SUMAS ENERGY 2 GENERATION FACILITY AIR QUALITY ISSUE SUMMARY

September 11, 2000

This report has been prepared at the request of the Canadian members of the
Lower Fraser Valley Air Quality Coordinating Committee
(BC Ministry of Environment, Lands and Parks,
Environment Canada – Pacific and Yukon Region,
Greater Vancouver Regional District, and
Fraser Valley Regional District).

The report was prepared by technical staff from the
BC Ministry of Environment, Lands and Parks,
Environment Canada - Pacific and Yukon Region and
the Greater Vancouver Regional District.

The portions of the report addressing health impacts were reviewed by
BC Ministry of Health and Health Canada.

Editorial Note:

This document reflects analysis based on the emissions from the proposed Sumas Energy 2 power generation facility, as specified in Section 6 of the Application for Site Certification Agreement submitted to the U.S. regulatory agency in January, 2000. The draft air permit (issued for public comment on August 25, 2000) indicates that the emissions of oxides of nitrogen are now 1/3 lower than originally proposed. This reduction would primarily affect the air quality assessment for ozone and gaseous oxides of nitrogen. It would not substantially alter the assessment and conclusions as they relate to air toxics, acid deposition, particulate matter and visibility. Appropriate notations are made in the document to indicate this.

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EXECUTIVE SUMMARY

This report was prepared for the Canadian agencies involved in air quality management in the Lower Fraser Valley airshed. This is an international airshed where Canadian agencies have been working together for over a decade, and also engage U.S. partners in efforts to manage air quality.

Technical staff from the Ministry of Environment, Lands and Parks, Environment Canada – Pacific and Yukon Region and the Greater Vancouver Regional District have produced this summary of the air quality issues associated with the 660 MW Sumas Energy 2 gas-fired power project proposed in the State of Washington. This review was undertaken to assess the potential for the facility emissions to aggravate poor air quality conditions that can occur in this airshed.

All of the agencies participate in an extensive air monitoring network that documents air quality levels from Hope to West Vancouver. Various short and medium-term air quality objectives and standards have been adopted by the different agencies, and comparisons with these aid in assessing both daily levels and long-term trends. Depending on which locations and criteria are used for comparison, air quality exceeds these benchmarks up to ten percent of the time. Recent studies on air quality and health indicate that effects on human health begin to occur at levels well below any of these objectives and standards.

Exceedances of air quality objectives and standards in the central and eastern sections of the Lower Fraser Valley (LFV) of British Columbia concern concentrations of ozone and inhalable particulate (PM10). Acid deposition occasionally exceeds criteria used to protect Pacific Northwest ecosystems, and visibility is also impaired. The existing sources of emissions that cause these conditions are many and varied, but include transportation and other engines, industry, agriculture, urban and rural living and population growth, and to an extent nature itself (e.g., some hydrocarbons are emitted by vegetation). The meteorology and topography of the area are also contributing factors in creating conditions that exacerbate the impact of any emissions. Improvement in air quality will require an overall decrease in emissions in the airshed. While this assessment has shown that the proposed Sumas Energy 2 power plant will not significantly cause the most stringent Canadian air quality objectives or standards to be further exceeded, it is expected to contribute to an increased frequency of poor visibility, and will increase emissions in an already sensitive airshed.

The following summary statements provide more details on the specific issues, as found by the inter-agency technical committee.

Emissions

The proposed facility will have modern gas-fired turbines with Selective Catalytic Reduction, an emission control technology that has been widely used for these facilities. An undesired by-product of Selective Catalytic Reduction technology is emissions of ammonia. Technologies that are capable of achieving reductions of nitrogen oxide emissions without the use (and emission) of ammonia are emerging.

The proposed facility will emit a variety of air contaminants. The percent contribution of individual contaminants to the entire airshed total ranges from .03% to as much as 1.48%. The oxides of nitrogen and inhalable particulate matter emissions (contaminants of primary concern) are about 140 Tonnes per year[1] and 200 Tonnes per year, respectively. The greatest emission rates occur when the facility is oil-fired – which may be permitted for a maximum of 15 days during the winter.

Assessment Methodology

Air quality computer models were used to predict the air quality impacts that could occur if the facility were to be built. These predictions were used in conjunction with historically measured air quality conditions in the region and existing air quality standards/objectives to assess the significance of the impact due to the facility emissions.

Air Quality Impacts - Regulated Pollutants and Air Toxics

Sulphur dioxide, carbon monoxide, nitrogen dioxide and a variety of residual air toxics emitted from the proposed facility are not expected to increase the frequency for exceeding B.C. or Washington State air quality objectives or standards.

Air Quality Impacts - Acid Deposition

The maximum deposition due to the proposed facility emissions is predicted to occur on Sumas Mountain and is expected to be less than 1.3% of the average deposition experienced during the past in the LFV. This percentage drops to 0.4% a few km away from Sumas Mountain. Although there are no official provincial or Canadian acid deposition criteria levels, historical measurements of deposition in the LFV indicate that deposition during some years has exceeded the criteria used by the U.S. Forest Service for the Pacific Northwest.

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[1] Reflects recent emissions revisions, see Editorial Note on page i

Air Quality Impacts - Ground Level Ozone

The LFV already exceeds current ambient air quality objectives for ozone. Under meteorological conditions typically associated with ozone exceedances, the facility emissions are predicted to result in a small increase in the ground level concentration (likely less than 2 parts per billion), but no perceptible increase in the period of time when the objective is exceeded. This increase is predicted to be limited to a few km around the facility.

It is unlikely that the facility emissions will cause additional exceedances of the new Canada Wide Standard for ground level ozone of 65 parts per billion (daily 8-hour maxima, based on the 4th highest annual measurement, averaged over 3 consecutive years, to be achieved by 2010) or result in an increase in ozone concentrations where the Canada Wide Standard is already exceeded (Hope) or where it is close to being exceeded (Chilliwack).

Air Quality Impacts - Particulate Matter

In the eastern portion of the LFV (Abbotsford-Hope), on a calendar day basis the B.C. PM10 ambient objective (50 micrograms per cubic meter, 24-hour average) is exceeded about 1.5% of the time. Model predictions indicate that the greatest PM10 impacts due to the emissions from the proposed facility occur on Sumas Mountain. Analysis of the predictions, in conjunction with historical PM10 measures, suggest little chance that the facility emissions will cause perceptible increases in exceedances of the PM10 objective or an increase in the peak values.

The new Canada Wide Standard for fine particulate (PM2.5) is 30 micrograms per cubic meter (24-hour average, annual 98th percentile averaged over 3 years). The only available PM2.5 data to compare to this statistic is at Chilliwack. The more inclusive parameter of PM10 is measured at both Abbotsford and Chilliwack, and the similarity in the two station's results for this latter parameter suggest that Chilliwack measurements for PM2.5 are likely indicative of Abbotsford levels. Calculations based on the Chilliwack data show that since 1995 the PM2.5 Canada Wide Standard statistic has not exceeded 18.2 micrograms per cubic meter. When the maximum predicted impact of PM2.5 due to the facility emissions are added to this level it is unlikely that the proposed facility emissions will result in exceedances of this new standard. This assumes that future background PM2.5 levels will remain similar to historical levels.

Air Quality Impacts- Human Health

Although air quality in the Lower Fraser Valley is generally quite good compared to other urban areas of similar size in Western North America, it is not without effects on human health.

Recent studies on air quality and health indicate that effects on human health begin to occur at concentrations of air pollutants well below current air quality objectives and standards. The few days per year where air quality objectives and standards are exceeded only add to a base of many more other days when morbidity and mortality impacts attributable to air pollution occur.

There are many different approaches that can be used to estimate air pollution related effects on health; each has its strengths and weaknesses. The assumptions used in making these estimates introduce some uncertainty into the results; precise estimates are not possible.

Regardless of the difficulties in making quantitative estimates of air pollution-related effects on health, it is clear that air pollution is capable of affecting health at far lower concentrations than previously believed and that air pollution is an important public health problem. Because air quality in the Lower Fraser Valley and many other parts of British Columbia is frequently in the range where effects on health have been demonstrated, any further worsening of air quality will increase risks to human health.

Since most of the recent work on air quality and health has been based on community studies where people are exposed to multiple pollutants, it is difficult to make pollutant-specific estimates of health effects. However, because of their widespread distribution, particulate matter (PM) and ground-level ozone are likely two of the most important air pollutants affecting human health in Canada.

An assessment of potential health impacts indicates that ambient ozone concentrations above 40 ppb in Abbotsford may already contribute 4 extra deaths per million population per year. For an exposed population of 100,000 this would mean 0.4 deaths/year. Potential impacts related to exacerbation of illnesses such as asthma and other respiratory conditions are orders of magnitude higher. An estimate of the incremental ozone-related health risk associated with S2GF emissions is not possible due to current limitations of ozone modelling.

An assessment of potential health impacts indicates that current ambient PM10 concentrations in the Abbotsford area may already contribute up to 6 additional deaths per million per year. For an exposed population of 100,000 this would mean 0.6 deaths/year. As is the case for ozone, potential impacts related to less severe health outcomes would be orders of magnitude higher. The predicted risk from the proposed facility is less than 1 additional death per million population per year on Sumas Mountain and considerably less than this in Abbotsford. In percentage terms, this would correspond to a 10% increase in risk on Sumas Mountain and a 1–2% increase in risk in Abbotsford.

Air Quality Impacts – Visibility (Regional Haze)

"Visibility" is a measure of how the air looks. It can be described as the maximum distance that an object can be perceived against a background sky. Visibility also can refer to the clarity of objects in the distance, middle or foreground. Visibility involves human perception and judgement. While no formal visibility standards have been adopted for the LFV, citizens have expressed concern about current visibility conditions.

The eastern portion of the LFV already experiences frequent periods of poor visibility, especially during the summer. Although assessing visibility impacts is difficult due to the uncertainties involved, an assessment was conducted for six lines of sight. Based on one year of model predictions and measurements, the fall is expected to experience the greatest visibility impacts due to the facility emissions. Over a year, worst-case estimates (the upper bound of a range of estimates) indicate that a slight reduction in visibility could be expected for up to 14 days per year due to emissions from the proposed facility. The view from Abbotsford to Sumas Mountain is expected to be most affected.

