APPENDIX F

AIR QUALITY ASSESSMENT

FINAL REPORT

Air Quality Assessment for the Proposed Enbridge Edmonton South Terminal Development

ENBRIDGE PIPELINES INC.

JOB NO. 1018936

PROJECT NO. 1018936

FINAL REPORT TO: **Enbridge Pipelines Inc.**
10201 Jasper Avenue, PO Box 398
Edmonton, Alberta
T5J 2J9

FOR: **Air Quality Assessment for the Proposed Enbridge Edmonton South Terminal Development**

December 12, 2006

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1.0 INTRODUCTION

The Enbridge Pipelines Inc. Edmonton South Terminal Development (the 'Edmonton South Terminal') is a proposed two-tank oil-product storage and handling terminal, located in County of Strathcona, Alberta. Atmospheric emissions from the Edmonton South Terminal in the form of evaporative losses from storage tanks include vapours of various hydrocarbon and sulphur compounds.

This air quality assessment was completed to support regulatory applications to construct and operate the proposed oil-product storage tanks. This assessment includes an impact assessment for the main air substances of interest associated with the proposed tank emissions, including hydrogen sulphide (H_2S) and benzene. Emission rates for the proposed oil-product storage tanks vary depending on the type of tank, operating parameters, and the type of product stored in the tank. Detailed air emissions information was provided by Clearstone Engineering Ltd. and Jacques Whitford AXYS performed an analysis of the emissions, along with dispersion modelling using AERMOD, in order to predict the impacts of emissions from the proposed oil-product storage tanks on ambient air quality within the surrounding area.

1.1 Air Substances of Interest

Atmospheric emissions from the Edmonton South Terminal in the form of evaporative losses from storage tanks include H_2S and vapours of various hydrocarbon compounds, which have the potential to cause nuisance odours. For this assessment, H_2S and benzene were selected as the key air substances of interest with respect to emissions from the Edmonton South Terminal. H_2S was selected because of its potential to cause nuisance odours, while benzene was selected due to its effect on human health.

1.1.1 Hydrogen Sulphide

Hydrogen sulphide is a colourless gas which has the potential to cause nuisance odours. At low concentrations (*e.g.*, <100 µg m^{-3}) H_2S is readily detectable by its distinctive rotten egg odour. While it has an objectionable odour at very low concentrations (*e.g.*, < 20 µg m^{-3}), at these levels it does not negatively affect human health, nor does it have a substantial impact on the receiving environment.

1.1.2 Benzene

Benzene was selected as a key substance of interest due to its effect on human health. Benzene is a colorless, carcinogenic, flammable liquid with a sweet odour. It is a volatile chemical that evaporates quickly into air. Benzene is formed from natural processes such as forest fires, as well as from human activities. Benzene is also a natural part of crude oil, gasoline and cigarette smoke. Industrial handling of crude oil and gasoline fuels can result in emissions of benzene (Agency for Toxic Substances and Disease Registry (ATSDR) 2005). Prolonged exposure to benzene may develop symptoms including dizziness, headaches, rapid or irregular heartbeat and in serious cases death.

1.2 Ambient Air Quality Objectives and Criteria

Air quality was assessed through comparison of estimated ground-level concentrations to applicable regulatory objectives, guidelines, and/or criteria. Ambient criteria for the substances of interest are available through AENV and the Texas Commission on Environmental Quality (TCEQ). A summary of the objectives and criteria used in this assessment are provided in Table 1.

Table 1: Ambient Air Quality Objectives and Criteria for Air Substances of Interest.

Substance	Averaging Period	AAAQO [a] ($\mu g\ m^{-3}$)	TCEQ ESLs [b] ($\mu g\ m^{-3}$)
Hydrogen Sulphide (H_2S) [c]	One-hour	14	-
	24-hour	4	-
	Annual	-	-
Benzene (C_6H_6)	One-hour	30	75
	24-hour	-	12
	Annual	-	3

Notes:
[a] Alberta Environment (AENV) Alberta Ambient Air Quality Objectives (AAAQO) (AENV 2005).
[b] Texas Commission on Environmental Quality (TCEQ) Effects Screening Levels (ESLs) (TCEQ 2003).
[c] Odour-based guidelines.
\- Not applicable.

2.0 REGIONAL SETTING

The Edmonton South Terminal is located within south-eastern area of County of Strathcona at approximately 1.75 km west of Sherwood Park, as shown in Figure 1. The Strathcona Science Park is located approximately 1.5 km to the north of the site.

For this air quality assessment, it was determined that a 10 km by 10 km study area would be sufficient to evaluate the impacts associated with air emissions from the Edmonton South Terminal.

2.1 Topography

Topography within the 10 km by 10 km air quality study area is shown in Figure 2. The Edmonton South Terminal is situated at a base elevation of approximately 685 m above sea level (asl). Terrain elevations decrease to the northwest toward the North Saskatchewan River, which is oriented along a north-south axis. Terrain generally rises gently to the southeast, with hills to the southeast reaching elevations of greater than 750 m.

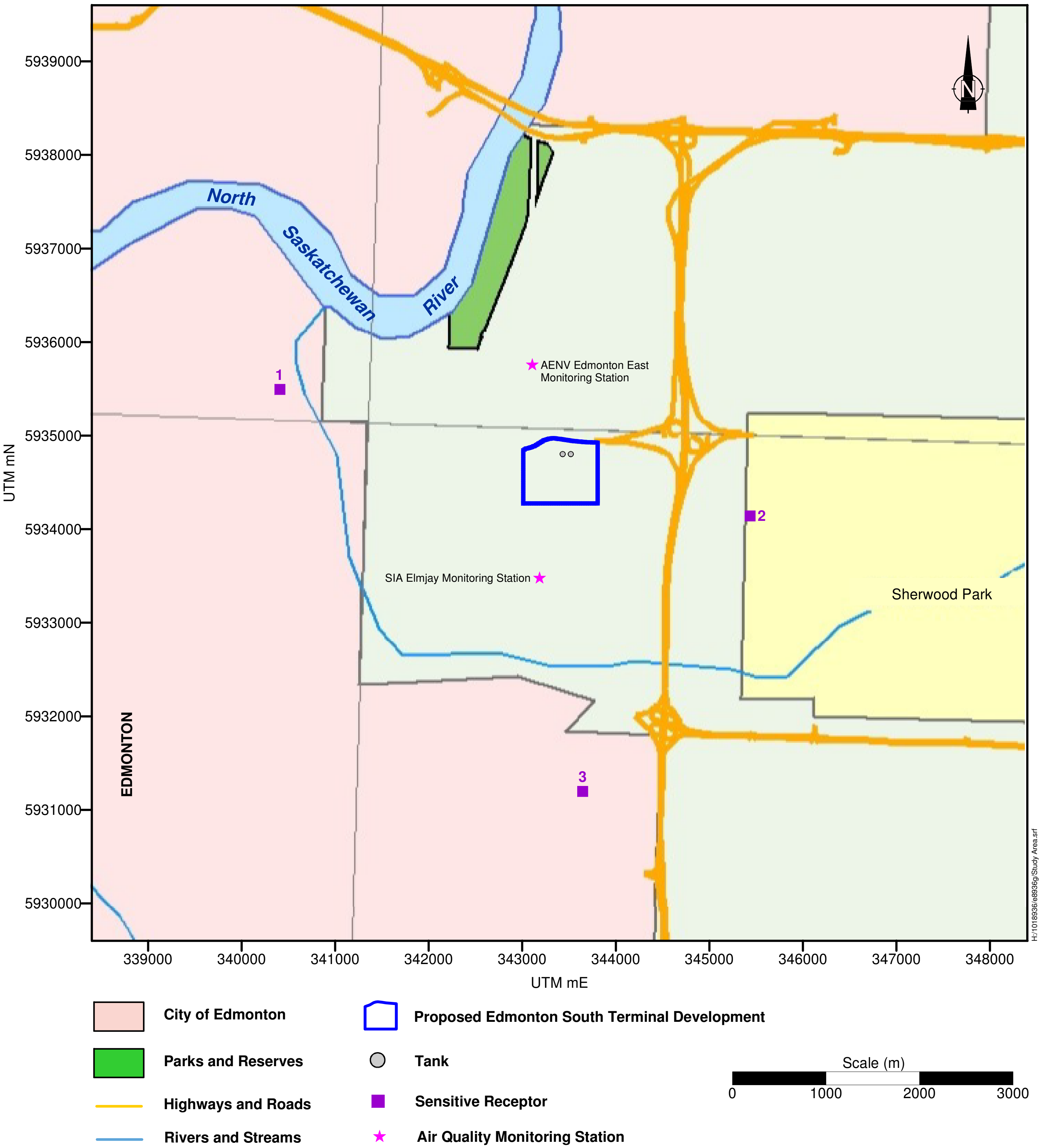

Figure 1: Air Quality Study Area Surrounding the Enbridge Edmonton South Terminal Development.

