The View Ahead

Identifying Options for a Visibility Management Framework for British Columbia

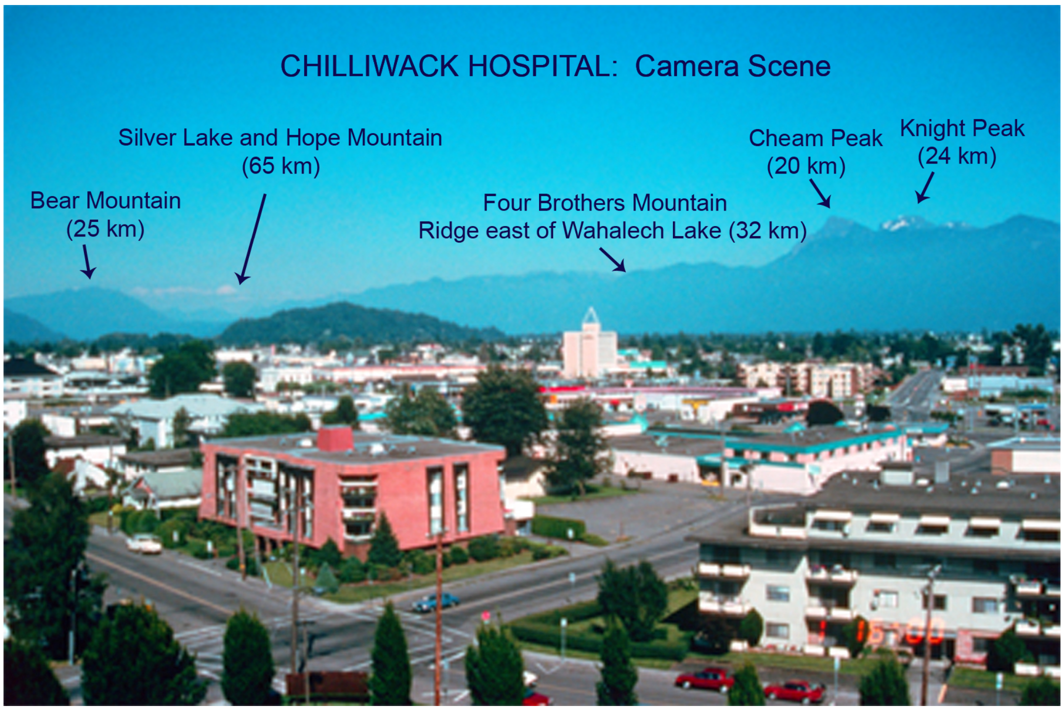
Jacques Whitford AXYS

The Two Photographs presented on the cover show the range of visibility conditions experienced in Chilliwack, British Columbia during the REVEAL program (July-August 1993). The photographs were both taken at 11:29 a.m. just four days apart. The camera scene looks east-northeast from the roof of the Chilliwack Hospital (Location: 49^0 10' 06" North by 121^0 57' 50" West). This remote automated camera system captured eight images per day between 07:00 and 18:30 with a manual camera (135 mm lens at f/8) and ASA-25 photographic slide film. Details of the two cover images (center & border) and the image below are presented.

Photo One (centre)
08/02/93 11:30
1-h NO_2 = 9 $\mu g/m^3$
24-h $PM_{2.5}$ = 6 $\mu g/m^3$
b_{scat}= 29 Mm^{-1}
b_{ext} = 41 Mm^{-1}
Mr = 96 km
RH = 40%

Photo Two (border)
08/06/93 11:30
1-h NO_2 = n/a
24-h $PM_{2.5}$ = 15 $\mu g/m^3$
b_{scat} = 225 Mm^{-1}
b_{ext} = 300 Mm^{-1}
Mr = 13 km
RH = 74%

Photo Three (right)
08/01/93 16:00
1-h NO_2 = 10 $\mu g/m^3$
24-h $PM_{2.5}$ = 9 $\mu g/m^3$
b_{scat} = 61 Mm^{-1}
b_{ext} = 111 Mm^{-1}
Mr = 35 km
RH = 54%



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FOR: **The View Ahead:**
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EXECUTIVE SUMMARY

From a technical perspective, visibility is generally taken to mean the distance one can see through the atmosphere. The term "visibility", however, is difficult to define due to the subjectivity of the observer. Clear air compliments the awe-inspiring viewscapes for which British Columbia is famous, while poor visibility is the most frequently cited indicator of the quality of the air by the public (Ely, 1990). In fact, a single poor visibility day could result in a loss of almost $9 million in future tourist revenues for the Lower Mainland and the Fraser Valley (McNeill and Roberge, 2000).