Oil-firing during the winter is expected to result in the greatest visibility impacts. A slight reduction in visibility could occur for every oil-firing day (maximum 15 days).

These are worst-case estimates and likely over-estimate the actual impacts, as they assume consistently good baseline visibility conditions.

Air Quality Impacts – Visibility (Plume Perception)

Based on a survey of operators of facilities that are similar to the proposed facility, the plume is not expected to be visible under gas-firing conditions (except for condensed water vapour with high humidity). One operator indicated that the plume was not visible even under oil-firing. Although this gives some assurance that the visual impact of proposed facility plume would be negligible, it is not absolutely certain whether the results of a survey of facilities operated elsewhere would apply here because local weather conditions affect plume visibility.

Air Quality Impacts - Cooling Tower Emissions

The water vapour emitted from the cooling towers can condense and have an additional visual impact. The average length of the condensed plume is expected to be less than 50 m, although there is a 1% chance that it will be 1 km or longer. Plume shadowing, ground level fog creation, icing of nearby roads, and the build-up of waterborne minerals are all expected to be minor and largely confined to within 100 m of the facility.

Greenhouse Gas Emissions

The facility will emit 2.2 million Tonnes per year of carbon dioxide. The related impact on the LFV region is not due to the direct influence of these substantial emissions but in their additive role to global climate change and the resulting impacts throughout the world.

1. INTRODUCTION

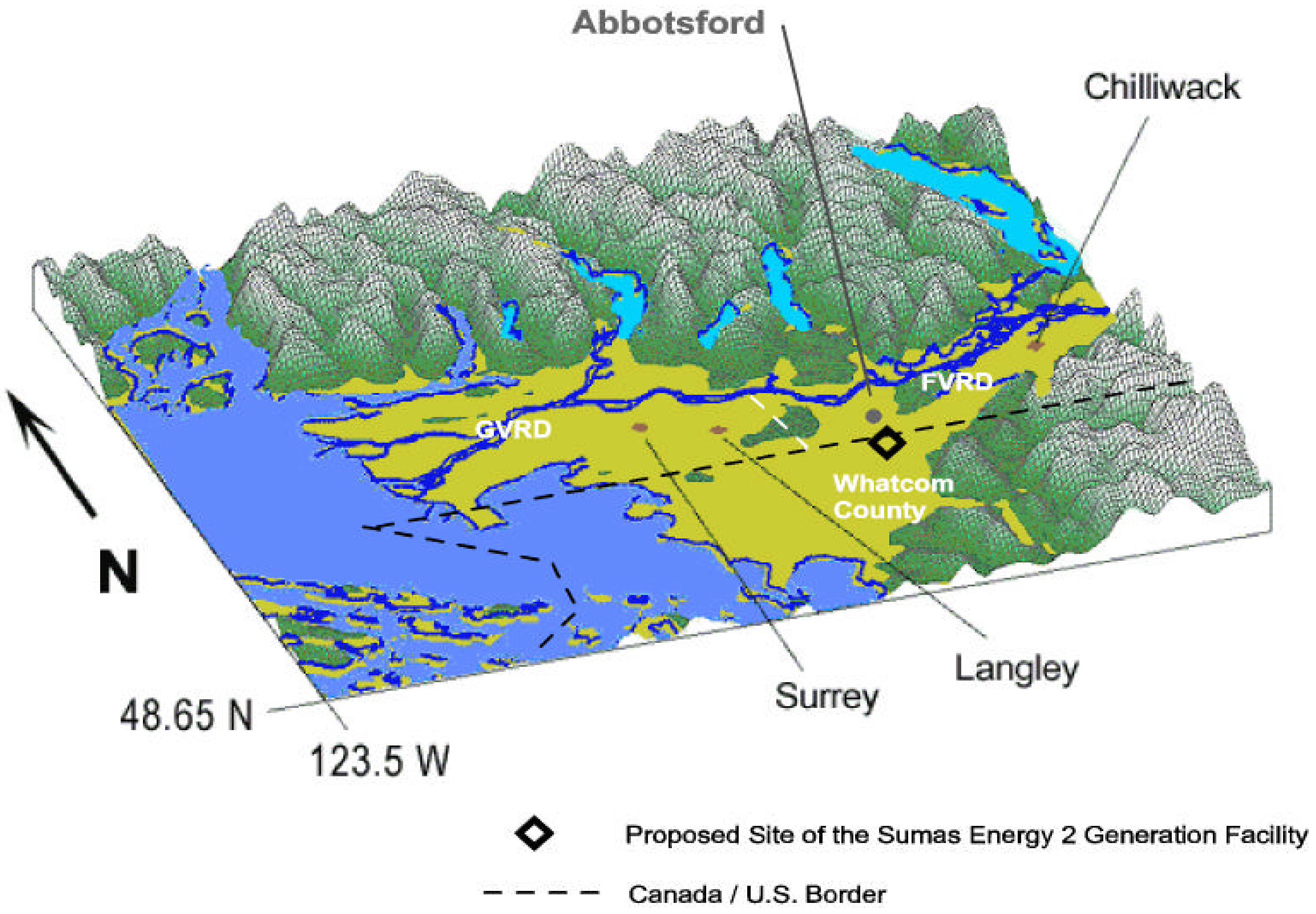
Sumas Energy 2, Inc. proposes to build a 660 MW natural gas-fired electrical power generation facility called the Sumas 2 Generation Facility (S2GF). It is proposed to be located south of Abbotsford in the State of Washington, less than 1 km from the Canada/U.S. border (see Figure 1). Nearby is the existing 125 MW Sumas generation facility.

Although located in the U.S., if built the S2GF will emit pollutants into the Lower Fraser Valley airshed, an area shared by the B.C. Lower Mainland and Whatcom County in the State of Washington. The Canadian portion of this airshed is under cooperative air quality management by federal, provincial and regional agencies as it is already prone to elevated levels of ground-level ozone, inhalable particulate and visibility impairment.

The Washington State Energy Facility Site Evaluation Council (EFSEC) co-ordinates all of the evaluation and licensing steps for siting major energy facilities in Washington. It has delegated authority from the U.S. Environmental Protection Agency (EPA) to issue permits under the Federal Clean Air and Clean Water Acts. The Ministry of the Environment, Lands and Parks and the other partner agencies involved in LFV airshed management have been interacting with EFSEC and the proponent regarding the air quality issues associated with this proposal.

An inter-agency committee was established to review the technical aspects of the air quality issues associated with S2GF and to ensure that the studies conducted by the proponent's air quality consultant (McCulley, Frick and Gilman, Inc. - MFG) were credible and relevant to B.C. decision makers. The inter-agency technical committee consists of members from the Ministry of the Environment, Lands and Parks, Greater Vancouver Regional District and Environment Canada – Pacific and Yukon Region. This air quality issues summary is based on a review of (i) analysis conducted by MFG (Application, 2000; Eaden, 2000 a,b), (ii) existing air quality conditions in the region, (iii) current ambient air quality objectives/standards, and (iv) independent analyses conducted by the inter-agency committee (as identified in the text).

Figure 1. Proposed Facility Site and Surrounding Area



2. PROJECT EMISSIONS

S2GF will have different operational modes, each with a corresponding emission rate. The maximum emissions occur under: a) base load with duct-firing and b) oil-firing. Oil-firing occurs when the gas supply is cut off during peak gas demand periods. This is anticipated to occur up to a maximum of 15 days/year during the winter. The pollutant emissions will be the greatest during oil-firing.

S2GF pollutant emissions include oxides of nitrogen (NOx), carbon monoxide (CO), sulphur oxides (SOx), volatile organic compounds (VOCs), inhalable particulate (PM10), carbon dioxide (CO2), ammonia and smaller amounts of other air contaminants. From an air quality perspective, it is usually most appropriate to compare S2GF emissions to total LFV airshed emissions rather than just to emissions in the local area (such as Abbotsford/Chilliwack area) because the periods of elevated ozone, particulate matter and visibility degradation (associated with smog) experienced in the eastern portion of the LFV during the summer are regional in nature. However, certain meteorological conditions and area topography can periodically lead to more localized impacts.

S2GF emissions of common contaminants and their contribution relative to all LFV sources are summarized in Table 1. The inter-agency committee calculated the percent contribution figures.

Table 1. S2GF Emissions Relative to 1995 LFV Emissions

Pollutant	S2GF Annual Emission [1] (Tonnes/year)	S2GF Annual Emissions Expressed as a Percentage of all (B.C. and Washington) 1995 LFV Sources
NOx as NO_2	214	0.33%
CO	92	0.03%
SO_2	41	0.29%
VOC	141	0.15%
PM10	202	1.48% (excludes road dust) [2]

Notes:

[1] Emissions conservatively based on a full 15 days of oil-firing (maximum anticipated) and 350 days with duct-firing (maximum electricity production). The NOx emission limit has recently been revised from 3 parts per million (ppm) to 2 ppm NOx. This means that the NOx emission rate is now 142 Tonnes/year. See Editorial Note on page i.

[2] Road dust is a significant contributor to the PM10 emissions in the LFV, however it is excluded from the calculation due to concerns that current road dust emission estimates are unrealistically high. With respect to *all* LFV PM10 emissions, the S2GF contribution of 1.48% would be a conservative estimate. If current road dust emissions estimates were included in the calculation, the percentage contribution of S2GF to LFV PM10 emissions would be less than 0.8%.

S2GF will emit many tonnes of pollutants into the LFV airshed and its relative contribution for these common contaminants to all emissions in the LFV is small – on a contaminant by contaminant basis, in the order of 1% or less. This illustrates the significance of other sources of pollution that contribute to existing periods of poor air quality across the entire LFV. S2GF emissions may make a larger contribution to the air quality in the communities which immediately surround the facility, as is discussed later.

Under both gas and oil-firing, there will also be residual emissions of air toxics. The short-term emission rates are listed in Tables 2a and 2b (Application, 2000).