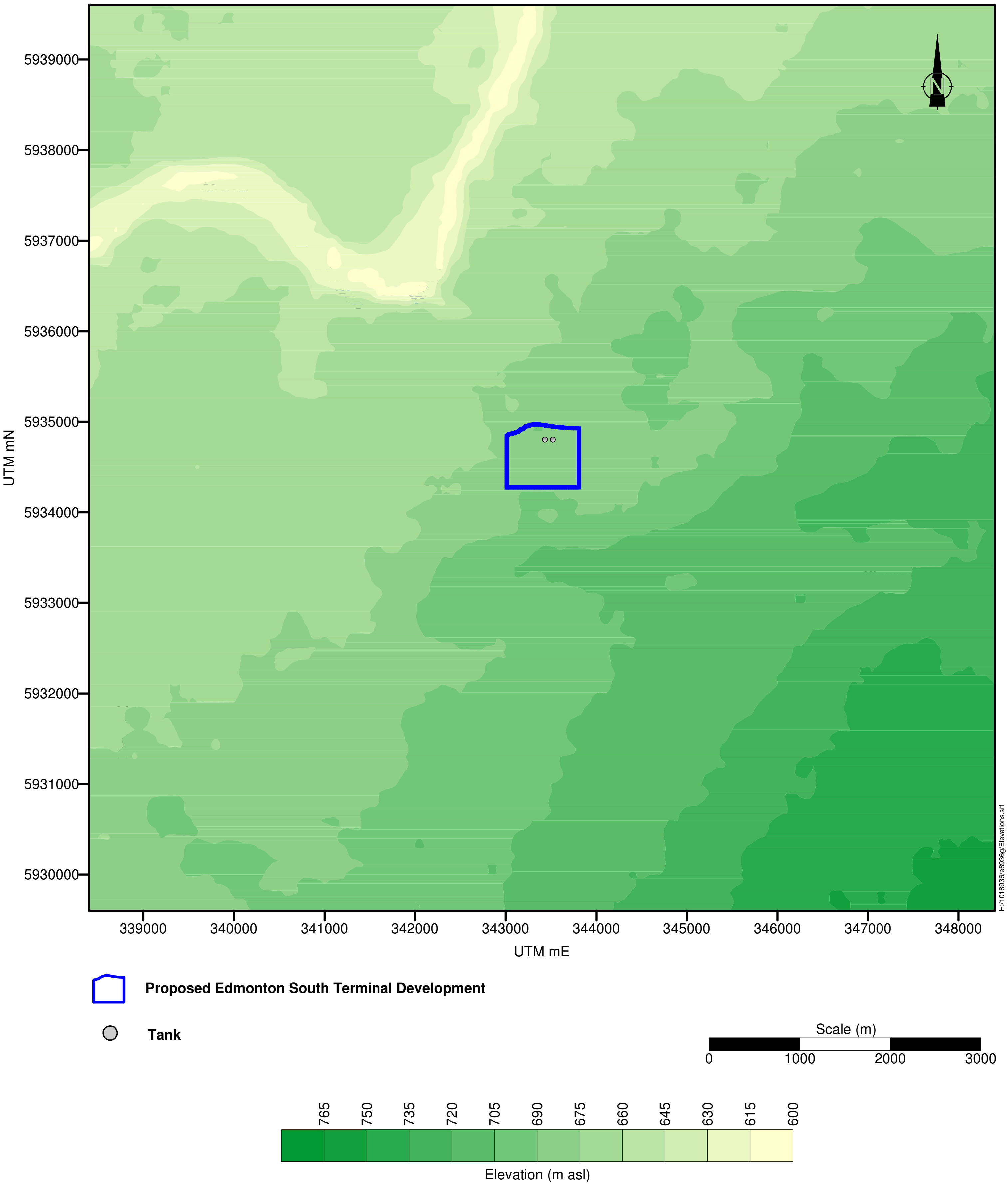

Figure 2: Terrain Elevations Within the Air Quality Study Area.

3.0 EDMONTON SOUTH TERMINAL AIR EMISSIONS

Enbridge Pipelines Inc. has proposed the construction of two new white painted external floating-roof oil-product storage tanks with primary and secondary seals located in County of Strathcona. Both tanks are 300,000 bbl in size and will be designed to the specifications of American Petroleum Institute (API) 650 and Canadian Council of Ministers of the Environment (CCME) Guide EPC-87E (Clearstone Engineering Ltd. 2006).

The location of these tanks within the property boundary of the Edmonton South Terminal is shown in Figure 3. A summary of oil-product storage tank physical dimensions is provided in Table 2.

Table 2: Locations and Physical Dimensions of Proposed Oil-product Storage Tanks at the Enbridge Edmonton South Terminal Development.

Facility	Tank ID	Tank Size (bbl)	Paint	Location UTM NAD83		Base Elevation (m asl)	Tank Height (m)	Tank Diameter (m)
				(mE)	(mN)			
Edmonton South Terminal	35	300,000	White	343432	5934802	685	18.3	58.5
	36	300,000	White	343520	5934802	685	18.3	58.5

The primary source of emissions from the Edmonton South Terminal will be product evaporation losses from the storage tanks. There may also be some emissions due to fugitive equipment leaks, however, these will be small in comparison (*i.e.*, less than one percent) and are therefore not considered in this assessment.

Clearstone Engineering Ltd. has completed an analysis of the two proposed oil-product storage tanks at the Edmonton South Terminal to determine the potential annual average emissions from each tank (Clearstone Engineering Ltd. 2006). The average amount of organic emissions from each individual tank was estimated by Clearstone Engineering Ltd. using the most current version of the United States Environmental Protection Agency (U.S. EPA) TANKS model (Version 4.09D), available data on the tank and product characteristics, and monthly meteorological data applicable to Edmonton for the full year.

Annual average H_2S and benzene emissions from each of the tanks were estimated by multiplying vapour mass fractions for each air substance with the total annual hydrocarbon ratio. Maximum hourly emissions from each of the tanks include typical operational activity rates for the tanks undergoing a complete volume change once every five to eight days.

Emission rates for H_2S and benzene, as well as tank content information, are provided in Table 3. More detailed information relating to the calculated emissions for the tanks can be found in **Appendix A**.

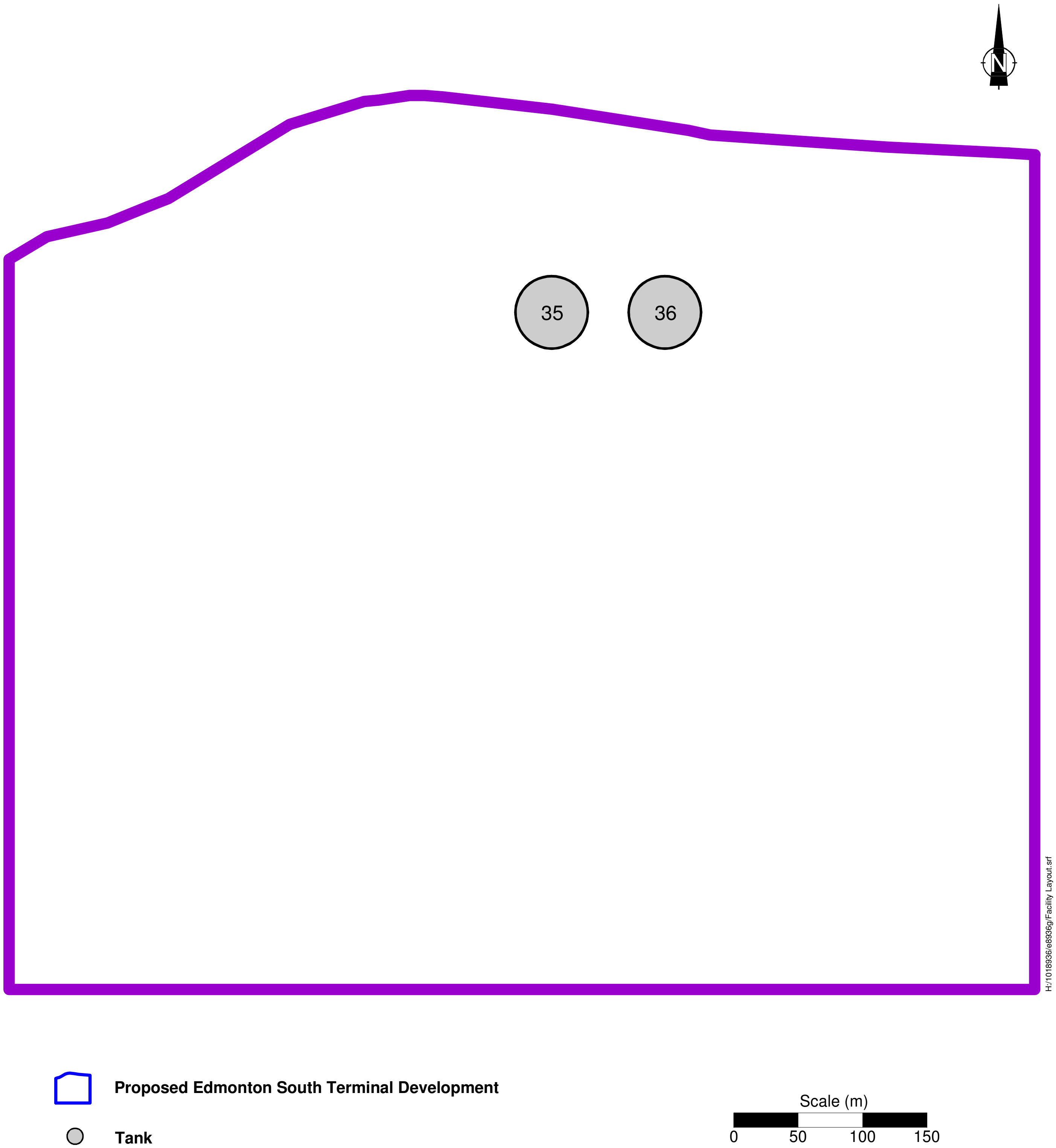

Figure 3: Simplified Plot Plan of the Enbridge Edmonton South Terminal Development.

Table 3: Summary of Tank Content and Annual Average Emission Rates for Oil-product Storage Tanks at the Enbridge Edmonton South Terminal Development.

Tank ID	Tank Content	Maximum Hourly Emission Rate (g s^{-1})		Average Annual Emission Rate (g s^{-1}) [a]	
		H_2S	Benzene	H_2S	Benzene
35	CNRL Synthetic Sweet Oil	8.92E-05	1.25E-03	5.95E-05	8.32E-04
36	CNRL Synthetic Sweet Oil	8.92E-05	1.25E-03	5.95E-05	8.32E-04
Total Annual Emission Rate (g s^{-1})		1.78E-04	2.50E-03	1.19E-04	1.66E-03
Total Annual Emission Rate (kg h^{-1})		6.42E-04	8.99E-03	4.28E-04	5.99E-03
Total Annual Emission Rate (kg yr^{-1})		-	-	3.8	52.5

Notes:
[a] Total hydrocarbon emissions from both of the two tanks is 14.3 t yr^{-1}.
\- Not applicable.

4.0 MODELLING METHODOLOGY

Dispersion models are used to predict how given emissions result in observed ground-level concentrations during a variety of meteorological conditions and terrain influences. All modelling conducted in this air quality assessment follows the current Air Quality Model Guideline (AQMG) (AENV 2003).

Plume dispersion modelling was employed to evaluate the potential impacts of H_2S and benzene emissions associated with the Edmonton South Terminal on ambient air quality.

4.1 AERMOD Dispersion Model

AERMOD is a steady-state plume dispersion model, developed by the U.S. EPA (1998a; 1998b) and recommended by AENV. The model is designed to estimate near-field (less than 50 km) ground-level concentrations from most types of industrial emission sources. The AERMOD modelling system consists of three programs: the model itself (AERMOD), a meteorological pre processor (AERMET), and a terrain pre-processor (AERMAP).

