicinity of the project are predicted to be less than the associated ambient air quality objectives. The overall predicted impact of the project on ambient concentrations of NO_x is predicted to be low.

4.6.5 Particulate Matter Emissions and Impacts

4.6.5.1 Introduction

Fine particulate matter ($PM_{2.5}$) concentrations due to the project result directly from the combustion emissions (i.e., primary) and indirectly from the formation of sulphates and nitrates in the atmosphere from SO_2 and NO_x emissions (i.e., secondary). Maximum ambient $PM_{2.5}$ concentration patterns are predicted for the 1-h and 24-h averaging periods associated with the ambient air quality objectives. The values represent the sum of the predicted primary and secondary values, as calculated by the CALPUFF model.

4.6.5.2 Results

Application scenario predictions for $PM_{2.5}$ concentrations for each averaging period are presented in Table 4.6-9 and Figures 4.6-7 and 4.6-8. The maximum predicted $PM_{2.5}$ concentrations in the AQLSA are less than the AAAQO. The maximum predicted $PM_{2.5}$ concentrations in the AQRSA exceed the AAAQO. Comparison of baseline and application scenarios shows the contribution of the project. For the AQRSA, the project contribution to the maximum value, which exceeds the AAAQO, is less than 1%.

Table 4.6-9: Maximum $PM_{2.5}$ Concentration Changes Due to the Project

Scenario	RSA		LSA	
	1-h	24-h	1-h	24-h
Baseline (µg/m^3)	**560**	**164**	5.9	2.1
Application (µg/m^3)	**560**	**164**	5.9	2.1
Increase Due to Project (%)	<1	<1	<1	<1
Objective	80	30	80	30

Notes:
Values that exceed the ambient objective are shown in boldface text.
The values do not include a background value.

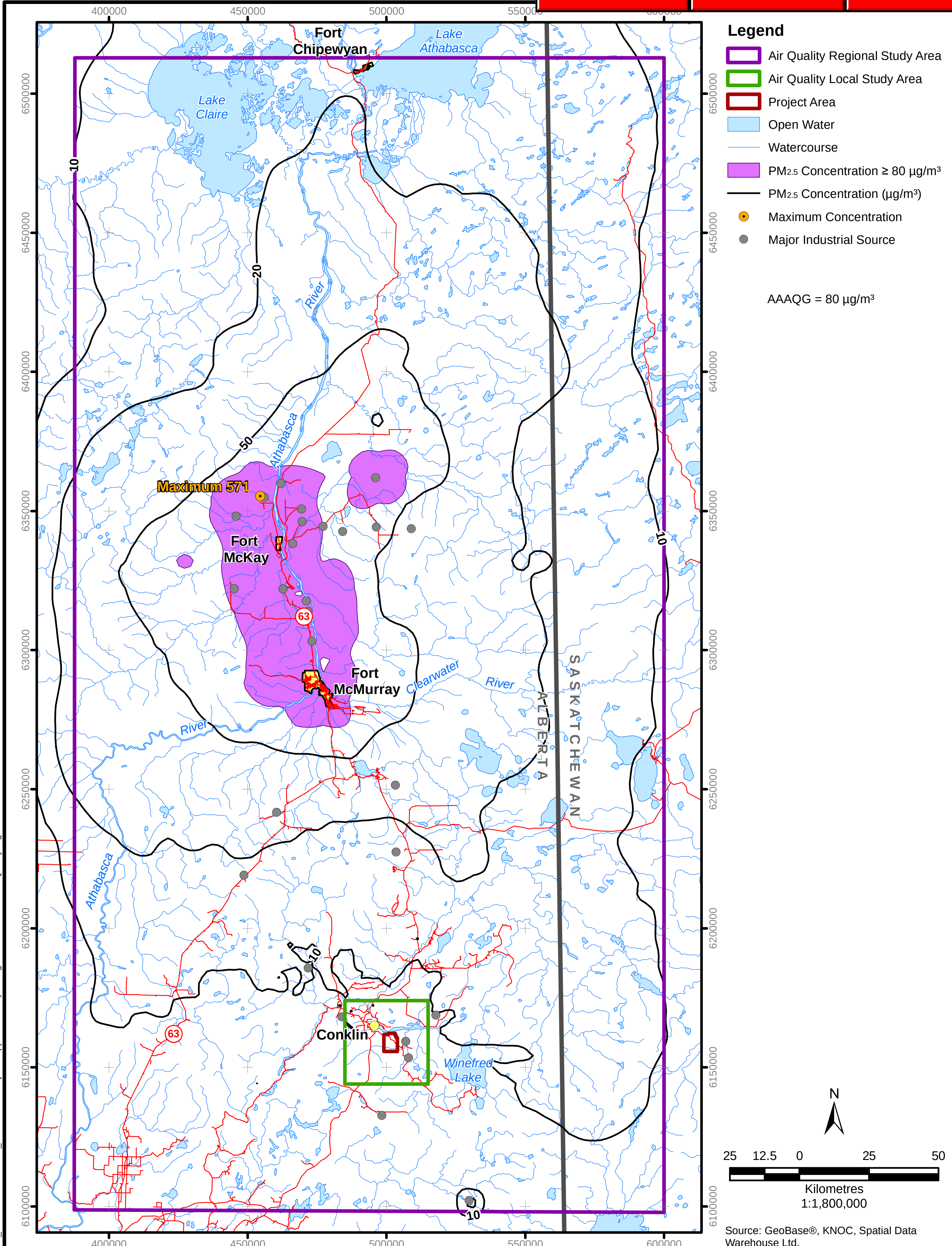
The concentration contour plots for the different averaging periods and the application scenario are shown in the following figures:

- Figure 4.6-7 shows the maximum *1-h average $PM_{2.5}$* concentrations for the application scenario. The differences between the predicted baseline and application concentrations are minimal.
- Figure 4.6-8 shows the maximum *24-h average $PM_{2.5}$* concentrations for the application scenario. The differences between the predicted baseline and application concentrations are minimal.

Table 4.6-10 provides the impact ratings for ambient $PM_{2.5}$ concentration changes due to the project.

Table 4.6-10: Impact Ratings for Ambient $PM_{2.5}$ Concentration Changes Due to the Project

Impact Attribute	Rating	Comment
Direction	Negative	Predicted ambient $PM_{2.5}$ concentrations within the RSA and LSA increase.
Geographic Extent	Regional	These emission changes occur in the LSA and RSA.
Magnitude	Low	In the RSA, the change is less than 1%.
	Low	In the LSA, the change is less than 1%. The maximum predicted values in the LSA are less than the AAAQO.
Temporal	Short-term	Daily average $PM_{2.5}$ concentrations will vary due to meteorological variations.
Confidence	High	The model and associated input parameters are sufficiently well understood.
Final Rating	Low	In the RSA.
	Low	In the LSA.



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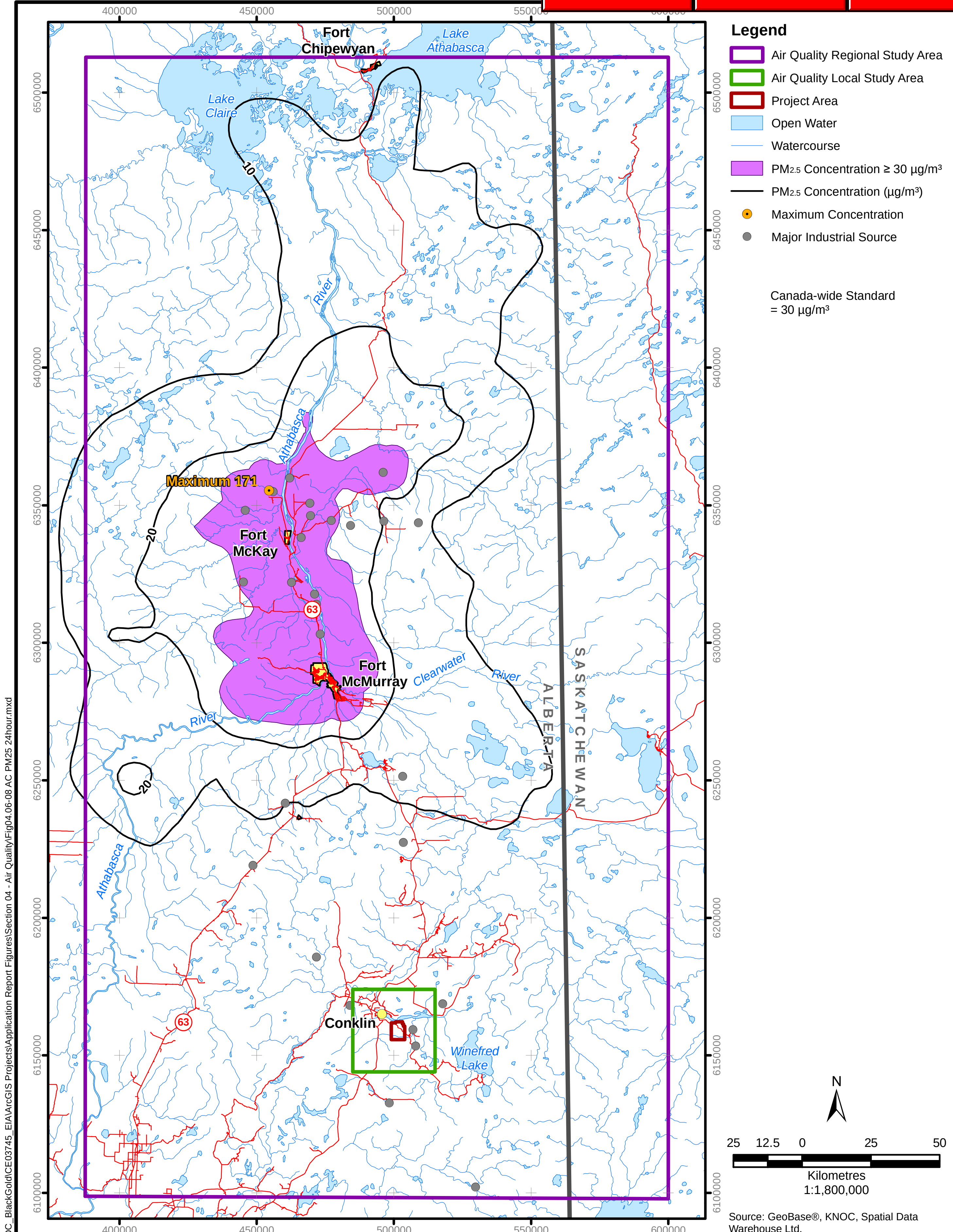
Korea National Oil Corporation

BlackGold Expansion Project

9th Highest 1-hour $PM_{2.5}$ Concentrations (µg/m³) Application Case

DATE: March 2010		Fig04.06-07 AC PM25 1hour 10-03-31	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.6-7



Korea National Oil Corporation

BlackGold Expansion Project

2nd Highest 24-hour $PM_{2.5}$ Concentrations (µg/m³) Application Case

DATE: March 2010		Fig04.06-08 AC PM25 24hour 10-03-31	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.6-8

The effects of project $PM_{2.5}$ and $PM_{2.5}$ precursor emissions on ambient $PM_{2.5}$ concentrations in the AQRSA and AQLSA are predicted to be low. The maximum $PM_{2.5}$ concentrations in the vicinity of the project are predicted to be less than the associated AAAQO.

4.6.6 Carbon Monoxide Emissions and Impacts

4.6.6.1 Introduction

Carbon monoxide (CO) concentrations due to the project result directly from the combustion of natural gas and produced gas. Maximum ambient CO concentration patterns are predicted for the 1-h and 8-h averaging periods associated with the ambient air quality objectives.

4.6.6.2 Results

Application scenario predictions for CO concentrations for each averaging period are presented Table 4.6-11 and Figures 4.6-9 and 4.6-10. The maximum predicted CO concentrations in the AQLSA and AQRSA are less than the AAAQO. Comparison of the baseline and application scenarios illustrates the contribution of the project. For both the AQRSA and AQLSA the project contribution is less than 1%.

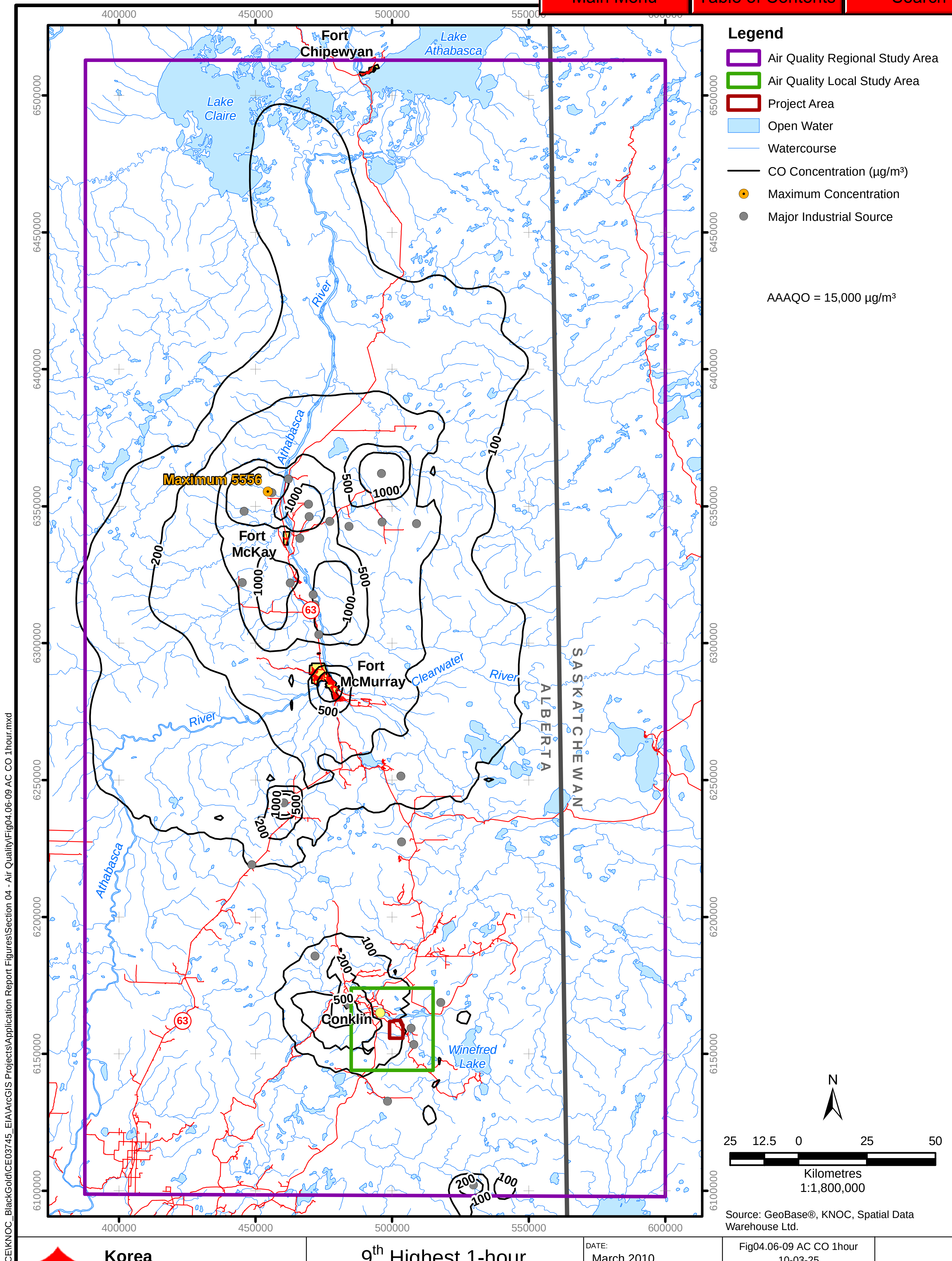
Table 4.6-11: Maximum CO Concentration Changes Due to the Project

Scenario	RSA		LSA	
	1-h	8-h	1-h	8-h
Baseline ($\mu g/m^3$)	5556	2835	1136	468
Application ($\mu g/m^3$)	5556	2835	1136	468
Increase Due to Project (%)	<1	<1	<1	<1
Objective	15 000	6 000	15 000	6 000

Notes:
Values that exceed the ambient objective are shown in boldface text.
The values do not include a background value.

The concentration contour plots for the different averaging periods and the application scenario are shown in the following figures:

- Figure 4.6-9 shows the maximum *1-h average CO* concentrations for the application scenario. The differences between the predicted baseline and application concentrations are minimal.
- Figure 4.6-10 shows the maximum *8-h average CO* concentrations for the application scenario. The differences between the predicted baseline and application concentrations are minimal.



Korea National Oil Corporation

BlackGold Expansion Project

9th Highest 1-hour CO Concentrations (µg/m³) Application Case

DATE: March 2010		Fig04.06-09 AC CO 1hour 10-03-25	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.6-9

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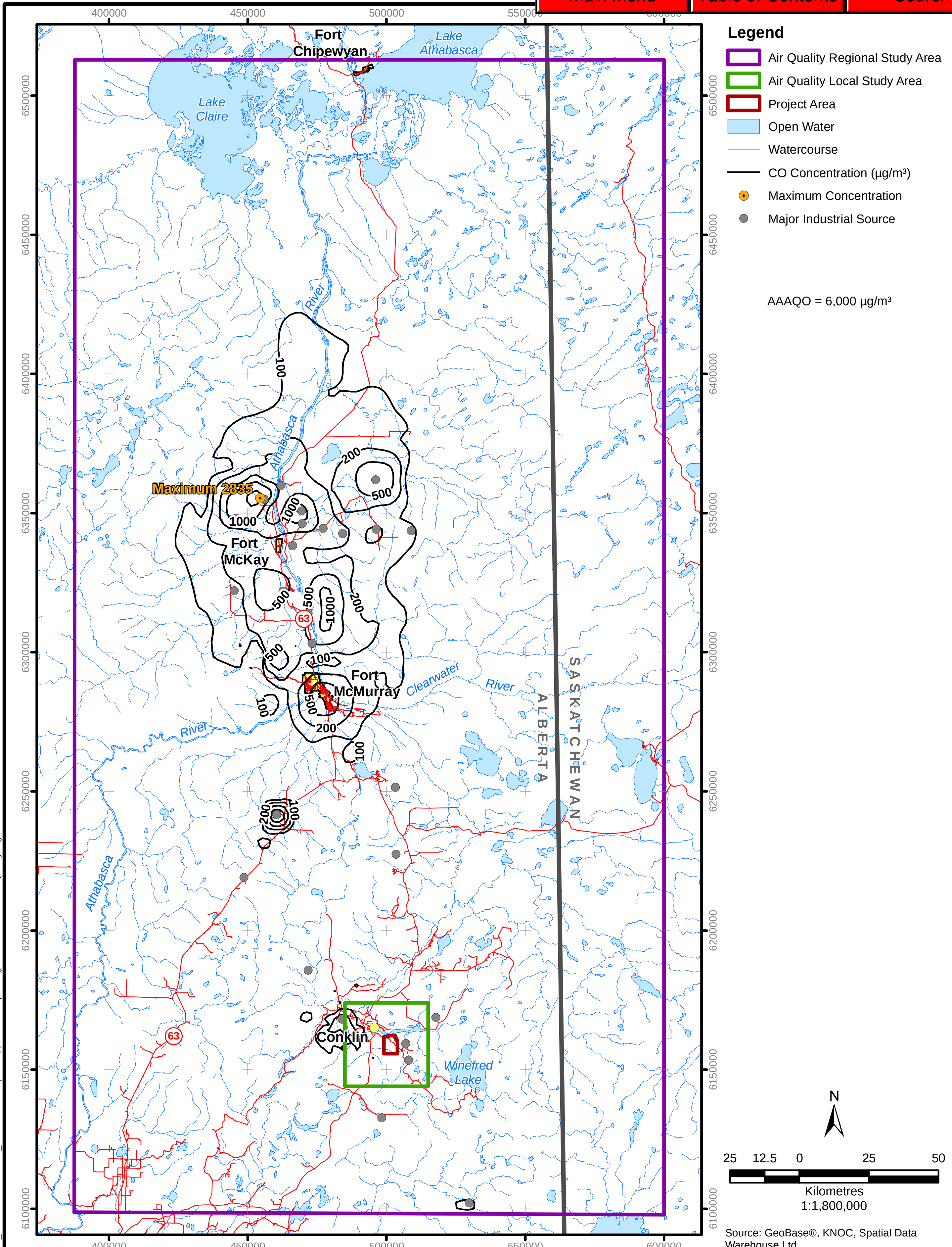


Korea National Oil Corporation

BlackGold Expansion Project

2nd Highest 8-hour CO Concentrations (µg/m³) Application Case

DATE: March 2010	Fig04.06-10 AC CO 8hour 10-03-25
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83
ANALYST: TM; QA/QC: KW EA DR	DRAWN BY: AMEC; PREPARED BY: AMEC

Figure 4.6-10

Table 4.6-12 provides the impact ratings for ambient CO concentration changes due to the project.