Table 2a. Facility Toxic Air Pollutant Emission Rates for Gas-Firing – Base Load with Duct-Firing

Compound	Short-term Emission Rates (kg/h)
Acrolein[2]	0.018
Ammonia[2]	29.0
Ethylbenzene	0.054
Naphthalene[1]	0.320
Sulphuric Acid Mist[4]	0.128
Toluene[3]	0.296
Xylenes (m-,o-,p-isomers) [3]	0.062
Mercury[1]	0.001
Acetaldehyde[2]	0.182
Benzene[1]	0.320
Formaldehyde[2]	0.0228
PAHs[1]	0.0018
Arsenic[1]	0.0001

Notes:

[1] Forms or compounds containing this pollutant have been listed as a Canadian Environmental Protection Act (CEPA) Schedule 1 Toxic

[2] Intent to Declare as Toxic under CEPA after Priority Substances List 2 Assessment

[3] Assessed as Not Toxic under CEPA after listing on Priority Substances List 1

[4] Not listed on CEPA Schedule 1 or Priority Substances Lists 1 or 2

Table 2 b Facility Toxic Air Pollutant Emission Rates – Oil-Firing

Compound	Short-term Emission Rates (kg/h)
Ammonia[2]	22.6
Chromium[1]	0.011
Lead[1]	0.0174
Manganese	0.698
Mercury[1]	0.001
Naphthalene[1]	0.05
Selenium[4]	0.0372
Sulphuric Acid Mist[4]	17.0
Acetaldehyde[2]	0.05
Arsenic[1]	0.0128
Benzene[1]	0.088
Beryllium[4]	0.0006
Cadmium[1]	0.0052
Chromium VI[1]	0.00018
Dioxins[1]	5.4E-07
Formaldehyde[2]	0.372
Furans[1]	1.5 E-06
Nickel[1]	0.140

Notes:

[1,2,3,4] See footnotes under Table 2 a.

3. EMISSION CONTROL TECHNOLOGY

S2GF will burn natural gas to produce electricity. The burning of natural gas produces nitrogen oxides (NOx) as well as a variety of other compounds. NOx is a key ingredient in the formation of ground-level ozone and inhalable particulate. It also contributes to both visibility degradation and acid deposition. As such, for these kinds of facilities, NOx is traditionally the focus of emission control methods.

3.1. S2GF Emission Control Technology

As part of the permit approval process, the proponent conducted a *Best Available Control Technology* (BACT) analysis. This involves a review of other facilities of this type, the emission control technology, and the state and local emission limits. On the basis of the BACT review, S2GF proposes to use modern gas-fired turbines in combination with a post-combustion NOx control device called Selective Catalytic Reduction (SCR) that will result in NOx emission of 3 ppm[1]. This technology employs a catalyst as well as the injection of ammonia into the exhaust gas to strip out NOx. One of the disadvantages of this control technology is the emission of residual ammonia into the atmosphere (called ammonia slip). This can have direct effects on the environment and can contribute to the formation of inhalable particulate.

In an effort to reduce emissions of carbon monoxide, an oxidation catalyst is also proposed. Good combustion practices will be used to control emissions of volatile organic compounds and other air contaminants.

Although SCR is widely used for facilities of this type, there is an emerging technology called SCONOX that can achieve NOx reduction without the use and emission of ammonia. It also can reduce CO and VOC emissions, something not possible with SCR alone.

3.2. Comparison to Other Gas-Fired Power Generation Facilities in B.C.

The combination of modern turbine and emission control technology means that S2GF is more efficient and generally cleaner than other similar facilities in B.C. Burrard Thermal is an older gas-fired power generation plant in the LFV that has just recently completed a six year program for installing SCR control technology on all its boilers. Gas-fired boilers produce steam that is used to turn the turbines. If natural gas is unavailable, other hydro-based power resources in the B.C. Hydro integrated network can be used; thus there is no need for oil as a back up fuel. The Burrard Plant discontinued the use of oil 20 years ago.

[1] The NOx emission limits have been revised downward from 3 ppm to 2 ppm. The current assessment is based on a NOx emission limit of 3 ppm. See the Editorial Note on page i.

ICP (Campbell River) is a gas-fired, electrical generation facility currently under construction. It shares many similarities with S2GF. Gas combustion produces hot exhaust that is used to turn a turbine. The exhaust is further used to produce steam that turns yet another turbine (steam turbine). This two-step process is called combined-cycle technology. More electricity can be generated from S2GF and ICP than Burrard Thermal for the same amount of natural gas. However, unlike S2GF, the ICP facility does not have SCR or an oxidation catalyst system.

ICP is unique in that it is a cogeneration facility. As the steam exits from the steam turbine, it is sent to the adjacent Elk Falls paper mill. This new source of process steam means that the mill can shut down two wood/oil fired burners and reduce the use of a gas-fired boiler. Thus, the availability of this steam reduces the mill energy requirements and air emissions.

Table 3 compares the emissions for each of these facilities. The figures for S2GF are based on information supplied by the proponent. The inter-agency committee produced the Burrard data.

Table 3. Potential Maximum Emissions (for ICP and S2GF) and Average Emissions (Burrard Thermal)

Facility	Generation Capacity (MW)	Emissions (Tonnes/Year)				
		CO	VOC	SOx	PM	NOx
ICP (Campbell R) [1]	245	912	169	214	70 [4]	612
Burrard Thermal [2]	960	49[2]	34[2]	19[2]	52[2]	126[2]
S2GF [3]	660	92	142	41	202	214

Notes:

[1] ICP potential maximum emissions based on permit application information. No oil-firing conditions included, although there is a potential of a maximum of 10 oil-firing days/year.

[2] For Burrard Thermal these emissions represent the average from 1997 to 1999. An average is provided since the plant only provides a supportive role in the electricity grid and its potential operation varies from year to year. The permitted or theoretical maximum potential emissions from the plant are about four times higher than the average values shown here.

[3] S2GF potential maximum emissions assume 15 days/year oil-firing (maximum anticipated) and 3 ppm NOx limit. With the revision to achieve a 2 ppm NOx limit, the NOx emission rate is now estimated to be 142 T/y. See Editorial Note page i.

[4] PM emissions can be expressed as “front catch” and “back catch” PM, terms that refer to the PM stack sampling methodology and how PM emissions are reported. The ICP PM emissions represent only the front catch, whereas the Burrard Thermal and S2GF represent the sum of both front and back catch.

Comparisons between these facilities are complicated by the fact that they have different power generation capacities and different primary operating roles. An alternate facility comparison is on the basis of emissions per unit energy produced (Table 4).

Table 4. Emissions Per Unit of Electricity Produced

Gas-Fired Power Generation Facility	Max Annual Electricity Production (GWh)	Emissions Per Unit of Electricity Produced (kg/GWh)				
		CO	VOC	SO2	PM	NOx (as NO2)
ICP (Campbell R)	2000	457	85	107	35 [1]	306
Burrard	7000	31	22	10	30	70
S2GF	5800	16	25	7	35 [2]	37[3]

Notes:

[1] See Note 4 above regarding ICP PM emission estimates.

[2] Based on turbine manufacturer emission specifications which are regarded as conservative. A full 15 days/year oil-firing scenario is factored into these estimates.

[3] With the revision of the NOx emission limit from 3 to 2 ppm (see Editorial Note on page i), the NOx emissions per unit of electricity produced for S2GF would now be approximately 25 kg/GWh.

The two pollutants of primary interest are NOx and PM. NOx is a critical pollutant to control due to its direct impacts, and its involvement in the formation of ground level ozone, acid deposition, inhalable particulate (PM10) and visibility degradation.

Although Burrard and S2GF both have SCR to control NOx emissions, the S2GF emissions/GWh are lower than Burrard as S2GF has new turbine technology and is more efficient than Burrard. However, maximum S2GF emissions of NOx on a Tonnes/year basis would exceed typical Burrard levels.

With respect to PM10, Tables 3 and 4 indicate only *primary* (or directly emitted) PM10. There is also a *secondary* PM10 component that should be included when quantifying the *total* PM10 emissions. Secondary PM is created when gaseous NOx and SO2 transform into PM10 through complex atmospheric processes. This complexity makes it difficult to estimate the amount of secondary and total PM formation.

Although the Burrard primary PM10 emission is less than S2GF on a kg/GWh basis, the NOx and SO2 are higher than S2GF. This means that Burrard emissions on a kg/GWh basis could produce more secondary PM10 than S2GF (assuming identical atmospheric conditions at both facilities). Thus it is possible that the *total* PM10 (primary + secondary) emissions for Burrard may be the same or higher than S2GF if the two facilities were ever operating at the same electrical generating capacity.

There are significant ammonia emissions from S2GF and Burrard due to the SCR control process. Ammonia can have direct impacts on the environment and it can react with NOx and SO2 to create PM10. For S2GF a conservative estimate indicates an annual emission of 250 T/y. Based on a 1990 emissions inventory (Levelton, 1995), this represents about 1.6% of the total ammonia emissions in the LFV. Burrard maximum permitted ammonia emissions are estimated to be 171 T/y, but actual stack sampling data indicate that under maximum power generation, ammonia emissions will be 1/7th the permitted amounts. The ammonia impacts are discussed in the Air Quality Issues section (Section 4).

3.3. Summary

- On the basis of the BACT review, the proponent proposes to use modern gas-fired turbines in combination with SCR control technology. In addition, an oxidation catalyst is proposed to achieve reductions of CO. This technology is generally cleaner than has been used to date for similar facilities in B.C.

- NOx emissions per unit of electricity produced from S2GF are about one tenth those of ICP and about half those of Burrard Thermal. On an annual tonnage basis, the maximum S2GF NOx emissions fall between the ICP and typical Burrard emissions. NOx is a critical pollutant to control due to its direct impacts, as well as its involvement in the formation of ground-level ozone, acid deposition, inhalable particulate and visibility degradation.

- The PM10 contribution is best characterized by both the primary and secondary PM attributed to the facility. Although primary Burrard PM emissions/GWh are lower than S2GF, due to its greater NOx and SO2 emissions it has a greater potential to create secondary PM on those occasions when the two facilities are operating at the same electrical generating capacity. On an annual tonnage basis, the maximum S2GF PM emissions fall between the ICP and typical Burrard emissions.

- The ammonia emissions associated with the SCR control technology proposed for S2GF are significant.

4. AIR QUALITY ISSUES

What kind of impact will S2GF have on local air quality (within 10 km of the plant), and on regional air quality in the LFV?

The answer to this question lies partly in the predictions produced by air quality computer models. These models solve mathematical equations that describe the behaviour of the S2GF emissions in the atmosphere. Computer models are used by regulatory agencies around the world to quantify the air quality impacts associated with emissions. They allow a consideration of "what if" scenarios and as such their application to assist decision-makers in assessing the air quality implications of a new source are invaluable. However, these models attempt to simulate extremely complex atmospheric processes and can produce estimates with large uncertainty if they are not applied correctly or the model inputs are of poor quality.

