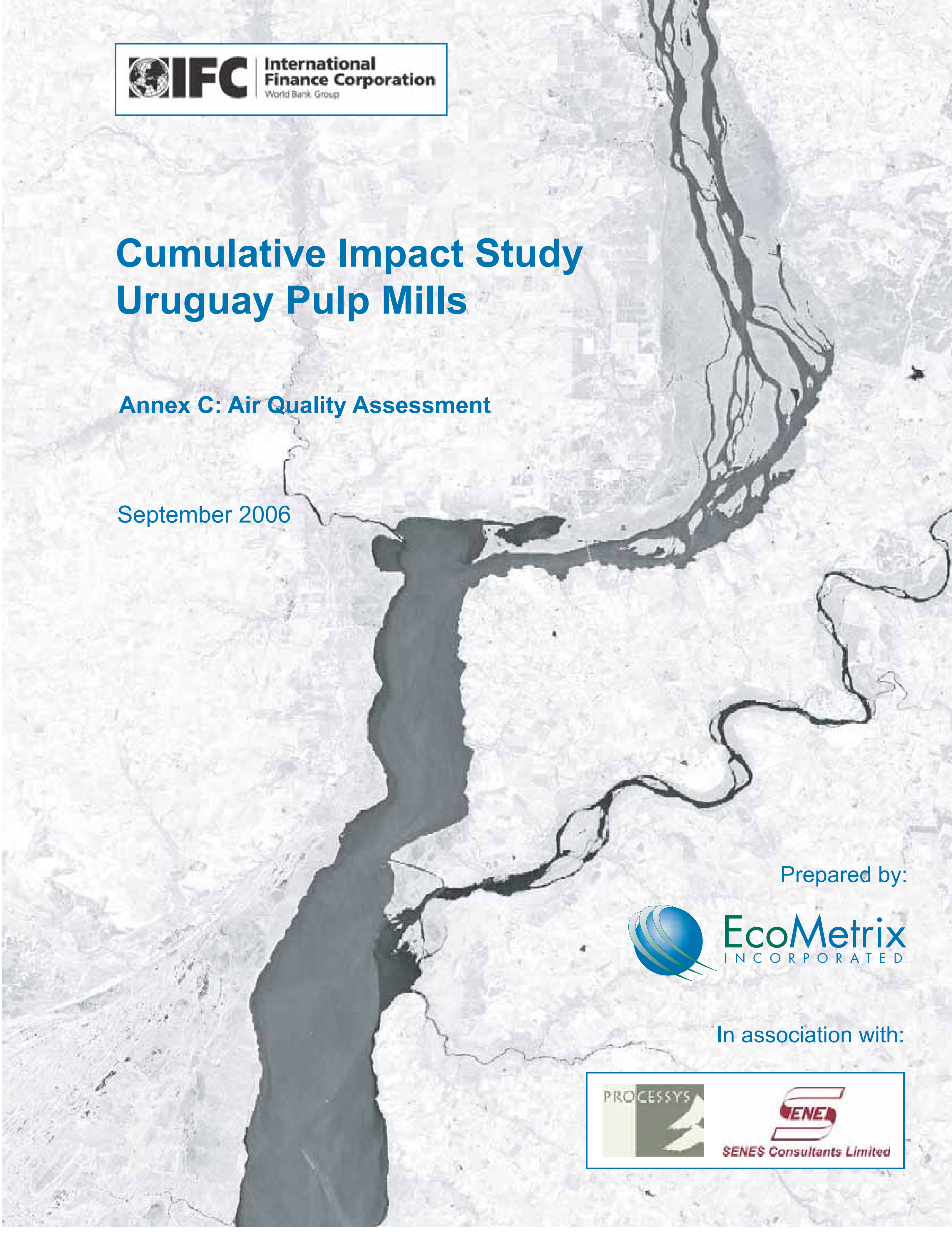

International Finance Corporation
World Bank Group

Cumulative Impact Study Uruguay Pulp Mills

Annex C: Air Quality Assessment

September 2006

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In association with:

PROCESSYS

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ANNEX C

Air Quality Assessment

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C1.0 INTRODUCTION

The International Finance Corporation of the World Bank Group (IFC) is currently assessing two pulp mill projects in Uruguay for financing. The mills are located on the Rio Uruguay near the city of Fray Bentos near the border with Argentina. In addition, the Multilateral Investment Guarantee Agency (MIGA) is evaluating whether to provide political risk insurance to one of the mills.

To complete the assessment of the combined environmental and social effects of the two proposed mills, IFC commissioned a Cumulative Impact Study (CIS) of the construction and operations of the two pulp mills and their respective raw material sourcing. The draft CIS was prepared by Pacific Consultants International and Malcolm Pirnie Incorporated and issued by IFC in December 2005. Following a period of public review and professionally facilitated consultations in Argentina and Uruguay, the IFC commissioned a panel of independent experts to review existing project documentation and all comments provided by stakeholders. The results of this review are summarized in a report issued by the independent experts in April 2005. The report, referred to as the Hatfield Report, also identifies additional information and analysis required to complete the environmental assessment for the two mills. EcoMetrix Incorporated (EcoMetrix) and its consultants, SENES Consultants Limited (SENES) and Processys Incorporated (Processys), revised and finalized the draft CIS in response to the recommendations of the Hatfield Report, the published Terms of Reference, original research, stakeholder commentary and other project related documentation.

The following report forms a portion of the revised CIS and specifically addresses the air quality affects arising from the two mills. It includes: a description of the projects and associated air emission characteristics; a discussion of the methodology by which potential effects are assessed; and a detailed discussion of the potential air quality and environmental effects associated with mill operations.

C1.1 Project Background

The two mills are located along the south shore of the Rio Uruguay River east of the city of Fray Bentos, Uruguay (shown in Figure C5.1-1). The mills are being developed by Botnia of Finland and ENCE of Spain, and are designed to produce approximately 1,000,000 tons of air dried pulp on an annual basis (ADt/a) and 500,000 ADt/a, respectively.

The mills have incorporated various process technologies to collect and treat all gaseous and particulate emissions of environmental significance that may be generated through the mill operations. As described in Annex A of the CIS report, these technologies are superior to the recommended standards outlined in the Integrated Pollution Prevention and Control (IPPC) reference documents on best available technologies (BAT) for the pulp and paper industry, particularly with respect to extended back-up to enhance reliability.

Emissions associated with the recovery boilers, lime kilns, and, in the case of ENCE, a biomass boiler, will be released as point sources through the main stack on each site. These stacks discharge 120 and 110 metres (m) above ground level for Botnia and ENCE, respectively. Emissions from the chlorine dioxide generation plant will be released through a separate stack.

The open water areas of the wastewater treatment systems, and the wood chip storage and handling areas generate fugitive emissions distributed over larger spatial areas and are generally released near or at ground level. In addition, truck traffic and other modes of transportation contribute to the emissions for the mill operations.

The main emissions of interest are: compounds from combustion sources, such as nitrogen oxides (NO_x), sulphur dioxide (SO_2), and particulate matter (PM, PM_{10} and $PM_{2.5}$); reduced sulphur compounds including hydrogen sulphide (H_2S), methyl mercaptan (CH_4S), dimethyl sulphide (DMS), and dimethyl disulphide (DMDS); volatile organic compounds (VOC); trace quantities of organic (e.g., polycyclic aromatic hydrocarbons, dioxins and furans) and inorganic compounds (e.g., heavy metals); and chlorine and chlorine dioxide emissions from the chlorine dioxide generation plant.

Specific receptors in Uruguay include: the areas adjacent to the mill properties; the cities of Fray Bentos, Mercedes and Nuevo Berlin; the beach areas of Las Cañas and Playa Ubici and the International Bridge. Specific receptors in Argentina include: the city of Gualeguaychú; and the beach resort at Ñandubaysal.

C1.2 Purpose and Objectives

The purpose of this Annex is to provide an assessment of the potential effects of the mill operations on the air quality within the areas of Uruguay and Argentina that neighbor the two mills. The specific objectives are as follows:

- to identify the specific sources of air emissions originating from the two mills;
- to estimate the emission rates of various air quality parameters from each of the identified sources;
- to predict the change in ground level air quality at each of the identified receptor locations; and
- to assess the potential human health and aesthetic effect of the air emissions at each identified receptor.

C1.3 Study Approach

The air quality assessment was prepared by a team of specialists within the disciplines of meteorology, chemistry, chemical engineering, source characterization, toxicology, fluid dynamics and air quality modelling. The contributing members of the project team include:

- Michael Sills, Ph.D., a senior consultant with SENES, Richmond Hill, Canada, responsible for coordination of the air quality impact assessment;
- Jim Young, Ph.D., P.Eng., an air quality specialist with SENES, Richmond Hill, Canada, responsible for the oversight of the air quality impact assessment;
- Richard Urbanski, M.B.A. Chem., an air quality specialist with SENES, Richmond Hill, Canada, responsible for data validation;
- Dan Hrebenyk, M.Sc., an air modeling specialist with SENES, Vancouver, Canada, responsible for model activities and data compilation;
- Zivorad Radonjic, B.Sc., a senior meteorologist with SENES, Richmond Hill, Canada, responsible for the verification of meteorology data and implementation of CALMET model;
- Harriet Phillips, Ph.D., a specialist in risk assessment and toxicology with SENES, Richmond Hill, Canada, responsible for the assessment human health effects;
- Paul Stuart, Ph.D., a Principal of Processys Incorporated and professor of Chemical Engineering at the Ecole Polytechnique, Montreal, Canada, responsible for emissions inventory;
- Peter Gleadow, B.Eng., a process specialist with Processys Incorporated, Vancouver, Canada, responsible for emissions inventory; and
- Bruce Rodgers, M.Sc., P.Eng, an environmental engineer at EcoMetrix, Brampton, Canada, project manager for the CIS project team and responsible for report review.

Dr. Sills, Dr. Stuart and Mr. Rodgers traveled to Uruguay and Argentina to tour the cities and country side neighboring the mills, to collect up-to-date information regarding the mills, and to gain perspective of the project and stakeholder concerns. Information and context was provided through meetings with representatives from Botnia, ENCE, the Department of the Environment (Direccion Nacional de Medio Ambiente, DINAMA), the Administrative Commission of the Rio Uruguay (Comision Administradora del Rio Uruguay, CARU), and the municipal office for the Río Negro Department in Fray Bentos. Mr. Gleadow also traveled to Spain to meet with the design engineers for ENCE, to tour ENCE's existing mills, and to gain further information regarding process technologies and emission characteristics.

Various sources of information were utilized to support the assessment of air quality. The environmental impact assessments (EIAs) for the mills (Botnia, 2004; ENCE, 2003) were used as the initial source of information regarding the mills and associated process technologies and source emissions. This information was up-dated through discussions and exchanges with representative of Botnia and ENCE, and through an assessment of the process technologies for each mill. This assessment is presented in Annex A of the CIS.

The process configuration for each mill was reviewed in detail to identify potential sources of air emissions. The design of the non-condensable gas collection systems was evaluated, and potential point source volumes were identified. Area sources of air emissions, particularly the effluent treatment system, were also identified and characterized.

Emission factors were compiled and substantiated from various sources of information. These sources included: Emission Factor Databases, such as, AWMA, Industrial Association Publications, Stack Test Reports, and technical papers (e.g. Resource Planning and Development Commission, 2004; Development of New Environmental Emission Limit Guidelines for Any New Bleached Eucalyptus Kraft Pulp Mill in Tasmania. Volumes II & I. Hobart, Tasmania).

The professional experience of Mr. Urbanski was also utilized to support the characterization of air emissions. Mr. Urbanski was part of a team in 2004 that evaluated the results of source sampling programs for 20 pulp and paper mills across Canada (G. Crooks, R. Murray, R. Urbanski, and T. Whitford, 2004).

Mathematical models were utilized to independently simulate the downwind concentrations of pollutants in order to assess potential effects. These models provide a quantifiable means to predict the change in air quality associated with the mill operations. Literature was also utilized to support the interpretation of air quality effects from the perspective of human health and aesthetics.

C2.0 AIR EMISSION INVENTORY

The mills have incorporated various process technologies to collect and treat the gaseous and particulate emissions that may be generated through the mill operations. These technologies are described in Annex A of the CIS report. The following section provides a summary of the expected air emissions during differing operating conditions, including start-up, normal operations and up-set conditions.

C2.1 Air Emission Sources

The main sources of air emissions for each mill can be categorized as point-source emissions, fugitive emissions, and transportation-related emissions.

Point source emissions include those air emissions that are released through stacks. These include emissions associated with the recovery boilers, lime kilns, chlorine dioxide generation mill, and, in the case of ENCE, a biomass boiler. As presented in Table C2.1-1, these emissions are released through a single stack at each mill. The main stacks for Botnia and ENCE are 120 and 110 m high, respectively. The mills have incorporated process technologies that provide for comprehensive collection and incineration of odorous gas streams. These technologies exceed the IPPC-BAT standards, as concluded through the comprehensive review presented in Annex A.

Table C2.1-1: Stack Characteristics for Identified Point Source Emissions

Source	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temperature (^oC)	Exhaust Volume, Dry (Nm^3/s)	Exhaust Volume, Wet (m^3/s)
Botnia Mill						
Recovery Boiler	120	4.6	22	160	179	340
Lime Kiln	120	2.5	14	220	25	68
ClO_2 plant	20	0.3	8	20		0.6
ENCE Mill						
Biomass Boiler	110	2.0	22	164		69
Recovery Boiler	110	3.6	20	170		204
Lime Kiln	110	2.5	5	80		25
ClO_2 plant	20	0.3	8	20		0.6

Fugitive emissions are primarily associated with odourous vapour releases from the wastewater treatment systems, and dust from the wood chip storage and handling areas. Traditionally this may have included occasional venting of non-condensable gases from the mill but this is not the case for the Botnia and ENCE mills since the collection system will route all vented gases to the main stack. Fugitive emissions are distinct from point source emissions since they are distributed over a larger spatial area and are generally released near or at ground level.