AERMOD makes use of two continuous stability parameters, friction velocity, and Monin-Obukhov length to characterize the atmosphere. The friction velocity is a measure of mechanical effects alone, such as wind shear at ground level. The Monin-Obukhov length indicates the relative strengths of mechanical and buoyancy effects on atmospheric turbulence. Thus, AERMOD can account for turbulence both from wind shear and from buoyancy effects due to solar heating during the day and radiational cooling at night. To properly account for these effects, AERMOD requires three land use parameters: albedo, Bowen ratio, and surface roughness. Modern planetary boundary layer theory is used to scale turbulence and other parameters to the height of the plume. The AERMOD system (specifically, the AERMET meteorological pre-processor) derives hourly mixing heights based on the morning upper air sounding and the surface meteorology, including available solar radiation. The AERMAP pre-processor uses gridded terrain data to calculate a representative terrain-influence height (h_c) also referred to as the terrain height scale. This height scale, which is uniquely defined for each receptor location, is used to calculate the dividing streamline height along which a plume is assumed to travel.

4.2 Dispersion Meteorology

Climate and meteorology influence the manner in which air emissions from industrial and natural sources disperse into the atmosphere, and hence help determine air quality. Atmospheric dispersion of emissions is governed by the amount of turbulence that exists in the mixed layer of air in contact with the ground. Turbulence levels are dependent on thermal effects (*e.g.*, vertical temperature stratification) and mechanical effects caused by topography, surface roughness, and wind speed. The height of the mixing layer determines the vertical extent to which emissions are able to diffuse.

For the purpose of this study, dispersion modelling calculations were performed using a five-year dataset from January 1, 2001 to December 31, 2005. The meteorological dataset was compiled from upper air data collected at Stony Plain and from surface data collected at the Edmonton International Airport and AENV Edmonton East monitoring stations. The results of the analysis that was performed on this meteorological dataset can be found in **Appendix B**.

4.3 Receptors and Terrain

Calculations of ground-level air concentrations were made for locations outside the Edmonton South Terminal property boundary using a series of nested Cartesian grids with increasing receptor density with proximity to the facility. The receptor grids and their corresponding spacing are as follows:

- 10 km by 10 km grid with 1,000 m spacing;
- 5 km by 5 km grid with 500 m spacing;
- 2.5 km by 2.1 km grid with 250 m spacing;
- 1.5 km by 1.5 km grid with 50 m spacing; and
- 20 m spacing in maximum impact areas and on the Edmonton South Terminal property boundary.

The receptor grids are presented in Figure 4. Actual terrain elevations were applied to all receptors used in dispersion modelling.

Three residences were selected as sensitive receptors within the study area such that maximum predicted ground-level concentrations of air contaminants of interest could be determined for these locations. The locations of the selected sensitive receptors that were included in dispersion modelling are shown in Figure 4 and summarized in Table 4.

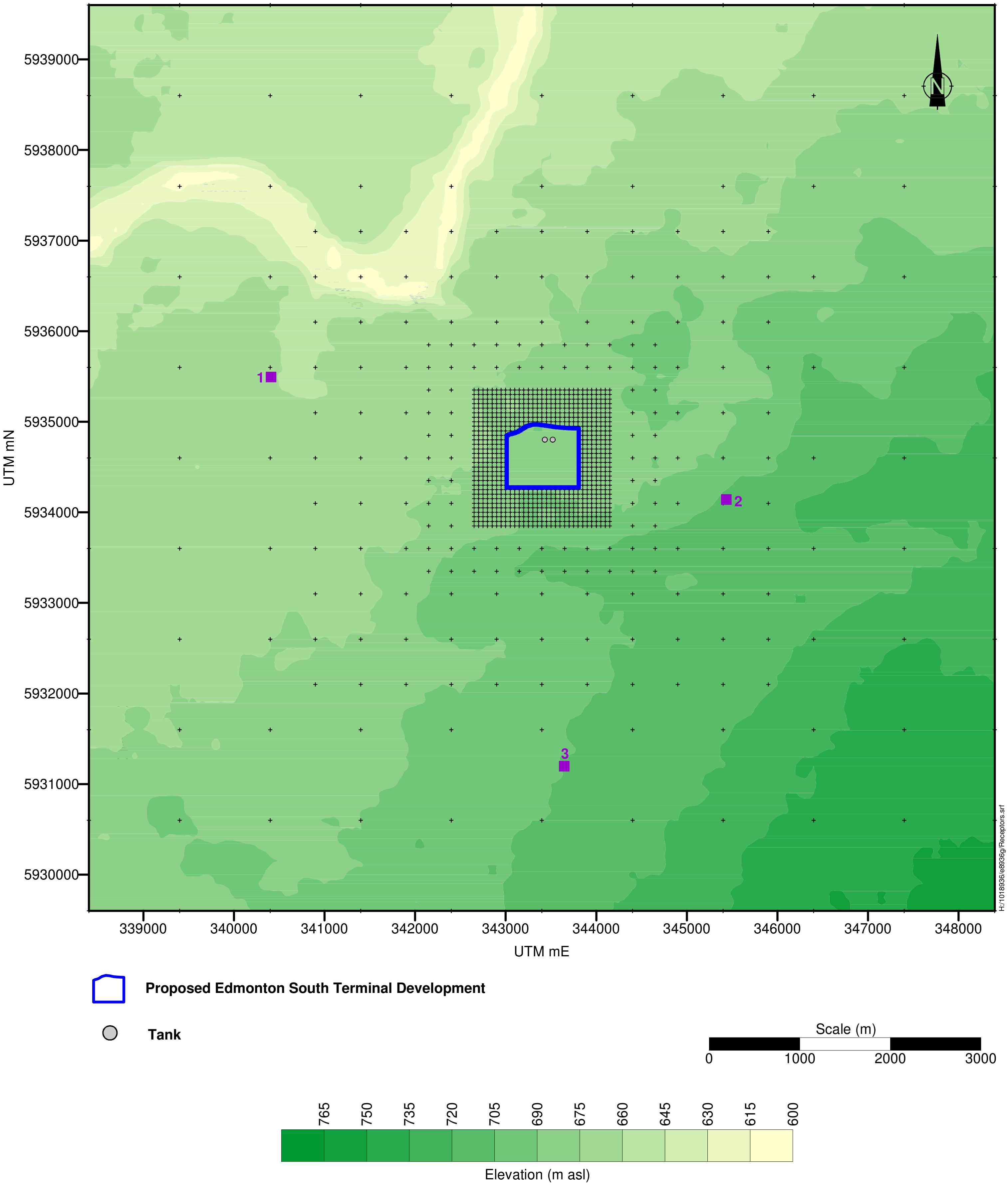

Figure 4: Receptors Included in the Dispersion Modelling of the Enbridge Edmonton South Terminal Development.

Table 4: Sensitive Receptors Including in Dispersion Modelling of the Enbridge Edmonton South Terminal Development.

Receptor ID	Receptor Name	Location UTM NAD83		Base Elevation (m asl)
		(mE)	(mN)	
1	Residential Area 1 Edmonton (Closest Residence)	340409	5935493	664
2	Residential Area 2 Sherwood Park (Closest Residence)	345436	5934142	709
3	Residential Area 3 Mobile Home Park (Closest Residence)	343646	5931196	706

4.4 Regional Ambient Background Concentrations

In order to account for the contribution to ground-level concentrations of air substances attributable to sources on a regional scale, available ambient background concentrations were selected from regional air quality monitoring stations and added to the results of the dispersion modelling.

Table 5 presents regional ambient background concentrations for the AENV Edmonton East and the Strathcona Industrial Association (SIA) Elmjay monitoring stations based on available data during the five-year period from January 1, 2001 to December 31, 2005. Refer to Figure 1 for the locations of these two monitoring stations relative to the Edmonton South Terminal.

Table 5: Regional Ambient Background Concentrations of Air Substances within the Region of the Enbridge Edmonton South Terminal Development.

Monitoring Station [a]	Air Substance	Average Background Concentration ($\mu g\ m^{-3}$)
AENV Edmonton East Station	H_2S	0.8
	Benzene	1.8
SIA Elmjay Station	H_2S	0.3

Notes:
[a] Based on available data for the five-year period from January 1, 2001 to December 31, 2005.
- Not applicable.

As shown in Table 5, H_2S concentrations are monitored at both stations while benzene is only monitored at the AENV Edmonton East station. Monitoring data for benzene at the AENV Edmonton East station is collected on a daily (24-hour) basis. The H_2S concentrations are higher at the AENV Edmonton East station than those at the Elmjay station (over two times higher) since the AENV Edmonton East station is located within a highly industrialized area.

For the purposes of this air quality assessment, average ambient background H_2S and benzene concentrations from the AENV Edmonton East monitoring station were conservatively selected and added to the results from dispersion modelling.

5.0 DISPERSION MODELLING RESULTS

Dispersion modelling results for predicted ground-level concentrations of H_2S and benzene associated with emissions from the proposed oil-product storage tanks at the Edmonton South Terminal are summarized in Table 6.

Table 6: Maximum Predicted Ground-level Concentrations of H_2S and Benzene Associated with the Enbridge Edmonton South Terminal Development.

Air Substance	Averaging Period	Regional Ambient Background [a] ($\mu g\ m^{-3}$)	Maximum Predicted Concentration ($\mu g\ m^{-3}$)	Maximum Predicted Concentration, Including Regional Ambient Background ($\mu g\ m^{-3}$)	Relevant Regulatory Guideline ($\mu g\ m^{-3}$)
H_2S	One-hour	0.8	0.027	0.83	14 [b]
	24-hour		0.011	0.81	4 [b]
	Annual		0.002	0.80	-
Benzene	One-hour	1.8	0.379	2.18	30 [b]
	24-hour		0.160	1.96	12 [c]
	Annual		0.028	1.83	3 [c]

Notes:
[a] Regional ambient background concentrations based on available data collected at the AENV Edmonton East monitoring station from January 1, 2001 to December 31, 2005.
[b] Alberta Environment (AENV) Alberta Ambient Air Quality Objectives (AAAQO) (AENV 2005).
[c] Texas Commission on Environmental Quality (TCEQ) Effects Screening Levels (ESLs) (TCEQ 2003).
\- Not applicable.

5.1 Hydrogen Sulphide

The maximum predicted one-hour average ground-level H_2S concentration associated with the Edmonton South Terminal alone is 0.027 $\mu g\ m^{-3}$. Including the regional ambient background concentration of 0.8 $\mu g\ m^{-3}$, this maximum is equal to 0.83 $\mu g\ m^{-3}$. This maximum concentration is less than six percent of the relevant AAAQO limit of 14 $\mu g\ m^{-3}$. As shown in Figure 5, the one-hour average maximum H_2S concentration is predicted to occur along the eastern edge of the Edmonton South Terminal property boundary.

The maximum predicted 24-hour and annual average ground-level H_2S concentrations associated with the Edmonton South Terminal alone are equal to 0.011 and 0.002 $\mu g\ m^{-3}$, respectively. Including the regional ambient background concentration of 0.8 $\mu g\ m^{-3}$, these maximum concentrations are respectively equal to 0.81 and 0.80 $\mu g\ m^{-3}$. The 24-hour maximum is approximately 20 percent of the corresponding AAAQO limit of 4 $\mu g\ m^{-3}$. As shown in Figures 6 and 7, the 24-hour and annual average maximum concentrations are predicted to occur along the northern edge of the Edmonton South Terminal property boundary.