In order to provide assurance that the models were producing usable predictions, the U.S. regulatory agencies and the Ministry of Environment, Lands and Parks approved the air quality models used by the consultant (MFG) and provided guidance as to their proper application. These models were ISC – Industrial Source Complex and CALPUFF, a gridded photochemical model suitable for regional modelling. Environment Canada also applied a sophisticated regional model (UAM – the Urban Airshed Model, also used by the U.S. EPA and California Air Resources Board) to examine ground-level ozone changes that would occur as a result of S2GF emissions.

One of the key model inputs is the emission rate. S2GF will have different operational modes, each with a corresponding emission rate. Since predictions of the maximum potential impacts are of interest, maximum emissions rates were input to the models. It is assumed that these maximum rates apply for every hour of the simulation period (at least one year), even though these rates may only occur for a few days. This provides some assurance that the model predicted concentrations are conservative.

For S2GF, there will be two operating conditions under which maximum emissions occur: a) operation at maximum generation capacity (duct-firing) and b) oil-firing. It is these emission scenarios that were the focus of the modelling studies.

4.1. Criteria Pollutants (SO2, NO2, CO) and Air Toxics

Tables 5, 6 and 7 provide the maximum model-predicted concentrations for a variety of pollutants and air toxics. The predictions were based on the results of the ISC model, which was run for a 5-year period using meteorological data collected at Abbotsford airport. As well, air quality monitoring information in the

Table 5. Predicted Maximum Ambient Concentrations Of SO2, NO2 And CO In British Columbia Due To Emissions From S2GF, And Comparison With Canadian Objectives – Background Levels Included

Air Contaminant	Averaging Period	Predicted Maximum Ambient Concentration from S2GF [1] (µg/m^3)	Maximum Background Level [2] (µg/m^3)	Total Maximum Ambient Concentration (µg/m^3)	Most Stringent Canadian Objective (µg/m^3)	Total Maximum Concentration as a Percentage of Objective (%)
Sulphur Dioxide (SO_2)	1-hour	57	37	94	450	21
	3-hour	35	28	63	375	17
	24-hour	11	9	20	150	13
	1-year	0.06	2	≅2	25	8
Nitrogen Dioxide (NO_2)	1-hour	51	117	168	400	42
	24-hour	9	62	71	200	36
	1-year	0.44[3]	33	≅33	60	55[3]
Carbon Monoxide (CO)	1-hour	31	7,760	7,791	14,300	55
	8-hour	12	3,419	3,431	5,500	62

[1] There are higher maximum concentrations occurring in Washington State. All the short-term maxima occur under oil-firing.

[2] The maximum background level is the maximum concentration measured at the Abbotsford monitoring station between 1996 - 1998.

[3] With the revision of the NOx emission rate to 1/3 lower that originally proposed, the values should be reduced by about 1/3. See Editorial Note on page i. This applies to annual NO_2 concentrations only since the maximum short-term concentrations occur under oil-firing.

Note: With the exception of the maximum 1-hour averaging period, the maximum concentrations are located at the same receptor on Sumas Mountain (elevation 180 m, 6 km NNE of S2GF). The maximum 1-hour concentration occurs on a small hill on the B.C. side of the border, 800 m N of S2GF. These 1-hour maxima were predicted to occur once in five years.

Table 6. Predicted Maximum 24-Hour Average Ambient Concentrations Of Toxic Air Contaminants In British Columbia Due To Emissions From S2GF, And Comparison With Washington State Acceptable Source Impact Level (ASIL) Values - Background Levels Not Included When Using ASIL Values

Air Toxic	Predicted Maximum[1] 24-hour Average Concentration from S2GF (µg/m^3)	Washington 24-hour Average ASIL (µg/m^3)	Maximum Concentration as a % ASIL	British Columbia Objectives (µg/m^3)[2]
Acrolein	0.0033	0.02	16.5	
Ammonia	5.2	100	5.2	
Chromium	0.0014 *	1.7	<0.1	0.05-0.1
Ethylbenzene	0.0099	1000	<0.1	
Lead	0.0022 *	0.5	0.4	1.0-2.5
Manganese	0.0891 *	0.4	22.3	
Mercury	0.0002	0.17	0.12	0.1-1.0
Naphtalene	0.0578	170	<0.1	
Selenium	0.0048 *	0.67	0.7	0.1-1.0
Sulfuric Acid Mist	2.17 *	3.3	65.8	
Toluene	0.0536	400	<0.1	
Xylenes	0.011	1500	<0.1	

* Occurs under oil-firing.

[1] There are higher maximum concentrations occurring in Washington State.

[2] From Pollution Control Objectives for the Mining, Smelting and Related Industries of British Columbia 1979. Averaging times are up to the discretion of regional managers. However, for the purpose of this evaluation, they are taken to be 24-hour averages.

Table 7. Predicted Maximum Annual Toxic Air Pollutant Concentrations Due To Emissions From S2GF

Pollutant	Maximum Annual Concentration in B.C. from S2GF (μg/m^3) [1]	Annual Washington ASIL (μg/m^3)	Maximum Annual Concentration as a % of ASIL
Acetaldehyde	3.03 E-03	4.50 E-01	0.67
Arsenic	8.04 E-06	2.03 E-04	4.0
Benzene	5.77 E-03	1.20 E-01	4.8
Beryllium	2.52 E-07	4.20 E-04	0.06
Cadmium	2.47 E-06	5.60 E-04	0.44
Chromium VI	6.58 E-08	8.30 E-05	0.08
Dioxins	2.58 E-10	3.00 E-08	0.86
Formaldehyde	5.85 E-04	7.70 E-02	0.76
Furans	7.13 E-10	3.00 E-08	2.4
Nickel	6.58 E-05	2.10 E-03	3.13
Polynuclear aromatic hydrocarbons	3.33 E-05	4.80 E-04	6.9

[1] Annual concentrations based on a full 15 days of oil-firing and 350 days gas-fired with supplemental duct burners.

Abbotsford area provided estimates of the existing levels experienced in the region. The maximum measured levels are also listed along with the most stringent Canadian Air Quality Objective, and in the case of air toxics, the relevant Washington criteria levels and applicable B.C. Objectives.

The tables indicate that for NO2, SO2, CO and residual toxics, predicted impacts due to S2GF emissions are below the most stringent Canadian, B.C. and Washington State criteria.

4.1.1. Summary

- The impact due to the S2GF emissions of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and CO to the existing air quality is not expected to result in any exceedances of the most stringent B.C. or national air quality objectives for these pollutants.

- The impacts of S2GF emissions are not expected to cause exceedances of the short and long-term Washington State criteria or applicable B.C. objectives for air toxics.

- The highest short-term maximum concentrations for NO2, SO2 and CO and several air toxics occur under oil-firing.

4.2. Acid Deposition

The nitrogen and sulphur oxides (and the resulting nitrates and sulphates that form in the atmosphere) emitted by S2GF will deposit on surfaces, either through direct surface contact (dry deposition) or through precipitation (wet deposition). The fraction of wet and dry to the total deposition depends on factors such as precipitation amounts and surface characteristics. There are natural sources of these compounds, thus depositions occur even in remote areas. Depositions of these compounds are linked to acidification of the water and soil and are thus referred to as acidic deposition.

Recent measurements (Feller, 2000) of annual deposition at the University of British Columbia research forest (just north of Haney) range from 2.5 to 7.0 kilograms per hectare per year (kg/ha/y) for nitrogen (average 4.4) and 2.3 to 7.9 kg/ha/y for sulphur (average 5.2). The measurement methodology provides the wet deposition component and some portion of the dry deposition component (although the exact fraction is not known). For this discussion it is assumed that these numbers represent an estimate of total deposition.

There are no official Canadian or B.C. deposition threshold values (critical loads) to help address the acceptability of current levels. Studies in Eastern Canada showed that critical loads for lakes varied from 2.67 to 6.67 kg/ha/y sulphur (wet deposition only) (FPRMCC, 1990). Alberta has adopted critical loading criteria that use the Potential Acid Input method to express acid deposition in kiloequivalents of H ion/ha/y (TLS, 1999). Areas of high, moderate and low sensitivity to acid deposition in Alberta are identified as well as the corresponding critical loads.

The critical loading levels applicable for Eastern Canada or Alberta may have little relevance for coastal B.C., as the values depend on the characteristics of the receiving environment. Perhaps more relevant to the LFV are levels used by the U.S. Forest Service for the Pacific Northwest, where levels of less than 5 kg/ha/y nitrogen are considered protective of terrestrial ecosystems and less than 3 kg/ha/y sulphur for sensitive lakes.

Model predictions indicate that the maximum annual deposition due to S2GF emissions will be 0.05 kg/ha/y nitrogen and 0.07 kg/ha/y sulphur. These maxima occur over a small area on top of Sumas Mountain.

This suggests that the deposition increase due to S2GF emissions measured are predicted to be less than 1.3% of average current values for both nitrogen and sulphur. This percentage drops to less than 0.4% at a distance of a few km from the maximum impact area on Sumas Mountain.

4.2.1. Summary

- The predicted incremental contribution due to S2GF emissions relative to historical average deposition levels is small, and is limited to an area on Sumas Mountain.

- The historical LFV deposition measurements indicate some years where depositions have been higher than the U.S. Forest Service deposition criteria for terrestrial ecosystems and sensitive lakes in the Pacific Northwest.

4.3. Ground-Level Ozone

The oxides of nitrogen and other compounds called volatile organics that are emitted from S2GF can undergo complex chemical reactions and form ground-level ozone under conditions of elevated temperature and sunlight. Ozone is also produced from natural processes in the atmosphere, and thus ground-level ozone occurs in remote areas of the world. Two issues were considered in assessing the related influence of S2GF: the impact on meeting air quality objectives and standards, and the impact on public health which can occur below these levels.

During the summer, the LFV can exceed the current ambient air quality objective for ozone. The LFV was designated in the Canadian Council of Ministers of the Environment NOx/VOC Management Plan (1990) as one of three regions in Canada with ozone problems that warrant remedial actions (e.g. Air Care and the GVRD Air Quality Management Plan). There are concerns that the emissions from S2GF will aggravate this situation.