Table 4.6-12: Impact Ratings for Ambient CO Concentration Changes Due to the Project

Impact Attribute	Rating	Comment
Direction	Negative	Predicted ambient CO concentrations within the RSA and LSA increase.
Geographic Extent	Regional	These emission changes occur in the LSA and RSA.
Magnitude	Low	In the RSA, the change is less than 1%.
	Low	In the LSA, the change is less than 1%. The maximum predicted values in the LSA are less than the AAAQO.
Temporal	Short-term	Daily average $PM_{2.5}$ concentrations will vary due to meteorological variations.
Confidence	High	The model and associated input parameters are sufficiently well understood.
Final Rating	Low	In the RSA.
	Low	In the LSA.

The effects of project CO emissions on ambient CO concentrations are predicted to be low in the AQRSA and AQLSA. The maximum CO concentrations in the vicinity of the project are predicted to be less than the associated AAAQO.

4.6.7 Acid Deposition Emissions and Impacts

4.6.7.1 Introduction

SO_2 and NO_x emissions result in the deposition of acidifying compounds (i.e., SO_2, SO_4, NO, NO_2, HNO_3 and nitrate) that are quantified as PAI through the relationship:

$$PAI = \sum (SO_4^{-2}) + \sum (NO_3^{-}) - \sum (\text{base cations}) + \text{Background PAI}$$

where:

$\sum (SO_4^{-2})$ = total sulphur compound contribution (i.e., SO_2 and SO_4^{-2}) expressed in keq/ha/y

$\sum (NO_3^{-})$ = total nitrogen compound contribution (i.e., NO, NO_2, HNO_3 and NO_3^{-}) expressed in keq/ha/y

$\sum$ (base cations) = primarily calcium (Ca^{+2}) plus magnesium (Mg^{+2}) = 0.12 keq/ha/y (Chaikowski 2001)

Results of sulphate and nitrate deposition are presented separately as these compounds are modeled independently.

4.6.7.2 Results

Application scenario predictions for PAI are presented in Table 4.6-13 and Figure 4.6-11. The results in the table reflect the maximum small-scale grid (i.e., representing distance scales that are determined by modeling receptor spacing and are much less than the 1° longitude by 1° latitude grid cell) sulphate equivalent deposition, nitrate equivalent deposition and PAI for the baseline and the application scenarios. Comparison of baseline and application scenarios illustrates the relative contribution of the project. For the AQRSA, the project contribution to the maximum values is less than 1%. For the AQLSA, the predicted project contribution to the maximum values is 1.3%.

Table 4.6-13: Maximum Small-Scale Grid Acid Deposition Changes Due to Project

Scenario	RSA			LSA		
	Sulphate	Nitrate	PAI	Sulphate	Nitrate	PAI
Baseline (keq H^+/ha/yr)	2.43	12.31	13.13	1.11	0.29	0.59
Application (keq H^+/ha/yr)	2.43	12.31	13.13	1.12	0.29	0.60
Increase Due to Project (%)	<1	<1	<1	<1	<1	1.3

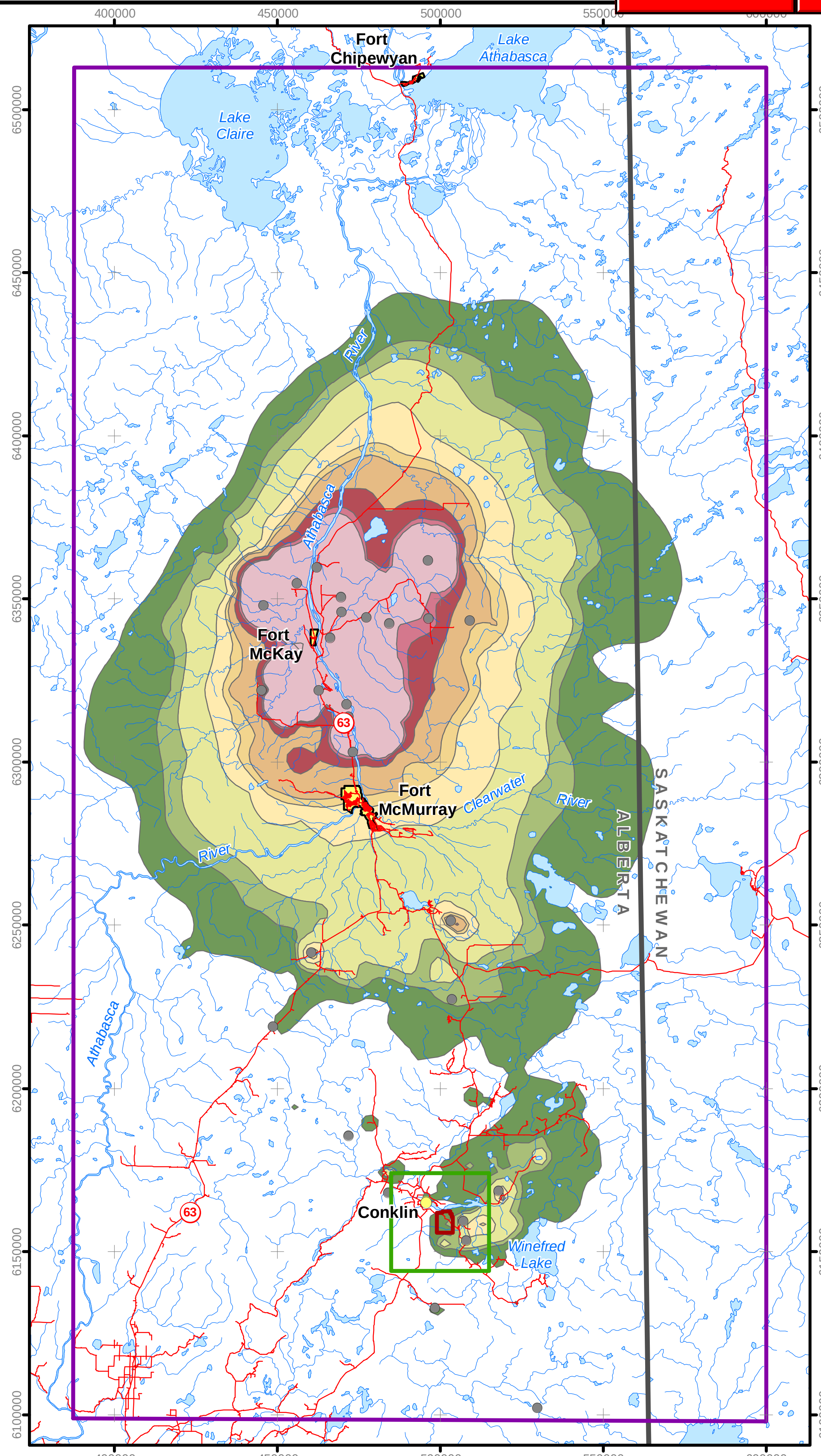
Notes:

Maximum values represent small-scale grid peaks.
Sulphate equivalent and nitrate equivalent deposition without background.
PAI = Potential Acid Input (includes background).

Figure 4.6-11 shows the annual PAI for the application scenario. The predicted baseline and application deposition patterns are virtually identical beyond the boundary of the AQLSA. Within the AQLSA, slight changes are distinguishable. Table 4.6-14 provides the impact ratings for ambient PAI changes due to the project.

Table 4.6-14: Impact Ratings for PAI Changes Due to the Project

Impact Attribute	Rating	Comment
Direction	Negative	Predicted PAI within the LSA and RSA increases.
Geographic Extent	Regional	These emission changes occur in the LSA and RSA.
Magnitude	Low	In the RSA, the change is less than 1%.
	Low	In the LSA, the small-scale grid deposition change is less than 2%
Temporal	Long-term	Annual values, by definition, represent a continuous exposure. Higher deposition tends to occur during the spring and summer when vegetation activity is greater.
Confidence	Moderate (Relative) Low (Absolute)	While the model and associated input parameters are sufficiently well understood, there is less certainty with the prediction of deposition.
Final Rating	Low	In the RSA.
	Low	In the LSA.



Legend

- Air Quality Regional Study Area
- Air Quality Local Study Area
- Project Area
- Open Water
- Watercourse

PAI (keq/ha/yr)

- 0.17 - <0.22
- 0.22 - <0.25
- 0.25 - <0.35
- 0.35 - <0.45
- 0.45 - <0.5
- 0.5 - <0.7
- 0.7 - <0.9
- 0.9 - <1
- ≥ 1
- Major Industrial Source

N

25 12.5 0 25 50

Kilometres

1:1,800,000

Source: GeoBase®, KNOC, Spatial Data Warehouse Ltd.

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Korea National Oil Corporation

BlackGold Expansion Project

PAI in keq/ha/yr for the Application Case

DATE: March 2010		Fig04.06-11 AC PAI 10-03-03	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: NH	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.6-11

The effects of the project SO_2 and NO_x precursor emissions on the predicted PAI values are predicted to low. Some small-scale grid values higher than the critical loads for the various receptor sensitivities are predicted to occur. Note that small-scale grid PAI values greater than the deposition loads are not viewed as an exceedance, since the regulatory deposition loads are only to be applied at a 1° latitude by a 1° longitude scale and estimated using the RELAD model applied at a sub-continental scale.

4.6.8 Nitrogen Deposition Emissions and Impacts

4.6.8.1 Introduction

NO_x emissions result in the deposition of nitrates that are quantified as nitrogen.

4.6.8.2 Results

Application scenario results for small-scale grid (i.e., representing distance scales on the order of modeling receptor spacing) nitrogen deposition are summarized Table 4.6-15 and Figure 4.6-12. Comparison of baseline and application scenarios illustrates the contribution of the project. For both the AQRSA and AQLSA, the project contribution to the maximum values is less than 1%.

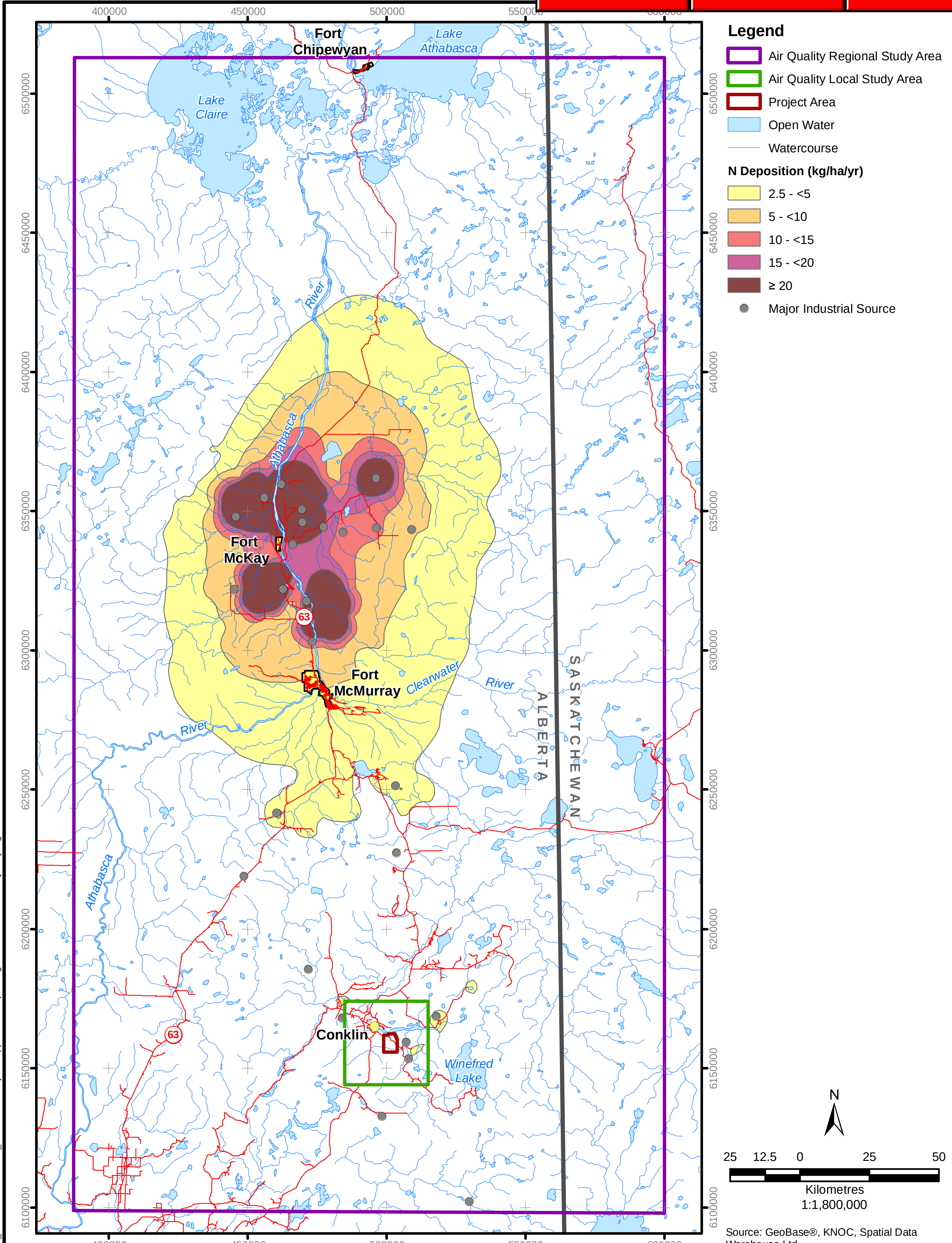
Table 4.6-15: Maximum Small-Scale Grid Nitrogen Deposition Changes Due to Project

Scenario	RSA	LSA
Baseline (kg/ha/yr)	172	4.1
Application (kg/ha/yr)	172	4.1
Increase Due to Project (%)	<1	<1
Critical Loads (1° by 1°) (kg/ha/yr)	5 to 20	5 to 20

Notes:
Critical loads depend on land use and vegetation (WHO 2000).

Figure 4.6-12 shows the annual nitrogen deposition for the application scenario. The predicted baseline and application deposition patterns are virtually identical. Table 4.6-16 provides the impact ratings for ambient nitrogen deposition changes due to the project.

The effects of project nitrogen emissions on nitrogen deposition are predicted to be low. Some small-scale grid values higher than the critical loads for the various receptor sensitivities are predicted to occur.



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Korea National Oil Corporation

BlackGold Expansion Project

Nitrogen Deposition in kg/ha/yr for the Application Case

DATE: March 2010		Fig04.06-12 AC N 10-03-03	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.6-12

Table 4.6-16: Impact Ratings for Nitrogen Deposition Changes Due to the Project

Impact Attribute	Rating	Comment
Direction	Negative	Predicted nitrogen deposition within the LSA and RSA increases.
Geographic Extent	Regional	These emission changes occur in the LSA and RSA.
Magnitude	Low	In the RSA, the change is less than 1%.
	Low	In the LSA, the small-scale grid deposition change is less than 1%
Temporal	Long-term	Annual values, by definition, represent a continuous exposure. Higher deposition tends to occur during the spring and summer when vegetation activity is greater.
Confidence	Moderate (Relative) Low (Absolute)	While the model and associated input parameters are sufficiently well understood, there is less certainty with the prediction of deposition.
Final Rating	Low	In the RSA.
	Low	In the LSA.

4.7 Cumulative Effects

4.7.1 Cumulative Emissions

4.7.1.1 Introduction

In addition to the existing and approved projects, there are a number of proposed projects located in the AQRSA that are currently in the approval process or have been publicly disclosed (up to June 2009). This group of sources plus the application scenario sources form the planned development scenario. Combustion source emissions from the project and from other existing, approved and proposed sources in the air AQRSA have been identified and quantified. The cumulative effects of these sources on ambient air quality have been evaluated and presented as follows.

4.7.1.2 Methods

Emissions from the other production operations were obtained from the other operators through their respective air quality impact assessments and/or published data.

4.7.1.3 Results

Table 4.7-1 summarizes the air AQRSA emissions for the planned development scenario.

There are increases in emissions relative to the baseline due to the addition of proposed operations. Increases are in the 3 to 25% range for the AQRSA and in the 9 to 55% range for the AQLSA. The AQRSA planned development emissions are factors of 23 (for SO_2) to 2 576 (for VOC) times greater than the AQLSA planned development emissions. For the application scenario, the project emissions are a small percentage of total AQRSA emissions (e.g., 1 t SO_2/d due to the project compared to 249 t SO_2/d for the application scenario or 0.4% of the total). For the planned development scenario, the project contribution is similar on a relative basis when compared to AQRSA emissions (e.g., 1 t SO_2/d due to the project compared to 250 t SO_2/d for the planned development scenario).

Table 4.7-1: Planned Development Scenario Emissions

	SO_2 (t/d)	NO_x (t/d)	CO (t/d)	VOC (t/d)	$PM_{2.5}$ (t/d)
Operator					
Albian Sands Energy Inc.	0.61	31.81	27.10	26.85	1.64
Birch Mountain Resources Ltd.	16.80	27.66	13.81	3.00	1.31
CNRL Horizon	18.38	52.44	37.85	73.83	2.75
CNRL Kirby	1.99	2.88	2.45	0.17	0.22
Connacher Great Divide	0.16	0.98	0.80	0.00	0.08
ConocoPhillips Surmont	0.86	3.25	5.15	0.00	0.37
Deer Creek Energy Ltd.	1.75	13.88	11.11	46.65	0.49
Devon Jackfish (LSA)	3.96	4.02	2.72	0.12	0.24
Encana Christina Lake (LSA)	6.33	1.89	1.59	0.09	0.09
Encana Foster Creek	3.00	5.96	7.03	0.00	0.32
Encana Borealis	1.35	1.36	1.23	0.08	0.10
Husky Sunrise	1.10	6.68	20.66	0.20	0.00
IOL/ExxonMobil Kearl Lake	0.66	42.68	28.61	156.71	1.96
JACOS Hangingstone	3.94	4.56	4.76	0.98	0.27
KNOC Blackgold	***1.00***	***1.24***	***0.91***	***0.04***	***0.13***
MEG Energy Corp	2.80	16.09	12.99	0.77	1.16
Northlands Forest Products	0.02	0.19	25.00	1.71	0.19
OPTI/Nexen Long Lake North and South	21.87	24.17	19.73	1.03	1.65
Petro-Canada MacKay River / Meadow Creek	2.70	16.64	11.57	0.51	0.94
Petro-Canada Lewis	1.63	7.01	5.39	0.22	0.47
Petro-Canada/UTS Fort Hills	1.68	26.50	5.14	15.24	0.68
Shell Jackpine	0.50	26.87	18.16	26.90	1.26
StatoilHydro Kai Kos Dehseh	2.88	16.19	9.71	0.93	1.22
Suncor Baseplant, Millenium, Voyageur	65.18	90.70	54.55	215.52	7.60
Suncor Firebag	7.09	21.18	14.34	0.84	1.65
Syncrude Mildred Lake and Aurora	97.99	91.78	77.62	71.54	6.75
Whitesands In-situ Ltd.	0.08	0.04	9.23	0.00	0.00
Williams FMM Chemical Plant	0.01	0.02	0.02	0.26	0.01
Gas Production Facilities (LSA)	0.00	2.72	1.53	0.00	0.00
Gas Production Facilities (RSA)	0.00	41.26	21.50	0.10	0.00
Non-Industrial Sources (LSA)	0.00	0.11	0.49	0.00	0.05
Non-Industrial Sources (RSA)	0.78	10.14	57.91	0.00	5.45
RSA Total	255.81	582.92	503.42	644.04	38.54
LSA Total	11.29	9.98	7.24	0.25	0.51
Total (RSA + LSA)	267.10	592.90	510.66	644.29	39.05
RSA					
Baseline Total	247.62	505.96	414.14	585.24	30.85
Application Total	248.62	507.20	415.05	585.28	30.98
Increase Relative to Baseline (%)	0.4	0.2	0.2	0.0	0.3
Planned Development Total	255.81	582.92	503.42	644.04	38.54
Increase Relative to Baseline (%)	3.3	15.2	21.6	10.0	24.9
LSA					
Baseline Total	10.29	8.63	5.84	0.21	0.33
Application Total	11.29	9.87	6.75	0.25	0.46
Increase Relative to Baseline (%)	9.7	14.4	15.6	19.0	39.4
Planned Development Total	11.29	9.98	7.24	0.25	0.51
Increase Relative to Baseline (%)	9.7	15.6	24.0	19.0	54.5

4.7.2 Cumulative Effects

4.7.2.1 Introduction

Additional facilities will increase emissions in the air AQRSA and AQLSA leading to an increase in ground-level concentrations and PAI. While the AQLSA emissions are much lower than the AQRSA emissions, the increases relative to the baseline scenario warrant further evaluation in the AQRSA and AQLSA.