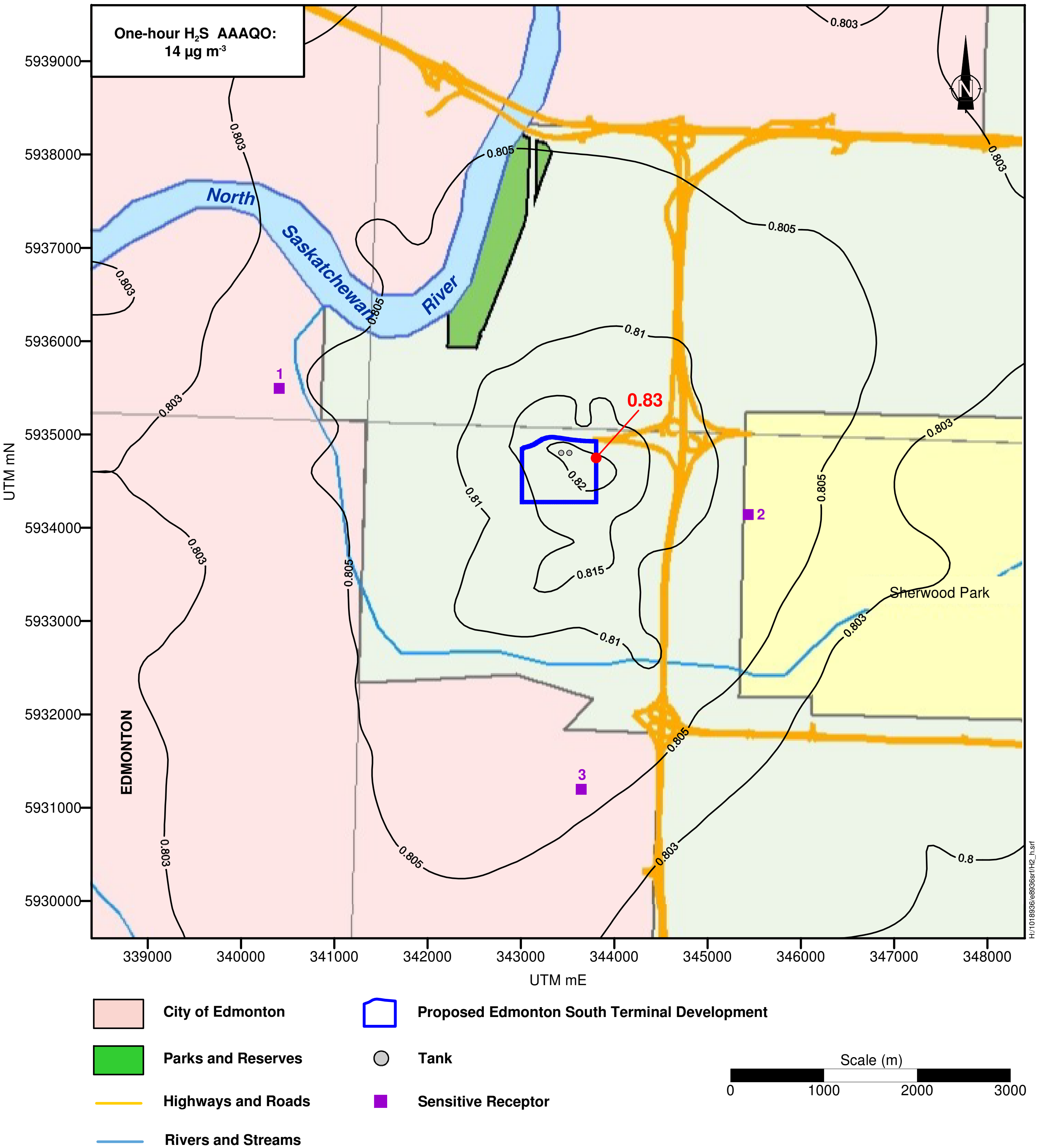

Figure 5: Maximum predicted one-hour average ground-level H_2S concentrations (µg m^{-3}) associated with emissions from the Enbridge Edmonton South Terminal Development.

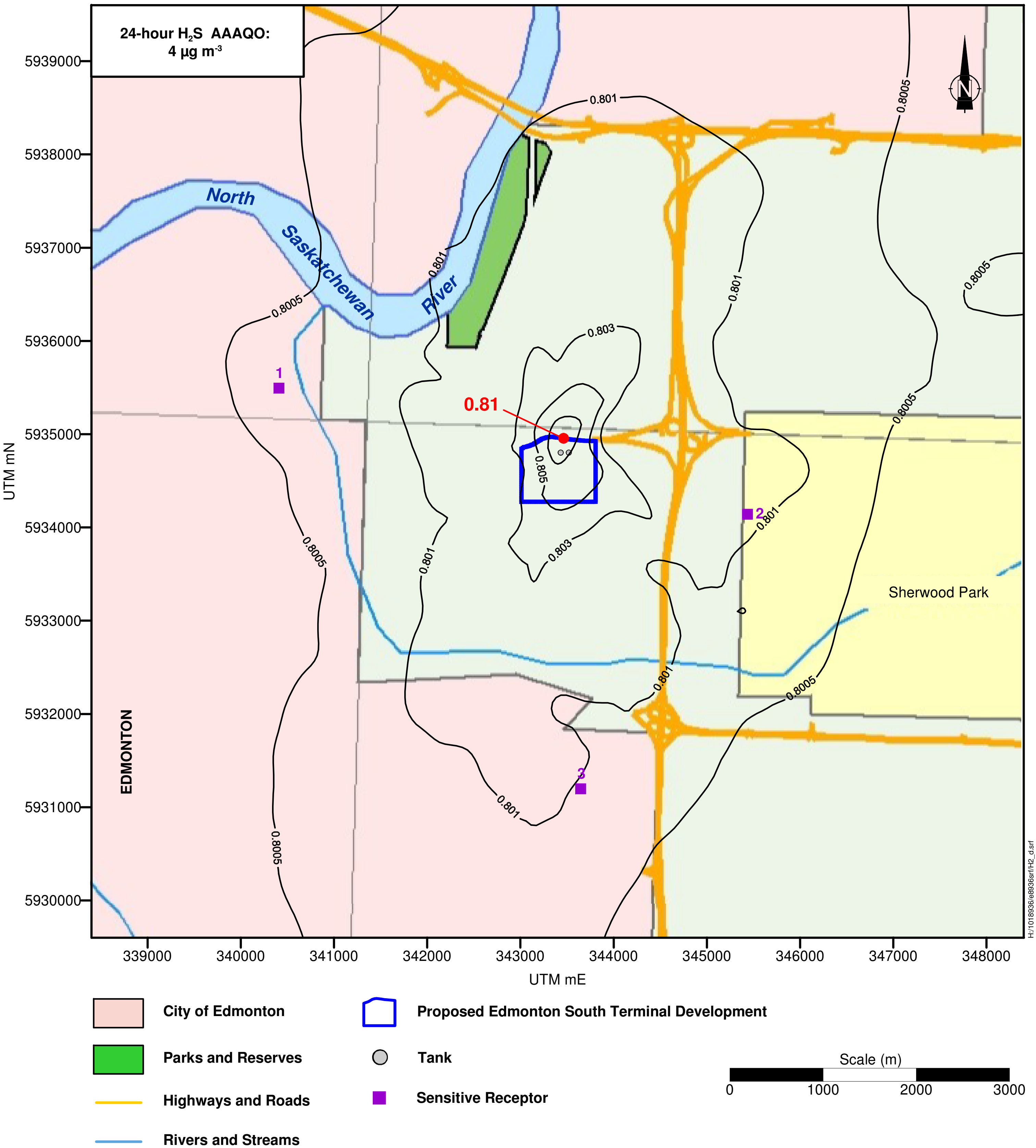

Figure 6: Maximum predicted 24-hour average ground-level H_2S concentrations (µg m^{-3}) associated with emissions from the Enbridge Edmonton South Terminal Development.