4.3.1. Comparison to The Current Ambient Air Quality Objective

The most stringent ozone objective which has historically been used for ozone assessments is the Canadian national ambient air quality maximum desirable objective (1-hour average) level of 51 parts per billion. (This objective is the GVRD goal for air management). In the eastern Lower Fraser valley, approximately 1% of the measurements exceed this objective each year – a significant decrease from the 1980’s.

In order to determine the impact on ground-level ozone concentrations as a result of S2GF emissions, Environment Canada applied a sophisticated model for a select set of meteorological conditions that are considered to be associated with a typical summer episode period. The results show that close to S2GF the ozone concentrations might be up to 5 parts per billion higher but more likely will be less than 2 parts per billion higher under episode conditions. Beyond 5 kilometres from the facility, the increases drop off rapidly to values less than 0.5 parts per billion higher. The duration of ozone episodes does not increase.

4.3.2. Comparison to The New Canada Wide Standard

A new air quality standard for ground-level ozone was approved by the Canadian Council of Ministers of the Environment (CCME) in June 2000 through the Canada Wide Standards (CWS) process. The original air quality objectives have not been rescinded; discussions on their role and use are underway. An assessment was conducted by the inter-agency committee to determine the implications of the S2GF emissions relative to this new standard.

The Canada Wide Standard represents a balance between achieving the best health and environmental protection possible and the feasibility and costs of reducing the pollutant emissions that contribute to ground-level ozone in ambient air. It is recognized that the CWS is not fully protective of human health. All air quality jurisdictions are thus encouraged to take additional actions to reduce emissions, where possible, to protect public health.

The new CWS for ozone is 65 ppb (daily 8-hour maxima, based on the 4th highest annual measurement, averaged over three consecutive years, to be achieved by 2010). Based on analysis of LFV data collected between 1994-1998, the CWS was exceeded in Hope. At Chilliwack for 1997 and 1998 the analysis showed that the ozone was within 10% of the CWS. Other areas of the LFV which previously exceeded the current ozone objective did not exceed the CWS.

Since there are no present ozone CWS exceedances in Abbotsford, and the predicted ozone increase due to S2GF is small and limited in time and space, it is unlikely that the S2GF emissions will result in exceedances of the new ozone CWS in either Abbotsford or Chilliwack.

4.3.3. Ozone Health Impact Assessment

It is now recognized that ozone-related health effects occur at levels below current and proposed air management levels (FPWGAQOG, 1999a). While there is good evidence to link ozone to increases in respiratory illness, including hospitalization, there is controversy whether the association between ozone and mortality found in some studies may be due to other gaseous air pollutants that go up and down along with ozone. Evidence of ozone-related effects on health has been found for concentrations as low as 20 ppb for mortality and 25 ppb for hospitalizations due to respiratory illnesses (both 1-h daily maximum concentrations). These concentrations should not be regarded as thresholds or ‘no-effect’ levels, as there is insufficient evidence to conclude whether these effects are, or are not, associated with lower ozone concentrations.

Ozone observations taken in rural remote areas (background levels – far from any human caused emissions) indicate daily maxima (May-September) in the range of 35-48 ppb (CCME, 1997). Hence, even background or naturally occurring levels of ozone may be in the range where effects on health have been found. Sources of naturally-occurring ground-level ozone include transport of stratospheric ozone to the surface and reactions of naturally-occurring oxides of nitrogen and volatile organic compounds in sunlight.

Since there is little that can be done to control background levels, two levels of risk are identified: total risk and manageable risk. Total risk refers to all risk calculated for concentrations above the reference level. Manageable risk refers to that portion of the risk above background that regulatory agencies may have some influence on (where background is assumed to be 40 ppb). Calculations were undertaken by the committee to assess the health impacts of ozone in the LFV. These calculations reflect manageable risk and not total risk, which would be substantially higher.

There are various approaches used to estimate health effects resulting from air pollution. The different approaches that can be used have different strengths and weaknesses and none of them are able to produce precise estimates. In the current analysis, excess mortality and morbidity (i.e. illness) due to ambient concentrations of ozone in the Abbotsford area were determined by following methodologies used by the Federal Provincial Working Group (FPWGAQOG, 2000). This entails first obtaining the annual cumulative exposure above the assumed background concentration over an ozone season (May-September), based on data collected in Abbotsford.[1] This value is then multiplied by the incidence of health impacts per ppb per million population (or concentration-response coefficient). (FPWGAQOG, 2000; Stratus Consulting, 1999), and normalized over a 153-day period (ie., the ozone season). Inherent assumptions involved in using this methodology are that the national end-point statistics (such as percentage of population with asthma) and that the recommended concentration-response coefficients are applicable to the LFV. A report by Brauer et al prepared for the Lower Mainland medical health officers (anticipated for release this fall) will provide an evaluation of the air quality-related health effects based on actual LFV data.

Based on this analysis, it appears that excess mortality and morbidity due to ozone concentrations above 40 ppb are already occurring in the Abbotsford area, even without the addition of S2GF emissions or other sources (Table 8). Between 1992-1999, annual mortality risks due to ozone exposure above 40 ppb averaged 4 extra deaths per million population per year. For an exposed population of 100,000 this would mean 0.4 deaths/year. Estimated impacts

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[1] Although the Federal Provincial Working Group recommended reference levels for mortality and respiratory hospitalizations only, they found sufficient evidence to conclude an association between ambient ozone levels and several other health end-points (FPWGAQOG, 1999a). They assumed that the methodology used to calculate manageable risk due to mortality and respiratory hospitalizations was also valid for these additional health end-points in subsequent risk calculations (FPWGAQOG, 2000). This approach appears to be reasonable, as most studies report a continuum of effect through all ambient levels (even below reference levels).

related to less adverse health end-points such as asthma symptom days, minor restricted activity days, and net days with acute respiratory symptoms are orders of magnitude higher than mortality estimates.

Table 8. Summary Of Estimated Mortality And Morbidity Rates Due To Ozone Exposure Over 40 ppb In Abbotsford (Manageable Risk)

Ozone	**Net Health Impacts (per million pop. per year)**					
				Symptom Days of Morbidity		
	Mortality	**RHAs**	**NERVs**	**ASDs**	**MRADs**	**NARSs**
Current Ambient	4.2	8.4	26	6,400	25,000	48,000

Acronyms used to describe health end-points are defined as follows:

- RHAs – respiratory hospital admissions,
- NERVs – net emergency room visits (excluding RHAs),
- ASDs – asthma symptom days, where notable increases in asthma symptoms such as shortness of breath, wheezing, and/or increased use of medication,
- MRADs – minor restricted activity days, in which some but not all activities are restricted because of illness, and
- NARSs – net days with acute respiratory symptoms such as chest discomfort, coughing, wheezing, sore throat, head cold, chest cold, sinus trouble, hay fever, headaches and doctor-diagnosed flu.

In order to calculate the incremental ozone-related health risks due to S2GF emissions, the photochemical model must be run for a complete year (rather than just for a few days, as described in Section 4.3.1). This is presently not possible due to the huge effort required to develop the detailed input files for this extended period. The results of the ozone modelling study for a limited episode suggests that the incremental ozone-related health risks due to S2GF emissions are likely to be small and limited to a few kilometers around the facility. Applying a 2 ppb ozone increment (such as is calculated in Section 4.3.1 for a few day period) uniformly over a complete ozone season would increase mortality and morbidity risks by 20% within a few km of the facility. Such an extrapolation is highly speculative and thus more detailed estimates of incremental ozone health impacts have not been attempted here.

4.3.4. Summary

- Approximately 1% of the ozone measurements in the eastern LFV exceed the most stringent Canadian objective for this contaminant.

- Environment Canada modelling indicates that S2GF emissions are expected to result in a small increase in the intensity, but no increase in duration of common ozone episodes. The small increase in ozone concentrations is limited to a few kilometres around S2GF.

- Analysis by the inter-agency committee indicates that there have been no exceedances of the new ozone CWS in the Abbotsford area for the analysis period (1994-1998). Given the limited magnitude and area of the predicted ground level ozone impact due to S2GF emissions, it is unlikely that S2GF will result in an exceedance of the new ozone CWS.

- An assessment of potential health impacts indicates that ambient ozone concentrations above 40 ppb in Abbotsford may already contribute 4 extra deaths per million population per year. For an exposed population of 100,000 this would mean 0.4 deaths/year. Potential impacts related to exacerbation of illnesses such as asthma and other respiratory conditions are orders of magnitude higher.

- An estimate of the incremental ozone-related health risk associated with S2GF emissions is not possible due to current limitations of ozone modelling.

4.4. Particulate Matter

Particulate matter (PM) refers to microscopic solid and liquid particles, other than pure water, that are found in the atmosphere. Those particles less than 10 micrometres in diameter are referred to as PM10 (inhalable particulate – small enough to be inhaled into the lungs), and those less than 2.5 micrometres are referred to as PM2.5. PM impacts due to S2GF emissions are a result of direct PM emissions, and also PM formed in the atmosphere from emitted gases (secondary PM). As was the case for the ozone analysis, two issues were considered in assessing the related influence of S2GF: the impact on meeting air quality objectives and standards, and the impact on public health which can occur below these levels.

Monitoring data indicate that PM10 concentrations in the eastern end of the LFV periodically contribute to periods of poor air quality (GVRD/FVRD, 1999). Given the PM10 emissions from S2GF, and the gases emitted that could transform into PM10, there is a potential for the S2GF emissions to aggravate this situation.

The assessment of the PM10 impacts involved two different air quality models (ISC and CALPUFF). The model output was used with existing Abbotsford PM data to examine two aspects of the PM impacts: relative to the current B.C. air quality objective and relative to the new Canada Wide Standard (CWS) for PM2.5.

4.4.1. The PM10 Prediction Methodology – Two Air Quality Models

The ISC model was applied to simulate S2GF PM10 impacts over 5 years. ISC is commonly used to assist regulators understand the air quality implications of an industrial source. Although a valuable tool, it does not account for the formation of secondary PM and does not handle light wind conditions. This could lead to an under-prediction of PM10 concentrations. However, the model has other assumptions (such as its treatment of terrain interaction with the plume) that can result in an over-prediction bias. ISC was used as its relative simplicity allowed it to provide long-term statistics needed for the CWS assessment.