4.7.2.2 Methods

The CALPUFF dispersion model was used to predict the SO_2, NO_2 and $PM_{2.5}$ concentrations and the PAI for the planned development scenario. Summary results are presented in Table 4.7-2. As indicated previously, the CALPUFF model was applied with variable receptor grid spacing, with greater density (i.e., 50 m spacing) near the project and decreasing density with increasing distance from the project area (to a maximum 10 km spacing). For this reason, the peak concentrations and deposition in the area external to the AQRSA may be underestimated in the more distant areas where increased development is proposed (e.g., the area to the north of Fort McMurray and the Cold Lake region to the south). As the primary objective for this assessment focuses on the project AQLSA, this deceasing density is not considered to be a limitation. Caution is advised in drawing comparisons between the predictions provided in this assessment with those provided in other assessments that focus on these more distant regions.

4.7.3 Sulphur Dioxide Emissions and Impacts

4.7.3.1 Introduction

Maximum ambient SO_2 concentration patterns are predicted for the three averaging periods associated with the ambient air quality objectives (namely 1-h, 24-h and annual).

4.7.3.2 Results

Planned development scenario predictions for SO_2 are presented in Table 4.7-3 and Figures 4.7-1 to 4.7-3. Overall increases in maximum predicted values associated with the planned development scenario are minimal relative to the application and baseline scenarios for the AQLSA. The largest change in the AQLSA is associated with the predicted annual average maximum values, which have increases of up to 9.6%.

Table 4.7-2: Maximum Predicted SO_2, NO_2, CO and $PM_{2.5}$ Concentrations and PAI and Nitrogen Deposition Values Associated With the Planned Development Scenario

Maximum Predicted Concentrations	Maximum RSA	Maximum LSA	Objective
SO_2			
1-h concentration (μg/m^3)	343	199	450
24-h concentration (μg/m^3)	95	53	150
Annual concentration (μg/m^3)	14.9	9.6	30
NO_2			
1-h concentration (μg/m^3)	**762**	185	400
24-h concentration (μg/m^3)	**287**	111	200
Annual concentration (μg/m^3)	**113**	19.8	60
$PM_{2.5}$			
1-h concentration (μg/m^3)	**560**	11.8	30
24-h concentration (μg/m^3)	**164**	3.4	30
CO			
1-h concentration (μg/m^3)	5 663	1 138	15 000
8-h concentration (μg/m^3)	2 838	475	6 000

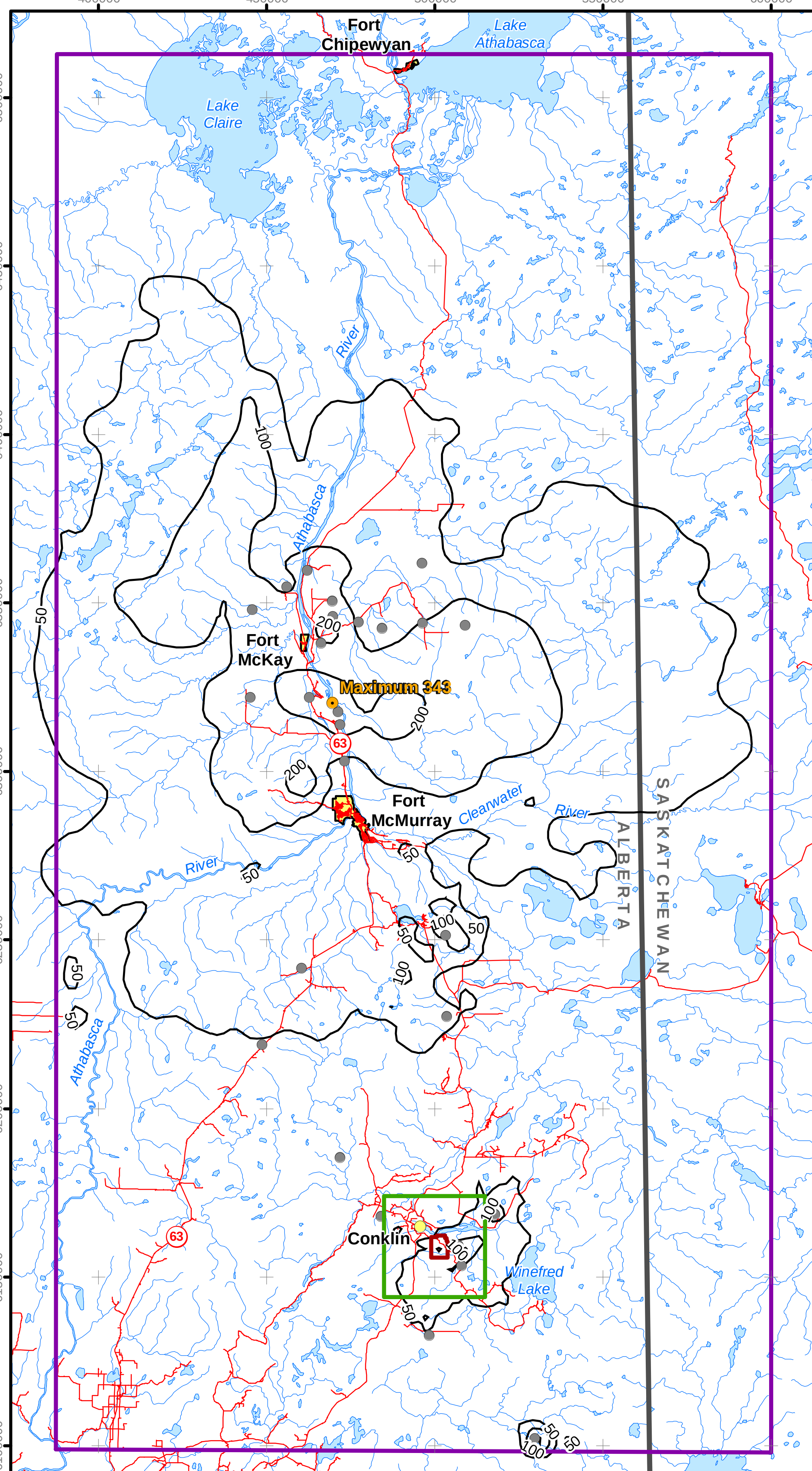
Notes:
Values that exceed the ambient guideline are shown in boldface text.
The values do not include a background value.

Maximum Predicted PAI (small-scale grid)	Maximum RSA	Maximum LSA	Critical Loads (1° by 1° scale)
Sulphate (keq H^+/ha/a)	2.47	1.13	–
Nitrate (keq H^+/ha/a)	12.41	0.32	–
PAI (no background) (keq H^+/ha/a)	13.23	0.62	0.25 to 1.00
PAI (with background) (keq H^+/ha/a)	13.24	0.63	0.25 to 1.00

Notes:
The sulphate and nitrate values do not include a background value.
The maximum sulphate and nitrate are not additive, since they occur at different locations.
The PAI target loads (as defined by CASA and AENV 1999) includes low, moderate and sensitive receptors.

Maximum Predicted Nitrogen Deposition (small-scale grid)	Maximum RSA	Maximum LSA	Critical Loads (1° by 1° scale)
Nitrogen Deposition (kg/ha/yr)	174	4	5 to 20

Notes:
Values do not include background.
Critical loads depend on land use and vegetation (WHO 2000).



Legend

- Air Quality Regional Study Area
- Air Quality Local Study Area
- Project Area
- Open Water
- Watercourse
- SO_2 Concentration (µg/m³)
- Maximum Concentration
- Major Industrial Source

AAAQO = 450 µg/m³

N

25 12.5 0 25 50

Kilometres

1:1,800,000

Source: GeoBase®, KNOC, Spatial Data Warehouse Ltd.

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KNOC

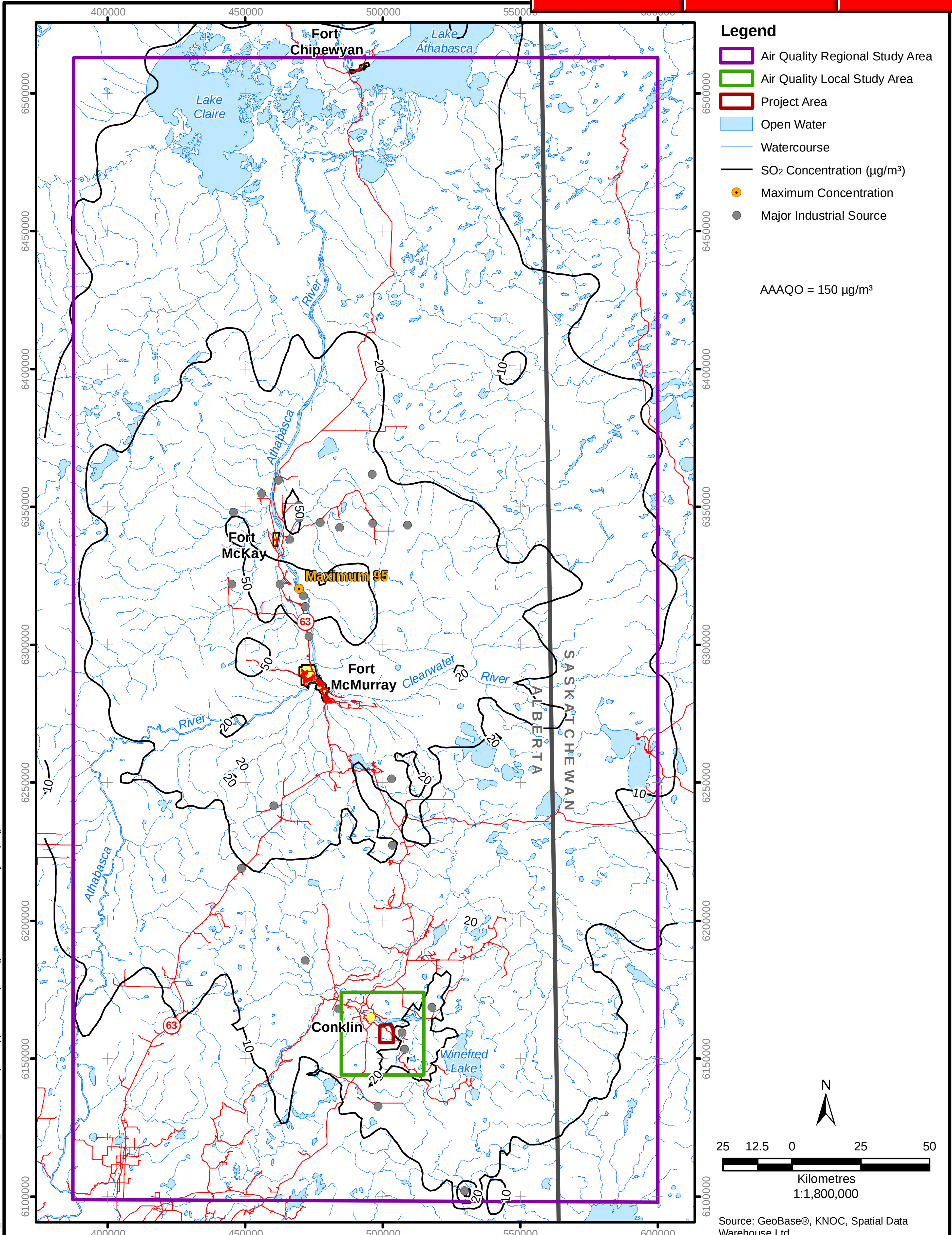
Korea National Oil Corporation

BlackGold Expansion Project

9th Highest 1-hour SO_2 Concentrations (µg/m³) Planned Development Case

DATE: March 2010		Fig04.07-01 PDC SO2 1hour 10-03-02	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: CP	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.7-1



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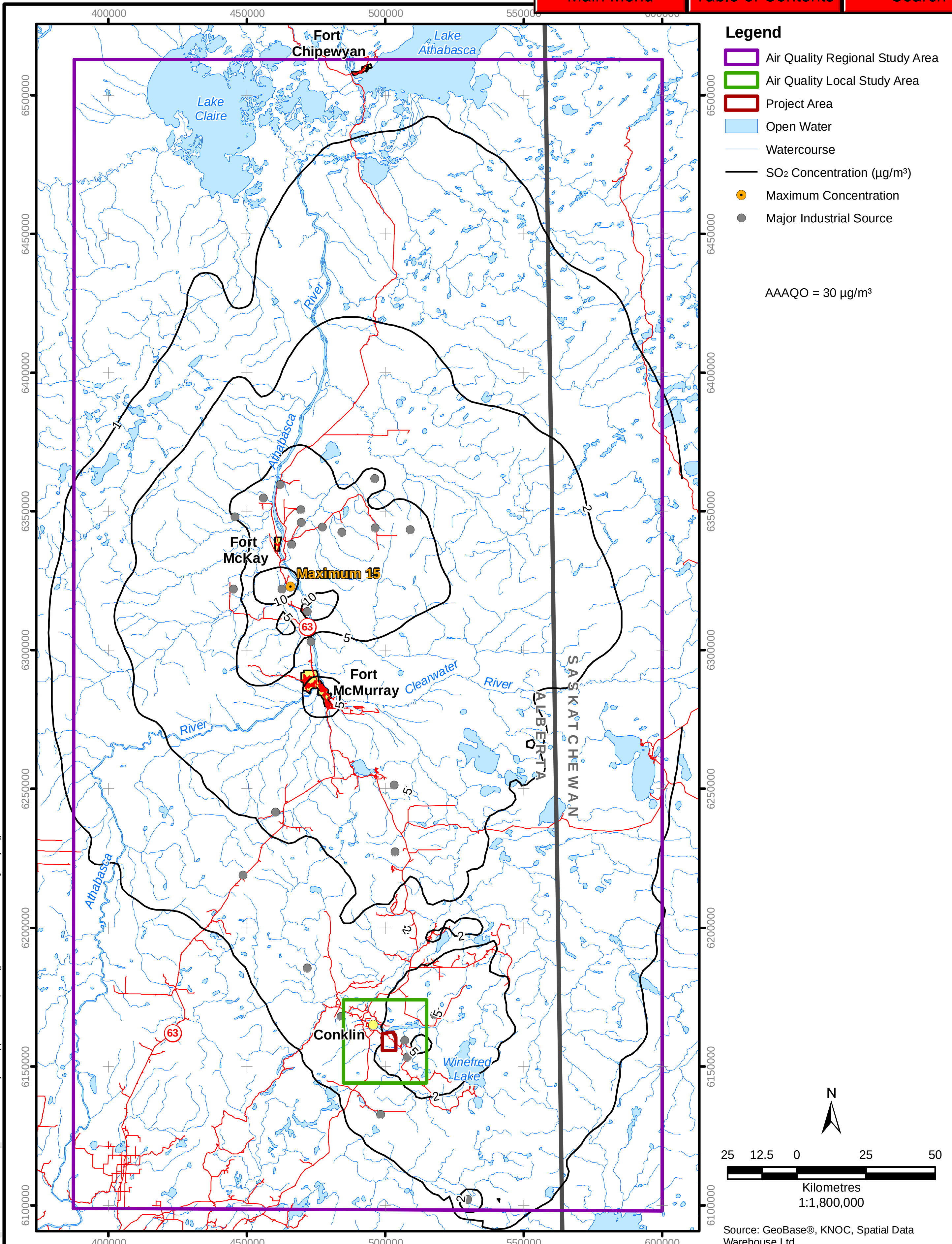
Korea National Oil Corporation BlackGold Expansion Project	2nd Highest 24-hour SO_2 Concentrations (µg/m³) Planned Development Case	DATE: March 2010 PROJECT: CE03745/200 ANALYST: CP QA/QC: KW EA DR	Fig04.07-02 PDC SO2 24hour 10-03-02 PROJECTION/DATUM: UTM Zone 12 NAD83 DRAWN BY: AMEC PREPARED BY: AMEC

Figure 4.7-2



Korea National Oil Corporation

BlackGold Expansion Project

Annual Average
SO_2 Concentrations (µg/m³)
Planned Development Case

DATE: March 2010		Fig04.07-03 PDC SO2 Annual 10-03-02	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: CP	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.7-3

Table 4.7-3: Comparison of Maximum SO_2 Concentrations for the Baseline, Application and Planned Development Scenarios

Scenario	RSA			LSA		
	1-h	24-h	Annual	1-h	24-h	Annual
Baseline ($\mu g/m^3$)	322	92	13.6	199	52	9.2
Application ($\mu g/m^3$)	322	92	13.6	199	52	9.3
Increase Relative to Baseline (%)	<1	<1	<1	<1	<1	1.7
Planned Development ($\mu g/m^3$)	343	95	14.9	199	53	9.6
Increase Relative to Baseline (%)	6.5	3.3	9.6	<1	<1	4.3
Objective ($\mu g/m^3$)	450	150	30	450	150	30

Notes:
Values that exceed the ambient objective are shown in boldface text.
The values do not include a background value.

The concentration contour plots for the different averaging periods for the planned development scenario are shown in the following figures:

- Figure 4.7-1 shows the maximum *1-h average SO_2* concentrations for the planned development scenario. The area within any concentration contour increases for the planned development scenario relative to the baseline scenario both within the AQRSA and the AQLSA, however the effect in the AQLSA is negligible.
- Figure 4.7-2 shows the maximum *24-h average SO_2* concentrations for the planned development scenario. The area within any concentration contour increases for the planned development scenario relative to the baseline scenario both within the AQRSA, however the effect in the AQLSA is negligible.
- Figure 4.7-3 shows the *annual average SO_2* concentrations for the planned development scenario. The area within any concentration contour increases for the planned development scenario relative to the baseline scenario both within the AQLSA and external to the AQLSA.

The maximum 1-h, 24-h and annual average AQRSA concentration patterns for the planned development scenario change relative to the baseline scenario, indicating a greater extent of increased ambient SO_2 concentrations. Within the AQLSA, the effects are generally minimal.

Table 4.7-4 provides the impact ratings for ambient SO_2 concentration changes due to the planned development scenario.