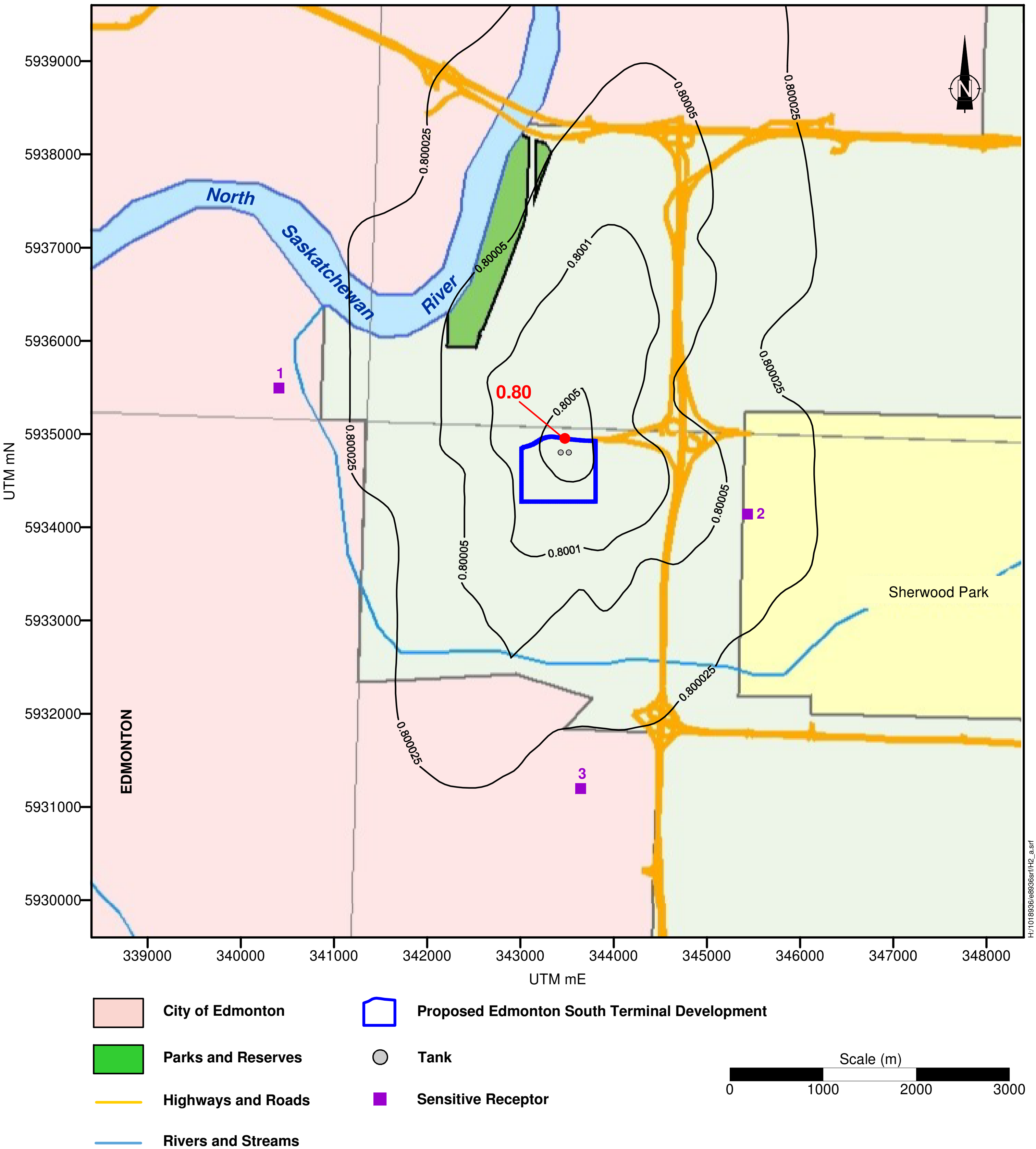

Figure 7: Maximum predicted annual average ground-level H_2S concentrations ($\mu g\ m^{-3}$) associated with emissions from the Enbridge Edmonton South Terminal Development.

5.2 Benzene

The maximum predicted one-hour average ground-level benzene concentration associated with the Edmonton South Terminal alone is equal to 0.379 µg m^{-3}. Including the regional ambient background concentration of 1.8 µg m^{-3}, this maximum is equal to 2.18 µg m^{-3}. This maximum concentration is less than the relevant AAAQO limit of 30 µg m^{-3}. Figure 8 presents isopleths of maximum one-hour average ground-level benzene concentrations. Similar to the results for H_2S, the maximum one-hour average benzene concentration is predicted to occur along the eastern edge of the Edmonton South Terminal property boundary.

Maximum predicted 24-hour and annual average ground-level benzene concentrations for the Edmonton South Terminal are equal to 0.160 and 0.028 µg m^{-3}, respectively. Including the regional ambient background concentration of 1.8 µg m^{-3}, these maximum concentrations are respectively equal to 1.96 and 1.83 µg m^{-3}. These maximums are much lower than the relevant regulatory limits of 12 and 3 µg m^{-3} for the 24-hour and annual averaging periods, respectively. In Figures 9 and 10, the 24-hour and annual average maximum concentrations are located on the northern edge of the Edmonton South Terminal property boundary.

5.3 Predictions at Sensitive Receptors

Table 7 presents details regarding predicted concentrations of air substances at the selected sensitive receptors within the study area. As shown, all predicted concentrations at these locations are much lower than the relevant guidelines.

Table 7: Maximum Predicted Ground-level Concentrations of H_2S and Benzene at Sensitive Receptors Associated with the Enbridge Edmonton South Terminal Development.

Air Substance	Averaging Period	Regional Ambient Background [a] (µg m^{-3})	Maximum Predicted Concentration, Including Regional Ambient Background (µg m^{-3})			Relevant Regulatory Guideline (µg m^{-3})
			Residential Area 1 Edmonton	Residential Area 2 Sherwood Park	Residential Area 3 Mobile Home Park	
H_2S	One-hour	0.8	0.8037	0.8075	0.8053	14 [b]
	24-hour		0.8006	0.8011	0.8006	4 [b]
	Annual		0.8000	0.8000	0.8000	-
Benzene	One-hour	1.8	1.8519	1.9051	1.8739	30 [b]
	24-hour		1.8084	1.8157	1.8087	12 [c]
	Annual		1.8003	1.8006	1.8003	3 [c]

Notes:
[a] Regional ambient background concentrations based on available data collected at the AENV Edmonton East monitoring station from January 1, 2001 to December 31, 2005.
[b] Alberta Environment (AENV) Alberta Ambient Air Quality Objectives (AAAQO) (AENV 2005).
[c] Texas Commission on Environmental Quality (TCEQ) Effects Screening Levels (ESLs) (TCEQ 2003).
\- Not applicable.

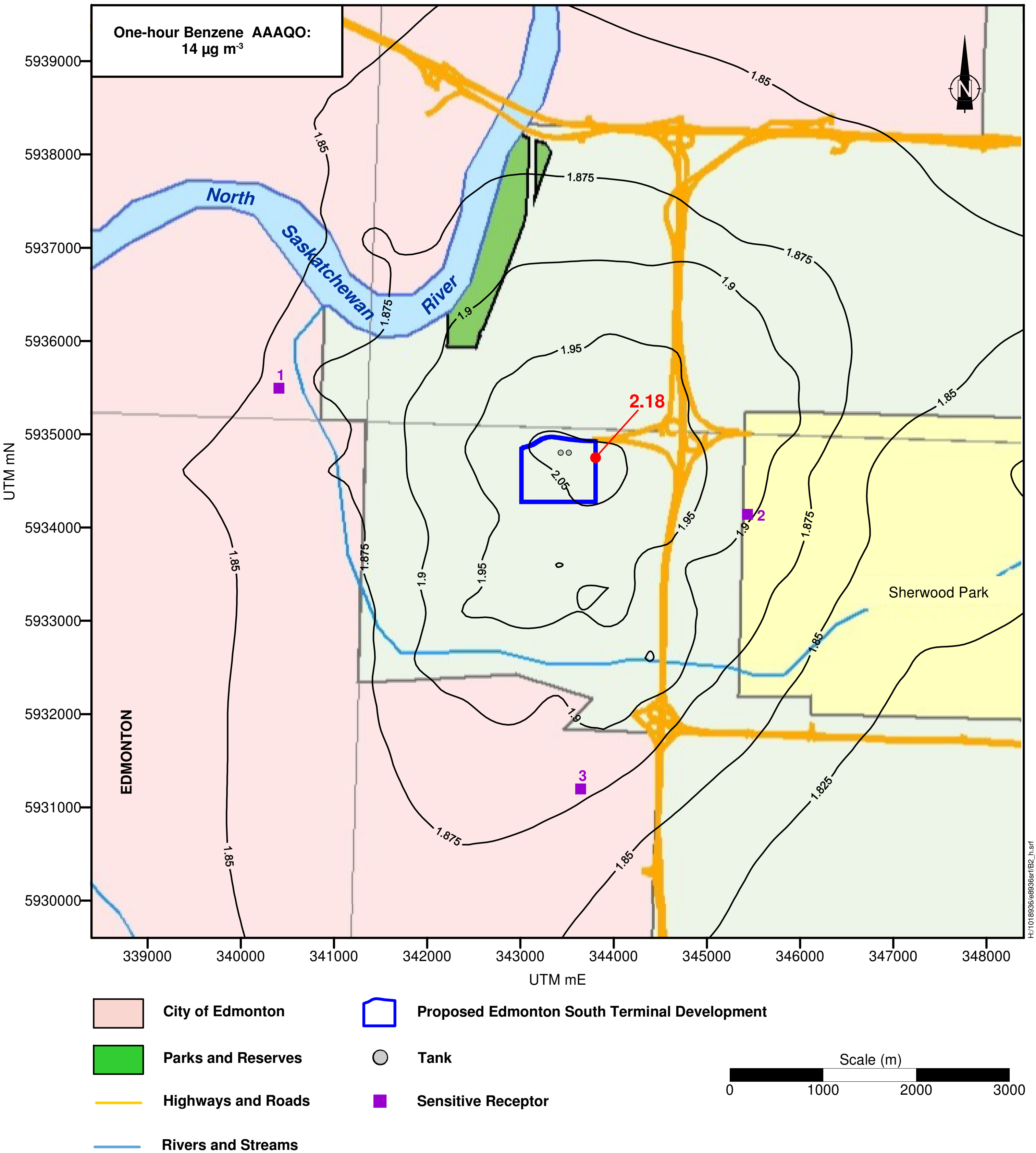

Figure 8: Maximum predicted one-hour average ground-level Benzene concentrations (µg m^{-3}) associated with emissions from the Enbridge Edmonton South Terminal Development.