The other model, CALPUFF, is more sophisticated in that it accounts for the formation of secondary PM and light wind conditions. In theory, it should provide a better prediction of PM10 than ISC. However, due to its complexity the CALPUFF model demands considerable computer resources. For practical reasons, CALPUFF simulations of S2GF PM10 impacts were limited to a 1-year period.

PM10 predictions from both models were compared for two locations: downtown Abbotsford and the top of Sumas Mountain. Both models predicted maximum impacts on Sumas Mountain. CALPUFF does in fact predict higher concentrations than ISC, although the differences are quite small. For example, the maximum PM10 24-hour average concentrations are 8.2 μg/m^{3}for CALPUFF and 7.4 μg/m^{3}for ISC. This finding suggests that the long-term statistics required for the CWS analysis can be based on the 5-year simulation generated by ISC.

4.4.2. Comparison to the B.C. Objective

The B.C. PM10 ambient objective is 50 μg/m^3 (24 hour average). On a calendar day basis, Abbotsford monitoring data from 1996 to 1998 indicate that exceedances of this objective occur about 1.5% of the time.

The maximum predicted PM10 concentration in B.C due to S2GF emissions is predicted to occur on Sumas Mountain. For worst-case oil-firing conditions, the maximum 24-hour concentration is 8 μg/m^3 (one day during the winter) and for the more common gas-firing condition, the maximum is 6.2 μg/m^3 (one day during the fall).

The predicted PM10 impacts for areas surrounding Sumas Mountain are far lower. For example, the 24-hour PM10 impacts for downtown Abbotsford are predicted to be on the order of 1 μg/m^{3}under worst-case oil-firing conditions and 0.5 μg/m^{3}under maximum gas-fired (duct-firing) emission conditions. Both of these maxima are less than the detection limits of current PM10 monitoring methods and correspond to 1% and 2% of the PM10 objective, respectively. As such the impacts of S2GF on the exceedance frequencies and magnitude of PM10 concentrations are expected to be minimal for the City of Abbotsford.

For Sumas Mountain, the predicted 24-hour maxima (8 μg/m^3 and 6.2 μg/m^3) correspond to approximately 15% of the PM10 objective. The inter-agency committee examined the wind direction during occasions of elevated PM10 levels. The wind analyses indicated that during the summer and fall, hourly winds were at times blowing from the southwest during the 24-hour period of elevated (greater than 43 $\mu g/m^3$) 24-hour PM10 concentrations. If it is assumed that the PM10 levels on Sumas Mountain are comparable to those measured at Abbotsford, this suggests that S2GF emissions could be carried to Sumas Mountain and contribute to exceedances of the objective under these conditions. Thus it is possible that emissions from S2GF might cause an increase in both the exceedance frequency of the PM10 objective and the magnitude of the higher PM10 levels.

In order to assess the likelihood of this possibility, the measured PM10 levels (at Abbotsford) were added to the predicted values due to S2GF emissions for the same time. This approach is essentially an estimate of the PM10 levels that would have prevailed in the past had S2GF been in operation then. This was conducted for the CALPUFF simulation period of April 1998 to May 1999. Based on this approach, had S2GF been in operation during April 1998 to May 1999, the model estimates indicate that its emissions would not have increased the number of exceedances of the PM10 objective at Sumas Mountain (nor at Abbotsford). Also, S2GF's contribution to the PM10 levels during the exceedances would not have been more than 1%.

An alternate presentation of the data helps provide further insights. This involves adding the predicted maximum 24-hour impacts due to S2GF emissions to the measured 24 hour average concentration for the same date and time of the predicted maximum impact. On these days, had S2GF been in operation during April 1998 to May 1999, the model estimates indicate that its emissions would not have caused any exceedances of the PM10 objective at either Sumas Mountain or Abbotsford (Table 9). Also, the S2GF contributions to the total PM10 on these days would have been on the order of less than 20%. This analysis was based on calendar day PM10 averages. If rolling averages were applied, the modelled and observed PM10 values would be higher. However, given the low total PM10 values relative to the objective, even if rolling averages were applied it is still not likely that the S2GF emissions would result in an increase in exceedances at Abbotsford.

Table 9. Seasonal Maximum 24-Hour PM10 Predicted by CALPUFF

Period	Day	Max. Predicted 24 Hour PM10 (µg/m^3) due to S2GF (Sumas Mtn)	Simultaneous Obs. PM10 (µg/m^3) @ Abbotsford (background)	Total PM10 (µg/m^3) (S2GF+ Background)	Predicted S2GF Contribution to Total PM10 (%)
Spring 98	4/23/98	2.9	15	18	16
Summer 98	7/22/98	5.2	25	30	17
Fall 98	9/23/98	6.2	27	33	19
Winter 98/99	1/4/99	3.4	25	28	12
Oil-Fired 98/99	1/4/99	8.2	25	33	25

The above PM10 analysis has focussed on one year. It is possible that if an analysis over 5 years was conducted with modelled and observed data, there may be some years where S2GF PM10 impacts are less than indicated here, and other years where they may be greater. However, given that the total concentrations in Table 9 are low relative to the objective, the S2GF impacts and/or current ambient levels would have to be far greater to create an increase in exceedances.

4.4.3. Comparison to the New Canada-Wide Standard

A CWS for PM2.5 of 30 µg/m^3 (24-hour average, annual 98th percentile, averaged over 3 years) was approved by the CCME in June, 2000. As is the case for ozone, it is recognized that the CWS for PM is not fully protective of human health. All air quality jurisdictions are thus encouraged to take additional actions to reduce emissions, where possible, to protect public health.

The inter-agency committee evaluated the potential impacts of S2GF on CWS attainment by using the PM10 predictions produced by ISC for a five-year period. Chilliwack is the only site in the LFV with sufficient data to calculate the PM2.5 CWS metric. However, the more inclusive parameter of PM10 is measured at both Abbotsford and Chilliwack, and the similarity in the two station's results for this latter parameter suggest that Chilliwack measurements for PM2.5 are likely indicative of Abbotsford levels.

Since monitoring began in 1995, the PM2.5 CWS metric has not exceeded 18.2 µg/m^3. Assuming PM10 emissions from Sumas2 are 100% PM2.5, and given a maximum predicted impact of 7.4µg/m^3, a conservative estimate of the resulting CWS metric is 26µg/m^3. Hence, it is unlikely that emissions from S2GF would result in the exceedance of the PM2.5 CWS, providing current ambient PM2.5 concentrations remain similar to estimated historical levels.

4.4.4. PM Health Impact Assessment

There is clear evidence of health effects occurring at levels below the current PM10 air quality objective of 50 µg/m3 (24-hr average) and the PM2.5 CWS of 30 µg/m3 (24-hr average, annual 98th percentile concentration, averaged over 3 years). These concerns led the technical committee to assess the health impacts related to current and predicted PM10.

There are various approaches to estimating the effects of air pollution on human health. These approaches have different strengths and weaknesses, and none of them can give a precise estimate of PM-related impacts on health. As outlined in the method proposed by the Federal-Provincial Working Group on Air Quality Objectives and Guidelines (FPWGAQOG, 1999b), health impacts were calculated as the product of the annual cumulative exposure to PM above a health reference level, and central estimates of the incidence of health impacts per unit of exposure to PM, or concentration-response coefficients.[1] The health reference level reflects the lowest level at which statistically significant increases in health responses have been demonstrated. Current evidence supports reference levels of 25 µg/m3 (24-hr averages) for PM10. Inherent in the use of this methodology are the assumptions that concentration-response coefficients and national end-point statistics (such as percentage of population with asthma) are valid for the LFV. A report by Brauer et al (anticipated for release this fall) will provide an evaluation of air quality-related health effects based on actual LFV data.

Cumulative exposure estimates were calculated from observations in downtown Abbotsford[2], as well as total predicted impacts (i.e. the sum of ambient and S2GF impacts) for both gas-fired and oil-fired scenarios. Resultant mortality and morbidity risks are calculated for two sites: downtown Abbotsford (Table 10), where the monitoring site is located, and Sumas Mountain (Table 11), where maximum impacts are predicted to occur.

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[1] Concentration-response factors were based on those used in the PM Science Assessment Document (FPWGAQOG, 1999b) and the Air Quality Valuation Model (Stratus Consulting, 1999).

[2] Local PM data were restricted to PM10 measurements in downtown Abbotsford. The Abbotsford PM10 data were assumed to be valid for Sumas Mountain.

Table 10. Estimated PM10 Health Impacts In Abbotsford (With And Without S2GF), Based On Central Estimates Of Concentration-Response Coefficients

PM10	Health Impacts (per million pop. per year)						
					Symptom Days of Morbidity		
	Mortality	**RHAs**	**CHAs**	**NERVs**	**ASDs**	**RADs**	**NARSs**
Ambient	5.7	3.2	2.7	15	4,200	61,000	130,000
Ambient+S2GF (gas-fired)	5.7	3.2	2.7	15	4,200	61,000	130,000
Ambient+S2GF (oil-fired)	5.7	3.2	2.7	15	4,200	61,000	130,000

Table 11. Estimated PM10 Health Impacts On Sumas Mountain (With And Without S2GF), Based On Central Estimates Of Concentration-Response Coefficients

PM10	Health Impacts (per million pop. per year)						
					Symptom Days of Mortality		
	Mortality	**RHAs**	**CHAs**	**NERVs**	**ASDs**	**RADs**	**NARSs**
Ambient	5.7	3.2	2.7	15	4,200	61,000	130,000
Ambient+S2GF (gas-fired)	6.1	3.4	2.9	16	4,500	66,000	140,000
Ambient+S2GF (oil-fired)	6.2	3.5	2.9	16	4,600	67,000	140,000

Note: "Oil-fired" in Tables 10 and 11 refers to a scenario that includes 15 days of oil-firing during the winter with gas-firing occurring for the other days of the year.

Acronyms used to describe health end-points are defined as follows:

- RHAs – respiratory hospital admissions,
- CHAs – cardiac hospital admissions
- NERVs – net emergency room visits (excluding RHAs),
- ASDs – asthma symptom days, where notable increases in asthma symptoms such as shortness of breath, wheezing, and/or increased use of medication,
- RADs – restricted activity days, including days spent in bed, missed from work and days when activities partially restricted due to illness, and
- NARSs – net days with acute respiratory symptoms such as chest discomfort, coughing, wheezing, sore throat, head cold, chest cold, sinus trouble, hay fever, headaches and doctor-diagnosed flu.