Table 4.7-4: Impact Ratings for Ambient SO_2 Concentration Changes Due to the Planned Development Scenario

Impact Attribute	Rating	Comment
Direction	Negative	Predicted ambient SO_2 concentrations within the RSA and LSA increase. The maximum predicted RSA annual values increases by 9.6% relative to the baseline scenario. The maximum predicted LSA annual concentration increases by 1.7% relative to the baseline scenario.
Geographic Extent	Regional	The changes occur in the LSA and RSA. Air quality changes occur over a wider area than that predicted for the application scenario and the aerial extent of high SO_2 concentrations is the greatest for the oil sands area north of Fort McMurray.
Magnitude	Low	The changes in the LSA are all less than 2% relative to the baseline.
	Moderate	The changes in the RSA range from 3.3 to 9.6%. All maximum 1-h, 24-h and annual concentrations are predicted to be less than the ambient air quality objectives.
Temporal	Infrequent	The planned development scenario facilities will produce increased SO_2 concentrations due to short-term upset events.
	Short-term	Hourly and daily average SO_2 concentrations will vary due to meteorological variations. High concentration events tend to be infrequent and of limited duration due to meteorological variability.
	Long-term	Annual values, by definition, represent a continuous exposure.
Confidence	Moderate	While the model and associated input parameters are generally well understood, there is less certainty of all projects being developed.
Final Rating	Low	In the LSA.
	Moderate	In the RSA.

The planned development scenario evaluation indicates that project emissions will not substantially contribute to ambient concentrations across the AQLSA or AQRSA. The planned development scenario increases the maximum predicted AQRSA 1-h SO_2 concentration by 6.5% (i.e., from 322 to 343 $\mu g/m^3$). In the planned development scenario, the maximum 24-h SO_2 concentration increases by 3.3% (i.e., from 92 to 95 $\mu g/m^3$).

The comparison between the baseline and application scenarios indicates that the predicted effect of the project emissions on ambient SO_2 concentrations is so small that it is unlikely to be detected. When considered in the context of a cumulative effects assessment, this conclusion is valid for the planned development scenario as well.

4.7.4 Nitrogen Oxide Emissions and Impacts

4.7.4.1 Introduction

Maximum ambient NO_2 concentration patterns are predicted for the three averaging periods associated with the ambient air quality objectives (namely 1-h, 24-h and annual).

4.7.4.2 Results

Planned development scenario predictions for NO_2 are presented in Table 4.7-5 and Figures 4.7-4 to 4.7-6. External to the AQLSA, the overall maximum predicted 1-h, 24-h and annual values associated with the planned development scenario increase by up to 2.9%. Within the AQLSA, the largest change is associated with the predicted annual average maximum value, with increases up to 5.9%.

Table 4.7-5: Comparison of Maximum NO_2 Concentrations for the Baseline, Application and Planned Development Scenarios

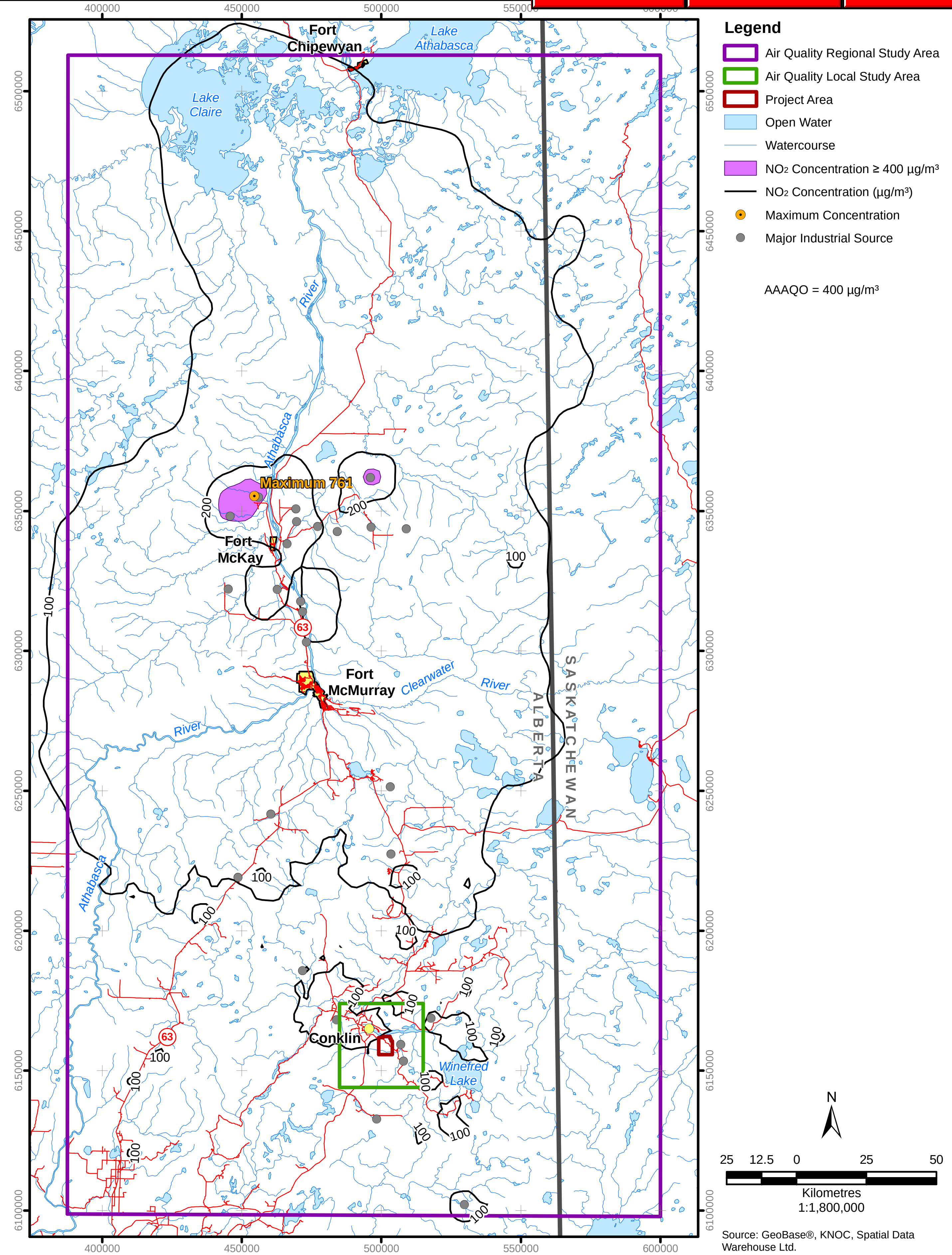
Scenario	RSA			LSA		
	1-h	24-h	Annual	1-h	24-h	Annual
Baseline ($\mu g/m^3$)	**748**	**279**	**110**	184	111	18.7
Application ($\mu g/m^3$)	**748**	**279**	**110**	184	111	18.7
Increase Relative to Baseline (%)	<1	<1	<1	<1	<1	<1
Planned Development ($\mu g/m^3$)	**761**	**287**	**113**	184	111	19.8
Increase Relative to Baseline (%)	1.7	2.9	2.7	<1	<1	5.9
Objective ($\mu g/m^3$)	400	200	60	400	200	60

Notes:
Values that exceed the ambient objective are shown in boldface text.
The values do not include a background value.

The concentration contour plots for the different averaging periods for the planned development scenario are shown in the following figures:

- Figure 4.7-4 shows the maximum *1-h average NO_2* concentrations for the planned development scenario. The area within any concentration contour increases for the planned development scenario relative to the baseline scenario both within the AQLSA and external to the AQLSA.
- Figure 4.7-5 shows the maximum *24-h average NO_2* concentrations for the planned development scenario. The area within any concentration contour increases for the planned development scenario relative to the baseline scenario both within the AQLSA and external to the AQLSA.
- Figure 4.7-6 shows the *annual average NO_2* concentrations for the planned development scenario. The area within any concentration contour increases for the planned development scenario relative to the baseline scenario both within the AQLSA and external to the AQLSA. The greatest changes are associated with the area to the north of Fort McMurray.

The maximum 1-h, 24-h and annual average AQRSA and AQLSA concentration patterns for the planned development scenario change relative to the baseline scenario, indicating an extension of increased ambient NO_2 concentrations. Table 4.7-6 provides the impact ratings for ambient NO_2 concentration changes due to the planned development scenario.



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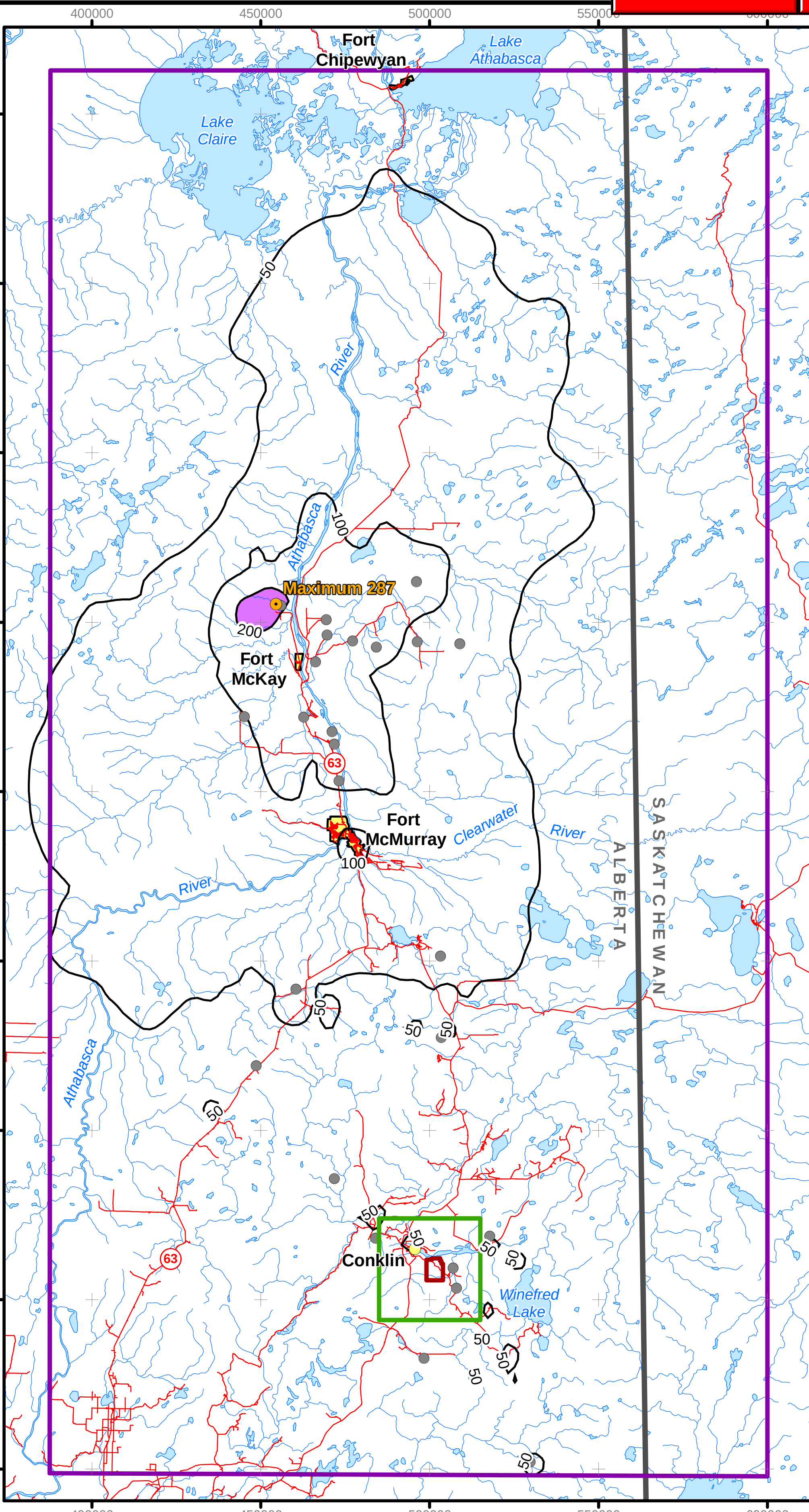
Korea National Oil Corporation

BlackGold Expansion Project

9th Highest 1-hour NO_2 Concentrations (µg/m³) Planned Development Case

DATE: March 2010	Fig04.07-04 PDC NO2 1hour 10-03-31
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83
ANALYST: TM / QA/QC: KW EA DR	DRAWN BY: AMEC / PREPARED BY: AMEC

Figure 4.7-4



Legend

- Air Quality Regional Study Area
- Air Quality Local Study Area
- Project Area
- Open Water
- Watercourse
- NO_2 Concentration ≥ 200 µg/m³
- NO_2 Concentration (µg/m³)
- Maximum Concentration
- Major Industrial Source

AAAQO = 200 µg/m³

N

25 12.5 0 25 50

Kilometres

1:1,800,000

Source: GeoBase®, KNOC, Spatial Data Warehouse Ltd.

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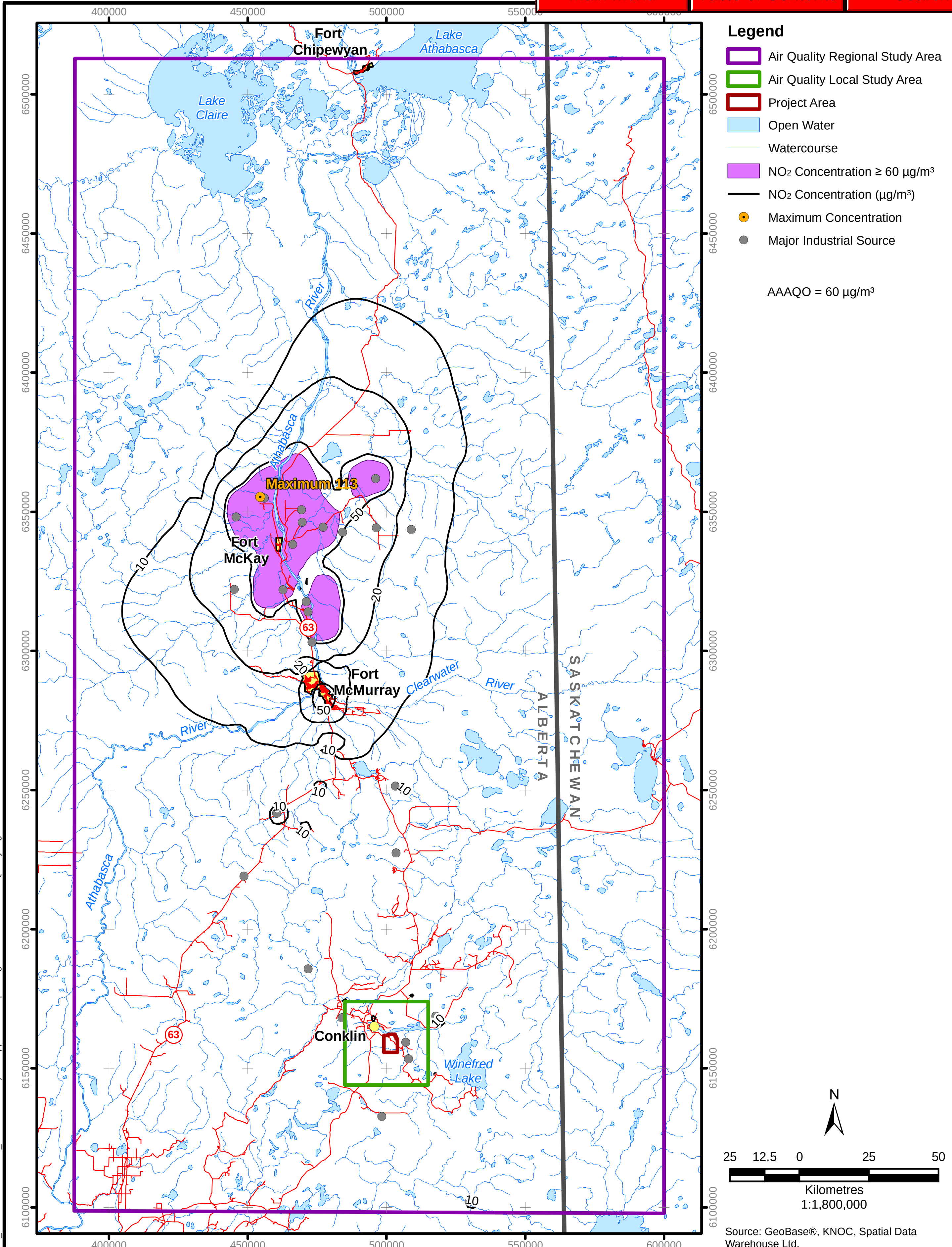
Korea National Oil Corporation

BlackGold Expansion Project

2nd Highest 24-hour NO_2 Concentrations (µg/m³) Planned Development Case

DATE: March 2010	Fig04.07-05 PDC NO2 24hour 10-03-31		**Figure 4.7-5**
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83		
ANALYST: TM / QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC	



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Korea National Oil Corporation

BlackGold Expansion Project

Annual Average
NO_2 Concentrations (µg/m³)
Planned Development Case

DATE: March 2010	Fig04.07-06 PDC NO2 Annual 10-03-31		
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83		
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.7-6

Table 4.7-6: Impact Ratings for Ambient NO_2 Concentration Changes Due to the Planned Development Scenario

Impact Attribute	Rating	Comment
Direction	Negative	Predicted ambient NO_2 concentrations within the RSA and LSA increase.
Geographic Extent	Regional	The changes occur in the LSA and RSA. Air quality changes occur over a wider area than that predicted for the application scenario and the aerial extent of NO_2 concentrations above the ambient guidelines is greatest for the oil sands area north of Fort McMurray.
Magnitude	Moderate	Maximum annual average concentrations are predicted to increase by 5.9% in the LSA. All maximum concentrations in the LSA are predicted to be less than the ambient air quality objectives.
	High	Within the RSA, the objectives are predicted to be exceeded for all averaging periods.
Temporal	Short-term	Hourly and daily average NO_2 concentrations will vary due to meteorological variations. High concentration events tend to be infrequent and of limited duration due to meteorological variability.
	Long-term	Annual values, by definition, represent a continuous exposure.
Confidence	Moderate	While the model and associated input parameters are generally well understood, there is less certainty of all projects being developed.
Final Rating	High	In the RSA.
	Moderate	In the LSA.

The planned development scenario evaluation indicates that maximum ambient NO_2 concentrations will increase in the vicinity of new or increasing emission sources. The predicted increases in ground-level concentrations within the AQLSA are the result of increasing emissions immediately outside the AQLSA. The objectives are predicted to be exceeded in a region north of Fort McMurray. The aerial extent of the annual exceedance is predicted to increase in this region due to the planned development scenario.

Within the AQLSA, there are no major changes associated with the maximum 1-h and 24-h concentration for the planned development scenario. The planned development scenario emissions increase the maximum predicted AQLSA annual concentrations by about 6% (i.e., from 18.7 to 19.8 $\mu g/m^3$). The maximum annual value for the AQLSA is about one-third the AAAQO.

The comparison between the baseline and application scenarios indicates that the predicted effect of the project emissions on ambient NO_2 concentrations outside the AQLSA is sufficiently small that they are unlikely to be detected. When considered in the context of a cumulative effects assessment, this conclusion is valid for the planned development scenario as well.

4.7.5 Particulate Matter Emissions and Impacts

4.7.5.1 Introduction

Maximum ambient $PM_{2.5}$ concentrations are predicted for the 1-h and 24-h averaging periods associated with ambient air quality objectives.

4.7.5.2 Results

Planned development scenario predictions are presented in Table 4.7-7 and Figures 4.7-7 and 4.7-8. External to the AQLSA, the maximum predicted 1-h and 24-h values associated with the planned development scenario increase by <1%. Within the AQLSA, the maximum predicted 1-h and 24-h values associated with the planned development scenario increase by 100 and 55%, respectively.