Transportation-related emissions are primarily dusts generated by, or emitted from, trucks delivering wood chips to the mills, trucks, trains or barges delivering some process chemicals to the mills; and the shipment of finished bleached pulp product during loading of the material directly onto ocean-going vessels at the mills or by barging it to a deep water port downstream from the mills.

C2.2 Air Quality Parameters

The atmospheric emissions from the various sources include the following:

- compounds from combustion sources (i.e., biomass boiler, recovery boiler and lime kiln) such as nitrogen oxides (NOx), sulphur dioxide (SO_2), and particulate matter (PM, PM_{10}[1] and $PM_{2.5}$[2]);
- reduced sulphur compounds including hydrogen sulphide (H_2S), methyl mercaptan (CH_4S), dimethyl sulphide (DMS), and dimethyl disulphide (DMDS) from the combustion of the non-condensable gases (NCG) in the boilers and kilns, as well as fugitive emissions from the waste water treatment systems and general mill process area;
- volatile organic compounds (VOC) primarily consisting of compounds such as methanol, methyl ethyl ketone, methyl isobutyl ketone, acetaldehyde, as well as smaller quantities of other compounds from both combustion sources and fugitive emissions from the WWTP and the mill process stream;
- trace quantities of organic (e.g., dioxins and furans) compounds from combustion sources;
- particulate matter (PM) from wood chip storage and handling (primarily wood or bark with some soil-based particulates); and
- chlorine and chlorine dioxide emissions from the chlorine dioxide generation plant and the pulp bleaching operations.

C2.3 Estimated Air Emissions

The rates of pollutant emission from each of the three main sources (i.e., point, fugitive and transportation) are quantified in the following sections.

[1] PM_{10} –particulate matter having a mean diameter less than or equal to 10 microns;
[2] $PM_{2.5}$ – particulate matter having a mean diameter less than or equal to 2.5 microns.

C2.3.1 Point Source Emissions

The point source emissions at the two mills include all stack emissions from the recovery boilers, lime kilns, chlorine dioxide generating plants, and, in the case of ENCE, a biomass boiler. They also include venting of the NCG system during upset conditions. The estimated emission rates for these various point source emissions are summarized in Tables C2.3-1 and C2.3-2 for normal operating conditions, and in Tables C2.3-3 and C2.3-4 for upset conditions, and discussed in the sections below. The basis for these load estimates is described in greater detail in Annex A, Process Technologies.

Table C2.3-1: Estimated Emission Rates during Normal Operations for Identified Point Sources, Biomass and Recovery Boilers and Lime Kilns

Parameter	units	Botnia[a]			ENCE[b]		
		Recovery Boiler	Lime Kiln	NGS incinerator	Biomass Boiler	Recovery Boiler	Lime Kiln
SO_2 (as S)	kg/Adt	0.20	0.07	0.03	0.06	0.06	0.11
NO_x (as NO_2)	kg/Adt	0.80	0.45	0.10	0.26	0.43	0.60
TSP	kg/Adt	0.24	0.04	0.02	0.08	0.12	0.14
PM_{10}	kg/Adt	0.22	0.04	0.02	0.08	0.11	0.13
$PM_{2.5}$	kg/Adt	0.16	0.03	0.01	0.06	0.08	0.09
TRS (as H_2S)	kg/Adt	0.033	0.014	0.003	-	0.009	0.021
VOC	kg/Adt	0.08	0.02	-	0.23	0.08	0.02

[a] Based on annual average emission rates, Annex A, Table A4-3; source distribution from Botnia (2006);
[b] Based on annual average emission rates, Annex A, Table A4-3; source distribution from AF-Process (2006);
Botnia Mill – based on production capacity of 1,000,000 ADt/a and 350 days per year of operation;
ENCE Mill – based on production capacity of 500,000 ADt/a and 350 days per year of operation.

Table C2.3-2: Estimated Emission Rates for Identified Point Sources, Chlorine Dioxide Generating Plants

Parameter	Emissions
Design Maximum (Dry Air Basis):	
ClO_2	116.0 mg/Nm^3
Cl_2	1.0 mg/Nm^3
Typical Emission Rate (Dry Air Basis):	
ClO_2	32.8 mg/Nm^3
Cl_2	0.3 mg/Nm^3
Actual Emission Rate:	
ClO_2	0.07 kg/h
Cl_2	0.0006 kg/h

Note: Estimated emission rates provided by Botnia; as a conservative measure, the same values are used for both mills, although the emissions for ENCE are expected to be approximately 50% since they should be proportional to production.

Table C2.3-3: Estimated Emission Rates during Upset Conditions for Identified Point Sources, Biomass and Recovery Boilers and Lime Kilns

Parameter	units	Botnia[a]		ENCE[b]		
		Recovery Boiler	Lime Kiln	Biomass Boiler	Recovery Boiler	Lime Kiln
SO_2 (as S)	kg/Adt	1.67	0.58	0.37	0.38	0.66
NO_x (as NO_2)	kg/Adt	0.95	0.53	0.40	0.66	0.92
TSP	kg/Adt	0.64	0.11	0.22	0.31	0.37
PM_{10}	kg/Adt	0.59	0.10	0.20	0.29	0.34
$PM_{2.5}$	kg/Adt	0.43	0.07	0.15	0.21	0.25
TRS (as H_2S)	kg/Adt	0.32	0.08	-	0.06	0.14
VOC	kg/Adt	-	-	-	-	-

[a] Based on daily maximum emission rates, Annex A, Table A4-3; source distribution from Botnia (2006);
[b] Based on daily maximum emission rates, Annex A, Table A4-3; source distribution from AF-Process (2006);
Botnia Mill – based on production capacity of 1,000,000 ADt/a and 350 days per year of operation;
ENCE Mill – based on production capacity of 500,000 ADt/a and 350 days per year of operation.

Table C2.3-4: NCG System Venting Estimated Emission Rates during Process Upset Conditions

	Concentrated NCG System venting rate as TRS	Dilute NCG System venting rate as TRS
Botnia-Orion	500 kg/hr for the first 15-minutes then 250 kg/hr	75 kg/hr as TRS at 16.1 normal m^3/s 50°C
ENCE-CMB	260 Kg/hr for the first 15-minutes then 130 kg/hr	40 kg/hr as TRS at 6.6 normal m^3/s at 50°C

C2.3.1.1 Normal Operating Conditions

The estimated emission rates for identified point sources are summarized in Tables C2.3-1 and C2.3-2. Table C2.3-1 presents emission rates for the recovery boilers, lime kilns, and, in the case of ENCE, biomass boiler. The values are based on the expected annual average emission characteristics for each mill.

Nitric oxides (NO), in the exhaust from pulp mill recovery boilers, are typically 20-30 times higher than quantities of NO_2 (Springer 2000). For this reason, it is assumed that 95% of the NO_x emissions from the recovery boilers will be emitted as NO, and will be converted to NO_2 during the downwind transport of the plume in the atmosphere. As a conservative approach, all NO_x emissions are modelled as if they were immediately converted to NO_2 and compared to the NO_2 standards.

The emission rates for particulate matter (PM) from the point sources are estimated from the TSP emission rates. PM_{10} emission rates for the boilers are assumed to be 92% of the TSP emission rates based on information supplied by ENCE and corroborated by literature (US EPA, 1995). For the lime kilns equipped with electrostatic precipitators, PM_{10} are assumed to represent 88.5% of the TSP emission rate (US EPA, 1995). $PM_{2.5}$ emission rates for the boilers are assumed to represent 67% of the TSP emission rates (US EPA, 1995), while those for the lime kilns are estimated at 83% of the TSP emission rates (US EPA, 1995).

The TRS emission rates provided by Botnia and ENCE are expressed as H_2S equivalents. The TRS emissions are partitioned into their component compounds (i.e., H_2S, CH_4S, DMS, and DMDS) based on measured emission data from other mills. The distribution of each TRS compound used is listed in Table C2.3-5.

Table C2.3-5: Estimated TRS Fractions in Recovery Boilers and Lime Kilns

Parameter	Percent of TRS Emissions	
	Recovery Boiler	Lime Kiln
Hydrogen sulphide (H_2S)	34%	97%
Methyl Mercaptan (CH_4S)	40%	1%
Dimethyl Sulphide (DMS)	16%	1%
Dimethyl Disulphide (DMDS)	10%	1%

Emissions of chlorine (Cl_2) and chlorine dioxide (ClO_2) from the chlorine dioxide generation plant at the Botnia Mill as provided by Botnia are summarized in Table C2.3-2. As a conservative assumption, it is assumed that the emission rates for ENCE are the same as for Botnia, although they are expected to be approximately 50% of Botnia's emissions based on the lower production rates. The higher values were selected as a conservative measure since details of the design are still being developed.

While internationally there is no general standard or guideline for total VOC emissions or VOC ambient concentrations, they are important in the formation of ambient ozone downwind of sources. Ozone is formed by the mixing of VOCs and NO_x in the presence of sunlight and usually peaks 20 to 40 kilometres downwind of the location that the precursors (VOC and NO_x) are released. In the USA, any sources that emit more than 100 tons/year of VOC are required to undertake an analysis of ozone formation within the downwind airshed. As shown in Table C2.1-1, the VOC emissions from the Botnia and ENCE mills are estimated to be 0.1 and 0.33 kg/ADt, respectively. This translates into 100 and 165 tons/year of VOC emissions. These mills are located in an area that is predominantly rural with few other sources of VOC emissions. Ozone formation is generally not a concern in these rural areas, and the VOC emissions from these mills are not expected to change this situation. As such, an analysis of ozone formation has not been completed for the two mills since the mills will have a minimal impact on downwind ozone formation.

The mills do not have paper machines and there are no organic compounds used in the pulp dryers, so no significant VOC emissions are expected.

C2.3.1.2 Upset Conditions

The estimated emission rates for upset conditions are summarized in Table C2.3-3 for the recovery boilers, lime kilns and, in the case of ENCE, biomass boiler. These values are based on the expected daily maximum emission characteristics for each mill.

The estimated emission rates for upset of the NCG system are summarized in Table C2.3-4. As previously discussed, the non-condensable gases are collected and incinerated prior to release through the main stacks. This system is expected to be more reliable than those in other mills because the back-up systems are more extensive than found elsewhere. However, it is possible, although extremely unlikely, that an upset may occur. In such an event, the systems are designed so that the NCG gases are vented through the main stack, which provides a high degree of dispersion and limited potential effect on ground level concentrations. This condition is described in further detail in Annex A.

During the first year of operation, it is possible that the concentrated NCG (CNCG) system may vent more frequently until all systems are fully operational. For modeling purposes, it is assumed that there may be two 4-hour events, four 15-minute events and ten 15-second events. In subsequent years there may be two 30-minute events, four 15-minute events and ten 15-second events. During an upset event the emission rates of the CNCG system are estimated to be as follows:

- for Botnia, the emission rate is estimated to be 140 g/s as TRS for the first 15-minutes of the event and 70 g/s thereafter; and
- for ENCE, the emission rate is estimated to be 70 g/s as TRS for the first 15-minutes of the event and 35 g/s thereafter.

Similarly, the dilute NCG (DNCG) system may vent more frequently during the first year of operation. The assumed frequencies are: two 8-hour events; eight 15-minute events; and ten 30-second events. In subsequent years there may be one 4-hour events, eight 15-minute events, and ten 30-second events. During an upset event the emission rates of the DNCG system are estimated to be as follows:

- for Botnia, the emission rate is estimated to be 20 g/s TRS at 16.1 Nm^3/s and 50^oC; and
- for ENCE, the emission rate is estimated to be 10 g/s TRS at 6.6 Nm^3/s and 50^oC.

The reduction in strong gas vent rate after 15-minutes is consistent with mitigation through stopping operation of the super concentrators and condensate stripper, which will reduce concentrated NCG flow by about half.

Both dilute and concentrated NCG will vent through the main stack. Half of the dilute events may coincide with concentrated events (i.e. recovery boiler driven events) and the other can be considered independent. The chances of both mills having simultaneous upset conditions are extremely remote and therefore mill upset conditions are considered independently. The worst case events are estimated to be as follows:

- for Botnia, the worst event occurs in the first year during the first hour of a coincident weak and strong gas venting, resulting in an estimated emission rate of 108 g/s as TRS; and

- for ENCE, the worst event occurs in the first year during the first hour of a coincident weak and strong gas venting, resulting in an estimated emission rate of 49 g/s as TRS.

C2.3.2 Fugitive Emissions

Fugitive emissions include the open water areas of the wastewater treatment system, the wood chip storage piles and handling areas.

There are limited data available regarding VOC emissions from wood chip storage piles (MERAF, 2002). In general, the VOC emissions from the wood chip storage piles should be comparable to that of the forested areas neighboring each mill due to the nature of the materials involved. Hardwood chip piles appear to emit about 10% of the level of softwood chips, due to lower turpentine and volatile content, and our initial estimates would indicate the likely range of VOC emission from the chip piles may represent between 5 and 30% of the total mill VOC emission. However, these limited loadings would only apply to Botnia since ENCE will store the wood chips in silos thereby the potential VOC emissions are significantly less. The oxygen blow tank and peroxide stage bleaching vents are also minor contributors to VOC. The CIS project team concluded that from the limited data that fugitive VOC emissions are not significant compared to point sources of VOCs emitted from the recovery and biomass boilers. Therefore, fugitive VOC emissions have not been considered in the dispersion modelling assessment.