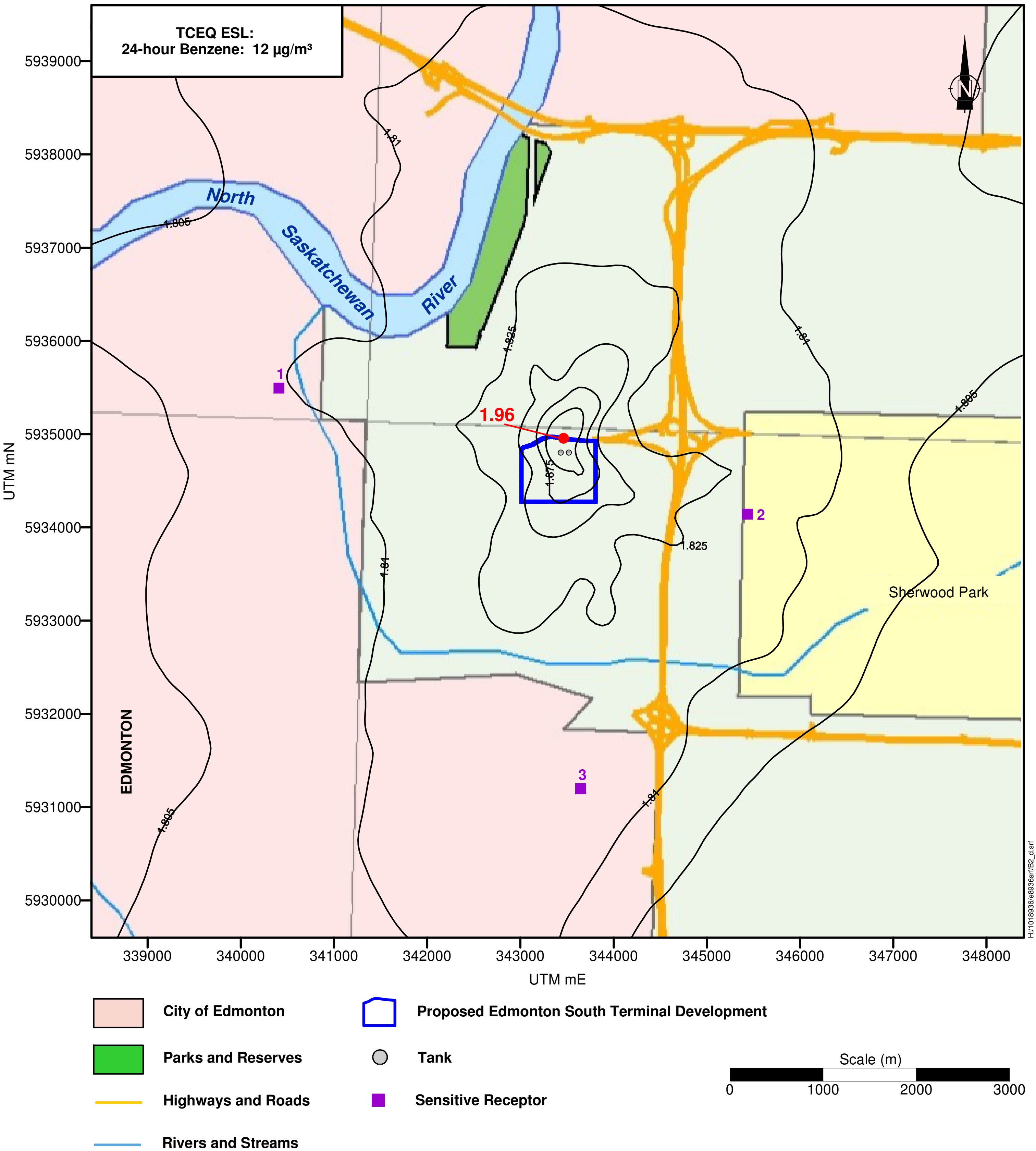

Figure 9: Maximum predicted 24-hour average ground-level Benzene concentrations (µg m^{-3}) associated with emissions from the Enbridge Edmonton South Terminal Development.

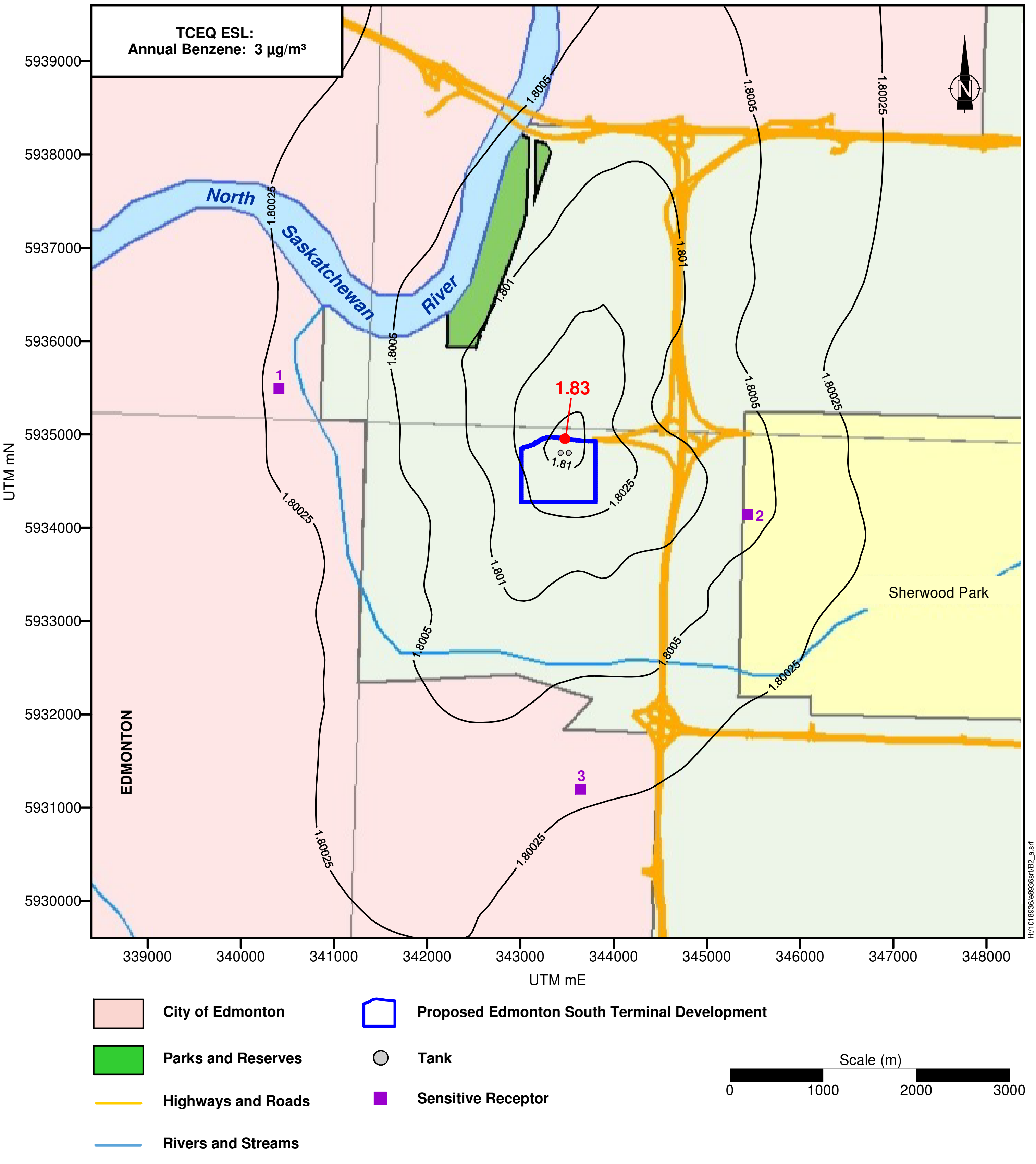

Figure 10: Maximum predicted annual average ground-level Benzene concentrations (µg m^{-3}) associated with emissions from the Enbridge Edmonton South Terminal Development.

5.4 Results Summary

Generally, all maximum predicted ground-level concentrations of H_2S and benzene associated with emissions from the Edmonton South Terminal and applicable regional ambient background concentrations are below the relevant regulatory limits for ambient air quality. The areas of maximum impact from the Edmonton South Terminal air emissions are to the east and to the north of the proposed tanks, along the facility property boundary. All predicted ground-level concentrations in and around the sensitive receptor areas are well below acceptable regulatory limits.

6.0 CONCLUSIONS

The Enbridge Pipelines Inc. Edmonton South Terminal Development (the 'Edmonton South Terminal') is a proposed construction of two new white painted external floating-roof oil-product storage tanks with primary and secondary seals located in County of Strathcona, Alberta. Atmospheric emissions from the Edmonton South Terminal in the form of evaporative losses from storage tanks include vapours of various hydrocarbon and sulphur compounds.

This air quality assessment was completed to support regulatory applications to construct and operate the proposed oil-product storage tanks. This assessment includes an impact assessment for the main air substances of interest associated with the proposed tank emissions, including H_2S and benzene.

The results of this assessment show that the maximum predicted ground-level concentrations for all substances of interest were below the applicable regulatory objectives and criteria. Therefore, potentially adverse impacts on ambient air quality associated with the proposed development are not expected to occur and air quality within the study area is expected to remain acceptable relative to the applicable regulatory ambient air quality objectives and criteria.

7.0 CLOSURE

This report was prepared for the sole benefit of Enbridge Pipelines Inc. and their representatives. The report may not be relied upon by any other person or entity without the express written consent of Jacques Whitford AXYS and Enbridge Pipelines Inc.

Any uses which a third party makes of this report, or any reliance on decisions made based on it, are the responsibilities of such third parties. Jacques Whitford AXYS accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Should additional information become available which differs significantly from our understanding of conditions presented in this report, we request that this information be brought to our attention so that we may reassess the conclusions provided herein.

8.0 REFERENCES

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APPENDIX A

Emissions Assessment for the Edmonton South Terminal

December 5, 2006

ENBRIDGE PIPELINES INC.
10201 Jasper Avenue S.W.
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T5J 2J9

Attention: Jeannette Gasser

Reference: Emissions Assessment for the Edmonton South Terminal

This letter presents an assessment of the amount of total hydrocarbon (THC) and volatile organic compound (VOC) emissions that may result from the proposed installation of two 300,000 bbl external floating roof storage tanks at the Enbridge Edmonton South Pipeline Terminal. Background information on the proposed tanks and a description of the methodology used to estimate and speciate these emissions is also provided.

Background Information

The two tanks to be installed at the Edmonton South Terminal will be 58.52 m in diameter, 18.29 m height and will be designed to the specifications of API 650 and CCME Guide EPC-87E). Each tank will have a working volume of 40,000 m^3 and will feature a mechanical shoe seal with a rim mounted secondary wiper seal.

The tanks will be installed in the northeast quadrant of Edmonton on lands located on the south side of Baseline Road. The development is required to accommodate the initial synthetic crude oil production volumes associated with the CNRL Horizon project. This product (CNS) will be a light sweet synthetic crude oil similar to the sweet synthetic crude oil produced by Syncrude. The Reid vapaour pressure of the product will be 32 kPa. It will have a density of 835 to 865 kg/m^3 and a sulphur content of 0.2 weight percent. The initial throughput of the facility will be 19,900 m^3/d and will ultimately increase to 27,000 m^3/d. Activity levels for the tanks will be an annual average of 85 to 90 percent of the expected flow rates.

Overview of the Estimated Emissions

The primary source of emissions from the site will be product evaporation losses from the storage tanks. There may also be some emissions due to fugitive equipment leaks; however, these will be small in comparison (i.e., less than 1 percent) and are neglected for simplification purposes. The small amount of emissions from equipment leaks reflects the relatively small number of equipment components in hydrocarbon service at tank farms and their low leak potential.

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The maximum annual evaporation loss from the two tanks is estimated to be 14,322 kg per year (kg/y). A summary of these losses by tank and type of evaporation loss is presented in Table 1. Total annual flow through the terminal is assumed to be distributed evenly between the two tanks. Consequently, both tanks have the same estimated emissions. The total estimated amount of emissions from the two tanks is equivalent to the loss of approximately 106 bbls per year of product, which represents only 0.0002 percent of the total throughput of the facility. This relatively low amount of evaporation loss is attributed to the application of vapour controls (i.e., floating roofs) on the storage tanks and the low volatility of the stored product.

The predicted composition of the emitted product vapours, for use in speciating these emissions, is presented in Table 2.

Emission Calculations

The average amount of organic emissions from each individual tank was estimated using the most current version of US EPA's TANKS model (i.e., Version 4.09D), available data on the tank and product characteristics, and monthly meteorological data applicable to Edmonton for the full year. Details regarding the design and operation of the tanks were provided by Enbridge.