Table 4.7-7: Comparison of Maximum $PM_{2.5}$ Concentrations for the Baseline, Application and Planned Development Scenarios

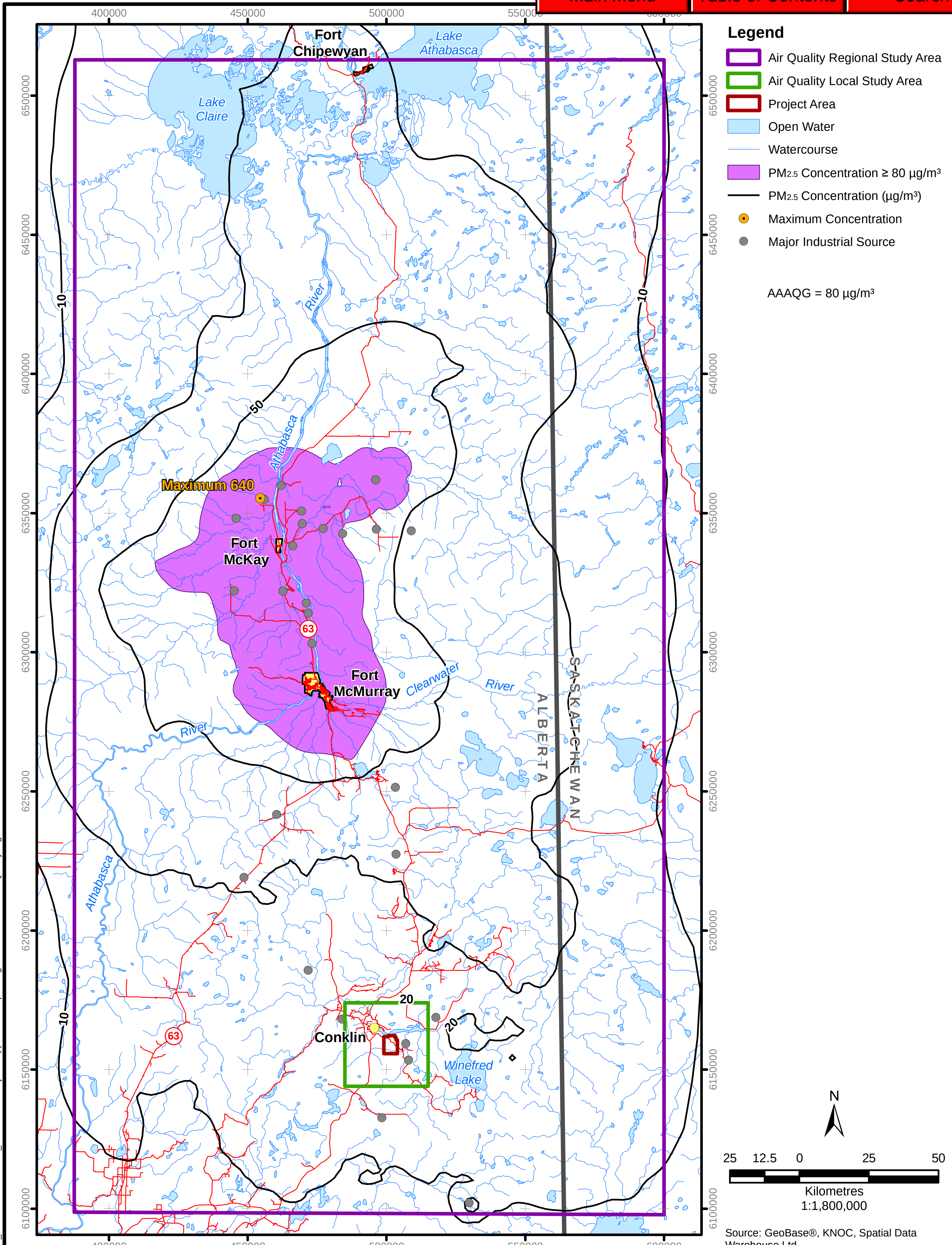
Scenario	RSA		LSA	
	1-h	24-h	1-h	24-h
Baseline ($\mu g/m^3$)	**560**	**164**	5.9	2.2
Application ($\mu g/m^3$)	**560**	**164**	5.9	2.2
Increase Relative to Baseline (%)	<1	<1	<1	<1
Planned Development ($\mu g/m^3$)	**560**	**164**	11.8	3.4
Increase Relative to Baseline (%)	<1	<1	100	55
AAAQO ($\mu g/m^3$)	80	30	80	30

Notes:
Values that exceed the ambient objective are shown in boldface text.
The values do not include a background value.

Figure 4.7-7 shows the maximum *1-h average $PM_{2.5}$* concentrations for the planned development scenario. The area within any concentration contour increases for the planned development scenario relative to the baseline scenario both within the AQLSA and external to the AQLSA.

Figure 4.7-8 shows the maximum *24-h average $PM_{2.5}$* concentrations for the planned development scenario. The area within any concentration contour increases for the planned development scenario relative to the baseline scenario both within the AQLSA and external to the AQLSA.

Table 4.7-8 provides the impact ratings for ambient $PM_{2.5}$ concentration changes due to the planned development scenario.



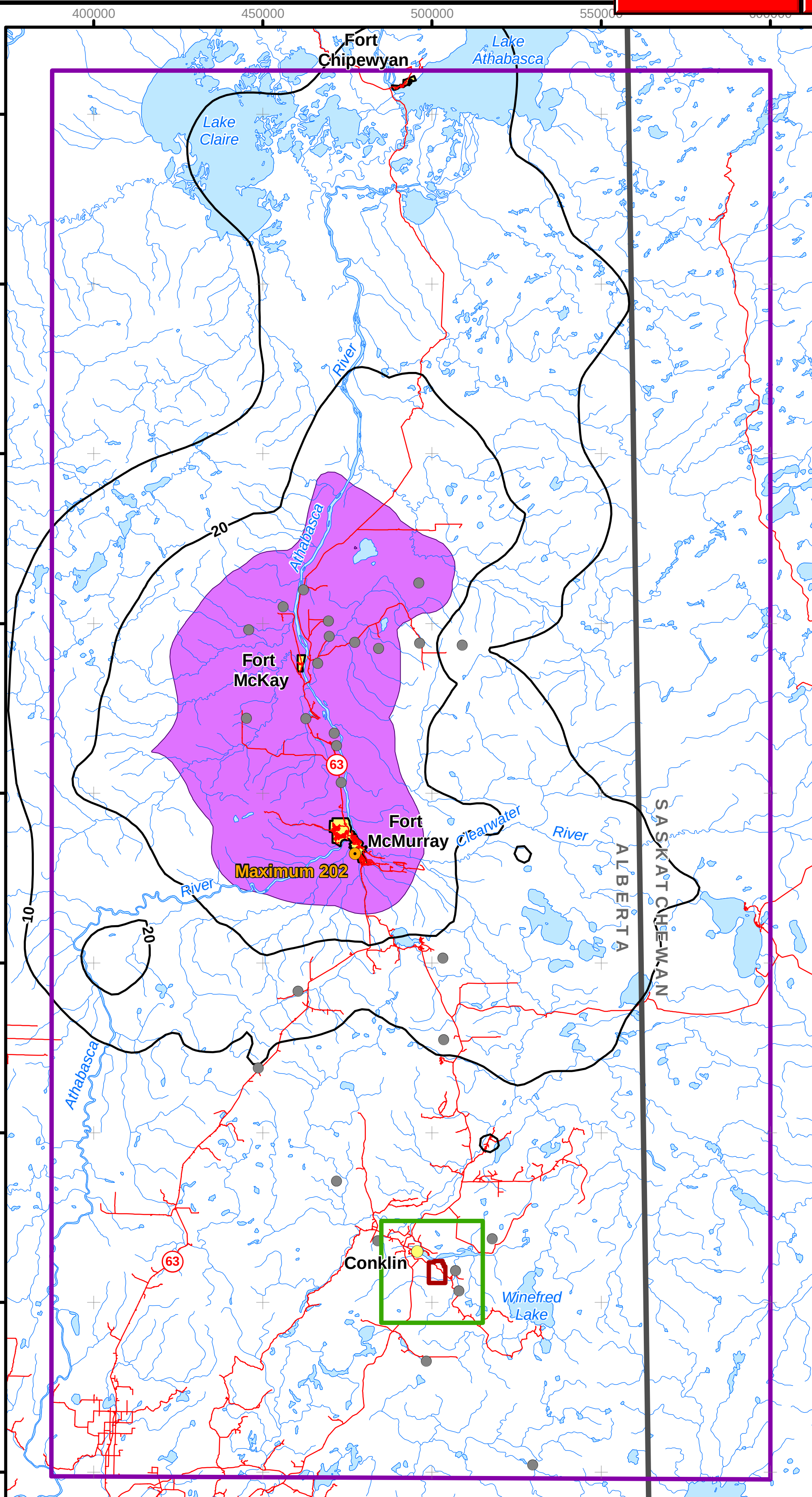
Korea National Oil Corporation

BlackGold Expansion Project

9th Highest 1-hour $PM_{2.5}$ Concentrations (µg/m³) Planned Development Case

DATE: March 2010		Fig04.07-07 PDC PM25 1hour 10-03-31	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.7-7



Legend
- Air Quality Regional Study Area
- Air Quality Local Study Area
- Project Area
- Open Water
- Watercourse
- $PM_{2.5}$ Concentration ≥ 30 µg/m³
- $PM_{2.5}$ Concentration (µg/m³)
- Maximum Concentration
- Major Industrial Source

Canada-wide Standard = 30 µg/m³

N

25 12.5 0 25 50

Kilometres

1:1,800,000

Source: GeoBase®, KNOC, Spatial Data Warehouse Ltd.

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Korea National Oil Corporation

BlackGold Expansion Project

2nd Highest 24-hour $PM_{2.5}$ Concentrations (µg/m³) Planned Development Case

DATE: March 2010		Fig04.07-08 PDC PM25 24hour 10-03-31	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.7-8

Table 4.7-8: Impact Ratings for Ambient $PM_{2.5}$ Concentration Changes Due to the Planned Development Scenario

Impact Attribute	Rating	Comment
Direction	Negative	Predicted ambient $PM_{2.5}$ concentrations within the RSA and LSA increase.
Geographic Extent	Regional	Changes occur in the LSA and RSA. Air quality changes occur over a wider area than that predicted for the application scenario. The aerial extent of $PM_{2.5}$ concentrations above the ambient objectives is greatest north of Fort McMurray.
Magnitude	Low	Within the RSA, maximum concentrations are predicted to exceed the ambient objectives near the primary oil sands area.
	High	Within the LSA, the maximum concentration is predicted to increase by 55 to 100%.
Temporal	Short-term	Hourly and daily average $PM_{2.5}$ concentrations will vary due to meteorological variations. High concentration events tend to be infrequent and of limited duration due to meteorological variability.
	Long-term	Annual values, by definition, represent a continuous exposure.
Confidence	Moderate	While the model and associated input parameters are generally well understood, there is less certainty of all projects being developed.
Final Rating	High	In the RSA.
	High	In the LSA.

The planned development scenario evaluation indicates that maximum ambient concentrations will increase across the AQRSA. Maximum 1-h and 24-h values are predicted to be exceeded in a region north of Fort McMurray. The aerial extent of the annual exceedance is predicted to increase in this region in the planned development scenario.

The planned development scenario emissions increase the maximum predicted AQLSA hourly concentration by 100% (i.e., from 5.9 to 11.8 $\mu g/m^3$) relative to the baseline scenario. Within the AQLSA, the maximum 1-h and 24-h concentrations for the planned development scenario are well within the AAAQO.

The comparison between the baseline and application scenarios indicates that the predicted effect of the project emissions on ambient $PM_{2.5}$ concentrations within the AQRSA is sufficiently small that they are unlikely to be detected. When considered in the context of a cumulative effects assessment, this conclusion is valid for the planned development scenario as well.

4.7.6 Carbon Monoxide Emissions and Impacts

4.7.6.1 Introduction

Maximum ambient CO concentrations are predicted for the 1-h and 8-h averaging periods associated with ambient air quality objectives.

4.7.6.2 Results

Planned development scenario predictions for CO concentration are presented in Table 4.7-9 and Figures 4.7-9 and 4.7-10. The maximum predicted values in the AQRSA and AQLSA associated with the planned development scenario increase by less than 2%.

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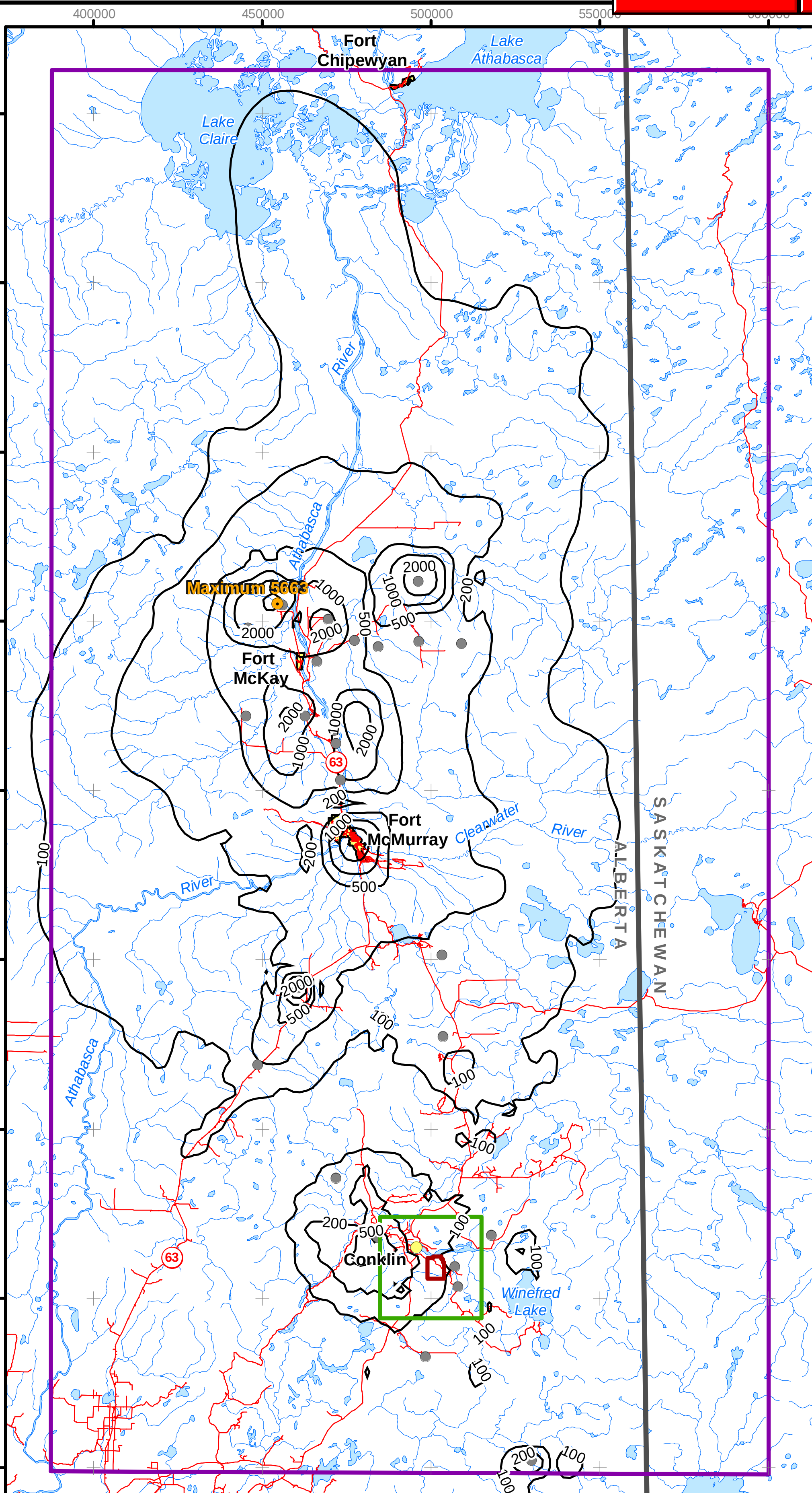

Legend

- Air Quality Regional Study Area
- Air Quality Local Study Area
- Project Area
- Open Water
- Watercourse
- CO Concentration (µg/m³)
- Maximum Concentration
- Major Industrial Source

AAAQO = 15,000 µg/m³

N

25 12.5 0 25 50

Kilometres

1:1,800,000

Source: GeoBase®, KNOC, Spatial Data Warehouse Ltd.

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Korea National Oil Corporation

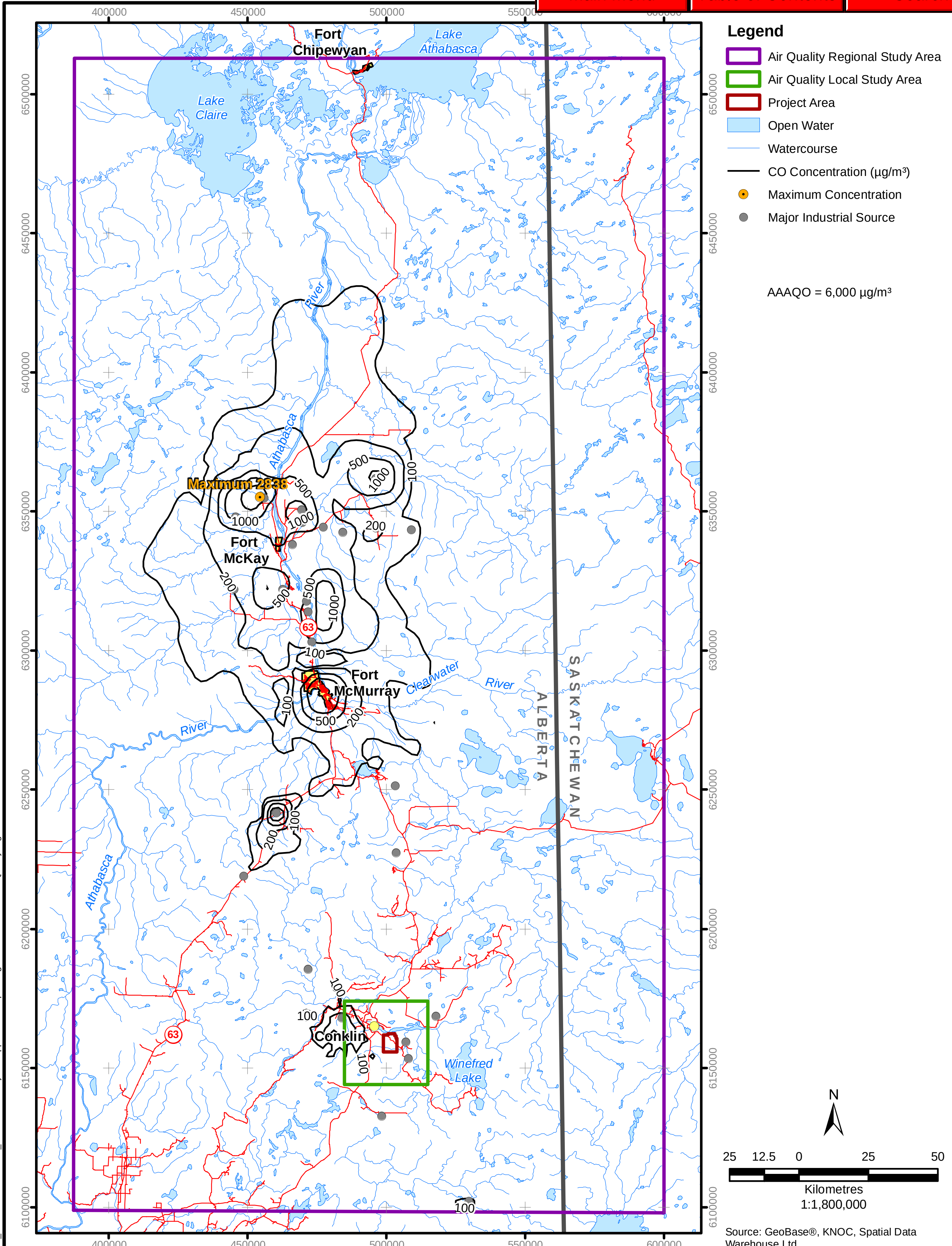
BlackGold Expansion Project

9th Highest 1-hour CO Concentrations (µg/m³) Planned Development Case

DATE: March 2010		Fig04.07-09 PDC CO 1hour 10-03-02	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: CP	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.7-9

Main Menu | Table of Contents | Search



Korea National Oil Corporation

BlackGold Expansion Project

2nd Highest 8-hour CO Concentrations (µg/m³) Planned Development Case

DATE: March 2010	Fig04.07-10 PDC CO 8hour 10-03-02	
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: CP / QA/QC: KW EA DR	DRAWN BY: AMEC / PREPARED BY: AMEC	

Figure 4.7-10

Table 4.7-9: Comparison of Maximum CO Concentrations for the Baseline, Application and Planned Development Scenarios

Scenario	RSA		LSA	
	1-h	8-h	1-h	8-h
Baseline ($\mu g/m^3$)	5556	2835	1136	468
Application ($\mu g/m^3$)	5556	2835	1136	468
Increase Relative to Baseline (%)	<1	<1	<1	<1
Planned Development ($\mu g/m^3$)	5663	2838	1138	475
Increase Relative to Baseline (%)	<1	<1	<1	1.4
CWS ($\mu g/m^3$)	15 000	6 000	15 000	6 000

Notes:
Values that exceed the ambient objective are shown in boldface text.
The values do not include a background value.