Based on existing ambient concentrations, current mortality risks due to PM10 exposure in the Abbotsford area are approximately 6 extra deaths per million population per year. For an exposed population of 100,000 this means 0.6 deaths per year. Risks due to other health endpoints such as asthma symptom days, restricted activity days and net acute respiratory symptom days are orders of magnitude higher.

The predicted impact of S2GF is greatest on Sumas Mountain, where mortality and morbidity risks will increase by about 10% for PM10. This compares with Abbotsford, where mortality and morbidity impacts are expected to increase by 1-2%.

4.4.5. Summary

- Based on historical PM10 measurements and model estimates for the same period, the addition of S2GF emissions did not cause an increase in the exceedance frequency of the PM10 objective (for Sumas Mountain and Abbotsford). During such exceedances, S2GF's contribution to the total PM10 was not more than 1%.

- When S2GF PM10 impacts were predicted to be the greatest, the observed background PM10 for the same day indicates that the total PM10 impact (S2GF increment + background) would not compromise the objective. This suggests that if S2GF were to be built, its greatest incremental PM10 impacts are expected to occur during days when the background PM10 levels are low enough so that the total PM10 levels would not exceed the ambient objective.

- It is possible that the above findings would change if a different period was analyzed. However, given that the total PM10 concentrations are low relative to the objective for the year analysed, for other years the impacts of the S2GF emission and/or the background levels would have to increase dramatically to change the conclusion regarding the S2GF contribution to PM exceedances.

- Based on ISC-generated data and historical measured levels of PM10, the inter-agency committee does not expect that the new CWS for PM2.5 will be exceeded as a result of the emissions from S2GF.

- The area may already be subject to PM10-related mortality risks of 6 extra deaths per million population per year. For an exposed population of 100,000 this means 0.6 deaths per year. Less adverse health impacts, such as increased hospital admissions, emergency room visits, and missed days from school and work, are orders of magnitude higher.

- With respect to PM10-related health effects, the technical committee estimated that S2GF emissions may result in a 10% increase in PM10-related mortality and morbidity impacts. These findings are valid for a limited area on Sumas Mountain. In Abbotsford, estimated impacts due to PM10 are a 1-2% increase.

- Finally, it should be stressed that the estimates of S2GF related health effects are based on the results of air dispersion modelling and other assumptions that introduce a degree of uncertainty into the estimates.

4.5. Visibility

4.5.1. Introduction

During the summer in the eastern reaches of the LFV, there are frequent occurrences of an intense white haze. Observations indicate that the haze can completely obscure the bounding mountain ranges even during what apparently is a clear summer day.

Visibility (or the clearness with which an object stands out from its surroundings) is a result of a complex series of interactions between light and fine particles (primarily PM2.5) and gases in the atmosphere. In general, visibility deteriorates due to an increased amount of these visibility-reducing particles and gases.

Since S2GF will emit visibility-reducing pollutants, there are concerns that such emissions will result in more frequent and intense haze events. The proponent has conducted studies on this matter. However, due to the complex physical and human factors involved in visibility perception, it must be appreciated that the assessment of S2GF visibility impacts is extremely difficult and the uncertainties large.

Studies show that visibility perception depends on variables such as sky conditions, the background vista, and human factors (i.e. internalized values, etc.). What may be acceptable to one person may not be acceptable to another. Furthermore, judgements may change depending on location, the vista and the viewing conditions.

Although a difficult issue to assess, at the request of the inter-agency committee MFG has produced quantitative estimates using CALPUFF on visibility impacts due to the S2GF emissions under different emission scenarios, seasons and visibility conditions.

4.5.2. Visibility Parameters

Visibility can be described in terms of visual range and light extinction. Visual range refers to the distance at which the contrast of a visual target against a background is equal to the threshold contrast value for the eye (i.e., the target is just visible). It is commonly used in aviation forecasts, and is typically expressed in miles or kilometers. It is a subjective measurement, based on an individual's judgement. It is affected by background colour, sun angle, time of day and season.

Light extinction is inversely proportional to visual range. It is a function of the absorption and scattering of light due to gases and particles in the atmosphere. The greater the light extinction, the poorer the visibility and the lower the visual range. An estimate can be made of light extinction from PM composition and concentration and relative humidity data.

4.5.3. Visibility Criteria

There are no national or provincial criteria for assessing visibility impacts. However, there are criteria that apply to U.S. national parks and wilderness areas (FLM, 1999). In additional, a local criteria was suggested based on visibility public perception studies in the LFV (Pryor, 1996). Both of these criteria were used in this assessment.

4.5.3.1. The U.S. Pristine Area Criteria

For evaluations of source impacts affecting national parks and wilderness areas in the U.S., a “just perceptible” deterioration in visibility is defined to occur when there is a 5% increase in daily averaged light extinction. For these areas, if there is one day which exceeds the 5% criteria, further analysis is conducted to assess the significance of the impact. Washington regulators used this criteria to evaluate the impact of S2GF on “Class I” areas in Olympic National Park and North Cascades National Park.

It may not be appropriate to use the U.S. criteria for this situation, as it is applied to visibility impacts on pristine areas where small changes in air quality can result in large, perceptible changes in visibility. Furthermore, such assessments for these areas typically involve sources at least 50 km from a view (i.e. farther than vistas in the Abbotsford area), or an aggregation of plumes from multiple sources (rather than the single S2GF source). Nevertheless, the U.S. criteria can be used to provide an indication of any possible future visibility deterioration as a result of S2GF emissions.

4.5.3.2. A Suggested Local Criteria

The preliminary public perception study of Pryor (1996) suggested a local visibility criteria to determine what level of visibility impairment the public deemed to be acceptable. The study participants (200 university students) were shown a series of scenic vistas in Abbotsford and Chilliwack, and then rated the visual air quality. The results showed a visibility acceptability limit of approximately 60 km and 40 km visual range for Abbotsford and Chilliwack, respectively. In other words, when visual range was less than these distances, visibility was considered unacceptable or impaired by the survey group.

The suggested criteria was used to determine the increase in the number of days of unacceptable or impaired visibility over current visibility conditions that could result due to emissions from S2GF. In other words, the criteria was used to determine whether the addition of S2GF emissions will cause the visual range to be less than 60 km on those days when the prevailing visual range is greater than 60 km in the absence of emissions from S2GF.

4.5.4. The Current (Baseline) Visibility in the LFV

In order to assess if emissions from S2GF will cause a further deterioration in visibility, a baseline visibility in the absence of S2GF must first be established. If the baseline visibility is a clear day when visual range is high, then the visual impact of S2GF emissions will be detected readily. If the baseline visibility is a hazy day when visual range is low, then S2GF emissions will not likely be noticed.

For U.S. national parks and wilderness areas, *good* and *poor* baseline visibility is defined by the seasonal averages of the 20% lowest PM concentrations days and the 20% highest PM concentration days respectively. For S2GF, the *good* and *poor* baseline visibility was based on the 10th and 90th percentile of measured PM concentrations. In addition, a *moderate* category, corresponding to the 50th percentile of the measured PM, was also considered.

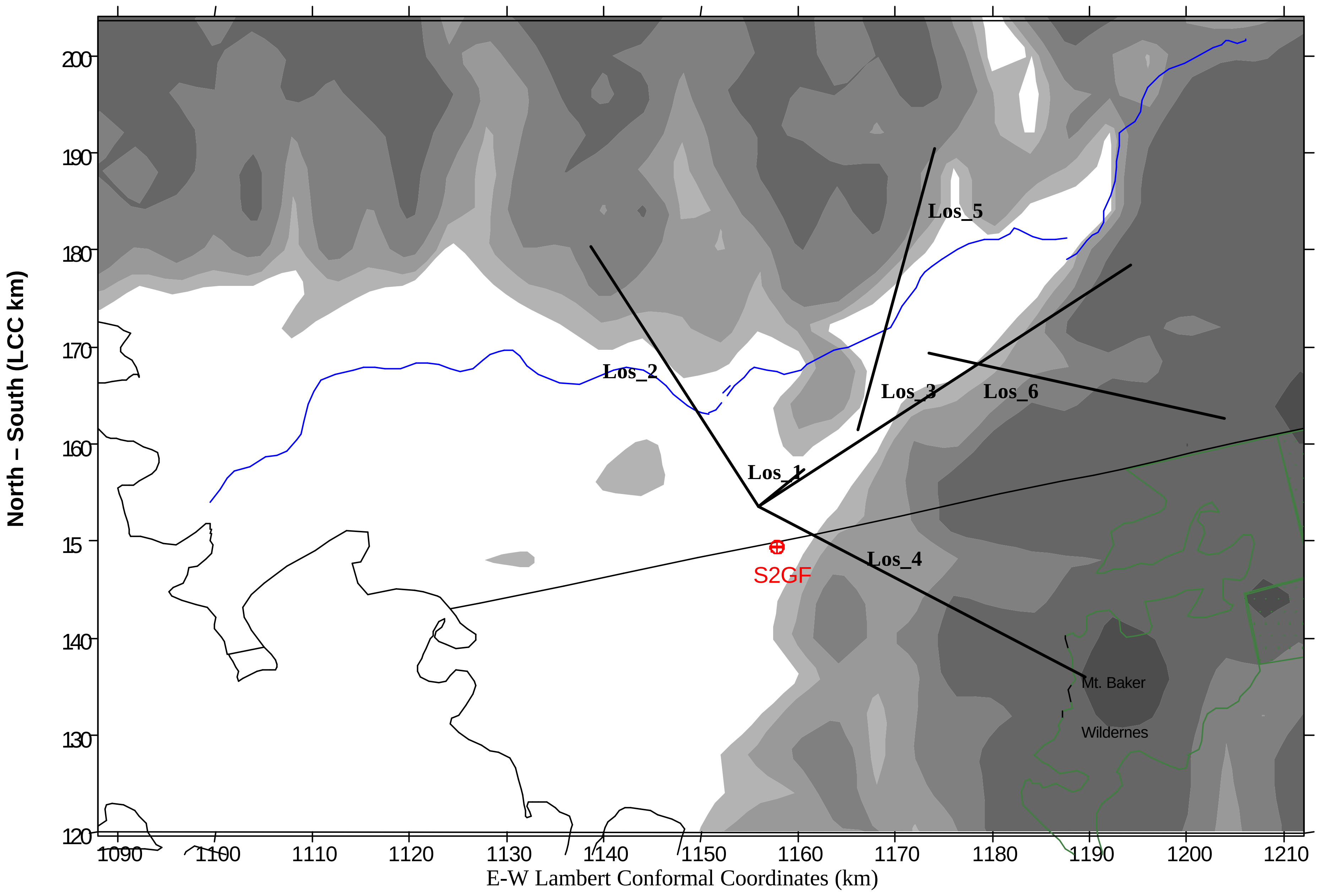
It should be noted that *good*, *moderate* and *poor* visibility conditions are relative terms that correspond to the 10th, 50th, and 90th percentile PM concentrations, respectively. For example, since PM concentrations are generally lower in winter than in the summer, the 10th percentile PM concentration will also be lower in winter than in summer. As such, *good* visibility in typical *winter* conditions will be better than *good* visibility during typical *summer* conditions.