The composition of the product vapours for use in speciation of the estimated emissions was calculated using Raoult's Law and a recent liquid analysis for Syncrude synthetic crude. The liquid analysis was obtained from the following web site which provides detailed analyses for all of the common types of crude oils handled in Alberta: www.crudemonitor.ca/asp/demo/custom/custom.php.

Please contact me at (403) 215-2730 if you have any questions or concerns regarding any of the information presented herein.

Thank you.

Yours truly,
CLEARSTONE ENGINEERING LTD.

David Picard

David J. Picard, M.Eng., P.Eng.
Principal

Table 1. Estimated evaporation losses from the two 300 kbbl storage tanks to be installed at the Edmonton South Terminal.									
Size (kbbl)	Diameter (m)	Height (m)	Product	Net Annual Turnovers	Annual Hydrocarbon Emissions				
					Rim Seal Losses (kg)	Withdrawl Loss (kg)	Deck Fitting Loss (kg)	Deck Seam Loss (kg)	Total (kg)
300	58.52	18.29	CNS	195.9	765.41	4,372	2,024	0.00	7,161
300	58.52	18.29	CNS	195.9	765.41	4,372	2,024	0.00	7,161
					1,530.82	8,744	4,048	0.00	14,322

Table 2. Predicted compositions of the product vapours expressed on an air-free basis.				
Class	Crude	Substance	Vapour (Mol Fraction)	Vapour (Mass Fraction)
Light Crude	CNS	Acenaphthene	1.33281E-09	3.33878E-09
Light Crude	CNS	Acenaphthylene	6.14422E-10	1.51901E-09
Light Crude	CNS	Anthracene	3.42979E-11	9.93037E-11
Light Crude	CNS	Benz(a)anthracene	7.21593E-44	2.67601E-43
Light Crude	CNS	Benzene	0.002887207	0.003663667
Light Crude	CNS	Benzo(a)pyrene	1.52759E-44	6.26111E-44
Light Crude	CNS	Benzo(b)fluoranthene	5.63376E-44	2.3091E-43
Light Crude	CNS	Benzo(e)pyrene	1.85878E-43	7.61852E-43
Light Crude	CNS	Benzo(ghi)perylene	4.86509E-44	2.18388E-43
Light Crude	CNS	Benzo(k)fluoranthene	7.57082E-45	3.10304E-44
Light Crude	CNS	Biphenyl	1.09413E-08	2.74091E-08
Light Crude	CNS	C10Aromatics	0	0
Light Crude	CNS	C10Napthenes	7.05002E-06	1.58322E-05
Light Crude	CNS	C10Paraffins	7.10995E-05	0.000164338
Light Crude	CNS	C1-Chrysene	1.35715E-42	5.34204E-42
Light Crude	CNS	C1-Fluorene	5.12859E-10	1.5017E-09
Light Crude	CNS	C1-Naphthalene	4.36945E-07	1.00933E-06
Light Crude	CNS	C1-Phenanthrene	1.46648E-41	4.5801E-41
Light Crude	CNS	C2-Chrysene	2.03284E-42	8.46502E-42
Light Crude	CNS	C2-Fluorene	7.45984E-42	2.3542E-41
Light Crude	CNS	C2-Naphthalene	0	0
Light Crude	CNS	C2-Phenanthrene	1.56738E-41	5.25218E-41
Light Crude	CNS	C3-Chrysene	1.8133E-42	7.96413E-42
Light Crude	CNS	C3-Fluorene	7.09693E-42	2.40142E-41
Light Crude	CNS	C3-Naphthalene	4.52936E-07	1.25266E-06
Light Crude	CNS	C3-Phenanthrene	1.04347E-41	3.73444E-41
Light Crude	CNS	C4-Naphthalene	2.0629E-09	6.1754E-09
Light Crude	CNS	C4-Phenanthrene	6.387E-42	2.43138E-41
Light Crude	CNS	C7Aromatics	0.001903519	0.002849151
Light Crude	CNS	C7Napthenes	0.00258991	0.004130954
Light Crude	CNS	C7Paraffins	0.002868723	0.00466968

Table 2. Predicted compositions of the product vapours expressed on an air-free basis.				
Class	**Crude**	**Substance**	**Vapour (Mol Fraction)**	**Vapour (Mass Fraction)**
Light Crude	CNS	C8Aromatics	0.000835399	0.001440763
Light Crude	CNS	C8Napthenes	0.000492177	0.000897179
Light Crude	CNS	C8Paraffins	0.001148754	0.00213169
Light Crude	CNS	C9Aromatics	0.000378722	0.000739456
Light Crude	CNS	C9Napthenes	0.000197338	0.000404688
Light Crude	CNS	C9Paraffins	0.000166616	0.000347148
Light Crude	CNS	Carbon Dioxide	0	0
Light Crude	CNS	Carbon Disulphide	0	0
Light Crude	CNS	Carbonyl Sulphide	0	0
Light Crude	CNS	Chrysene	6.60083E-43	2.4479E-42
Light Crude	CNS	Dibenz(a,h)anthracene	1.99689E-44	9.0293E-44
Light Crude	CNS	Ethane	0	0
Light Crude	CNS	Ethyl Mercaptan	1.27497E-05	1.28693E-05
Light Crude	CNS	EthylBenzene	0.000159916	0.000275798
Light Crude	CNS	Fluoranthene	6.42437E-43	2.11071E-42
Light Crude	CNS	Fluorene	9.89974E-09	2.67311E-08
Light Crude	CNS	Hexanes	0.060725157	0.085010815
Light Crude	CNS	Hydrogen Sulphide	0.000473283	0.000261958
Light Crude	CNS	isoButane	0.160963589	0.151982038
Light Crude	CNS	Iso-Butyl Mercaptan	5.62685E-07	8.24336E-07
Light Crude	CNS	isoPentane	0.085801971	0.100565436
Light Crude	CNS	Iso-Propyl Mercaptan	5.86527E-06	7.25617E-06
Light Crude	CNS	Methane	0	0
Light Crude	CNS	Methyl Mercaptan	8.86357E-06	6.92698E-06
Light Crude	CNS	Naphthalene	2.82528E-07	5.88262E-07
Light Crude	CNS	nButane	0.448291102	0.423277063
Light Crude	CNS	nDecane	4.42004E-05	0.000102164
Light Crude	CNS	nHeptane	0.003504899	0.005705241
Light Crude	CNS	nNonane	0.000131406	0.000273787
Light Crude	CNS	nOctane	0.000614806	0.001140868
Light Crude	CNS	nPentane	0.102400168	0.120019592
Light Crude	CNS	Other Heavy Ends	5.03972E-06	1.73903E-05
Light Crude	CNS	Perylene	3.20184E-44	1.31233E-43
Light Crude	CNS	Phenanthrene	3.84396E-10	1.11295E-09
Light Crude	CNS	Propane	0.121428813	0.086984109
Light Crude	CNS	Pyrene	3.26825E-43	1.07377E-42
Light Crude	CNS	Toluene	0.001508685	0.002258191
Light Crude	CNS	Xylenes	0.00037121	0.00064021

APPENDIX B

Meteorological Data Applied in Dispersion Modelling

1.0 INTRODUCTION

The following sections present information on the source of meteorological data applied in the dispersion modelling assessment of the Enbridge Edmonton South Terminal Development and the results of the analysis performed on the meteorological dataset.

1.1 Meteorological Data Sources

The local meteorology of the region must be characterized to evaluate the short-term atmospheric dispersion and transport of air emissions. The data required to predict dispersion and transport includes wind speeds and direction, temperature, atmospheric stability, and mixing layer depth. Wind and temperature data are readily available from meteorological stations, but atmospheric stability and mixing layer depth are calculated from additional raw meteorological data, including cloud cover and opaque sky cover.

Most of the surface meteorological data for the five year period from January 1, 2001 to December 31, 2005 was obtained from the Edmonton International Airport Station maintained by Environment Canada. However, due to the low start-up threshold and low directional resolution of the Environment Canada wind instrumentation, wind fields from the nearby Alberta Environment (AENV) Edmonton East Station were used. The data were obtained from the Clean Air Strategic Alliance (CASA) online data warehouse (CASA 2006). Missing wind speeds and directions from the Alberta Environment Station were filled with Environment Canada fields where possible.

Upper air data for the same period was obtained for Stony Plain from the United States National Oceanic and Atmospheric Administration (NOAA) Online Radiosonde Database (NOAA 2006). The Stony Plain site is approximately 40 km from the Edmonton International Airport and is very representative of upper air parameters in the study area. A total of 51 radiosonde measurements were missing over the five-year period from January 1, 2001 to December 31, 2005. Of these missing soundings, 25 were approximated by using the previous days sounding. The remaining missing soundings could not be filled as values were missing for consecutive days. A summary of all meteorological data used is shown in Table B-1.

Table B-1: Summary of Data Sources for Meteorological Data Applied in Dispersion Modelling.

Parameter	Station Type		
	Upper Air Station	**Surface Stations**	
Station Name	Stony Plain	Edmonton Airport	Edmonton East
Location	53.550N 114.100W	53.317N 113.567W	53.547N 113.368W
Period	Jan 1, 2001– Dec 31, 2005	Jan 1, 2001 – Dec 31, 2005	Jan 1, 2001 – Dec 31, 2005
Parameters	Pressure Altitude Temperature Wind Speed / Direction Relative Humidity	Wind Speed / Direction (fill only) Temperature Cloud Cover Cloud Opacity Relative Humidity Ceiling Height	Wind Speed and Direction

2.0 AERMET INPUT PARAMETERS

Monin-Obukhov length (a stability parameter), mixing layer depth, surface friction velocity, and convective velocities are calculated with the aid of the AERMET meteorological pre-processor. AERMET merges the surface data set with the upper air data, to provide a QA/QC'd meteorological data set.

There are three stages to processing the data. The first stage extracts meteorological data from archive data files and processes the data through various quality assessment checks. The second stage merges all data available for 24-hour periods and stores these data together in a single file. The third stage reads the merged meteorological data and estimates the necessary parameters to be used in the dispersion modelling.

The AERMET processor requires hourly estimates of wind speed, direction, temperature, cloud cover, as well as the 1200 GMT sounding to generate the requisite data for modelling. In addition, seasonal estimates of the surface albedo, roughness height, and Bowen ratio in the vicinity of the project location are required. Four land use sectors were identified for in the analysis and are presented in Table B-2.

These values were taken from tables of suggested values for various surface conditions recommended by the United States Environmental Protection Agency (U.S. EPA 1998). AERMET calculates the hourly surface heat flux and subsequently determines the surface friction velocity (u_*) and the Monin-Obukhov length (L) through an iterative procedure using surface layer similarity for each hour.