The open water areas of the wastewater treatment system are a potential source of TRS emissions at both mills. The emission rates for this fugitive source are estimated based on consideration of available data and literature for operating mills, estimated emission rates for a proposed eucalyptus mill in Tasmania (RPDC, 2004), and professional judgment. As presented and further described in Annex A, Subsection A8.7.5, the estimated fugitive emissions of TRS from the wastewater treatment systems are estimated as follows:

- for Botnia the TRS emission rate is estimated to be 0.00174 kg/ADt during normal operating conditions and 0.00246 kg/ADt during upset conditions; and
- for ENCE the TRS emission rate is estimated to be 0.0007 kg/ADt during normal operating conditions and 0.00342 kg/ADt during upset conditions.

C2.3.3 Transportation Emissions

The transportation of wood chips to the mill site by truck represents a potential source of emissions within the Fray Bentos area. Other transportation related emissions, such as barge transport, may also contribute to the emissions, although these emissions are expected to be significantly less as compared to truck transport due to the number and frequency of trucks traveling to and from each site.

The traffic assessment identified that the road between the two mills will potentially have the highest traffic due to the number of trucks traveling between the mills and plantations. Based on the production numbers, it is estimated that 511 trucks per day travel to the Botnia mill and 274 trucks per day travel to the ENCE mill. This translates into a worst case of 33 trucks per hour.

The estimated emission factors for diesel trucks traveling at 50 km/h are: 0.05, 8.1 and 0.19 grams per vehicle kilometre traveled (g/VKT) for PM, NO_2 and SO_2, respectively. These data are from the MOBILE 6 emissions model used by the USEPA. This model was created using manufacturer's data on actual vehicles following normal driving cycles. Assumptions for dust emissions from trucks travelling on paved roads included a silt loading of 0.6 g/m^2 (US EPA; 1995) and an average vehicle weight of 20 tonnes.

C2.4 Emissions of Dioxin and Furan

The emission rates for dioxin and furan from the Botnia and ENCE mills are based on the estimated emission rates for the proposed eucalyptus pulp mill in Tasmania (RPDC, 2004). The emissions discharge limits for this mill expressed in standard units[3] are:

- 100 pg I-TEQ/NDm^3 for the recovery boiler; and
- 100 pg I-TEQ/NDm^3 for the lime kiln.

The CIS Annex A (Process and Technology) estimates atmospheric emissions of dioxins and furans from the proposed mills, based on an emission factor of 0.07 µg/ton of pulp (UNEP 2001) from the recovery and power (biomass boilers). The upper limit of potential dioxin and furan emissions are estimated to be 100 µg/day from the ENCE mill and 200 µg/day from the Botnia mill. Based on the reported stack flow rates for the ENCE and Botnia mills, these emissions meet the RPDC discharge limits listed above.

A review of the literature and emission data compiled for Environment Canada (Uloth and van Heek 2002) provided the following dioxin and furan emission rates (in picograms toxic equivalency per dry, standard cubic metre – pg TEQ/dscm) for kraft mill recovery boilers:

- range from 0.022 to 13.88 pg I-TEQ/NDm^3;
- average of 0.028 pg I-TEQ/NDm^3;
- median of 0.021 pg I-TEQ/NDm^3.

These values are 10 to 1000 times below the emission limits recommended by the RPDC (2004) for the proposed mill in Tasmania.

In order to put the emissions of total dioxin and furan of 300 µg/day outlined above into some perspective, a dilution factor was calculated based on the modelling results. This

[3] pg I-TEQ/NDm^3 – picograms International Toxicity Equivalent units per normal, dry cubic metre of exhaust at 3% O_2

dilution factor for Fray Bentos was 0.006 µg/m^3 per g/s emitted for the 24-hour average concentrations. This dilution factor converts the emission of 300 µg/day of dioxins and furans to 0.019 pg/m^3 in Fray Bentos. This value is 1000 times lower than the Ontario, Canada standard for dioxins and furans of 5 pg TEQ/m^3. It can also be compared against the 500 ambient concentrations of dioxins and furans measured at 34 different monitoring sites across Canada over the period 1989 to 1997. The range of measured background dioxin and furan concentration was 0.01 to 0.33 pg/m^3. The estimated impact in Fray Bentos was near the lower end of the background measurements. While the levels at Fray Bentos are the highest predicted for a populated location, even the maximum predicted location is still 1000 times lower than the standard noted above.

C3.0 METHODOLOGY

The potential effects of the mill operations on ambient air quality are estimated through the air quality assessment. Specifically, this assessment identifies the specific sources of air emissions originating from the two mills; estimates the emission rates of various air quality parameters from each of the identified sources; and predicts the change in ground level air quality at each of the identified receptor locations. The potential for health and aesthetic effects are determined based on the results of this assessment.

The method of assessment utilizes mathematical models to quantify the potential change in air quality. These models are widely used to support the assessment of air quality effects since they can reliably calculate the change in air quality as a result of air emissions based on fundamental laws of physics, chemistry and mass conservation. They provide the only viable means to estimate change under a wide range of meteorological conditions especially when the industry being evaluated has not yet been built.

Two types of models are utilized for this assessment. Meteorological models are used to augment the available meteorological data thereby providing a complete representation of the three-dimensional wind field within the general area of the mill sites. Air dispersion models are used to predict atmospheric dispersion and the change in ground level ambient air quality attributed to the air emissions from the mill operations. Each of these models has been used widely by a variety of international experts for a number of years, in projects comparable to the Fray Bentos pulp mills. They are described in the sections below.

C3.1 Meteorological Models

Meteorological data are available for various time periods at three different locations within the general area of the mills - the airport at Gualeguaychú, Argentina, for the period 2000 to 2004, although it is limited to eight-compass directions; the ENCE and Botnia mill sites for the period March 2004 to February 2006 and December 2005 to June 2006, respectively. The wind roses for the three sites are compared in Figure C3.1-1. As illustrated, the on-site wind roses show similar wind flows between the ENCE site and the Gualeguaychú Airport in Argentina but the data from the Botnia site shows a shift in prevailing wind direction of approximately 45 degrees.

Mathematical models were used to independently check and augment this meteorological data. The specific model used was CALMET coupled with a non-hydrostatic meso-scale weather forecast model referred to as FReSH (Radonjic, *et al.*, 2005). The modeling approach involved three main steps. First, weather predictions were obtained at six-hour increments from the United States National Center for Environmental Prediction (NCEP) over a coarse grid that extended over the Southern portion of South America. Second, FReSH utilized the NCEP data to generate a three-dimensional wind field at hourly intervals over a 3.3 km square grid within the general region of the proposed mill facilities. Third, the CALMET model was used to refine the predicted wind field to a 200 m square grid within a 60 by 40 km area centered on the two mill sites.

The CALMET model utilized available topographic data for Uruguay and Argentina, as illustrated in Figure C3.1-2. The terrain data was processed through the TERREL CALMET pre-processor and was based on satellite data having approximately a 90 m resolution. Land use was included in the CALMET model. The representative land classifications included urban areas, range lands and open water.

The predicted and measured wind roses are compared in Figure C3.1-1. The figure shows that the wind speeds match almost perfectly but that the wind directions are slightly skewed for the Botnia site. This skewing could be attributed to the different time periods being compared (i.e., predicted based on January to June 2004 as compared to measured based on January to June 2006). Based on this comparison, it is concluded that the predicted wind field provides a suitable representation of the winds near the two mill sites.

Figure C3.1-3 provides a comparison of the predicted wind rose for the ENCE and Botnia sites. As shown predicted results are almost identical for the two sites and therefore the predicted results for the ENCE mill site was selected for use in the dispersion analysis. The analysis was based on a one-year period for 2004. This wind-year was selected based on availability of local meteorological data and data for the CALMET model.

C3.2 Air Dispersion Models

Two air dispersion models were considered for this assessment – the Industrial Source Complex Short Term version 3 (ISCST3) model and the CALPUFF model. These models are widely used and accepted, and, in the case of CALPUFF, considered state-of-the-science. Both models are approved by the United States Environmental Protection Agency (USEPA) and are available within the public domain. A key factor is that both models have full disclosure of equations and are extensively tested.

The ISCST3 model is the straight-line, steady-state Gaussian plume equation, whereas CALPUFF is an advanced non-steady-state air dispersion model. Both models provide options to simulate the dispersion of emissions from a wide range of typical industrial sources. While the basis of the models is different, both account for the effects of aerodynamic downwash due to the stack itself and nearby buildings, and both can simulate emissions from isolated vents, multiple vents, storage piles, and other common source emissions.

The models utilized the hourly meteorological data generated using the meteorological models described in Section C3.1, and the terrain elevation data presented in Section C3.1-2. The terrain data was obtained from the United States Geological Survey Digital Elevation Model (http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html).

The models were implemented over a 200 m square grid within the region extending out to 5 km from the mills, and a 1 km square grid for the region beyond. In addition, a number of specific receptors were identified. These include: the cities of Fray Bentos, Mercedes and Nuevo Berlin in Uruguay, and Gualeguaychú in Argentina; the beach areas of Playa Ubici and Las Cañas in Uruguay, and Ñandubaysal in Argentina; and waterfront area of Rio

Uruguay; and the International Bridge on both the Uruguayan and Argentina sides. These receptors are described in further detail in Section C5.0.

All known point and fugitive source emissions were included in the models. Air emissions associated with traffic were also included for a stretch of road where it is probable that both trucks from the Botnia and ENCE mill would travel at the same time.

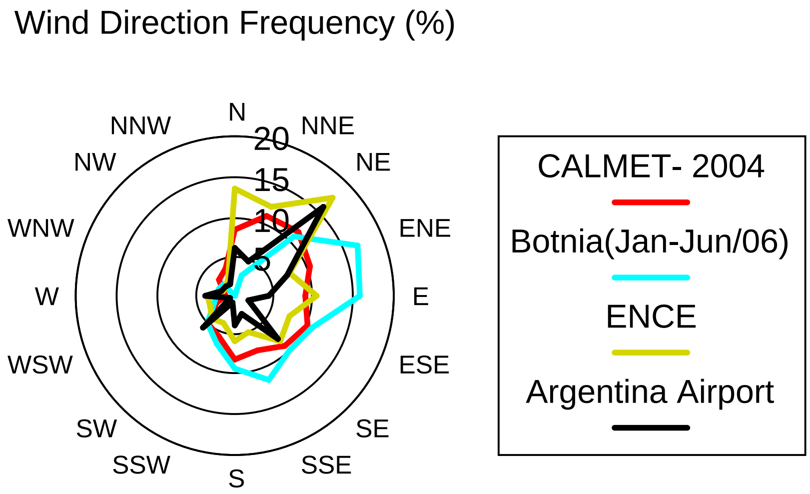
A series of model simulations were completed using both models to test sensitivity. These results are presented in Figure 3.2-1. The figure presents a comparison of the predicted ground level concentration of SO_2, NO_x and TSP at each of the identified receptors using each of the two models. The receptors are listed based on the proximity to the mills (with the distance to the Botnia mill being used for reference). The results clearly show that CALPUFF provides a higher estimate of ground level air concentration at receptors nearest to the mills, whereas ISCST3 provides a higher estimate at receptors located further away.

For the near-field receptors (within 5 km), CALPUFF tends to predict a higher concentration than ISCST3 since it is a non-steady state model, and therefore is capable of predicting air dispersion during calm conditions (i.e., no wind) whereas ISCST3 cannot. This results in a higher predicted concentration of the respective air quality parameters at the nearfield receptors when using CALPUFF as compared to ISCST3. As shown in Figure 3.1-3, calm conditions occur approximately 2% of the time.

For the far-field receptors (beyond 5 km), CALPUFF tends to predict a lower concentration than ISCST3 since it estimates higher dispersion within this complex river environment.

Prior model investigations of the two mills utilized the ISCST3 model (Algoritmos, 2006; Malcolm Pirnie, 2005), and as per the original terms of reference, this model is also used in the present investigation. The results from the ISCST3 model are presented in Section C5.0 and are used to support the assessment of potential air quality impacts for the two mills. However, in recognition of concerns raised by various stakeholders, the CALPUFF model has also been utilized to account for potential uncertainty in the model predictions. This uncertainty is described in Section C5.0 in the interpretation of the model results.