In 1996 and 1997, Environment Canada made measurements of visibility related particles near Abbotsford. These PM measurements were used to obtain the required 10th, 50th and 90th percentile concentrations. The baseline visibility associated with these three PM concentration levels was constructed for six lines of sight (LOS) with the corresponding commonly viewed vistas in the region (Figure 2). The seasonal baseline visibility conditions were adjusted for each LOS according to humidity conditions prevailing along each LOS as predicted by CALPUFF.

The current baseline visibility (i.e. no S2GF emissions) was evaluated relative to the suggested local visual range criteria of 60 km. Unacceptable or impaired visibility occurred whenever the visual range was less than 60 km.

Based on the Environment Canada data, the best baseline visibility occurred during the winter and fall, as they had the lowest number of impaired visibility days (i.e. days with calculated visual range less than 60 km). However, even on good fall days (low PM levels), there is up to a 40% chance of impaired visibility depending on the LOS considered. For winter good days, depending on the LOS

Figure 2. Lines of Sight Evaluated for Visibility Assessment (Eaden 2000b)



there is a 15 - 25% chance that the visibility during a good day will be impaired (unacceptable). This indicates that even under so-called good visibility conditions (low PM levels), there is a good chance of visibility impairment.

In summer, PM concentrations are consistently high enough so that even under so called “good” visibility conditions, there is a 100% chance of visibility impairment. In other words, when 24-hour periods are considered, the analysis suggests that visual range is less than 60 km *at all times* during the summer. Although this seems surprising, it supports anecdotal reports of consistently impaired summertime visibility in this part of the LFV.

4.5.5. Predicted S2GF Visibility Impacts

CALPUFF calculated the light extinction values for each LOS due to the S2GF emissions under maximum gas-fired and oil-fired conditions. A combination of baseline visibility conditions for different seasons and different emission scenarios and the light extinction due to S2GF emissions for each LOS was evaluated. The impacts were judged relative to the U.S. pristine area criteria and the suggested local criteria.

4.5.5.1. Visibility Impacts Relative to the U.S. Pristine Areas Criteria

Under the maximum gas-firing scenario, with few exceptions the greatest visibility impacts due to S2GF emissions were predicted to occur along LOS1 (Abbotsford to Sumas Mountain). Under good baseline conditions, the greatest visibility impacts are predicted to occur during the fall. For this case, predictions show that S2GF emissions will result in exceedances of the U.S. pristine areas visibility criteria along LOS1 through to LOS5. Furthermore, the number of days where there would be a just perceptible deterioration in visibility due to S2GF emissions ranges from 0 to 8 days. The number of days depends on whether the baseline visibility is poor or good, respectively, for each day of the fall. For the other seasons, this range is 0 to 2 days. Thus the total of all seasons would yield an estimate of up to 14 days/year where is possible that there would be a slight difference in visibility. The upper bound of the range assumes the baseline visibility for every day of the season is associated with good conditions (i.e. low PM levels occur for every day - an unlikely event).

The greatest overall impacts are expected to occur during the winter under oil-firing. Assuming oil-firing occurs for every day during the winter, and if good conditions prevail every day, the U.S. pristine area criteria is exceeded along 5 of 6 lines of sight. There is predicted to be from 0 to 23 days where there will be a perceptible reduction in visual range due to S2GF oil-fired emissions. The 23 days estimate is unrealistic, since oil-firing is only anticipated to occur for a maximum of 15 days during the winter. However, the analysis indicates some lines of sight (LOS1,3,5) are prone to a noticeable reduction in visual range every oil-firing day under good baseline conditions – thus a range of 0 to 15 days is possible.

4.5.5.2. Visibility Impacts Relative to the Suggested Local Criteria

With respect to the suggested local criteria (i.e. a visual range of at least 60 km), for good baseline conditions during the fall, S2GF maximum gas-fired emissions caused an additional 0 to 5 days of impaired visibility. The range reflects the upper and lower bounds of the predictions. For summer, since the visibility is already impaired all the time (based on the baseline visibility analysis), S2GF emissions will not cause any additional days of impaired visibility. The estimate for the year (the sum of the individual season ranges) is predicted to have an upper bound of 10 days.

Under oil-firing, S2GF emissions were predicted to cause the visual range to be less than the suggested local criteria (60 km) from 0 to 7 days depending on the LOS. The 7 days is a very conservative and unlikely estimate as it assumes that both oil-firing and good conditions occur for every day of the winter.

4.5.5.3. Winter Oil-Firing and Visibility Deterioration

As mentioned above, the greatest impacts on visibility may occur in the winter for those limited days (not more than 15) when S2GF burns oil instead of natural gas. Oil-fired operations only occur during rare gas shortages during the winter, when temperatures are low and demand for natural gas is high. Based on MFG's analysis, winds tend to be from the north when temperatures are low. This suggests that S2GF oil-fired emissions will blow into the U.S. rather than B.C. during these periods. The inter-agency committee also found that Abbotsford Airport wind data collected during the REVEALII study (1994-1995) confirms that during the 15 coldest days in the winter, the prevailing wind direction was from the NNE-NE. Hence, actual visibility impacts during oil-fired operations in B.C. may be significantly less than the conservative upper bound of the predicted ranges given above.

4.5.6. Visible Plume Perception

There is a concern that the gas turbine plume can be a visual detriment. This is different than the previous visibility assessment, where the contribution of S2GF to regional visibility was analyzed. Based on a survey of plant operators of these types of facilities, there was unanimous agreement that there is no visible plume (except from condensed water vapour with high humidity) from those plants with NOx emissions less than 10 ppm (S2GF meets this criteria). One operator familiar with gas and oil-fired plants asserted that the plume was not visible with either fuel.

4.5.7. Summary

- The assessment of visibility impacts is difficult due to the subjective nature of visibility perception, the uncertainties associated with calculations of visibility related parameters, the lack of long-term visibility data, and the absence of national and provincial visibility standards.

- Abbotsford already experiences frequent periods of poor visibility, especially during the summer.

- Based on model predictions, S2GF emissions are expected to impact visibility in the Abbotsford area. The magnitude of these impacts depends on the time of year, the line of sight, and the background visibility conditions.

- Irrespective of season or operating conditions, the greatest visibility impacts due to S2GF emissions are predicted to occur along the Abbotsford to Sumas Mountain line of sight (LOS1). There are no predicted visibility impacts along the Chilliwack to Mt. Sleese line of sight (LOS6) at any time.

- When S2GF is gas-fired, based on model predictions and PM measurements for one year suggest:
  - S2GF emissions are predicted to cause a just perceptible deterioration in visibility on 0 to 14 days per year (8 of which occur in the fall). The upper bound of this range is considered to be a conservative estimate.
  - S2GF emissions are predicted to cause an additional 0 to 10 days per year (5 of which occur in the fall) of visibility impairment. The upper bound of this range is considered to be a conservative estimate.

- The greatest visibility impacts are predicted to occur during the winter when S2GF is oil-fired. There is a possibility of exceedances of the U.S. pristine area criteria whenever oil-firing occurs (i.e. a just noticeable deterioration in visibility is expected for every oil-firing period – 15 days maximum). Very conservative estimates also show that oil-fired emissions will cause an increase of up to 7 days when visibility is impaired over current conditions. However, there are indications that during rare gas-shortage events (when oil-firing occurs), B.C. will lie upwind of the facility (i.e. S2GF emissions will not be transported into B.C.).

- Based on a survey of other operators of similar power generation facilities, there should be no visible plume (other than water vapour under high humidity conditions) when gas-fired, and little likelihood of a visible plume even under the uncommon, oil-fired conditions. Whether the survey results would apply to this location is not known as local weather conditions affect plume visibility.

4.6. Cooling Tower Plume Impacts

The cooling towers emit water vapour that can have a variety of impacts, depending on the meteorology and facility operation. These impacts are: (1) visible impacts due to condensed plumes, (2) fogging and/or icing involving the ground contact of visible plumes, (3) shadowing effects (where the condensed plume casts a shadow), and (4) the impact of sustained deposition of droplets of cooling water, called drift. A cooling tower plume computer model was used with 5 years of meteorology as input. The modelling showed:

- Based on model predictions, visible plumes are expected to be of short duration and predicted not to obscure visual resources in the area. During periods when condensed plumes would be noticed (i.e. daytime, good background visibility), predictions show a condensed plume would likely be less than 50 m in length on average. Under such conditions, there is a 1% chance that a condensed plume longer than 1 km will occur.

- Except for an area within 100 meters of the cooling tower, plume shadows are expected to be limited to less than 120 hours per year.

- Plume induced ground-level fog would be expected to occur less than one hour per year.

- Icing was not predicted to occur.

- The deposition of water droplets and minerals in the water (drift) is predicted to be low and confined to an area within 100 m of the cooling tower. No build-up of drift in the surrounding area is anticipated.

4.7. Greenhouse Gas Emissions

Greenhouse gases emissions are relevant to the issue of global climate change. S2GF is anticipated to emit 2.2 million Tonnes/year of CO2.

An assessment of the impact of these substantial greenhouse gas emissions on global climate change was not conducted by the technical committee in this review. While these gases will have no direct or regional impacts, they will contribute to global climate change which in turn will have both environmental and health impacts.

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