Missing data were dealt with according to U.S. EPA protocols. Where data were missing for a particular hour, the missing data were set to AERMET/AERMOD missing flags, so the hour would not be included in the dispersion modelling.

The following sections describe the analysis performed on the meteorological data.

Table B-2: Summary of Land Characteristics.

Season	Sector (Degrees)	Albedo	Bowen Ratio	Surface Roughness (m)
Winter	0-90 (Mixed Urban/Cultivated Land)	0.4750	1.5000	0.51500
Spring		0.1400	0.6500	0.60000
Summer		0.1800	1.2500	0.52500
Fall		0.1800	1.3500	0.50500
Winter	90-180 (Urban)	0.3500	1.5000	1.00000
Spring		0.1400	1.0000	1.00000
Summer		0.1600	2.0000	1.00000
Fall		0.1800	2.0000	1.00000
Winter	180-270 (Mixed Urban/Cultivated Land)	0.4750	1.5000	0.51500
Spring		0.1400	0.6500	0.60000
Summer		0.1800	1.2500	0.52500
Fall		0.1800	1.3500	0.50500
Winter	270-360 (Urban)	0.3500	1.5000	1.00000
Spring		0.1400	1.0000	1.00000
Summer		0.1600	2.0000	1.00000
Fall		0.1800	2.0000	1.00000

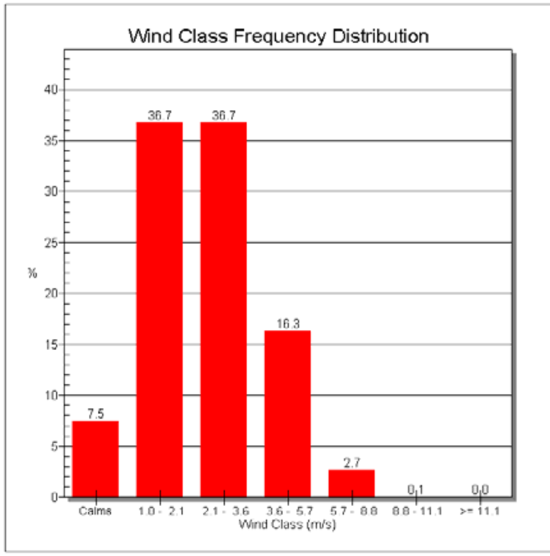
2.1 Wind Speed and Direction

The frequency distribution of wind speeds (from AERMET) obtained at the AENV Edmonton East monitoring station is provided in Figure B-1. High wind speeds greater than 11 m s^{-1} occur relatively infrequently, while wind speeds between 1.0 and 3.6 m s^{-1} occurs the most frequently (about 73.4 percent of the time). A wind rose plot from the AENV Edmonton East monitoring station is presented in Figure B-2. Wind roses are an efficient and convenient means of presenting wind data. The length of the radial barbs gives the total percent frequency of winds from the indicated direction, while portions of the barbs of different widths indicate the frequency of associated with each wind speed category. The predominant winds for the five-year modelling period (from January 1, 2001 to December 31, 2005) are from the south-southwest.

2.2 Mixing Layer Heights

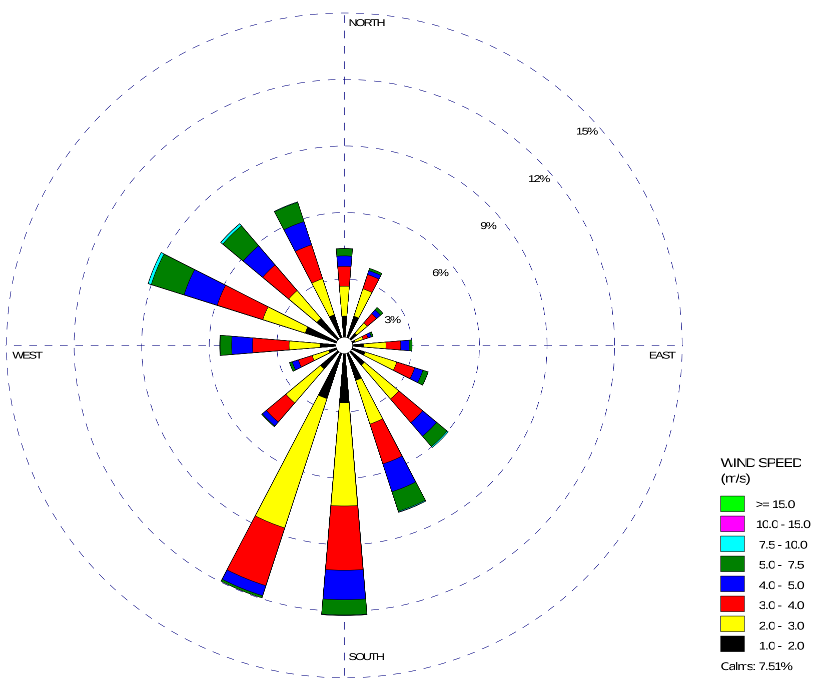
The mixing layer height is a parameter used to define the effective depth of the atmosphere through which dispersion of pollutants can take place. Heat transfer to the atmosphere at the earth's surface results in convective (vertical) mixing and consequently changes the vertical temperature profile, which defines the atmospheric lapse rate.

An elevated inversion (increase in temperature with height) can form above a convective boundary layer. The base of the inversion effectively forms a barrier, restricting vertical motion and dispersion. Pollutants can build-up in the boundary layer if there is a strong inversion and the plume is contained beneath the inversion base.



Data Period: January 1, 2001 to December 31, 2005.

Figure B-1: Wind Class Frequency Distribution for Meteorological Data Applied in Dispersion Modelling.

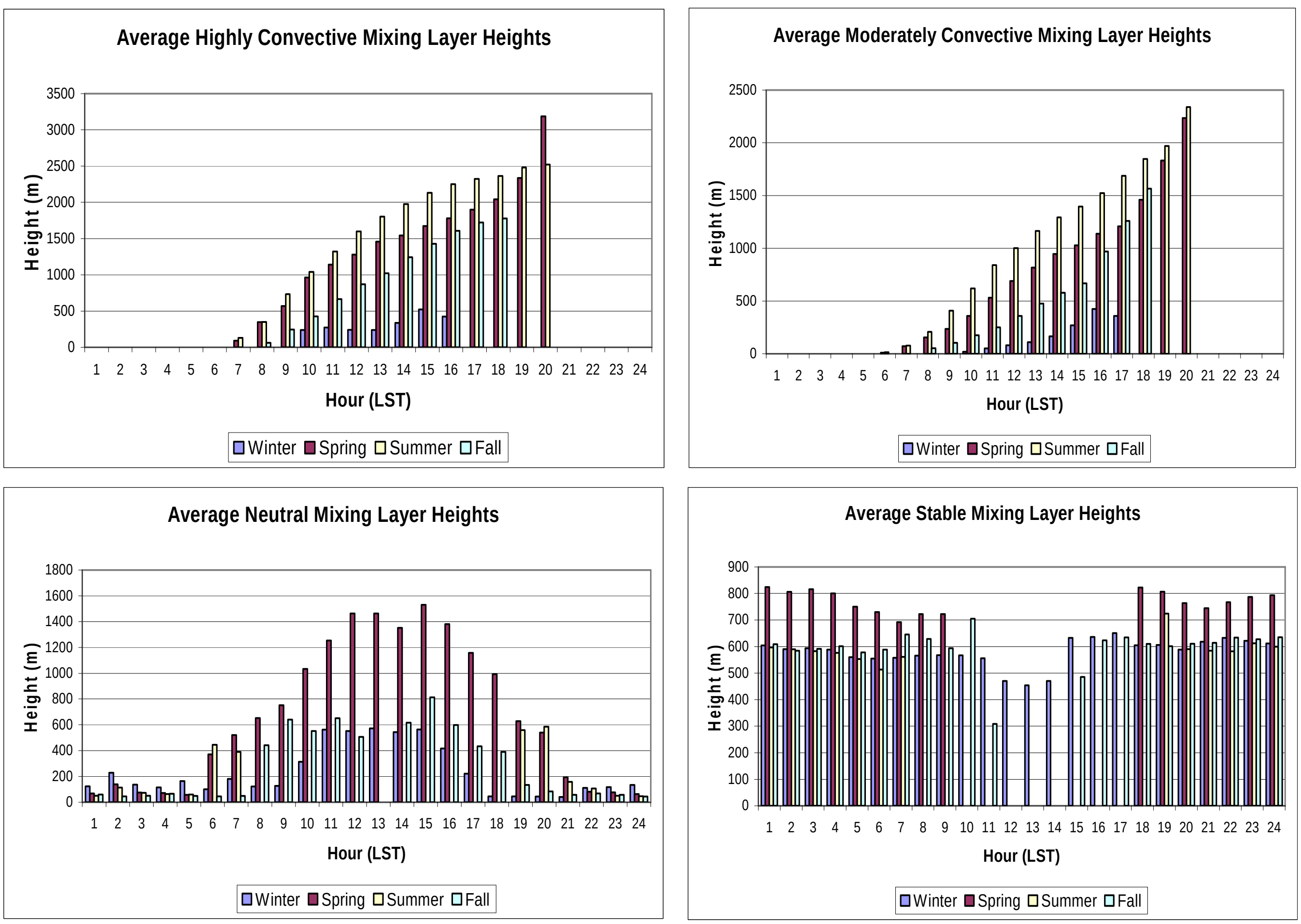


Data Period: January 1, 2001 to December 31, 2005.

Figure B-2: Wind Rose Plot for Meteorological Data Applied in Dispersion Modelling.

Surface based inversions are most common during the early morning hours following radiative cooling of the earth's surface during clear nights. This inversion height defines the height of the Convective Boundary Layer (CBL). Early in the morning, when the inversion can be close to the ground (*i.e.* a low CBL), the trapping of pollutants between the inversion and the ground in a relatively narrow band, can potentially lead to high ground level pollutant concentrations.

Figure B-3 presents the average mixing layer heights as calculated by the AERMET processor from the surface and upper air data. The height of the CBL with time of day and season at the site is shown in the upper 2 panels in Figure B-3. Convective mixing layers show a general increase in height from about 6:00 to about 20:00 local standard time (LST) and a collapse shortly thereafter. The diurnal variation of average neutral mixing layer heights is presented in the lower left panel of the Figure B-3. For neutral conditions, the mixing layer heights typically show highest heights during the spring. Stable mixing layer heights are presented in the lower right panel of Figure B-3 and are higher during the night time and generally highest during the spring.



Data Period: January 1, 2001 to December 31, 2005.

Figure B-3: Average Mixing Depth Heights (From AERMET) for Meteorological Data Applied in Dispersion Modelling.

3.0 REFERENCES

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