Figure C3.1-1: Wind Rose for Available Meteorological Data and Model Prediction



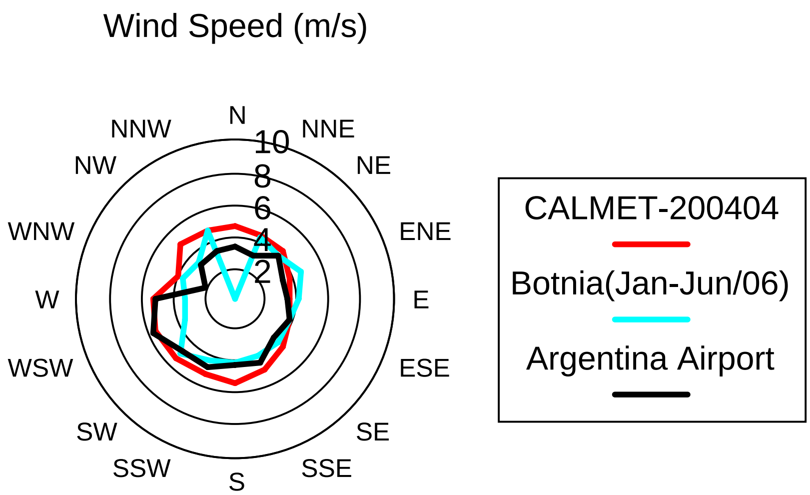


Figure C3.1-2: Topography Used Over Modelling Domain

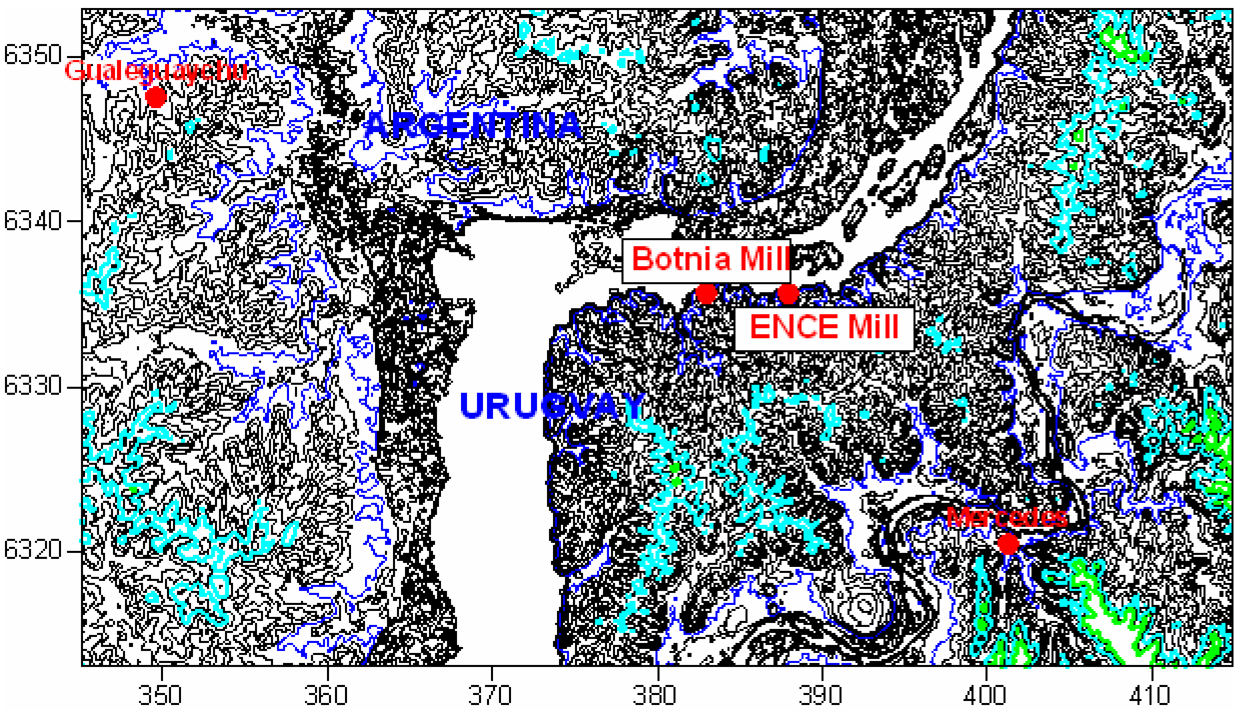
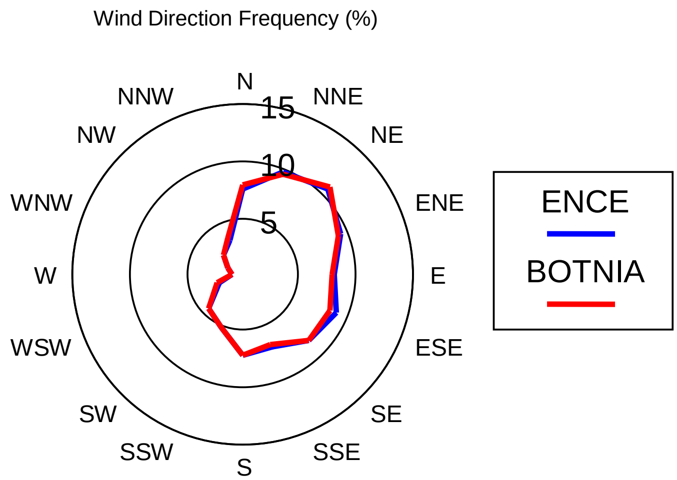
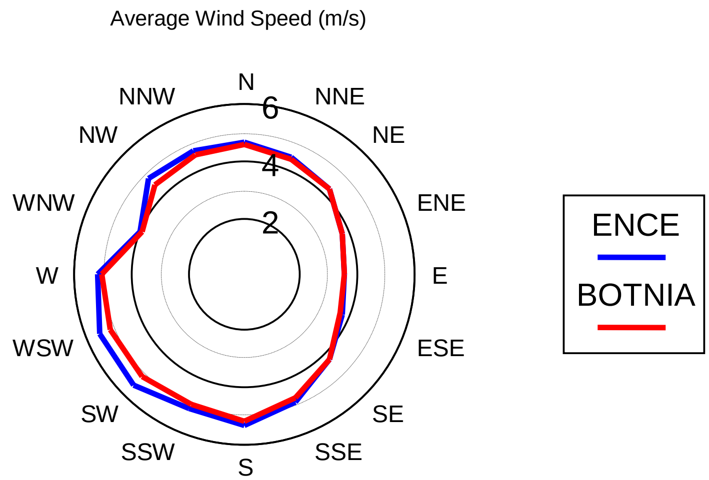


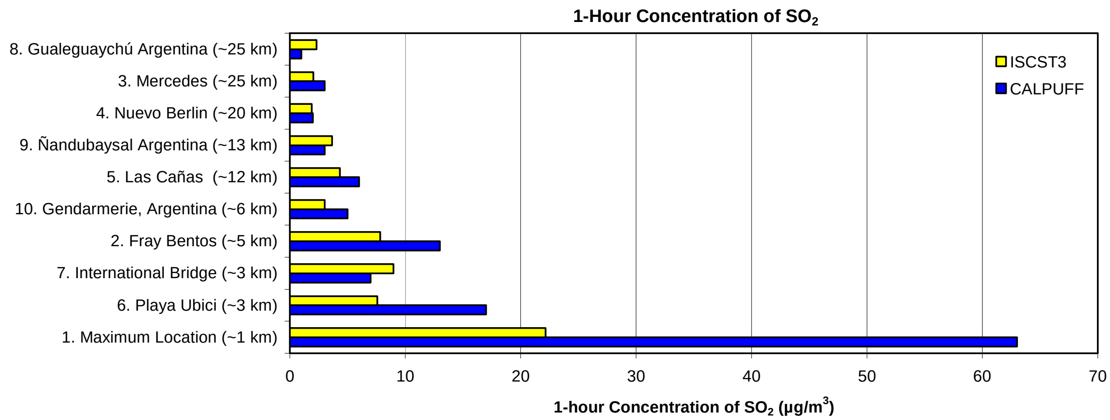
Figure C3.1-3: Comparison of Predicted Wind Rose for the ENCE and Botnia Mills

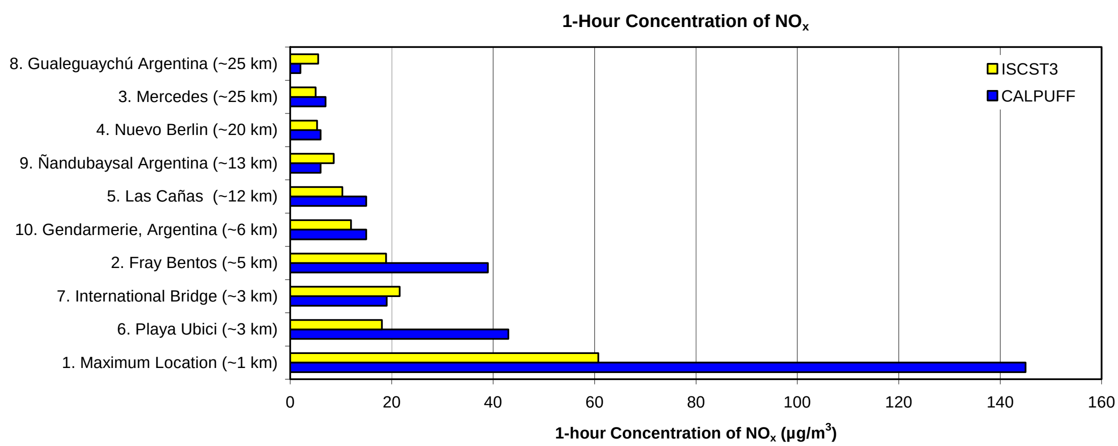


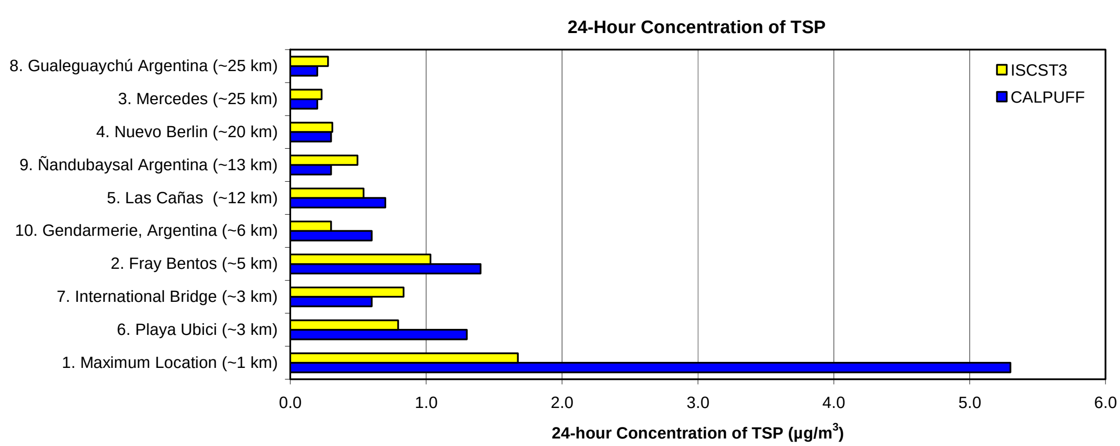


Percentage of Calms
CMB: 1.76%
ORM: 2.06%

Figure C3.2-1: Comparison of ISCST3 and CALPUFF Model Predictions







C4.0 AMBIENT AIR QUALITY CRITERIA

The air quality assessment is based on a comparison of the predicted change in air quality associated with mill operations to appropriate air quality criteria. Criteria are established by various international regulatory authorities and agencies, as wells as by DINAMA. The criteria used in the assessment are presented in the following sections for combustion products, total reduced sulphur compounds, volatile organic compounds, chlorine compounds, and odour thresholds.

When examining the impact of air pollutants on the environment, the length of time that a pollutant persists near a receptor is an important factor in determining its impact. Typically modelling simulates on an hour-by-hour basis and the results are combined into longer term averages like daily (worst 24-hour average) and yearly (8760-hour average). The shorter the averaging period, the wider the range of average values, and the higher the worst of those values will be. Under neutral atmospheric conditions, a daily average will be about half of an hourly average and a yearly average will be about 2% of the hourly average. As time gets shorter, say to a 10-minute average, the value will become about 1.5 times the hourly average.

C4.1 Criteria for Combustion Products

Ambient air quality criteria for SO_2, NO_2 and particulate matter (PM, PM_{10} and $PM_{2.5}$) are presented in Table C4.1-1. These standards are based on short term exposures (10-minutes, 1-hour and 24-hours) and long term exposure (annual). The criteria are based on California (recognized stringent standards), Ontario (well documented standards and the World Health Organization (WHO, 2005).

C4.2 Total Reduced Sulphur Compounds

Ambient air quality criteria for TRS are presented in Table C4.2-1. Three criteria are presented, including those established by DINAMA, the World Health Organization, and a summary of other regulatory jurisdictions. These other jurisdictions include: Canada (Provinces of Alberta, British Columbia, Manitoba and Ontario); the United States (California, Connecticut, Idaho, Illinois, Minnesota, Nebraska, New Mexico, New York, North Dakota, Pennsylvania, Texas, Washington, Bay Area of California, and New York City); Australia (New South Wales); Finland; Japan; and Korea.

As a further source of comparison, the ambient air quality limit of TRS for the proposed eucalyptus mill in Tasmania (RPDC, 2004) is 1.5 µg/NDm^3 based on a 3-minute moving average. The Resource Planning and Development Commission (RPDC) considers this to be an achievable level of air quality for a kraft pulp mill having a reasonable buffer zone and appropriate stack height for its emissions.

The lower end of the range of TRS criteria in the table is aimed at odour prevention rather than for health protection. The criteria set by DINAMA fall within the range of criteria adopted by other jurisdictions.