In both urban and wilderness areas, fine particles and selected gases scatter visible light, resulting in the loss of scene information to the eye. The same pollutants that create urban and non-urban haze also generate adverse health effects, damage forests and crops, soil buildings and vehicles, contaminate lakes and streams, and affect the amount of solar radiation reflected, absorbed and transmitted by the earth's atmosphere.

Despite the fact that visibility science has developed considerably in the last several decades (primarily owing to work conducted in the United States), there are no current programs to manage visibility in any province or nationally in Canada. To date, air management efforts have focused on human health and the integrity of ecosystems. However, experience elsewhere (described further in section 3) has proven that managing visibility is cost effective in the long run. Improved visibility results in a higher perceived quality of life for residents, as well as the ability to attract residents, workers, and businesses to a region.

This work addresses the policy options available to manage the visual aspect of air quality in British Columbia. It builds upon the work of a task force formed in the early 1990's (1993 Visibility Task Force), and subsequent works in visibility science and policy. It is intended to assist British Columbia's air management agencies in exploring management options that could contribute to a visibility management framework for both urban and wilderness areas. A management option for visibility is defined as the use of a particular policy mechanism by an air management agency to achieve visibility protection or improvement.

Featured in this report: i) a concise review of current management options implemented or contemplated by other jurisdictions; ii) a description of existing policy drivers and potential policy mechanisms that air management agencies may employ to achieve visibility protection in British Columbia ("How can we make this happen?"); and, iii) elements common to effective visibility management programs ("What needs to be done?").

There are five management options to consider: i) status quo – no new efforts for visibility protection; ii) include visibility considerations in the implementation of Canada-wide Standards, continuous improvement - keeping clean areas clean; iii) leverage existing policy directives and establish visibility as a protected value; iv) visibility protection by establishing visually important areas in BC through legislation; and, v) develop a national visibility management program.

Irrespective of the path air management agencies take to manage visual air quality in British Columbia, an effective visibility management program will include a strong visibility and air quality science component, support for socioeconomic studies, efforts to develop visibility standard, and regulatory change. The challenge will be to build a visibility management framework that supports and nurtures these activities.

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THE VIEW AHEAD: IDENTIFYING OPTIONS FOR A VISIBILITY MANAGEMENT FRAMEWORK FOR BRITISH COLUMBIA

1.0 INTRODUCTION

From a technical perspective, visibility is generally taken to mean the horizontal distance one can see through the atmosphere. While visibility can most simply be described as a distance, there are infinite nuances to appreciate in understanding the visual environment due to the subjectivity of the observer. Air pollution (fine particles and some trace gases) can limit visual range and lessen the aesthetic value of scenic vistas and urban viewscapes. This report discusses potential air management options that could be used to manage the visual aspect of air quality in British Columbia.

To date, air management efforts have focused predominantly on human health and the integrity of ecosystems. However, experience elsewhere (described further in section 3) has proven that managing visibility is cost effective in the long run. Improved visibility results in a higher perceived quality of life for residents, as well as the ability to attract residents, workers, and businesses to a region. And when visibility is good, tourism revenues increase - a single poor visibility day could result in a loss of almost $9 million in future tourist revenues for the Lower Mainland and the Fraser Valley (McNeill and Roberge, 2000).

At present, visibility is not being managed directly by any one air management program. Future visibility improvement or deterioration may be the unplanned outcome of programs directed at managing other air quality issues. For example, efforts to reduce fine particles ($PM_{2.5}$) and their precursors may provide health and visibility co-benefits.

Conducting visibility science offers an alternative perspective on air pollution, and through it, key information regarding the formation of pollutants. No other discipline focuses on measuring trace gases and particles in remote locations, and uses this data to understand the atmosphere as one global system.

Jacques Whitford AXYS Ltd. was retained by Environment Canada on February 9th 2007 to i) review current visibility management options implemented or contemplated by other jurisdictions and ii) present a range of potential management options for visibility management in British Columbia. This work resulted in a DRAFT Report that was completed by Jacques Whitford AXYS Ltd. under contract with the Environment Canada. The Steering Committee that guided this work includes the following agencies: the BC Ministry of Environment (BC MoE), Environment Canada (EC), the Fraser Valley Regional District (FVRD), and the Greater Vancouver Regional District (GVRD).