Figure 4.7-9 shows the maximum *1-h average CO* concentrations for the planned development scenario. The area within any concentration contour increases for the planned development scenario relative to the baseline scenario both within the AQLSA and external to the AQLSA.

Figure 4.7-10 shows the maximum *24-h average CO* concentrations for the planned development scenario. The area within any concentration contour increases for the planned development scenario relative to the baseline scenario, both within the AQLSA and external to the AQLSA.

Table 4.7-10 provides the impact ratings for ambient CO concentration changes due to the planned development scenario.

Table 4.7-10: Impact Ratings for Ambient CO Concentration Changes Due to the Planned Development Scenario

Impact Attribute	Rating	Comment
Direction	Negative	Predicted ambient CO concentrations within the RSA and LSA increase.
Geographic Extent	Regional	Changes occur in the LSA and RSA. Air quality changes occur over a wider area than that predicted for the application scenario.
Magnitude	Low	Maximum concentrations are predicted to increase by less than 2%. Maximum concentrations are predicted to be well within the ambient objectives.
Temporal	Short-term	Hourly and daily average CO concentrations will vary due to meteorological variations. High concentration events tend to be infrequent and of limited duration due to meteorological variability.
	Long-term	Annual values, by definition, represent a continuous exposure.
Confidence	Moderate	While the model and associated input parameters are generally well understood, there is less certainty of all projects being developed.
Final Rating	Low	In the RSA.
	Low	In the LSA.

The planned development scenario evaluation indicates that maximum ambient concentrations will increase slightly across the AQRSA and AQLSA. The maximum predicted concentrations for each averaging period remain substantially unchanged (i.e., less than a 2% change) relative to the baseline scenario. The maximum 1-h and 8-h concentrations for the planned development scenario are well within the AAAQO.

The comparison between the baseline and application scenarios indicates that the predicted effect of the project emissions on ambient CO concentrations within the AQRSA is sufficiently small that they are unlikely to be detected. When considered in the context of a cumulative effects assessment, this conclusion is valid for the planned development scenario as well.

4.7.7 Acid Deposition Emissions and Impacts

4.7.7.1 Introduction

PAI patterns are predicted for the planned development emission scenario.

4.7.7.2 Results

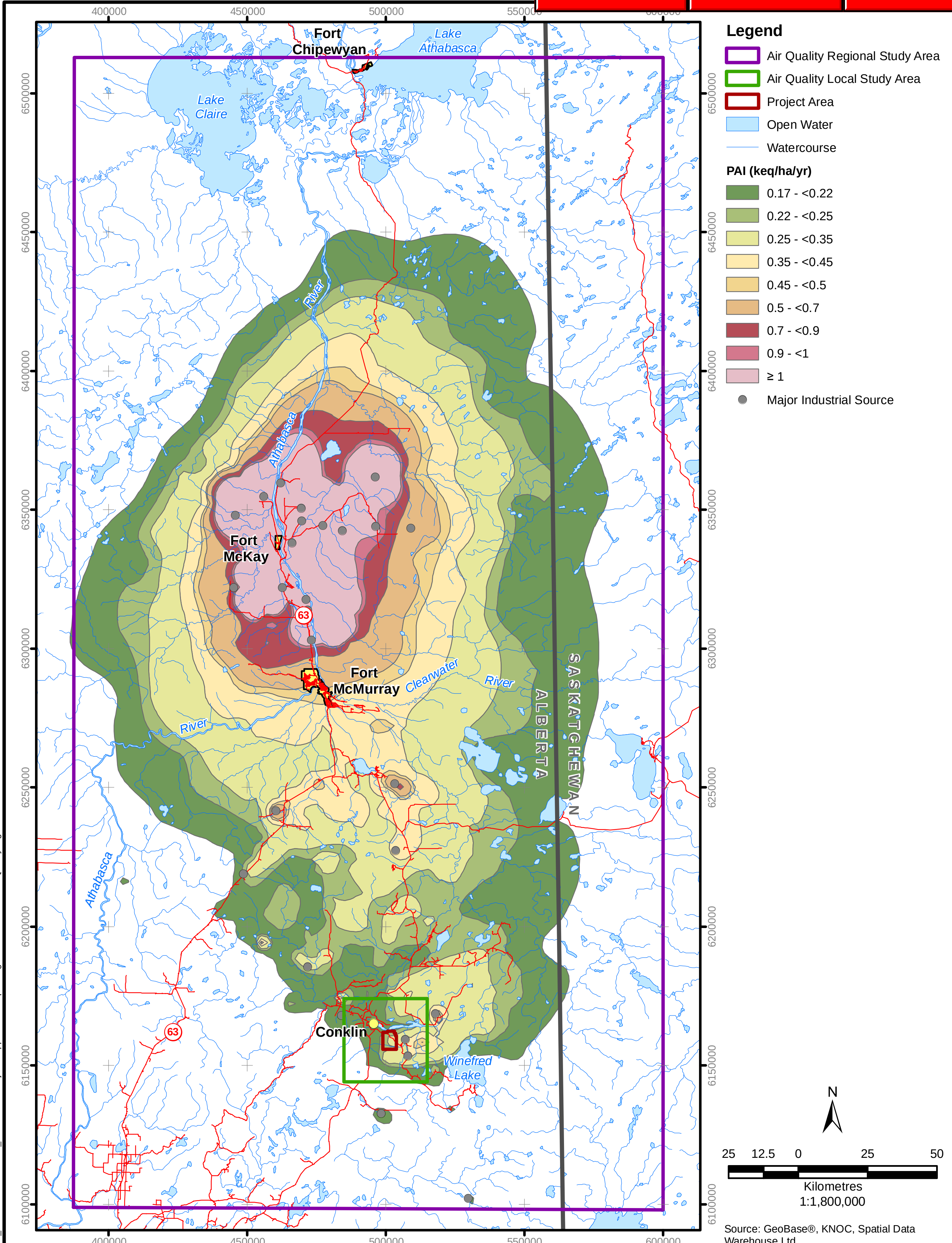
Planned development scenario results for small-scale PAI are summarized in Table 4.7-11 and Figure 4.7-11. For the AQRSA, the planned development scenario increases the maximum PAI by <1% relative to the baseline scenario. For the AQLSA, the planned development scenario increases the maximum PAI by 6.8% relative to the baseline scenario. It should be noted that the small-scale grid PAI values are not directly comparable to the critical loads as the latter are based on 1° latitude by 1° longitude grid cells and the RELAD model (CASA and AENV 1999).

Table 4.7-11: Comparison of Maximum Small-Scale Deposition Values for the Baseline, Application and Planned Development Scenarios

Scenario	RSA			LSA		
	Sulphate	Nitrate	PAI	Sulphate	Nitrate	PAI
Baseline (keq H^+/ha/yr)	2.43	12.31	13.13	1.11	0.29	0.59
Application (keq H^+/ha/yr)	2.43	12.31	13.13	1.12	0.29	0.60
Increase Relative to Baseline (%)	<1	<1	<1	<1	<1	1.3
Planned Development (keq H^+/ha/yr)	2.47	12.41	13.24	1.13	0.32	0.63
Increase Relative to Baseline (%)	1.6	<1	<1	1.8	10.3	6.8

Notes:
Maximum values represent small-scale peaks.
Sulphate equivalent and nitrate equivalent deposition without background.
PAI = Potential Acid Input (includes background).

Figure 4.7-11 shows the annual PAI for the planned development scenario. The predicted baseline and planned development scenario deposition patterns within and external to the AQLSA are slightly different. Specifically, the aerial extent within a given deposition contour has increased with the increased emissions associated with the planned development scenario.



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Korea National Oil Corporation

BlackGold Expansion Project

PAI in keq/ha/yr
for the
Planned Development Case

DATE: March 2010		Fig04.07-11 PDC PAI 10-03-03	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: NH	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.7-11

While the main location where the predicted PAI is greater than critical loads occurs in the area north of Fort McMurray, deposition greater than critical loads on a smaller scale are also predicted to occur in the AQLSA. Table 4.7-12 provides the impact ratings for PAI changes due to the planned development scenario.

Table 4.7-12: Impact Ratings for PAI Changes Due to the Planned Development Scenario

Impact Attribute	Rating	Comment
Direction	Negative	Predicted PAI within the RSA and LSA increase.
Geographic Extent	Regional	The changes occur in the LSA and RSA. The primary high deposition area is located in the oil sands area north of Fort McMurray.
Magnitude	Moderate	The maximum small-scale grid PAI values are higher than the CASA and AENV (1999) Critical Loads. Within the LSA, maximum small-scale grid PAI values increase by 6.8%
Temporal	Long-term	Annual values, by definition, represent a continuous exposure. Higher deposition will tend to occur during the spring and summer when vegetation activity is greater.
Confidence	Moderate (Relative) Low (Absolute)	While the model and associated input parameters are generally well understood, there is less certainty of all projects being developed.
Final Rating	Moderate	In the RSA.
	Moderate	In the LSA.

For the AQLSA, the maximum small-scale grid PAI near the project is predicted to increase by about 7%. Note that small-scale grid PAI values greater than the critical loads are not viewed as a regulatory exceedance, since these critical loads are to be applied to a 1° latitude by a 1° longitude scale, as predicted by RELAD modelling applied on a sub-continental scale.

The comparison between the baseline and application scenarios indicates that the predicted effect of the project emissions on small-scale grid PAI outside the AQLSA is sufficiently small that they are unlikely to be detected. When considered in the context of a cumulative effects assessment, this conclusion is valid for the planned development scenario as well.

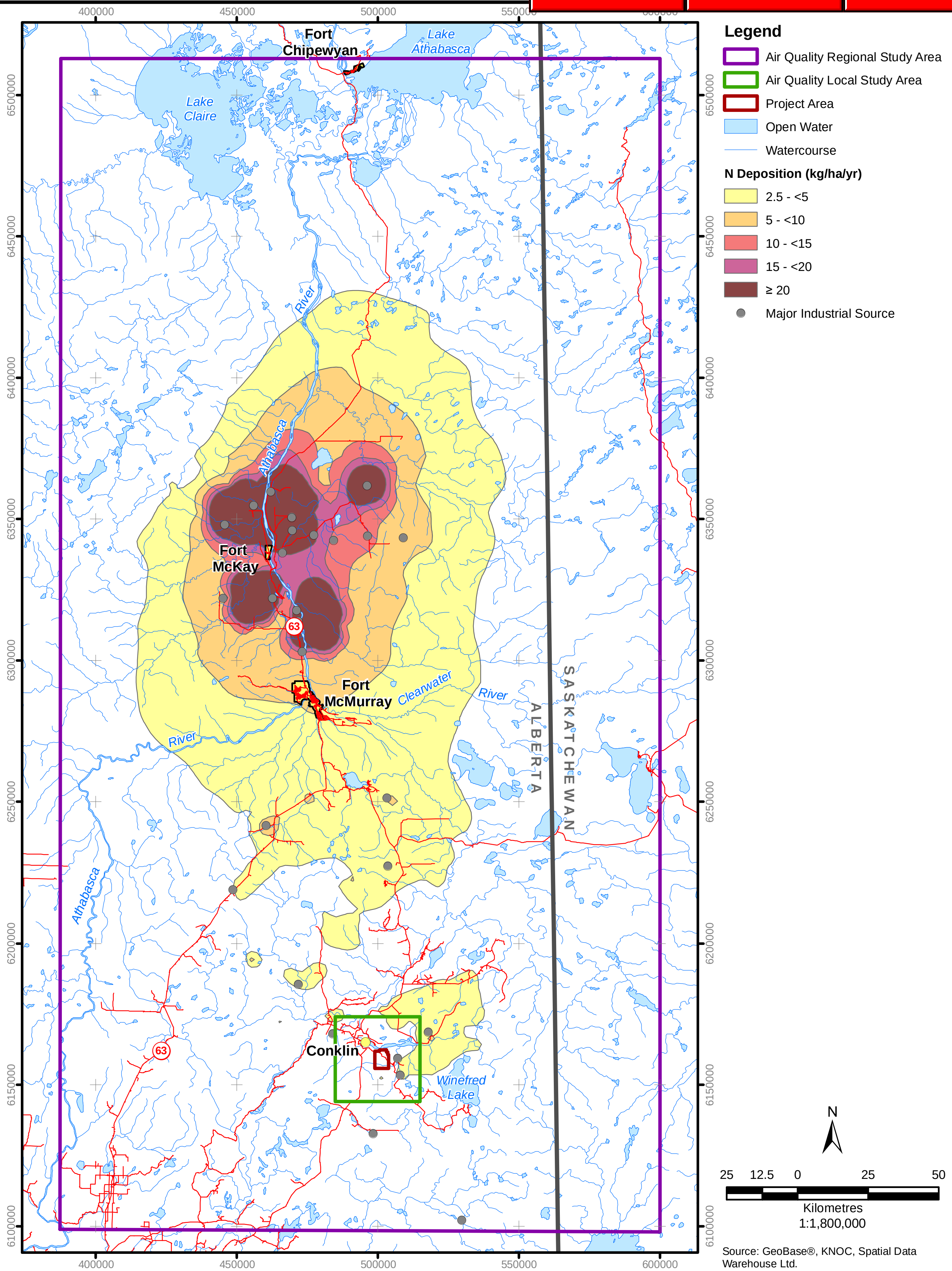
4.7.8 Nitrogen Deposition Emissions and Impacts

4.7.8.1 Introduction

Nitrogen deposition patterns are predicted for the planned development emission scenario.

4.7.8.2 Results

Planned development scenario results for small-scale grid nitrogen deposition are presented in Table 4.7-13 and Figure 4.7-12. For the AQRSA, the planned development scenario increases the maximum deposition by <1% relative to the baseline scenario. For the AQLSA, the planned development scenario increases the maximum deposition by 8.9% relative to the baseline scenario.



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Korea National Oil Corporation

BlackGold Expansion Project

Nitrogen Deposition in kg/ha/yr for the Planned Development Case

DATE: March 2010		Fig04.07-12 PDC N 10-03-03	
PROJECT: CE03745/200		PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: TM	QA/QC: KW EA DR	DRAWN BY: AMEC	PREPARED BY: AMEC

Figure 4.7-12

Table 4.7-13: Comparison of Maximum Small-Scale Grid Nitrogen Deposition Values for the Baseline, Application and Planned Development Scenarios

Scenario	RSA	LSA
Baseline (kg/ha/yr)	172	4.1
Application (kg/ha/yr)	172	4.1
Increase Relative to Baseline (%)	<1	<1
Planned Development (kg/ha/yr)	174	4.5
Increase Relative to Baseline (%)	1.1	8.9

Notes:
Nitrate equivalent deposition without background.

Figure 4.7-12 shows the annual nitrogen deposition for the planned development scenario. The predicted baseline and planned development deposition patterns within and external to the AQLSA are slightly different. Specifically, the aerial extent within a given deposition contour has increased with the increased emissions associated with the planned development scenario. Therefore, PAI is increasing within the AQLSA due to planned projects located outside the AQLSA.

While the main location where the predicted deposition is greater than critical loads occurs in the area north of Fort McMurray, deposition greater than critical loads on a smaller scale are also predicted to occur in the AQLSA. Table 4.7-14 provides the impact ratings for nitrogen deposition changes due to the planned development scenario.

Table 4.7-14: Impact Ratings for Nitrogen Deposition Changes Due to the Planned Development Scenario

Impact Attribute	Rating	Comment
Direction	Negative	Predicted deposition within the RSA and LSA increases.
Geographic Extent	Regional	The changes occur in the LSA and RSA. The primary high deposition area is located in the oil sands area north of Fort McMurray.
Magnitude	Moderate	The maximum small-scale grid deposition values in the RSA are higher than the Critical Loads (WHO 2000). Within the LSA, maximum small-scale grid PAI values increase by 8.9%
Temporal	Long-term	Annual values, by definition, represent a continuous exposure. Higher deposition will tend to occur during the spring and summer when vegetation activity is greater.
Confidence	Moderate (Relative) Low (Absolute)	While the model and associated input parameters are generally well understood, there is less certainty of all projects being developed.
Final Rating	Moderate	In the RSA.
	Moderate	In the LSA.

While deposition greater than critical loads (on a small-scale grid) are predicted to occur primarily in the Fort McMurray area, deposition greater than some critical loads is predicted within the AQLSA.

For the AQLSA, the maximum small-scale grid deposition near the project is predicted to increase by about 9%. The comparison between the baseline and application scenarios indicates that the predicted effect of the project emissions on small-scale grid nitrogen deposition outside the AQLSA is sufficiently small that they are unlikely to be detected. When considered in the context of a cumulative effects assessment, this conclusion is valid for the planned development scenario as well.