Table C4.1-1: Summary of Health-Based Ambient Air Quality Standards

Air Contaminant	Averaging Period	California Standards[a] ($\mu g/m^3$)	Ontario Standards[b] ($\mu g/m^3$)	WHO Guidelines[c] ($\mu g/m^3$)
SO_2	10 minute			500
	1-hour	655	690	
	24-hour	105	275	125
	Annual			50
NO_2	1-hour	470	400	200
	24-hour		200	
	Annual			40
PM (TSP)	24-hour		120	
PM_{10}	24-hour	50	50	50
$PM_{2.5}$	24-hour			25

[a] California Air Quality Standards (www.arb.ca.gov)
[b] Ontario Regulation 419/05 Standards (www.ene.gov.on.ca)
[c] WHO, Air Quality Guidelines for Europe, 2nd Edition (2000)

Table C4.2-1: Ambient Air Quality Criteria for Total Reduced Sulphur Compounds

Agency	Averaging Period	Ambient Air Quality Criteria ($\mu g/m^3$)				
		TRS (as H_2S)	H_2S	CH_4S	DMS	DMDS
Uruguay (DINAMA)	1-hour	15				
	24-hours	10				
WHO	30 minutes (odour)	7				
	24-hours (health)	150				
Other Jurisdictions	<3 minutes		1.4 - 85	1		
	30 minutes	40-141	14 - 170	20	30	40
	1-hour	7-40	1 - 141	20	30	40
	24-hours	3-10	6 – 14			

C4.3 Volatile Organic Compounds

There are no commonly accepted and used ambient air quality criteria, guidelines or standards for total VOCs. A review of individual VOC limits for several jurisdictions (WHO;

Ontario, Canada; Alberta, Canada and Texas, United States) are summarized in Table C4.3-1.

Table C4.3-1: Guidelines and Standards for Individual VOC Compounds

VOC	Guidelines/Standards (µg/m^3)		
	1 hour	24 hour	Annual
Acetaldehyde	90[a]	500[b] 2,000[c]	50[b]
Acetone	5,900[a]	11,880[b]	590[d]
Formaldehyde	65[a]	65[b]	1.5[d]
Methanol	2,600[a]	4,000[b]	262[d]
Phenol	100[a]	30[b]	15[d]

[a] Alberta, Canada;
[b] Ontario, Canada;
[c] World Health Organization.
[d] Texas, United States

C4.4 Chlorine Compounds

The World Health Organization has not established ambient air quality criteria or guidelines for Cl_2 or ClO_2. Texas, United States has a 24-hour standard of 15 µg/m^3 for Cl_2 and 3 µg/m^3 for ClO_2. Ontario, Canada, has a 24-hour standard of 10 µg/m^3 for Cl_2 and 30 µg/m^3 for ClO_2. Alberta, Canada, has a 1-hour standard of 15 µg/m^3 for Cl_2 and 28 µg/m^3 for ClO_2.

C4.5 Odour Effect Level

The odour effect level is calculated from air quality and corresponding odour detection thresholds. Odour detection thresholds from various literature sources are presented in Table C4.5-1. The table also presents the value selected for use in the assessment of potential odour effects. The odour detection threshold is defined as the lowest concentration of a substance in air that can be detected by humans. Odour thresholds are highly variable because of the differing ability of individuals to detect odours and because of differing environmental conditions that may alter the perception (US EPA, 2002).

Odour effects caused by combining several odourous gases can be synergistic, additive or antagonistic. The combined odour impact for the four compounds was estimated as the additive effect of the ratio of each compound to its odour detection threshold concentration. The resulting odour effect level is calculated in the following manner:

$$C_{odour} = \frac{C_{H_2S}}{ODT_{H_2S}} + \frac{C_{CH_4S}}{ODT_{CH_4S}} + \frac{C_{DMS}}{ODT_{DMS}} + \frac{C_{DMDS}}{ODT_{DMDS}}$$

Where C_{odour} is the combined odour effect level, C is the predicted 10-minute average concentration for each compound; and ODT is the odour detection threshold of each compound. The 10-minute average concentration is calculated from the 1-hour concentration predicted using the dispersion model as follows:

$$C = C_o \cdot \left(\frac{t_o}{t} \right)^{0.2}$$

Where C_o is the predicted concentration for the averaging period of the dispersion model, t_o is the averaging period of the dispersion model, and t is the averaging time of interest.

The assessment of odour impacts is based on the general understanding that odours are recognizable at an odour effect level of 3 (i.e., 3 times the odour detection threshold), that some complaints may occur at an odour effect level of 5 (i.e., 5 times the odour threshold), and that generally objectionable odours occur at an odour effect level of 10 (i.e., 10 times the odour threshold).

Table C4.5-1: Odour Detection Thresholds (µg/m^3)

Hydrogen Sulphide (H_2S)			Methyl Mercaptan (CH_4S)			Dimethyl Sulphide (DMS)			Dimethyl Disulphide (DMDS)			Source
Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	
0.7		14	1		16	3		52	23		352	Georgia-Pacific Corp. (2005)
0.7			2			3						Iowa State University (2004)
0.7		283										Harvard University (2005)
0.66			2			3						Lenntech (2006)
	6			2			51			66		Nagy (1991)
1.4	6	184	0.0004	1	82							AIHA (1989)
0.7		14	0.04		82	3		5	0.01		347	Ruth (1986)
0.7			2			6						3M Corp. (2005)
	0.7			2			3			23		Selected value for assessment of odour effects

The rationale for assuming an additive effect of the various TRS compounds is based on published studies (Vanderstaeten *et al.*, 1988) that have indicated that the perceived intensity of admixtures of sulphur-bearing compounds were more strongly influenced by the presence of mercaptans and other polysulphides than by the presence of H_2S, carbon disulphide (CS_2) and other non-SO_2 compounds. On this basis, it is not sufficient to reduce all TRS compounds to H_2S equivalents in order to estimate odour impacts. Vanderstaeten *et al.* suggest that the effect of mixing varying concentrations of sulphates, mercaptans and polysulphides may be synergistic, although a basis for establishing this synergistic effect is not established.

C4.6 Literature Review of Epidemiological Studies near Pulp Mills

The following review focuses on self-reported health symptoms at or near pulp and paper mills. Note that the purpose of this review is not to study the human health effect of individual chemical compounds that may be emitted, but rather, to examine epidemiological reports relevant to pulp and paper mills that are available in literature. It should be noted that there is a bias in this type of literature toward studies that report some kind of positive effect, since negative studies are difficult to publish. Moreover, the studies relate to older mills that do not use the best available technology that will be used at the Botnia and ENCE mills. It is well known that the pulp industry has reduced discharges of virtually all atmospheric pollutants progressively and dramatically since 1970, when widespread environmental protection regulations emerged in the developed countries.

For example, Kraft mills in the 1970's discharged well over 10 times the quantities of malodorous gases that will be discharged from the Botnia and ENCE mills. Discharges of TRS from the main combustion source (i.e., the recovery boiler) were typically between 300 and 10,000 mg/Nm^3 during that time, in comparison to an annual average emission of less than 5 mg/Nm^3 for the Botnia and ENCE mills. Likewise, older mills would have discharged roughly 3 kg/ADt of sulphur, in comparison to a maximum potential release of 0.05 kg/ADt that may escape the incineration system at the Botnia and ENCE mills. These gases will be incinerated in the Botnia and ENCE mills, as discussed in Annex A.

Rosenberg *et al.* (1994) have indicated that dioxin-like compounds have been detected in the atmospheres of pulp mills; however, a study which involved the collection and analysis of blood from community residents, low exposure-potential workers and high exposure-potential workers found no differences between these groups (Tepper *et al.* 1997). In addition the measured levels of dioxins in blood serum were within the range measured in populations with no known exposure. Significant improvements in mill process have drastically reduced dioxin emissions in modern mills as compared to mills referenced here.

Other studies available in the literature related to health effects in residential communities have been carried out around the south-eastern portion of Finland, South Karelia, where a cluster of pulp mills are located in close proximity to various residential townships and cities. These studies are discussed below. The operations of the pulp mills are different to the Kraft process to be used at Fray Bentos, and may result in different concentrations in atmospheric emissions; however many of the epidemiological surveys relate to people who are continuously exposed to elevated levels of malodorous sulphur compounds which are also emitted from Kraft pulp mills.

One of the earliest studies was published by Jaakkola *et al.* (1990). In this study, adult residents (older than 16 years) from two communities in Imatra, Rautio (high exposure) and Karhukallio (moderate exposure) as well as residents from a reference community in Finland were provided with a self-administered questionnaire. The 24-hour H_2S concentrations were estimated at 15 ug/m^3 (moderate exposure) and 100 ug/m^3 (high exposure). The questionnaire asked participants about the occurrence of eye (excretion and irritation) and nasal (blocked nose) symptoms, cough, breathlessness or wheezing, and headache or migraine during the previous 4 weeks and 12 months. Other information such as the number of respiratory infections during the previous 12 months, history of atopic eczema, urticaria, allergic conjunctivitis, hay fever, wheezing without and with periods of cold, asthma, allergies to different environmental agents, and chronic respiratory and heart diseases were also requested. Last, residents from all three locations were asked to provide information about personal characteristics (e.g., age, gender, education, smoking habits, certain diseases, and allergic manifestations). The results of the survey indicate the occurrence of eye and nasal symptoms and cough were statistically greater in the residents of the two exposed communities than in the reference community. The eye symptoms could not be adjusted for confounding variables due to lack of data, making it difficult to evaluate the true significance of the effect.

Marttila *et al*. (1994) examined the health effects in children, as well as parents as a result of long term exposure to malodorous sulphur compounds in ambient air from pulp mills in South Karelia, Finland. The study population consisted of children and parents from the same three communities as the Jaakkola *et al.* (1990) study, which represents populations that were expected to be severely exposed, moderately exposed, and not exposed, respectively. The questionnaire, as described in the study conducted by Jaakkola *et al.* (1990) was adopted in this study. Atmospheric malodorous sulphur concentrations were estimated using air dispersion models. Jaakkola *et al.* (1990) summarized the results for adults (above). The results for children indicated that there was no significant difference in comparison to the reference community.

Marttila *et al.* (1995) examined the daily symptom intensity in relationship to exposure levels of malodorous sulphur compounds from pulp mills in South Karelia, Finland. The study was carried out in an industrial town of Lappeenranta, approximately 1.5 km southeast of the pulp mill. Atmospheric concentrations of TRS, SO_2, total suspended particulates (TSP), and NO_x were monitored continuously for 15 months. Resident surveys were carried out once during a low exposure period, which was used as a reference point. Subsequent surveys, totalling six, were carried out immediately after a day classified into three daily mean TRS concentrations in the ambient air; low (TRS less than 10 µg/m^3), medium (10 to 30 µg/m^3) and high (greater than 30 µg/m^3). Survey questions were similar to those previously described by Jaakkola *et al.* (1990); however, subjects were also questioned on the intensity of symptoms observed (i.e., none, mild, moderate and severe). The results of the survey indicated that the intensity of eye, respiratory symptoms, and headache was significantly higher during the days of medium and high exposure to malodorous sulphur compounds than days of low exposure. No differences were observed in the intensity of symptoms in persons not exposed to TRS, which served as a control. As discussed in Section C5.0, the daily concentrations of TRS from the Botnia and ENCE mills are predicted to be in the order of 2.5 µg/m^3 which corresponds to the lower end of the low classification discussed above, and therefore similar symptoms are not expected in the vicinity of the project.

Partti-Pellinen *et al.* (1996) examined the health effects in adult residents related to continuous low level exposure to malodorous sulphur compounds in ambient air downwind of a pulp mill in South Karelia, Finland. An epidemiological survey was conducted for residents of a small town located in central Finland with a population of approximately 35,000 people. The exposed population was drawn from the adult population that lived in a residential area approximately 1 km northwest of the kraft mill. A second community was selected to serve as a reference community for the study as there are no sources of total reduce sulphur (TRS) compounds in the town. Concentrations of both SO_2 and TRS were measured in the exposed community, while only SO_2 was measured in the reference community. Symptoms and survey questions similar to those described by Jaakkola *et al.* (1990) were used. The results of the survey indicated that residents in the exposed community reported significantly more cough and headache symptoms than subjects in the reference community (approximately 50% greater), despite exposure to relatively low levels of TRS and SO_2 in ambient air (annual mean concentration of 3 µg/m^3, and 1 µg/m^3, respectively). Other symptoms including acute respiratory infections as well as the prevalence of hay fever were also greater in the exposed area in comparison to the reference community. It should be noted that in Fray Bentos, the annual mean concentrations of TRS is predicted to be 0.2 µg/m^3, as discussed in Section C5.0, which is an order of magnitude lower than the concentrations reported in this study and therefore no effect is expected to arise from the project.

Similar results were noted by Jaakkola *et al.* (1999), who examined the changes in respiratory health in relation to a reduction in emission of malodorous sulphur compounds from pulp mills in South Karelia, Finland. In this study, the occurrence of symptoms in people who lived in two exposed communities (a high and a moderately impacted community) and one reference community. In the most polluted area, the annual mean concentrations of H_2S and CH_3SH were 8 $\mu g/m^3$ and 2 to 5 $\mu g/m^3$, respectively. The annual mean concentration of H_2S in Fray Bentos is predicted to be 0.02 µg/m^3 (Section C5.0) which is at least 100 times lower than the concentrations reported in this study. Furthermore, the highest daily mean concentrations were approximately ten times greater than the annual mean concentration measured. Similar to the study conducted by Jaakkola *et al.* (1990), a self-administered questionnaire was randomly sent to adults in the three communities before and after the reduction in sulphur emissions. The initial questionnaire asked residents the number of acute respiratory infection episodes during the previous 12 month and 4 month period. A 19-month later follow-up questionnaire was administered in which questions about respiratory infections, symptoms, and perceptions were repeated. These symptoms included irritation of or excretion from eyes, stuffy or runny nose, pharyngeal irritation, breathlessness or wheezing, and headache or migraine. The study authors reported a decrease in the incidence rate of acute respiratory infections for individuals in the two exposed communities, with a greater decrease in the more exposed community. However, the authors noted that there was only a modest decrease in symptoms prevalence and frequency. It should be noted that seasonal effects complicate the interpretation of this study. Symptoms actually increased in the study period after emission reduction, in the reference community, and to a lesser extent in the exposed communities. The authors attributed the increase to a before-after difference in season, and interpreted the lesser increase in the exposed communities as a decrease.