Guidance respecting this work was provided in the Request for Proposal 'Statement of Work' and the minutes of a day-long multi-agency 'Visibility Meeting' held at the GVRD offices on October 26th 2006. Resources cited in the 'Statement of Work' were provided and included in an annotated bibliography. The Steering Committee met directly with Jacques Whitford AXYS Ltd. on three occasions (February

23rd, March 16th, and April 5th) and on April 26th via teleconference. The Steering Committee reviewed a number of draft versions of this report and provided valuable input, comments, and direction. They contributed selected passages of text, and played an editorial role in this Final Report. The findings and conclusions expressed in the report do not necessarily reflect the opinions of the agencies that the Steering Committee members represent.

A review of visibility management in other jurisdictions in included in Section 3. Existing policy drivers and potential visibility management options for British Columbia is presented in Section 4. These sections are preceded by a short backgrounder on visibility (Section 2). Included in Section 2 is a brief technical summary of visibility science, and a historical summary of visibility-related activities in British Columbia. Appendix A is a list of definitions and terminology.

An annotated bibliography citing books, articles, and documents pertinent to this work was created as a companion to this work. The purpose of the annotations is to inform the reader of the relevance, accuracy, and quality of the sources cited. The brief descriptive paragraphs for each citation are arranged chronologically by subject area. There are ten divisions in the annotated bibliography ranging from Smoke Management, Visibility in Canada and British Columbia, and Visibility Perception and Valuation, to General Air Quality Issues, and Canada-Wide Standards, PM and Ozone. The annotated bibliography is available from the Steering Committee upon request.

2.0 BACKGROUNDER

A very brief introduction to visibility science and issues pertinent to British Columbia is presented in the following backgrounder. It is not intended as a primer on visibility. Several documents, highlighted in text boxes in this report, should be consulted for additional information.

2.1 Technical Summary: Visibility Science

From a technical perspective, visibility is generally taken to mean the distance one can see through the atmosphere. However, the term “visibility” is complex and difficult to define due to the subjectivity of the observer. For example, even though a mountain may be clearly viewed, if the colour of the mountain is slightly faded, an observer may deem the visibility to be impaired.

One quantitative measure of visibility is “visual range” (the distance at which objects are just distinguishable from their background). At sea level, horizontal visual range is theoretically limited to 392 km owing to the light scattering properties of the gases that make up pure air. In reality, the trace amounts of fine particles and select gases that make up the natural background will limit visibility to less than 200 km on all but the very clearest of days. An excess of local anthropogenic or natural emissions can limit visibility to the extent that it is perceived as impaired.

The human eye is sensitive only to a very narrow band of electromagnetic radiation (visible light spectrum), and this band coincides with the peak of the sun’s energy output. We notice visibility impairment when landscapes become progressively more washed out and lacking in definition – this is generally when the visual range drops below one hundred kilometres. Pryor (1995), however, found that many urban dwellers in Vancouver considered a visual range of approximately 40 to 60 kilometres to be the limit of acceptability. When the visual range falls below a few hundred meters, the safety of marine, ground and air transportation could be negatively affected.

Visibility science has developed considerably in the last several decades (primarily owing to work conducted in the United States). Early works in the field of atmospheric optics were driven by a need to understand the range at which objects or lights could be detected mainly for military or transportation purposes. An early pioneer in the science was a Canadian, William Edward Knowles Middleton (1952). As civil aviation developed in the early-to-mid nineteenth century, airport weather stations began collecting visual range information along with weather observations. These qualitative observations seldom exceeded several tens of kilometres as they were based on the ability to see nearby landmarks. Information on visual range beyond 50 km was of little use as it was not a limiting factor in aviation, so it was not collected.

Measurements of atmospheric particles and gases in the mid-nineteenth century were of limited use in understanding visibility impairment. Deducing the causes of visibility impairment was not possible until: i) routine measurements of very fine particulate began, and ii) measurement technology allowed for the speciation of particulate chemistry. From that time, "visibility science" emerged and a growing body of knowledge has developed linking visibility (scene information), air pollution (particles and gases), and other optical measurements (light scattering, light extinction).