4.7.9 Community and Recreational Area Location Impacts

4.7.9.1 Introduction

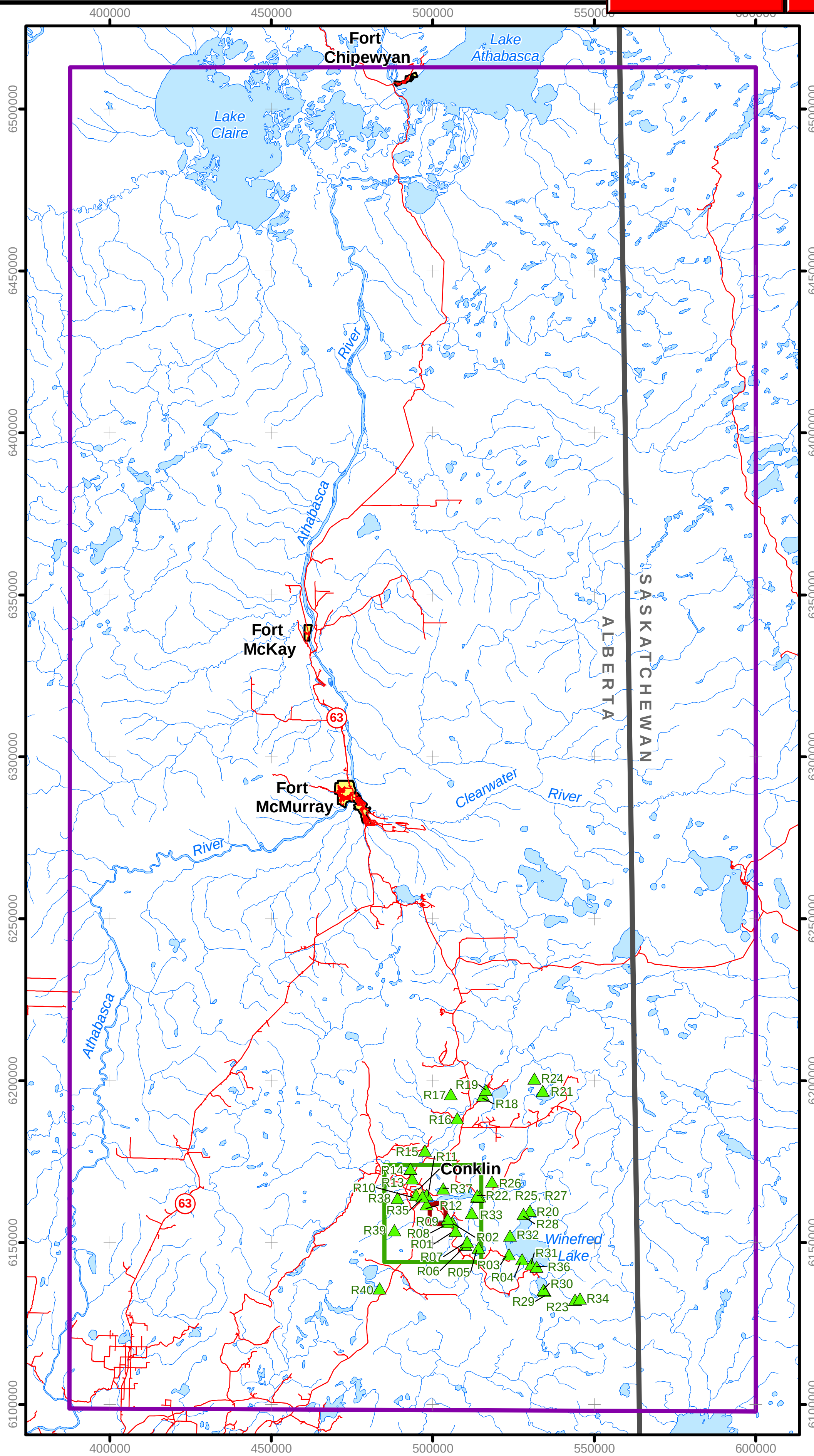
In addition to SO_2, NO_x, CO and $PM_{2.5}$ emissions, the combustion of natural gas and produced gas can generate trace gas emissions (e.g., VOC and PAH). The chemicals identified in Table 4.7-15 were selected to determine potential human health implications of the project emissions. These chemicals were selected through consideration of the trace chemicals that could be emitted by the proposed facilities and their potential health effects (see Section 18.0, Human Health).

Table 4.7-15: Chemicals Evaluated at Community and Recreational Locations

Chemical Name		
Benzene	3-Methylcholanthrene	Chrysene
Napthalene	7,12-Dimethylbenz(a)anthracene	Dibenzo(a,h)anthracene
Toluene	Acenapthalene	Dichlorobenzene
Xylenes	Acenaphthylene	Fluoranthene
Aliphatics	Acetaldehyde	Fluorene
Aromatics	Acrolein	Formaldehyde
RSC	Anthracene	Indeno(1,2,3-cd)pyrene
Thiophenes	Benzo(a)anthracene	n-hexane
Mercaptans	Benzo(a)pyrene	n-pentane
Ethyl Benzene	Benzo(b)fluoranthene	Phenanthrene
1,3-Butadiene	Benzo(k)fluoranthene	Pyrene
2-Methyl Napthalene	Benzo(g,h,i)perylene	SO_2
NO_x	CO	$PM_{2.5}$

4.7.9.2 Methods

Maximum concentrations for each chemical species or group were predicted at 40 community and recreational area locations (Figure 4.7-13) using the CALPUFF dispersion model. Maximum 1-h, 24-h and annual average concentrations were predicted for each location. These averaging periods represent the time periods that are frequently used for air quality management purposes. A maximum 8-h averaging concentration was also predicted for CO to coincide with the 8-h CO AAAQO.



Legend

- Air Quality Regional Study Area
- Air Quality Local Study Area
- Project Area
- Open Water
- Watercourse
- Recreational Area and Community Receptor

N

25 12.5 0 25 50

Kilometres

1:1,800,000

Source: GeoBase®, KNOC, Spatial Data Warehouse Ltd.

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Korea National Oil Corporation

BlackGold Expansion Project

Locations of Recreational Area and Community Receptors

DATE: March 2010	Fig04.07-13 Rec Area Community Receptors 10-03-23	**Figure 4.7-13**
PROJECT: CE03745/200	PROJECTION/DATUM: UTM Zone 12 NAD83	
ANALYST: NH; QA/QC: KW EA DR	DRAWN BY: AMEC; PREPARED BY: AMEC	

The CALPUFF model was used to predict the maximum contribution at these locations due to all emission sources that were considered for the criteria air contaminant assessment (i.e., within the AQRSA). From an impact assessment perspective, the focus of these predictions were the communities and recreational areas located both within the air AQLSA and external to the AQLSA. This approach not only ensures that the impacts associated with the operations in the AQLSA are documented but also takes into account the background influences associated with the industrial facilities located to the north.

4.7.9.3 Results

The maximum predicted concentrations at each community and recreational receptor are presented in the Human Health Risk Assessment (Section 18, Human Health). Maximum predicted concentrations for the application and planned development scenarios are compared to the baseline scenario to assess impacts associated with the project and other proposed facilities, respectively.

The project contribution to maximum predicted concentrations at the selected recreational areas and communities is less than 4% relative to the baseline scenario for all averaging periods. The planned development case results will be more variable as certain existing operations in the AQRSA plan to shift their operations to new mining areas. This shift will displace the emissions, which can cause increases as well as decreases in the maximum predicted concentrations.

In general, the maximum ambient concentration at any given community or recreational area location depends on the assessment scenario, the distance from the respective emission sources and the averaging period. As expected, the project emissions result in slightly higher predicted concentrations at the community and recreational area locations closest to the project.

4.7.10 Ozone

4.7.10.1 Introduction

Ozone is not emitted directly to the atmosphere by the project or other AQRSA facilities. Ozone, however, has the potential to form downwind of urban or industrial areas due to precursor NO_X and VOC emissions under conditions where there is high solar radiation, high temperature and low wind speeds (i.e., on a hot, calm summer day). High ozone concentrations are observed under these conditions in some parts of Canada (i.e., the Lower Fraser Valley in British Columbia; the Windsor to Quebec City corridor in Ontario and Québec; and the St John area in New Brunswick). Field studies conducted in the Oil Sands Region, however, have not indicated any appreciable ozone formation due to precursor emissions.

The project and other facilities emit the NO_X precursor emissions from combustion sources and VOCs from fugitive and combustion sources. Biogenic sources can also result in significant precursor VOC emissions. The ozone issue is addressed in a qualitative manner relative to the precursor emissions.

Ozone can be found in the atmosphere in the following locations:

- ozone concentrations peak in the *stratosphere* at an elevation of 25 km with a maximum concentration of about 12 ppmv. This ozone shields the earth's surface from ultraviolet radiation. This is beneficial since this radiation has sufficient energy to cause skin cancer in humans and to destroy acids in DNA; and
- near the surface (i.e., in the *troposphere*), ozone can form in the atmosphere from photochemical reactions between NO_x and VOC. In this case, ozone is referred to as a secondary pollutant. At sufficiently high concentrations, surface ozone can have adverse effects on vegetation and human health.

While there is minimal mixing between the stratosphere and the troposphere, stratospheric ozone can be mixed into the upper troposphere (Angle and Sandhu 1986, 1989; Davies and Schuepbach 1994).

For Northern Canada, the following natural sources of surface ozone have been identified:

- long-range transport of tropical Pacific air, which has concentrations in the 40 to 50 ppbv (80 to 100 $\mu g/m^3$) range;
- long-range transport of polar air that contains air mixed downward from the upper troposphere. Ozone concentrations in this air mass are in the 80 to 100 ppbv (160 to 200 $\mu g/m^3$) range;
- biomass burning (i.e., forest fires) and resulting photochemical reactions that produce typical ozone enrichments of 10 to 15 ppbv (20 to 30 $\mu g/m^3$) above background; and
- short duration stratospheric intrusions can lead to sudden increases of ground-level ozone.

In Alberta, there is a general tendency for greater ozone concentrations during the spring (March to April) and for greater values during the daylight hours. Ozone concentrations in and adjacent to, urban areas are generally less than those in the surrounding rural areas due to ozone depletion through reactions with the urban NO_x emissions (e.g., urban areas act as ozone sinks). There has been limited ozone monitoring downwind of urban source regions in Alberta. A review of some of the available data indicates photochemical ozone production is limited to a few hours per year during the summer period (Davies and Fellin 1999). Specifically:

- a review of data near the Calgary airshed indicated an enhancement of 20 ppbv (40 $\mu g/m^3$) due to urban emissions;
- a review of data near the Edmonton airshed indicated an enhancement of 10 to 15 ppbv (20 to 30 $\mu g/m^3$) due to urban and industrial emissions;
- a review of data downwind of the Athabasca oil sands region indicated an enhancement of 9 to 42 ppbv (18 to 82 $\mu g/m^3$) over the upwind values;

- ambient measurements in the Suncor power plant plume indicated enhancements of 10 ppbv (20 $\mu g/m^3$) 24 km downwind of the stack; and
- a comparison of seasonal ozone concentrations downwind of a forest fire in northeast Alberta indicated potential ozone enhancements of about 15 ppbv (30 $\mu g/m^3$).

In some cases, these enhancements resulted in values in excess of the 160 $\mu g/m^3$ (82 ppbv) ambient objective and in other cases the ambient objective was not exceeded.

4.7.10.2 Methods

Photochemical models can be used to predict the secondary formation of ozone based on precursor NO_x and VOC emissions. These models have been applied to the Athabasca oil sands region to determine the potential for ozone formation due to the developments proposed for the region. Specifically, two California Air Resources Board models (SMOG and CALGRID) have been applied to the oil sands region (Davies and Fellin 1999).

Both modelling exercises focused on summer periods when the photochemical production of ozone is expected to be the greatest. The results of the modelling relative to the NO_x and VOC emissions are provided in Table 4.7-16 and Figure 4.7-14. The results show a consistent trend even with differing models and differing assumptions. Most of the VOC emissions appear to originate from biogenic rather than anthropogenic sources.

Table 4.7-16: Comparison of SMOG and CALGRID Photochemical Model Predictions of Maximum Ozone Concentrations

Model	NO_x Emission (t/d)	Anthropogenic VOC Emissions (t/d)	Biogenic VOC Emissions (t/d)	Maximum Predicted Ozone (ppb)
SMOG	31	10	1 010	76
	59	29	1 010	95
	78	289	1 010	98
	66	37	1 010	85
	87	50	1 010	95
	107	62	1 010	100
	114	61	1 010	100
CALGRID	3.7	0	1 087	65
	74	172	1 087	92
	111	212	1 087	104
	222	435	1 087	111

Notes:
The SMOG biogenic emissions are normalized to represent a full day and the 148 by 159 km grid used by CALGRID.
The CALGRID biogenic emissions are the average for the summer period based on a 148 by 159 km grid. The CALGRID predictions represent the maximum 1-h value during the 6-d modelling period.
Source: Davies and Fellin (1999).

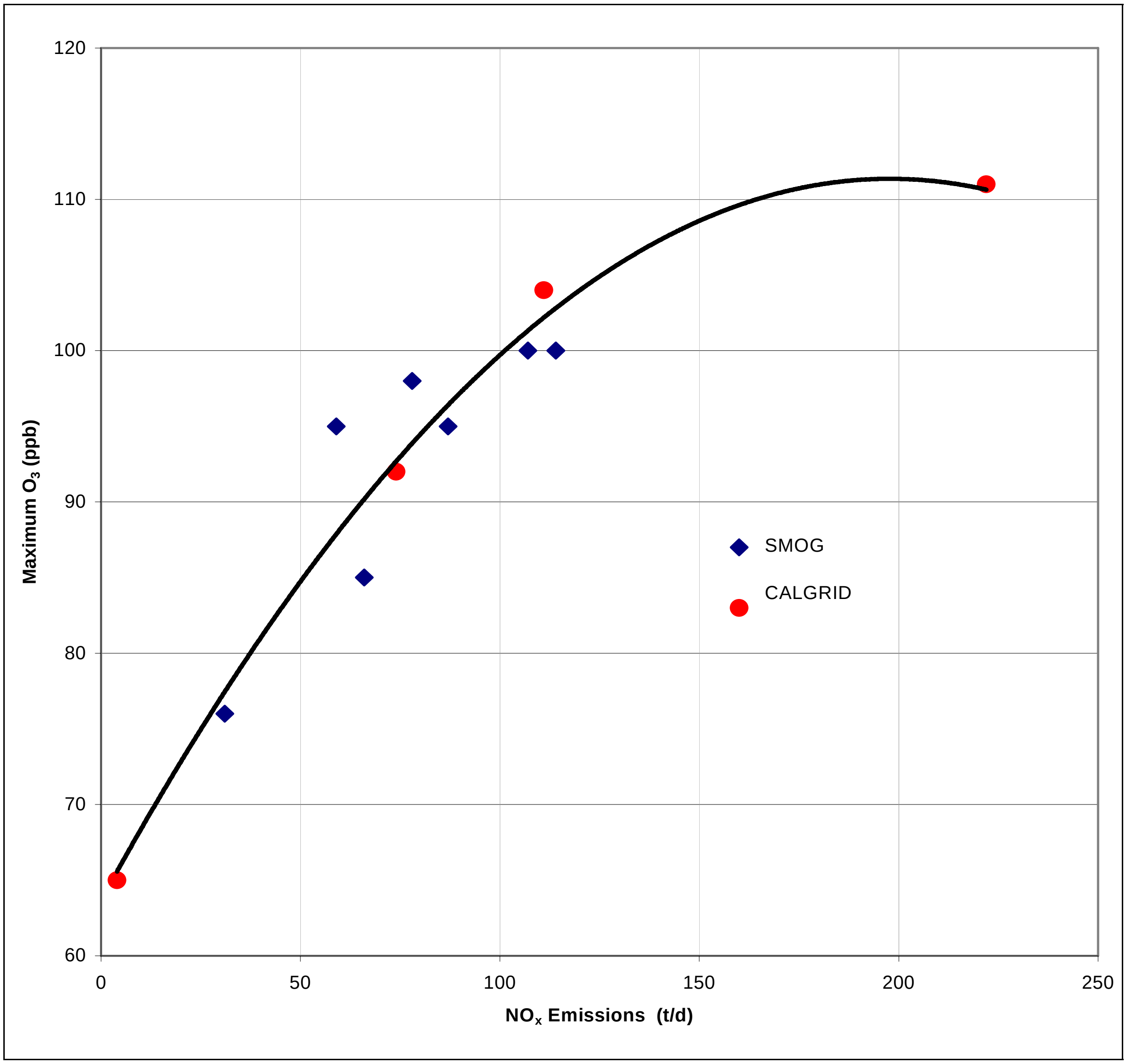

Figure 4.7-14: Maximum Predicted Ozone Concentration Dependence on Regional NO_x Emissions Based on the SMOG and CALGRID Photochemical Models

(Note 82 ppb = 160 $\mu g/m^3$)

4.7.10.3 Results

Tables 4.7-17 and 4.7-18 provide the impact ratings for ambient ozone concentration changes due to the application and the planned development scenarios, respectively.

Table 4.7-17: Impact Ratings for Ambient Ozone Concentration Changes Due to the Project

Impact Attribute	Rating	Comment
Direction	Positive/Negative	Immediately downwind of NO_x emission sources, natural ambient ozone concentrations would decrease due to scavenging reactions. Further downwind, the precursor NO_x and VOC emissions could increase ambient ozone concentrations.
Geographic Extent	Regional	The greatest changes are expected to occur several tens of kilometers downwind.
Magnitude	Low	The incremental change due to the project precursor emissions will be low (i.e., NO_x emissions increase by 0.2% or 1.2 t/d).
Temporal	Short-term	Natural ozone concentrations vary due to meteorological variations. High concentrations tend to occur in the spring with the occasional peak in the summer.
Confidence	Moderate	While recent regional monitoring has not indicated elevated photochemical ozone production, other situations in Alberta have shown elevated ozone levels.
Final Rating	Low	Due to low project precursor emissions in the RSA.
	Low	Due to low project precursor emissions in the LSA.

Table 4.7-18: Impact Ratings for Ambient Ozone Concentration Changes Due to the Planned Development Scenario

Impact Attribute	Rating	Comment
Direction	Positive/Negative	Immediately downwind of NO_x emission sources, natural ambient ozone concentrations would decrease due to scavenging reactions. Further downwind, the precursor NO_x and VOC emissions could increase ambient ozone concentrations.
Geographic Extent	Regional	The greatest changes are expected to occur several tens of kilometers downwind.
Magnitude	High	The incremental change due to the planned development scenario precursor emissions is high (i.e., NO_x emissions increase by 32% or 125 t/d).
Temporal	Short-term	Natural ozone concentrations vary due to meteorological variations. In the event of photochemical formation, higher peak concentrations will be expected in the summer.
Confidence	Low	While recent regional monitoring has not indicated elevated photochemical ozone production, other situations in Alberta have shown elevated ozone levels.
Final Rating	Moderate	In the RSA due to increased regional precursor emissions such NO_x and VOCs.
	Moderate	In the LSA due to increased regional precursor emissions such NO_x and VOCs.

Given the rural location of the project, higher ozone concentrations due to natural sources are expected. The potential photochemical formation of ozone is an AQRSA rather than an AQLSA issue due to the time-scale associated with the photochemical reactions. The incremental NO_x emissions due to the project are predicted to be low (i.e., 1.2 t/d or 0.2% of the application scenario) and therefore the incremental formation of ozone due to the project would also be expected to be low.

On a planned development scenario basis, however, the increase in precursor NO_x emissions has the potential to increase the magnitude and frequency of high ozone events during hot summer periods. Modelling indicates a potential for increased maximum ozone concentration due to increased NO_x emissions.

4.7.11 GHG Emissions and Impacts

4.7.11.1 Introduction

The project will result in GHG emissions from the combustion of fossil fuels that produce CO_2, CH_4 and N_2O. GHG emissions also result from fugitive hydrocarbon emissions that can include methane.

4.7.11.2 Methods

The GHG emissions from the project are estimated and are compared to the total Alberta emissions and the total emissions for Canada. GHG emissions are expressed in carbon dioxide equivalents (CO_2E). Factors for global-warming potential used in generating the GHG estimates are 1 for CO_2, 21 for CH_4 and 310 for N_2O emissions.

4.7.11.3 Results

The estimated GHG emissions from the project are 2 kt CO_2E/d, which is equivalent to 731kt CO_2E/yr. Table 4.7-19 compares the project GHG emissions estimate with the total Alberta and Canadian estimates. The project operations are estimated to contribute 0.29 and 0.10% to the 2007 provincial and national totals, respectively.

Table 4.7-19: Comparison of KNOC GHG Emissions

KNOC GHG Emissions Comparison	**Total GHG Emissions (kt CO_2E/yr)**
Alberta's GHG Emissions (2007)	245 700
Canada's GHG Emissions (2007)	747 000
KNOC Estimated GHG Emissions	731
KNOC GHG Emissions as a Percentage	**Percent of Total GHG Emissions (%)**
Percent of Alberta Total	0.29
Percent of Canada Total	0.10

Notes:
CO_2E = global warming equivalent that includes CO_2 and CH_4.
Source: Alberta and Canada totals are from Environment Canada (2009).

Table 4.7-20 provides the impact ratings for GHG emission changes due to the planned development scenario.

Table 4.7-20: Impact Ratings for GHG Emission Changes Due to the Project

Impact Attribute	Rating	Comment
Direction	Negative	The project will increase GHG emissions.
Geographic Extent	Global	GHG emissions are a potential global issue due to the likelihood of accelerated climate change.
Magnitude	Low	The proposed project GHG emissions represent 0.29 and 0.10% of the Alberta and National totals, respectively.
Temporal	Long-term	Climate changes have the potential for not being reversible.
Confidence	Uncertain	Some differences of opinion exist regarding the magnitude of the global temperature change and associated climate implications.
Final Rating	Not Rated	Not rated due to the confidence rating.