The results of the aforementioned studies indicate that self-reported health symptoms (headaches, respiratory irritations etc.) may occur at exposure levels below those reported by the WHO as thresholds for health effects. The WHO (2000) publishes a threshold concentration for the most sensitive health effect for exposure (namely eye irritation) to H_2S of 14 to 28 mg/m^3, this value is over 2000 times the odour threshold of 0.14 µg/m^3 to 1.4 µg/m^3 (WHO 2000). The concentrations reported in the above studies are similar to the half-hour concentration of 7 µg/m^3, which is considered to be an odour nuisance (WHO 2000) but not to result in adverse health effects. This difference was discussed in a letter by Shusterman (1992) which noted that studies in California reported odour annoyance and symptoms such as headache, nausea, and eye and throat irritation at levels well below those known to cause acute symptoms by any recognized toxicological mechanism. Shusterman (1992) suggested that the onset of these symptoms may be a result of a non-toxicological odour-related mechanism. As an alternative explanation, Marttila *et al.* (1995) suggests that a physiological mechanism, such as chemical irritation with possible psychological effects, could be responsible the reported responses.

These ideas are supported by Tatum (1995) who indicates that "*Although epidemiological studies have failed to provide any conclusive evidence for a relationship between reduced sulphur gas exposure and cancer or other disease, there are a number of reports linking such exposures to a variety of subjective annoyance-type physical symptoms such as headache, congestion and mucous membrane irritation. Because these symptoms have been reported at concentrations that are above the odor threshold for reduced sulphur compounds, but are well below the levels known to cause any measurable health effects, the suggestion has been made that these symptoms may be mediated through mechanisms related to the perception of odor rather than traditionally accepted toxicological mechanisms.*

Overall, the epidemiological studies are subject to confounding factors and are difficult to design, implement and interpret. They do not suggest a relationship between exposure to sulphur compounds from pulp and paper mills and the incidence of clinical public health effects. Some older studies have reported increased minor health symptoms in communities near mills, but the exposure concentrations in these studies have been well above those predicted for Fray Bentos. Therefore, it can be concluded that health effects are not expected within the communities neighboring the two mills.

C5.0 POTENTIAL EFFECTS ON AMBIENT AIR QUALITY

The potential effects of mill operations on the ambient air quality are reviewed in the following sections. The assessment focuses on sensitive receptors identified within Uruguay and Argentina, which includes population centres, recreational areas and other important landmarks. A separate water quality assessment is presented in Annex D to address specific concerns relating to the aquatic environment.

C5.1 Sensitive Receptor Locations

The identified sensitive receptors are located as illustrated in Figure C5.1-1. This figure also presents the location of the two mills. The sections that follow provide a detailed evaluation of potential effects for each of these receptors.

Sensitive receptors in Uruguay include the following:

- Receptor 1 – the area on or adjacent to the mill properties where the maximum ground based concentration occurs is identified as a receptor;
- Receptor 2 – the city of Fray Bentos (population 22,600) is the closest community to the two mills and is located approximately 5 km west of the Botnia mill and approximately 11 km west of the ENCE mill;
- Receptor 3 – the city of Mercedes (population 45,000) is located inland from the Rio Uruguay along the Rio Negro towards the south east located approximately 25 km from the Botnia mill and approximately 20 km from the ENCE mill;
- Receptor 4 – the city of Nuevo Berlin is located along the shores of Rio Uruguay towards the north of the two mills a distance of approximately 20 km and is located towards the southern end of the wetland areas of Esteros de Farrapos e Islas del Rio Uruguay;
- Receptor 5 – Las Cañas is a beach resort and important tourist area located along the shores of the Rio Uruguay approximately 12 km from Botnia, and 17 km from ENCE, towards the south west of the two mills;
- Receptor 6 – beach area of Playa Ubici is used by the people of Fray Bentos for recreation and camping, and is located to the west of the Botnia mill;
- Receptor 7 – the International Bridge, which is the nearest road access connecting Uruguay and Argentina, is located adjacent to the Botnia mill site and just over 5 km from the ENCE mill.

Sensitive receptors in Argentina include the following:

- Receptor 8 – the city of Gualeguaychú, Argentina, (population 76,220) is the nearest community in Argentina to the mills, and is located approximately 25 km towards the north west of the two mills;

- Receptor 9 – the beach area along the Argentina side of the Rio Uruguay at Ñandubaysal is an important tourist area for Argentina, particularly during the annual carnival, is located approximately 13 km from Botnia, and 19 km from ENCE, towards the north west of the two mills ; and
- Receptor 10 – a location along the highway and inland from the International Bridge on the Argentine side of the Rio Uruguay approximately 6 km from the Botnia mill and 9 km from the ENCE mill.

C5.2 Potential Effects at Identified Receptors in Uruguay

The potential effects of the air emissions from the Botnia and ENCE mills are described in the sections below. The discussion addresses each identified receptor separately. An overview of the air quality impacts by receptor is presented in Table C5.2-1, and the model predictions referred to in the discussion are presented in Tables C5.2-2 though C5.2-5. These model predictions refer to averaging periods as per the ambient air quality criteria described in Section C4.0, and account for exposure duration and meteorological variability.

The length of time that a person, or some part of the environment, is exposed to pollutants is important because impacts occur from different types of exposure. A long exposure, like an annual average concentration, is important when assessing the long term health risk on people. A daily exposure (24-hour average concentration) has been used to characterize short term health and material impacts, whereas short term exposure (1-hour average concentration) can have both immediate health and material impacts.

Odour is somewhat unique in that most people can sense and identify an odour within seconds and therefore standards are often set based on a 10-minute average concentration as well as 1-hour and 24-hour durations. Odours can also have varying thresholds of detection depending upon the ambient air quality and the degree of sensitivity of the person. For a person with a very sensitive nose, detection may occur at an odour effects level of 3, whereas the odour may be considered objectionable at an odour effects level greater than 10.

It should also be noted that winds don't blow in exactly the same direction for very long, and as a result, the ambient air quality at each receptor tends to be highly variable. This variability is accounted for by averaging the predicted air quality over the duration of exposure. The reported values in the tables represent the worst air quality that occur over the averaging period (1-hour, 24-hour and annual) and over the 1-year simulation. The 1-hour concentrations represent the highest concentration predicted for the year, and the annual average concentrations represent the average for the year.

For normal operating conditions where the emissions are relatively constant, variability is dependant on meteorological conditions only. However, for upset conditions, variability is also dependant upon the occurrence of the upset event relative to the meteorological condition. Caution is therefore required in the interpretation of the results for the upset condition since the likelihood of an upset condition coinciding with the worst case meteorological condition is small and may not be realistic.

C5.2.1 Receptor 1, the Areas Adjacent to the Mill Properties

The area adjacent to the mill properties where the maximum calculated ground based concentration occurs is identified as the receptor having the absolute worst case impact. Under most conditions, the location of the maximum concentration is just west of the ENCE mill within a predominantly forested area. However, at times the maximum concentration is located just east of the Botnia mill within their property boundary and within an area of mixed forest.

As presented in Table C5.2-2, the maximum ground level concentration will remain in compliance with all respective air quality criteria under all operating conditions. The concentration of SO_2 predicted using the ISCST3 model is estimated to change on an annual average basis by 0.2 µg/m^3. In comparison, the typical ambient concentration of SO_2 is approximately 13 µg/m^3 with a range of 5 to 30 µg/m^3. Likewise the incremental annual change of NO_2 and particulate matter (PM_{10} and $PM_{2.5}$) are predicted to be 0.5, 0.1 and less than 0.1 µg/m^3, respectively, which are significantly lower than typical ambient concentrations of 15, 20 and 8 µg/m^3, respectively. These incremental changes will not be measurable.

The typical ambient air quality concentrations, used as reference points in this document, are based on monitoring in the rural United States as published by the US EPA (1997). These typical ambient concentrations were used since ambient air quality data were not available for Uruguay or Argentina within the general area of the two mills.

Under normal operating conditions, the 1-hour concentration of SO_2 and NO_2 are predicted to change by 22 and 61 µg/m^3, respectively, which are significantly lower than the respective air quality criteria of 690 and 200 µg/m^3. The 1-hour concentrations for particulate matter (PM_{10} and $PM_{2.5}$), VOCs and chlorine compounds are also significantly below the ambient air quality criteria. These predictions are based on the ISCST3 model, which as described in Section C3.2, may underestimate the actual concentration at this near-field receptor. However, the uncertainty associated with the model prediction is well within the ambient air quality criteria.

During upset conditions, the 1-hour concentration of SO_2 and NO_2 are predicted to change by 141 and 90 µg/m^3, respectively, which are also significantly lower than the respective air quality criteria. Likewise, the 1-hour concentrations of TRS and particulate matter are well within the criteria. Uncertainty associated with the model prediction may approach the air quality criteria for NO_2, however, this is based on the conservative and perhaps extremely unlikely assumption that the upset condition occurs simultaneously at both facilities and during worst case meteorological condition (i.e., conditions of poor air dispersion).

Since the predicted concentrations of SO_2, NO_2 and particulate matter are all below their respective air quality criteria, it is concluded that there is no potential for health effects arising from air emissions due to mill operations at this receptor.

Odour will not likely be detectable under normal operating conditions on or immediately adjacent to the mill properties, although it may be detected and considered objectionable under upset conditions. The detection of odour does not represent a health concern since the 24-concentration of TRS is well below the WHO criteria, although, people on or near the site may notice a sewer type smell or, on occasion, a stronger unpleasant smell. During the first year of operation, it is possible that the NCG system may vent to the atmosphere on occasion for minutes to possibly hours at a time until the collection system is fully functional, after which venting will be limited to a few seconds to minutes in duration. As discussed in Section C2.3.1.2, for modeling purposes, it is assumed that 16 events may occur of varying duration, and that an upset of the NCG system may coincide with an upset of the wastewater treatment system. This assumption may not be realistic, but it provides a worst possible case assessment.

C5.2.2 Receptor 2, the City of Fray Bentos

The city of Fray Bentos is the nearest community to the two mills. As presented in Table C5.2-2, it is also the community which will receive the highest incremental change in air quality resulting from emissions from the two mills, although as discussed below, these changes will not adversely affect human health or aesthetic environment of the community.

The annual average concentrations of SO_2 and NO_2 are predicted to change by 0.1 and 0.3 $\mu g/m^3$, respectively, in comparison to the reference ambient concentration of 13 and 15 $\mu g/m^3$ for rural United States. The annual average concentrations of particulate matter are also well below the typical ambient concentrations. These incremental changes will not be measurable.

Under normal operational conditions, the 1-hour concentrations of SO_2 and NO_2 are predicted to change by 8 and 19 $\mu g/m^3$, respectively. These values are significantly lower (88 and 11 times) than the standard indicating that there will be no potential for health effects. Likewise, the 1-hour concentrations for particulate matter, VOCs and chlorine compounds are also significantly below the ambient air quality criteria, and therefore will not cause health effects.

During upset conditions, the 1-hour concentration of SO_2 and NO_2 are predicted to be 62 and 24 $\mu g/m^3$, respectively, which are also significantly lower (11 and 8 times) than the standard. Likewise, the 1-hour concentrations of TRS and particulate matter are well below the health criteria. These predictions assume that an upset occurred at both facilities at the same time and during worst case meteorological conditions, which collectively are extremely unlikely to occur.

Since the predicted concentrations of the identified parameters are all below their respective air quality criteria, it is concluded that there is no potential for health effects arising from air emissions due to mill operations within the city of Fray Bentos.

Odour will not be detectable within the city of Fray Bentos under normal operating conditions, but detection is possible during upset conditions. The 10-minute odour effect level is predicted to be 10 which is at the level which may be considered objectionable by someone with a sensitive sense of smell. As previously discussed, the duration of such events may range from a few minutes to a few hours during the first year of operation, and reduced to a few seconds to minutes thereafter. The detection of odour may range from a sewer type smell which may or may not be attributable to the mill, to a stronger odour that would be readily attributed to the mill. Although 16 upset events are assumed, it is likely fewer than 10 will be noticed by the residents of Fray Bentos based on operating experience at similar modern mills located near urbanized areas. Such mills may receive a few complaints per year regarding odour which may or may not always be related to mill activities.

These predictions are made using the ISCST3 model. As discussed in Section C3.2, the model may underestimate the actual concentration within a factor of two at this near-field receptor. However, the uncertainty associated with the model prediction is well within the ambient air quality criteria and odour detection thresholds used to support the interpretation of the model results.

C5.2.3 Receptor 3, the City of Mercedes

As presented in Table C5.2-2, the incremental change in air quality at the city of Mercedes is predicted to be lower than the incremental change at the city of Fray Bentos, and therefore it is concluded that these changes will not adversely affect human health or aesthetic environment of the community.

The concentrations of SO_2 and NO_2 are predicted to change by less than 0.1 $\mu g/m^3$ on an annual average basis and by less than 1 $\mu g/m^3$ on a 24-hour basis. These low changes in concentration are well below ambient air quality standards and well below the reference ambient air quality for rural United States. Likewise the incremental change of TRS, particulate matter, VOC and chlorine compounds are also very low. These incremental changes will not be measurable.

The odour effect level is also predicted to be lower than the detection threshold under both normal and upset conditions. This change will be imperceptible to the residents of Mercedes.

C5.2.4 Receptor 4, the City of Nuevo Berlin

The city of Nuevo Berlin located towards the southern of the wetland area of Esteros de Farrapos e Islas del Rio Uruguay, which is designated a Ramsar site because of the diversity of plant and wildlife species that it supports. The air quality predictions for the city of Nuevo Berlin provide a conservative estimate of the air quality over the wetland region.

As presented in Table C5.2-2, the predicted incremental change in air quality at the city of Nuevo Berlin is comparable to the incremental change at the city of Mercedes, and therefore the same conclusion of no effect applies. The change in air quality, for all parameters, is predicted to be far below the respective ambient air quality criteria, indicating no potential for human health effects.

The concentrations of SO_2 and NO_2 are predicted to change by less than 0.1 $\mu g/m^3$ on an annual average basis and by 0.5 to 1.2 $\mu g/m^3$ based on as 24-hour average. These low changes in concentration are well below ambient air quality standards and well below the reference ambient air quality for rural United States. Likewise the incremental change of TRS, particulate matter, VOC and chlorine compounds are also very low. These incremental changes will not be measurable. Since the incremental change in ambient air quality is not measurable, there should be no adverse effects to the wetland area of Esteros de Farrapos e Islas del Rio Uruguay.

Odour will not be detectable within the city of Nuevo Berlin during both normal operating and upset conditions. Under upset conditions, the odour effect level is predicted to be at the detection threshold for a person with a sensitive sense of smell, however the predicted 1-hour concentration of TRS is so low that odour detection is unlikely.

C5.2.5 Receptor 5, the Beach Resort of Las Cañas

Las Cañas is a beach resort community located further downstream than Fray Bentos along the shores of the Rio Uruguay. The beach attracts visitors from throughout Uruguay and Argentina, and is therefore an important resource for local tourism.

The predicted change in air quality for Las Cañas is presented in Table C5.2-2. As presented, the 24-hour concentration of SO_2, NO_2, PM_{10} and $PM_{2.5}$ are predicted to be 1.1, 2.6, 0.5 and 0.4 $\mu g/m^3$, which are significantly lower than the reference ambient air concentrations of 13, 15, 20 and 8 $\mu g/m^3$, respectively. These incremental changes will not be measurable. Furthermore, the concentration of all air quality parameters are predicted to be significantly lower than the ambient air quality criteria under both normal and upset operating conditions, and therefore no adverse effects to human health are expected as a result of the combined air emissions from the two mills.

Odour will not be detectable at Las Cañas under normal operating conditions, but during upset conditions and times of poor air dispersion, the odour effect level is predicted to be above the detection threshold for a person with a sensitive sense of smell. This means that during an upset someone in Las Cañas may detect an odour similar to that experienced in daily life (such as garbage, a poorly tuned car, a sewer) but may not be able to characterize its source. This occurrence is most likely during pre-dawn when air dispersion is poor, and may occur up to 10 times per year based on operational experience at modern mills.

C5.2.6 Receptor 6, the Beach Area of Playa Ubici

Playa Ubici is a recreational beach area located across Yaguareté Bay from the Botnia mill. The beach is a valuable resource for the city of Fray Bentos and for tourists who may visit the area. It is used for camping, swimming and other outdoor recreational activities.

The incremental change in air quality at the beach area is predicted to be comparable to that for the city of Fray Bentos. It is concluded that these changes will not adversely affect human health or the aesthetic environment of the beach and camping areas.

Odour will not be detectable at Playa Ubici under normal operating conditions, but detection is possible during upset and worst case meteorological conditions. The 10-minute odour effect level is predicted to be 9 which is below the level which may be considered objectionable by someone with a sensitive sense of smell. Detection of odour may occur up to 10 times per year based on operational experience at modern mills and is most likely to occur at night when air dispersion is poor.

C5.2.7 Receptor 7, the International Bridge

The International Bridge provides the nearest road access connecting Uruguay and Argentina. The change in air quality at the International Bridge is also predicted to be comparable to that at Fray Bentos, and therefore also concluded that human health and aesthetic environment are protected. It is predicted that odour will not be detectable during normal operating conditions but detection is possible during upset and times of poor air dispersion. Detection of odour may occur up to 10 times per year and most likely at night when air dispersion is poor.

C5.3 Potential Effects at Identified Receptors in Argentina

The airshed for the two mills extends across the Rio Uruguay into Argentina. As such, the potential air quality effects within Argentina are important, and in particular the air quality at the city of Gualeguaychú, the beach area at Ñandubaysal, and inland from the International Bridge. These receptors are described in further detail below.

C5.3.1 Receptor 8, the City of Gualeguaychú, Argentina

The city of Gualeguaychú is a thriving community located in the province of Entre Ríos, Argentina, on the bank of the Rio Gualeguaychú, a tributary of the Río Uruguay. It is located approximately 190 km north-west of Buenos Aires, and has a population of 76,220 according to the 2001 census. The city hosts an annual Carnival that is regionally well-known and attended by people from across Argentina and Uruguay.

As presented in Table C5.2-2, the predicted change in air quality at the city of Gualeguaychú, for all parameters, is predicted to be far below the respective ambient air quality criteria, indicating no potential for human health effects or odour related effects.

The concentrations of SO_2 and NO_2 are predicted to change by less than 0.1 µg/m^3 on an annual average basis and by 0.5 to 1.2 µg/m^3 based on as 24-hour average. These low changes in concentration are well below ambient air quality standards and well below the reference ambient air quality for rural United States. Likewise the incremental change of TRS, particulate matter, VOC and chlorine compounds are also very low. These incremental changes will not be measurable.

The odour effect level is predicted to be lower than the detection threshold under both normal and upset conditions. This change will be imperceptible to the residents of Gualeguaychú.

These predictions are made using the ISCST3 model which, as discussed in Section C3.2, may over-estimate the actual concentration by a factor of two at this far-field receptor. This conservative prediction reinforces the conclusion of no health or aesthetic effect at the city of Gualeguaychú.

C5.3.2 Receptor 9, the Beach Area at Ñandubaysal, Argentina

A beach and camping ground is located at Ñandubaysal in Argentina across the Río Uruguay from Fray Bentos. The site is a popular vacation and tourist destination for people from Argentina and Uruguay during the summer months and particularly during the annual Carnival.

The predicted change in air quality for Ñandubaysal is presented in Table C5.2-2. As presented, the 24-hour concentration of SO_2, NO_2, PM_{10} and $PM_{2.5}$ are predicted to be 0.9, 2.2, 0.5 and 0.3 µg/m^3, which are significantly lower than the reference ambient air concentrations of 13, 15, 20 and 8 µg/m^3, respectively. These incremental changes will neither be measurable nor perceptible. Furthermore, the concentration of all air quality parameters are predicted to be significantly lower than the ambient air quality criteria under both normal and upset operating conditions, and therefore no adverse effects to human health are expected as a result of the combined air emissions from the two mills.

Odour will not be detectable at Ñandubaysal under normal operating conditions, but during upset conditions and times of poor air dispersion the odour effect level is predicted to be above the detection threshold for a person with a sensitive sense of smell. This means that on occasion and for a short period of time, someone at Ñandubaysal may detect an odour similar to that experienced in daily life (such as garbage, a poorly tuned car, a sewer) but may not be able to characterize its source. This occurrence is most likely during pre-dawn when air dispersion is poor, and may occur up to 10 times per year based on operational experience at modern mills. The duration of the odour event is expected to range from a few seconds to minutes following the first year of operation.

These predictions are made using the ISCST3 model which, as discussed in Section C3.2, may over-estimate the actual concentration by a factor of 1.4 at this far-field receptor. Therefore, it is possible that the potential odour effects will be less than that described above.

The Botnia mill is slightly visible from the beach area at Ñandubaysal, as shown in the photograph in Figure C5.3-1, taken in July 2006 when the mill stack was completely erected. (The stack is visible on the skyline towards the right side of the photograph). The mill and its stack blend into the landscape of Fray Bentos. During cold humid weather, a white vapour plume may be visible extending from the stack. This visible plume may look similar to that shown in the photograph in Figure C5.3-2 of an ENCE mill operation in Spain.

C5.3.3 Receptor 10, Beyond the International Bridge, Argentina

Receptor 10 is located along the highway and inland from the International Bridge on the Argentine side of the Rio Uruguay approximately 6 km from the Botnia mill and 9 km from the ENCE mill. It is considered the most sensitive receptor within Argentina due to its close proximity to the two mills.

The annual average concentrations of SO_2 and NO_2 are predicted to change by 0.1 and 0.3 $\mu g/m^3$, respectively, in comparison to the reference ambient concentration of 13 and 15 $\mu g/m^3$. The annual average concentrations of particulate matter are also well below the reference ambient concentrations. These incremental changes will not be measurable.

Under normal operational conditions, the 1-hour concentrations of SO_2 and NO_2 are predicted to change by 3 and 12 $\mu g/m^3$, respectively. These values are significantly lower (230 and 17 times) than the standard indicating that there will be no potential for health effects. Likewise, the 1-hour concentrations for particulate matter, VOCs and chlorine compounds are also significantly below the ambient air quality criteria, and therefore will not cause health effects.

During upset conditions, the 1-hour concentration of SO_2 and NO_2 are predicted to be 42 and 16 $\mu g/m^3$, respectively, which are also significantly lower (16 and 12 times) than the standard. Likewise, the 1-hour concentrations of TRS and particulate matter are well below the health criteria. These predictions assume that an upset occurred at both facilities at the same time and during worst case meteorological conditions, which collectively are extremely unlikely to occur.

Since the predicted concentrations of the identified parameters are all below their respective air quality criteria, it is concluded that there is no potential for health effects arising from air emissions due to mill operations within Argentina.

Odour will not be detectable at this receptor under normal operating conditions, but detection is possible during upset conditions. The 10-minute odour effect level is predicted to be above the level which may be considered objectionable by someone with a sensitive sense of smell. As previously discussed, the duration of such events may range from a few minutes to a few hours during the first year of operation, and reduced to a few seconds to minutes thereafter. The detection of odour may range from a sewer type smell which may or may not be attributable to the mill, to a stronger odour that would be readily attributed to the mill. Although 16 upset events are assumed, it is likely that fewer than 10 will be noticed by at this location based on operating experience at similar modern mills.

These predictions are made using the ISCST3 model. As discussed in Section C3.2, the model may underestimate the actual concentration within a factor of 1.6 at this near-field receptor. However, the uncertainty associated with the model prediction is well within the ambient air quality criteria and odour detection thresholds used to support the interpretation of the model results.

Table C5.2-1: Summary of Potential Effects of Air Emissions on Local Sensitive Receptors

Receptor 1	**Area on or adjacent to the mill properties of maximum concentration**
Combustion Products (NO_2, SO_2, PM, PM_{10}, $PM_{2.5}$)	• Greatest potential change in ground based ambient air quality. Air quality remains in compliance with ambient air quality criteria under all meteorological conditions and operating conditions, therefore limited potential for human health effects associated with mill emissions.
Reduced Sulphur Compounds (Odour)	• Potential for infrequent (up to 10 times per year) detections of odour during upset conditions, and levels may be consider objectionable by someone with a sensitive sense of smell.
Volatile Organic Compounds	• Predicted ambient air concentration far below ambient air quality criteria, and therefore, emissions of VOCs from the mills are not anticipated to have a significant effect on the environment.
Chlorine and Chlorine Dioxide	• Predicted ambient air concentration is far below ambient air quality criteria, and therefore emissions from the chlorine plant are not anticipated to have a significant effect on the environment.
Receptor 2	**City of Fray Bentos**
Combustion Products (NO_2, SO_2, PM, PM_{10}, $PM_{2.5}$)	• Air quality remains well below ambient air quality criteria under all meteorological conditions and operating conditions, therefore no adverse human health effects associated with mill emissions.
Reduced Sulphur Compounds (Odour)	• Potential for infrequent (up to 10 times per year) detections of odour during upset conditions, and levels may be consider objectionable by someone with a sensitive sense of smell.
Volatile Organic Compounds	• No effect.
Chlorine and Chlorine Dioxide	• No effect.
Receptor 3	**City of Mercedes**
Combustion Products (NO_2, SO_2, PM, PM_{10}, $PM_{2.5}$)	• Immeasurable change in ambient air quality, well below any level that may cause any effect.
Reduced Sulphur Compounds	• Immeasurable change in ambient air quality, therefore no effect.
Volatile Organic Compounds	• No effect.
Chlorine and Chlorine Dioxide	• No effect.
Receptor 4	**City of Nuevo Berlin**
Combustion Products	• Immeasurable change in ambient air quality, therefore no effect.
Reduced Sulphur Compounds	• Immeasurable change in ambient air quality, therefore no effect.
Volatile Organic Compounds	• No effect.
Chlorine and Chlorine Dioxide	• No effect
Receptor 5	**Beach Resort of Las Cañas**
Combustion Products	• Immeasurable change in ambient air quality, therefore no effect.
Reduced Sulphur Compounds	• Potential for infrequent (up to 10 times per year) detections of odour during upset conditions, but at levels similar to that experienced in daily life (e.g., garbage, a poorly tuned car, a sewer).
Volatile Organic Compounds	• No effect.
Chlorine and Chlorine Dioxide	• No effect.