4.8 Monitoring

Monitoring is part of KNOC's adaptive management program, identifying and responding to environmental concerns that arise over the lifetime of the project.

Monitoring can be classified as source or ambient. Source monitoring relates to emission sources and can range from visual inspections to more formal stack measurement surveys. Ambient monitoring relates to the measurement of air quality in the vicinity of the facility.

4.8.1 Local Monitoring Commitments

Upon project commissioning and thereafter, KNOC will conduct source monitoring from the steam boilers and glycol heaters. The produced gas flow rates and H_2S contents will be measured and reported on a routine basis. The monitoring will be conducted in the manner described in the current operating approval (Approval No. 246984-00-00). Also, there will be a minimum of four exposure stations for ambient measurements of H_2S and total sulphation levels, and one ambient monitoring station for measurement of NO_2, SO_2, CO and wind speed and direction will be operated in accordance with the existing approval.

4.8.2 Regional Monitoring Commitments

Much of the regional (i.e., AQRSA) monitoring needs are addressed through the multi-stakeholder WBEA. While WBEA has focused primarily on the area north of Fort McMurray, there is increasing interest to extend the focus further to the south to include the *in-situ* developments in this area. KNOC is aware that WBEA is examining expansion of its regional air monitoring network south of Fort McMurray and into the Conklin area. When this occurs, KNOC will cooperate with WBEA to provide project-specific air monitoring data in support of the expanded regional monitoring network..

4.9 Climate Change

4.9.1 Introduction

New projects in Alberta are required to evaluate potential effects of climate change as part of the Environmental Impact Assessment (EIA) process. According to the Terms of Reference (TOR), both the project's effects on climate change (greenhouse gas emissions) as well as the effects of climate change on the project need to be considered. The effects of the project relative to GHG emissions and climate change are considered in Section 4.7.

This section provides a review of project contributions to climate change and possible effects on the project, according to these guidance documents.

4.9.2 Project Sensitivity to Climate Change

Considerable uncertainty exists about the potential impacts of climate change on the project, in part because the timing and magnitude of climate impacts are uncertain. However, increases in temperature, changes in precipitation due to climate change and possible increases in the intensity of extreme weather events and possible changes in regional water supply regimes, etc., have been considered over the lifetime of the project.

4.9.2.1 Construction Stage

Climate change is not likely to be an issue in the relatively short construction phase of the project as construction will begin before any effects of climate change are predicted to occur. The possible impacts could include extreme weather events that could delay and interfere with the construction process, although the probability is low.

4.9.2.2 Operational Stage

Over the life of the project, increased temperature, rainfall and evaporation may have an effect on the water table. However, the average changes in the water table are so moderate that no changes in water use for the project are expected due to climate change. Any predicted increase in precipitation could be offset by the concurrent predicted increase in temperature and evaporation. Groundwater flow systems contain large volumes of water which generally have a slow rate of movement, and are therefore, not as susceptible to short-term fluctuations in climate.

In terms of air quality, the increase in temperature could lead to a higher probability of ozone formation. An increase in precipitation would lead to a redistribution of deposition in the region as the wet deposition mechanism dominates the process. Overall, the effect of climate change on air quality as related to the project is predicted to be low.

Although there is no change expected with water use, water withdrawal from the Quaternary water source for domestic use may be sensitive to climate change as a result of changes in water table height. The factors that may potentially affect the shallow water table include increased rainfall, temperature and evaporation.

The run-off and storage system associated with the industrial runoff and other water management ponds will not be affected by climate change because the runoff collection and storm water ponds will be designed for a 1:100 year storm event. It is anticipated that any increase in precipitation due to climate change during the operational life of the project can be managed within this system. Also, water collected in storm water ponds will be recycled back to the atmosphere faster as a result of any increased temperature and evaporation.

As with the storm water pond, other collection ponds, such as process wastewater or blowdown, will experience increased evaporation, which will increase the rate at which water is recycled back into the atmosphere.

4.9.2.3 Decommissioning Stage

Climate change may potentially impact the establishment of target ecosite phases during the reclamation stage of the project. The severity of climate change will determine plant species mix and suitable soil types to incorporate in the reclamation program. An adaptive management approach is emphasized in the C&R plan (Volume 1, Section 3), to use suitable species and soils for specific environmental conditions. Overall, climate change is predicted to have a low impact on revegetation.

4.9.3 Adaptive Management Considerations

Adaptive management is a systematic process for continually improving management practices by learning from the outcomes of the project's operational programs responding to climate change.

Many of the technologies needed for existing projects to adapt to increased temperatures and precipitation are available and disruptions in project operations are unlikely. In reference to the operation and decommissioning stages under the project sensitivity section, KNOC plans to take an adaptive management approach to compensate for the effects of any climate change influenced events.

4.10 Summary

4.10.1 Overall Conclusion

The maximum effects of project emissions tend to be limited to the immediate area in the vicinity of the operations (i.e., within 10 km). Although the maximum PAI predicted in the vicinity of the KNOC operations is less than that to the north of Fort McMurray, the maximum small-scale grid PAI values in the vicinity of the project are predicted to exceed some of the critical loads.

Ambient concentrations due to air emissions from the project and other existing, approved and proposed facilities will tend to decrease with increasing distance from the respective operations. The concentrations at any time will depend on the prevailing meteorology. Ambient concentrations can therefore vary considerably with location and time. This assessment focuses on predicting maximum concentrations in the defined AQLSA and AQRSA regions.

Tables 4.10-1 to 4.10-3 provide a summary of the impacts on a quantitative basis and the predicted values are compared to the ambient criteria and deposition loads. When no criteria are available, the relative changes are expressed in percent. Table 4.10-4 provides a summary of the impacts on a qualitative basis.

4.10.2 Changes in AQLSA and AQRSA Emissions

The project will increase air AQRSA SO_2, NO_x, CO, VOC and $PM_{2.5}$ emissions by less than 1% relative to the baseline scenario. The corresponding AQLSA increases are between 1.6 to 15.6%.

4.10.3 Ambient SO_2, NO_2, CO and $PM_{2.5}$ Concentrations

Higher SO_2, NO_2, CO and $PM_{2.5}$ concentrations due to the operation of the project are predicted to occur in the vicinity of the KNOC operating area. The final impact ratings for the project (i.e., Application Case) and Planned Development cases relative to the Baseline Case are summarized in Table 4.10-5.

Table 4.10-1: Key Air Quality Issues

Key Issue	Parameter	Assessment Scenario		Regulatory Criteria	Comments
		Application Relative to Baseline	**Planned Development Relative to Baseline**		
Project emissions to the atmosphere	RSA SO_2 emission (t/d) RSA NO_x emission (t/d) RSA CO emission (t/d) RSA VOC emission (t/d) RSA $PM_{2.5}$ emission (t/d)	248.62 (+0.4%) 507.20 (+0.2%) 415.05 (+0.2%) 585.24 (+0.0%) 30.98 (+0.3%)	250.32 (+1.1%) 566.12 (+11.9%) 497.15 (+20.0%) 641.30 (+9.6%) 37.79 (+22.5%)	– – – – –	The project emissions are low relative to other sources in the RSA. The planned development emissions are more substantial.
	LSA SO_2 emission (t/d) LSA NO_X emission (t/d) LSA CO emission (t/d) LSA VOC emission (t/d) LSA $PM_{2.5}$ emission (t/d)	11.29 (+9.7%) 9.87 (+14.3%) 6.75 (+15.6%) 0.25 (+19.0%) 0.46 (+39.4%)	11.29 (+9.7%) 9.98 (+15.6%) 7.24 (+24.0%) 0.25 (+19.0%) 0.51 (+54.5%)	– – – – –	The project emissions contribute to a greater proportion in the LSA than the RSA. The LSA emissions are much less than those outside the LSA.
Project SO_2 emissions on regional SO_2 concentrations	RSA Maximum 1-h ($\mu g/m^3$) RSA Maximum 24-h ($\mu g/m^3$) RSA Maximum annual ($\mu g/m^3$)	322 (<1%) 92 (<1%) 13.6 (<1%)	343 (+6.5%) 95 (+3.3%) 14.9 (+9.6%)	450 150 30	The project has less than a 1% contribution to the maximum RSA concentrations. The project has less than a 1% contribution to the maximum LSA 1-h and 24-h concentrations. The predicted RSA and LSA annual concentrations increase by 1.7 and 4.3% respectively.
	LSA Maximum 1-h ($\mu g/m^3$) LSA Maximum 24-h ($\mu g/m^3$) LSA Maximum annual ($\mu g/m^3$)	199 (<1%) 52 (<1%) 9.1 (+1.7%)	199 (<1%) 53 (<1%) 9.6 (+4.3%)	450 150 30	
Project NO_x emissions on regional NO_2 concentrations	RSA Maximum 1-h ($\mu g/m^3$) RSA Maximum 24-h ($\mu g/m^3$) RSA Maximum annual ($\mu g/m^3$)	**748** (<1%) **279** (<1%) **110** (<1%)	**761** (1.7%) **287** (+2.9%) **113** (+2.7%)	400 200 60	The project does not contribute significantly to the maximum annual average value.
	LSA Maximum 1-h ($\mu g/m^3$) LSA Maximum 24-h ($\mu g/m^3$) LSA Maximum annual ($\mu g/m^3$)	184 (<1%) 111 (<1%) 18.7 (<1%)	184 (<1%) 111 (<1%) 19.8 (+5.9%)	400 200 60	Maximum predicted values in the LSA are all less than their ambient air quality guidelines.
Project $PM_{2.5}$ emissions on regional $PM_{2.5}$ concentrations	RSA Maximum 1-h ($\mu g/m^3$) RSA Maximum 24-h ($\mu g/m^3$)	**560** (<1%) **164** (<1%)	**560** (<1%) **164** (<1%)	80 30	The project has little effect on maximum RSA concentrations.
	LSA Maximum 1-h ($\mu g/m^3$) LSA Maximum 24-h ($\mu g/m^3$)	5.9 (<1%) 2.2 (<1%)	11.8 (100%) 3.4 (55%)	80 30	The project has little effect on maximum LSA concentrations. The planned development effects are more substantial.
Project CO emissions on regional CO concentrations	RSA Maximum 1-h ($\mu g/m^3$) RSA Maximum 8-h ($\mu g/m^3$)	5556 (<1%) 2835 (<1%)	5663 (<1%) 2838 (<1%)	15 000 6 000	The project does not contribute significantly to the maximum average values.
	LSA Maximum 1-h ($\mu g/m^3$) LSA Maximum 8-h ($\mu g/m^3$)	1136 (<1%) 468 (<1%)	1138 (<1%) 475 (1.8%)	15 000 6 000	Maximum predicted LSA values do not exceed the ambient objectives.

Key Issue	Parameter	Assessment Scenario		Regulatory Criteria	Comments
		Application Relative to Baseline	Planned Development Relative to Baseline		
Project SO_2 and NO_x emissions on regional acid deposition (PAI)	RSA Maximum (keq H^+/ha/yr)	13.13 (<1%)	13.24 (<1%)	–	The project has little effect on maximum small-scale grid RSA deposition.
	LSA Maximum (keq H^+/ha/yr)	0.60 (1.3%)	0.63 (6.8%)	–	The project has an effect on maximum small-scale grid LSA deposition.
Project SO_2 and NO_x emissions on regional nitrogen deposition	RSA Maximum (kg/ha/yr)	172 (<1%)	174 (1.1%)	–	The project has little effect on maximum small-scale grid nitrogen deposition.
	LSA Maximum (kg/ha/yr)	4.1 (<1%)	4.5 (8.9%)	–	The project has little effect on maximum small-scale grid LSA deposition. Planned Development effects are more pronounced.

Notes:
Boldface text indicates that the regulatory criteria are exceeded.
A dash (-) indicates no regulatory deposition criteria measured on a small-scale grid basis.

Table 4.10-2: Key Issues for Community and Recreational Areas

Key Impact Question		Location	Assessment Scenario		Regulatory Criteria	Comments
			Application Relative to Baseline	Planned Development Relative to Baseline		
Project combustion emissions on air quality at community and recreational area receptors	SO_2 concentrations (1-h average) $\mu g/m^3$	MEG Worker's Camp	217 (+0.3%)	299 (+37.4%)	450	Maximum predicted values are below the applicable criteria.
	NO_2 concentrations (1-h average) $\mu g/m^3$	Fire Lookout Tower	113 (<1%)	114 (<1%)	400	
	CO concentrations (1-h average) $\mu g/m^3$	Fire Lookout Tower	626 (<1%)	637 (+1.8%)	15 000	
	$PM_{2.5}$ concentrations (24-h average) $\mu g/m^3$	Janvier	15 (<1%)	31 (+105%)	30	
	Benzene concentrations (1-h average) $\mu g/m^3$	Janvier	0.67 (<1%)	1.40 (+109%)	30	
	Formaldehyde concentrations (1-h average) $\mu g/m^3$	Janvier	0.56 (<1%)	1.17 (+108%)	65	

Notes:
The above summary focuses on the predictions at the community of Conklin and on the pollutants for which there are AENV objectives or CWS.

Table 4.10-3: Key Issues for Ozone Concentration and GHG Emissions

Key Issue	Parameter	Assessment Scenario		Regulatory Criteria	Comments
		Application Relative to Baseline	Planned Development Relative to Baseline		
Project emissions on regional ozone concentrations	Ozone concentration ($\mu g/m^3$)	Low	Moderate	160	The project NO_x emissions are not expected to result in ambient ozone exceedances. The NSMWG is continuing a program to determine the ozone production potential in the region.

Key Issue	Parameter	Devon J2	Regulatory Criteria	Comments
Project contribution to GHG emissions	GHG Emissions (kt CO_2E/yr)	The project GHG emissions are 731 kt CO_2E/yr (0.29% of Alberta and 0.10% of Canada). See Section 4.7 for more details on project GHG emissions.	–	The project design incorporates features to minimize increases of GHG emissions.

Notes:
A dash (–) indicates no regulatory criteria.

Table 4.10-4: Summary of Key Issues, Mitigation, Impacts and Monitoring Related to Air Quality

Issue	Project Design Features and Mitigation Measures	LSA Planned Development Implications	RSA Planned Development Implications	Monitoring
Impact of project SO_2 emissions on regional SO_2 concentrations.	Design to ensure sufficient dispersion.	Maximum LSA 1-h, 24-h and annual average concentrations are less than the ambient objectives.	Maximum RSA 1-h, 24-h and annual average concentrations are less than the ambient objectives. The project contribution beyond the LSA is insignificant.	Periodic source monitoring and measurements to document SO_2 emissions. Passive integrated SO_2 monitors to measure monthly average concentrations. Cooperation and data sharing for local and regional air quality monitoring.
Impact of project NO_x emissions on regional NO_2 concentrations.	Low NO_x burners on steam generators. Efficiencies to reduce fuel use.	Maximum LSA 1-h, 24-h and annual average concentrations are less than the ambient objectives.	Maximum RSA average concentrations exceed than the ambient objectives for all averaging periods. The project contribution to the maxima external to the LSA is insignificant.	Periodic source monitoring and measurements to document NO_x emissions. Cooperation and data sharing for local and regional air quality monitoring.
Impact of project $PM_{2.5}$ emissions on regional $PM_{2.5}$ concentrations.	Design to ensure sufficient dispersion.	Maximum LSA 1-h and 24-h average concentrations are less than the ambient objectives.	Maximum RSA 1-h and 24-h average concentrations exceed than the ambient objectives. The project contribution to the maxima external to the LSA is insignificant.	None.
Impact of project CO emissions on regional CO concentrations.	Design to ensure sufficient dispersion.	Maximum LSA 1-h and 8-h average concentrations are less than the ambient objectives.	Maximum RSA 1-h and 8-h average concentrations are less than the ambient objectives.	None.
Impact of project emissions on regional acid deposition.	Low NO_x burners on steam generators. Efficiencies to reduce fuel use.	Maximum small-scale grid LSA PAI exceeds the CASA and AENV (1999) loads for moderately sensitive and sensitive receptors. The project contributes minimally to the LSA maxima.	Maximum small-scale grid RSA PAI exceeds the CASA and AENV (1999) loads for all receptor types. The project does not contribute to the maxima external to the LSA.	Passive integrated SO_2 monitors to measure monthly average concentrations. Cooperation and data sharing for local and regional air quality monitoring.
Impact of project combustion emissions on community and recreational area locations.	Design to ensure sufficient dispersion. Low NO_x burners on steam generators. Efficiencies to reduce fuel use. Control of fugitive plant and field emissions.	All predicted concentrations are less than the relevant ambient air quality criteria at all LSA community and recreational area receptors.	Not evaluated.	None.
Impact of project emissions on regional ozone concentrations.	Low NO_x burners on steam generators. Vent gas is collected rather than being emitted to the atmosphere.	Not applicable.	The project NO_x emissions will have a moderate effect on photochemical production of ozone due to low precursor emissions.	NSMWG efforts to confirm future cumulative implications. Cooperation and data sharing for local and regional air quality monitoring.
Project contribution to GHG emissions.	Efficiencies to reduce fuel use. Control of fugitive plant and field emissions. Minimize venting.	Not applicable.	Not applicable.	Continued fuel efficiency monitoring.

Table 4.10-5: Final Impact Ratings for the Project and Planned Development Cases Relative to the Baseline Case for SO_2, NO_2, CO and $PM_{2.5}$

Parameter	Application Case		Planned Development Case	
	AQRSA	AQLSA	AQRSA	AQLSA
SO_2 Concentrations	Low	Low	Moderate	Low
NO_2 Concentrations	Low	Low	High	Moderate
CO Concentrations	Low	Low	Low	Low
$PM_{2.5}$ Concentrations	Low	Low	Low	High

The planned development ratings are not specific to the KNOC project emissions. The comparison between the baseline and application scenarios indicates that the predicted effect of the KNOC emissions on ambient concentrations within the AQRSA is sufficiently small that they are unlikely to be detected. This conclusion is valid for the planned development scenario as well. The maximum predicted ambient concentrations due to the project emissions have little to no effect within the AQLSA for either the application or the planned development scenarios.

4.10.4 PAI and Nitrogen Deposition

On an AQRSA basis, the highest deposition is predicted near the primary oil sands area located north of Fort McMurray. The final impact ratings for the project (i.e., Application Case) and Planned Development cases relative to the Baseline Case are summarized in Table 4.10-6.

Table 4.10-6: Final Impact Ratings for the Project and Planned Development Cases Relative to the Baseline Case for PAI and Nitrogen Deposition

Parameter	Application Case		Planned Development Case	
	AQRSA	AQLSA	AQRSA	AQLSA
PAI	Low	Low	Moderate	Moderate
Nitrogen Deposition	Low	Low	Moderate	Moderate

The planned development ratings are not specific to the KNOC project emissions. The comparison between the baseline and application scenarios indicates that the predicted effect of the project emissions on small-scale grid PAI and nitrogen deposition within the AQRSA is sufficiently small that they are unlikely to be detected. This conclusion is still valid for the planned development scenario.

4.10.5 Community and Recreational Area Air Quality

Ambient concentrations of selected compounds due to AQRSA operations at representative community and recreational area locations are predicted to be less than the applicable ambient air quality objectives. The community exposure impact rating was rated as low for more distant receptors and moderate for the closer receptors.

4.10.6 Ambient Ozone

While naturally high ozone concentrations can occur in the area, the incremental impact due to the project NO_x emissions is expected to be low. The final ozone impact rating for the project is predicted to be low given the small relative increase in project precursor emissions. The final ozone impact rating for the planned development scenario is predicted to be moderate given the increasing precursor emissions in the regional study area.

4.10.7 GHG Emissions

GHG emissions from the project are <1% of the provincial and national totals. Although a final impact rating is not assigned to GHG emissions, KNOC is committed to environmental stewardship, meeting regulatory requirements and environmental protection initiatives including energy management and emissions reduction.

4.10.8 Climate Change

Overall, climate change is expected to have little or no impact on the project as it will be designed for construction, operation and decommissioning within a range of weather, water and ecological conditions over the life of the project.

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