Table C5.2-1: Summary of Potential Effects of Air Emissions on Local Sensitive Receptors (cont'd)

Receptor 6	**Beach Area of Playa Ubici**
Combustion Products (NO_2, SO_2, PM, PM_{10}, $PM_{2.5}$)	• Air quality remains well below ambient air quality criteria under all meteorological conditions and operating conditions, therefore no adverse human health effects associated with mill emissions.
Reduced Sulphur Compounds (Odour)	• Potential for infrequent (up to 10 times per year) detections of odour during upset conditions, and levels may be consider objectionable by someone with a sensitive sense of smell.
Volatile Organic Compounds	• No effect.
Chlorine and Chlorine Dioxide	• No effect.
Receptor 7	**International Bridge**
Combustion Products (NO_2, SO_2, PM, PM_{10}, $PM_{2.5}$)	• Air quality remains well below ambient air quality criteria under all meteorological conditions and operating conditions, therefore no adverse human health effects associated with mill emissions.
Reduced Sulphur Compounds (Odour)	• Potential for infrequent (up to 10 times per year) detections of odour during upset conditions, and levels may be consider objectionable by someone with a sensitive sense of smell.
Volatile Organic Compounds	• No effect.
Chlorine and Chlorine Dioxide	• No effect.
Receptor 8	**City of Gualeguaychú, Argentina**
Combustion Products	• Immeasurable change in ambient air quality, therefore no effect.
Reduced Sulphur Compounds	• Immeasurable change in ambient air quality, therefore no effect.
Volatile Organic Compounds	• No effect.
Chlorine and Chlorine Dioxide	• No effect.
Receptor 9	**Beach Area at Ñandubaysal, Argentina**
Combustion Products	• Immeasurable change in ambient air quality, therefore no effect.
Reduced Sulphur Compounds	• Potential for infrequent (up to 10 times per year) detections of odour during upset conditions, but at levels similar to that experienced in daily life (e.g., garbage, a poorly tuned car, a sewer).
Volatile Organic Compounds	• No effect.
Chlorine and Chlorine Dioxide	• No effect.
Receptor 10	**Beyond the International Bridge, Argentina**
Combustion Products	• Air quality remains well below ambient air quality criteria under all meteorological conditions and operating conditions, therefore no adverse human health effects associated with mill emissions.
Reduced Sulphur Compounds	• Potential for infrequent (up to 10 times per year) detections of odour during upset conditions, and levels may be consider objectionable by someone with a sensitive sense of smell.
Volatile Organic Compounds	• No effect.
Chlorine and Chlorine Dioxide	• No effect.

Table C5.2-2a: Incremental Impact of ENCE and Botnia Mills to Discrete Receptors – Normal Operations

Receptor	SO_2			NO_x (as NO_2)			TSP		PM_{10}		$PM_{2.5}$	
	1-hr	24-hr	Annual	1-hr	24-hr	Annual	24-hr	Annual	24-hr	Annual	24-hr	Annual
Standard (ug/m^3)	*690*	*125*	*50*	*200*	*200*	*40*	*120*	*-*	*50*	*-*	*25*	*-*
1. Maximum Location	22	1.3	0.2	61	6.9	0.5	1.7	0.1	1.5	0.1	1.1	0.1
2. Fray Bentos	8	1.9	0.1	19	5.1	0.3	1.0	0.1	0.9	0.1	0.7	0.0
3. Mercedes	2	0.4	0.0	5	1.0	0.0	0.2	0.0	0.2	0.0	0.2	0.0
4. Nuevo Berlin	2	0.5	0.0	5	1.2	0.1	0.3	0.0	0.3	0.0	0.2	0.0
5. Las Cañas	4	1.1	0.1	10	2.6	0.2	0.5	0.1	0.5	0.0	0.4	0.0
6. Playa Ubici	8	1.5	0.1	18	4.1	0.3	0.8	0.1	0.7	0.1	0.5	0.0
7. International Bridge	9	2.0	0.1	22	5.3	0.4	0.8	0.1	0.8	0.1	0.6	0.0
8. Gualeguaychú Argentina	2	0.5	0.0	6	1.2	0.1	0.3	0.0	0.3	0.0	0.2	0.0
9. Ñandubaysal Argentina	4	0.9	0.1	9	2.2	0.2	0.5	0.0	0.5	0.0	0.3	0.0
10. Gendarmerie, Argentina	3	0.6	0.1	12	3.2	0.3	0.3	0.0	0.5	0.1	0.4	0.0

Table C5.2-2b: Incremental Impact of ENCE and Botnia Mills to Discrete Receptors – Upset Conditions

Receptor	SO_2			NO_x (as NO_2)			TSP		PM_{10}		$PM_{2.5}$	
	1-hr	24-hr	Annual	1-hr	24-hr	Annual	24-hr	Annual	24-hr	Annual	24-hr	Annual
Standard (ug/m^3)	*690*	*125*	*50*	*200*	*200*	*40*	*120*	*-*	*50*	*-*	*25*	*-*
1. Maximum Location	141	21.3	1.6	90	10.5	0.7	4.4	0.3	4.1	0.3	3.0	0.2
2. Fray Bentos	62	14.5	0.9	24	6.7	0.4	2.7	0.2	2.5	0.1	1.8	0.1
3. Mercedes	16	2.8	0.1	6	1.3	0.1	0.6	0.0	0.6	0.0	0.4	0.0
4. Nuevo Berlin	14	3.0	0.2	8	1.8	0.1	0.8	0.0	0.8	0.0	0.6	0.0
5. Las Cañas	35	8.5	0.7	13	3.3	0.3	1.4	0.1	1.3	0.1	1.0	0.1
6. Playa Ubici	62	12.2	0.9	22	5.2	0.4	2.1	0.2	1.9	0.1	1.4	0.1
7. International Bridge	75	16.5	1.0	26	6.3	0.5	2.2	0.2	2.0	0.2	1.5	0.1
8. Gualeguaychú, Argentina	19	3.7	0.3	7	1.6	0.1	0.7	0.1	0.7	0.1	0.5	0.0
9. Ñandubaysal, Argentina	30	6.4	0.5	10	2.9	0.2	1.3	0.1	1.2	0.1	0.9	0.1
10. Gendarmerie, Argentina	42	10.2	0.8	16	3.8	0.4	1.4	0.2	1.3	0.1	1.0	0.1

Table C5.2-3a: Predicted Maximum Concentrations Combined Incremental Odour Impacts from the ENCE and Botnia Mills (in μg/m³) Under Upset Conditions – NCG System

Receptor	STACK EMISSIONS ONLY		
	TRS		Odour Effect[a]
	1-hour	24-hour	10-min
Odour Detection Threshold (ug/m³)	***15***	***10***	'-
1. Maximum Location	15	2	31
2. Fray Bentos	5	1	10
3. Mercedes	1	0	2
4. Nuevo Berlin	1	0	3
5. Las Cañas	3	1	4
6. Playa Ubici	5	1	8
7. International Bridge	6	1	10
8. Gualeguaychú, Argentina	2	0	2
9. Ñandubaysal, Argentina	3	1	4
10. Gendarmerie, Argentina	3	1	12

[a] Calculated 10-minute combined odour effect as described in Section C4.5.

Table C5.2-3b: Predicted Maximum Concentrations Combined Incremental Odour Impacts from the ENCE and Botnia Mills (in μg/m³) Under Upset Conditions – NCG System and Wastewater Treatment System

Receptor	STACKS AND WWTP EMISSIONS		
	TRS		Odour Effect[a]
	1-hour	24-hour	10-min
Odour Detection Threshold (ug/m³)	***15***	***10***	'-
1. Maximum Location	127	30	114
2. Fray Bentos	6	1	10
3. Mercedes	1	0	2
4. Nuevo Berlin	1	0	3
5. Las Cañas	3	1	4
6. Playa Ubici	9	1	9
7. International Bridge	6	2	10
8. Gualeguaychú, Argentina	2	0	2
9. Ñandubaysal, Argentina	3	1	4
10. Gendarmerie, Argentina	6	1	22

[a] Calculated 10-minute combined odour effect as described in Section C4.5.

Table C5.2-4: Combined Incremental VOC Impact of ENCE and Botnia Mills to Discrete Receptors

	Predicted Concentrations($\mu g/m^3$) - Average Emissions		
	Total VOCs		
Receptor Name	1-hr	24-hr	Annual
1. Maximum Location	6.7	1.2	0.08
2. Fray Bentos	2.2	0.6	0.04
3. Mercedes	0.8	0.2	0.01
4. Nuevo Berlin	1.0	0.3	0.01
5. Las Cañas	1.4	0.4	0.03
6. Playa Ubici	2.2	0.4	0.03
7. Internacional Bridge	2.6	0.5	0.05
8. Gualeguaychú, Argentina	0.7	0.2	0.01
9. Ñandubaysal, Argentina	1.3	0.3	0.02
10. Gendarmerie, Argentina	1.9	0.4	0.04

Table C5.2-5: Predicted Concentrations ($\mu g/m^3$) from ClO_2 Plant

	Cl_2			ClO_2		
Receptor Name	1-hr	24-hr	Annual	1-hr	24-hr	Annual
Standard ($\mu g/m^3$)	*15*	*10*	*-*	*28*	*30*	*-*
1. Maximum Location	0.005	0.0007	0.00005	0.51	0.08	0.005
2. Fray Bentos	0.005	0.0002	0.00002	0.51	0.02	0.002
3. Mercedes	0.0004	0.00002	<0.000001	0.04	0.002	0.00004
4. Nuevo Berlin	0.0006	0.00003	<0.000001	0.07	0.003	0.00008
5. Las Cañas	0.002	0.0001	0.00001	0.17	0.02	0.0009
6. Playa Ubici	0.005	0.0003	0.00002	0.51	0.03	0.002
7. Internacional Bridge	0.004	0.0007	0.00005	0.47	0.08	0.005
8. Gualeguaychú, Argentina	0.0005	0.00005	<0.000001	0.05	0.005	0.0003
9. Ñandubaysal, Argentina	0.001	0.0001	0.00001	0.14	0.01	0.0006
10. Gendarmerie, Argentina	0.003	0.0002	0.00001	0.37	0.025	0.001

Figure C5.1-1: Location of Identified Sensitive Receptors

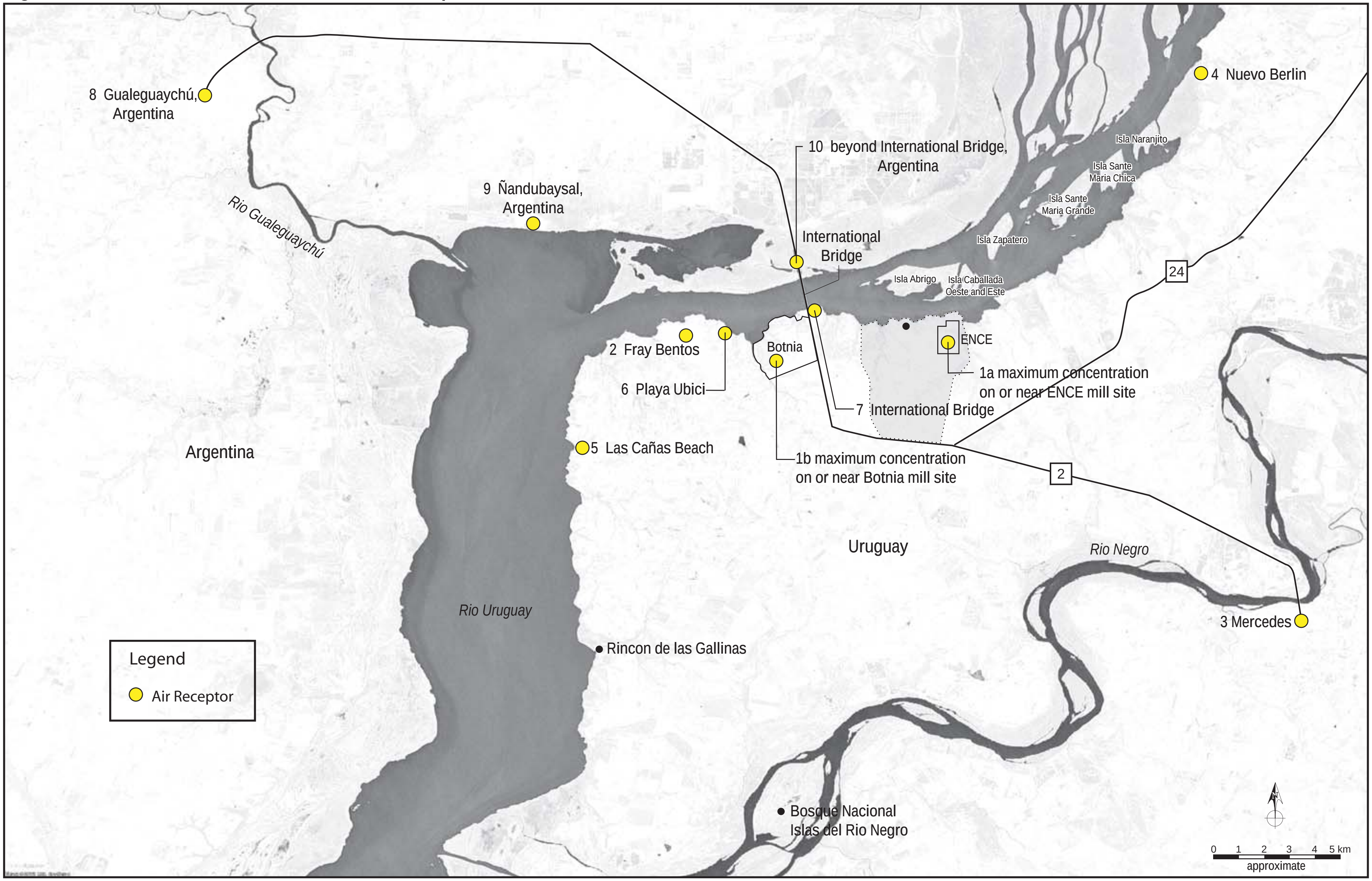


Figure C5.3-1: Photograph from Ñandubaysal, Argentina, Showing Botnia Site in Distance

(photo taken with 36 mm lens)

Figure C5.3-2: Example of ENCE Mill Operation in Spain

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