The science of atmospheric optics is propelled from both the need to protect visibility and the drive to understand global climate change. Fine particles that scatter light and cause haze also govern the amount of solar and terrestrial radiation reflected, absorbed and transmitted by the earth's atmosphere. These issues are of importance to scientists and policy makers in the US. The Air & Waste Management Association and the American Geophysical Union have held three Joint International Specialty Conferences on visibility science - "Aerosols and Atmospheric Optics" (1994); "Visual Air Quality, Aerosol, and Global Radiation Balance, (1997); and "Regional Haze and Global Radiation Balance – Aerosol Measurements and Models: Closure, Reconciliation and Evaluation" (2001).

The physical and chemical theories of light interaction with gases and particles are well understood. As a result, visible haze is one of the better understood environmental effects of air pollution. It is also related to a host of other air pollution issues. For example, the same emission sources that create urban and non-urban haze also generate adverse health effects, damage forests and crops, soil buildings and vehicles, contaminate lakes and streams, and affect the amount of solar radiation reflected, absorbed and transmitted by the earth's atmosphere.

To learn more about visibility, start by visiting the web site of the Integrated Monitoring of Protected Visual Environments Steering Committee (http://vista.cira.colostate.edu/improve/Default.htm). The IMPROVE web site has a large archive of materials on the US visibility program. It includes resources, presentations, interactive tools, and links to all other agencies involved in visibility in the USA.

The most frequently cited early treatise on atmospheric optics is Middleton's (1952) "Vision Through the Atmosphere"). "Protecting Visibility: An EPA Report to Congress" (1979) contains a chapter on the fundamentals of atmospheric visibility and numerous other subject areas (e.g. measurement, modelling, and protection of visibility). Visibility science and visibility protection are more simply described in "Visibility Protection for British Columbia: An Issue Paper" (BC MELP, 1993). A more recent and comprehensive summary of the issue is found in "Visibility: Science and Regulation" (Watson, 2002). Another comprehensive reference on visibility science and policy is Chapter 9 of "Particulate Matter Science for Policy Makers: A NARSTO Assessment" (Tombach and McDonald, 2006).

Amongst air management agencies, visibility impairment is broadly classed as either plume blight or regional haze. Plume blight is defined as "smoke, dust, coloured gas plumes, or layered haze emitted from stacks… relatable to a single source or small group of sources". Regional haze is defined as "widespread, regionally homogeneous haze from a multitude of sources". (Watson, 2002). Of the two, the former is most easily remedied as it easily attributable (usually back to a smoke stack or open fire). Regional haze can be particularly vexing to attribute, as the sources are varied and often out of sight (i.e. several tens or hundreds of kilometres away).

Attribution of light extinction to emissions from specific sources is the subject of intense scientific and regulatory scrutiny. The science has progressed beyond simply attributing plume blight to a single source, or connecting regional haze to local fires or urban sources. Present-day atmospheric chemists speak of 'chemical climate' and 'chemical weather' to describe long-term and short-term fluctuations of visibility-impairing gases and aerosols (McKendry, 2006). It is understood that the variability in background visibility may not simply be a local or regional issue.

In fact, visibility studies have led to some astonishing discoveries regarding the geographic reach of atmospheric aerosols (e.g., wintertime haze in the Grand Canyon as a result of industrial and vehicular emissions in Los Angeles). Further, visibility studies lend important insights into regional air quality issues, and in the process, sometimes uncover unlikely sources of pollutants (e.g. poultry farms and truck stops as important regional sources for $PM_{2.5}$ - visibility impairing aerosols). Both of these discoveries came about as a result of visibility studies in urban airsheds.

While visibility is related to nearly every other air pollution issue, it is often described as a "*welfare effect"*. In contrast to 'health effects' (e.g. pulmonary or cardiac effects), welfare effects include indirect ecosystem effects (e.g., acid rain, climate change, and depletion of stratospheric ozone) and aesthetic effects (e.g., odours, soiling, and decreased visibility).

While welfare effects are often viewed as secondary in importance to health effects, air pollutant effects are usually first detected in the environment before they manifest as effects in the human population. Visibility is therefore a measure of both aesthetic value and general air quality.

Currently, the visibility discipline is very well developed in the United States. Work on visibility continues in Canada and British Columbia, however, these efforts are constrained to a few localities and are relatively limited in scope. In general, support for visibility studies lags behind most other air quality concerns. Interestingly, visibility is the most frequently cited indicator of the quality of the air by the public (Ely, 1990).

2.2 Historical Background: Visibility-Related Activities in British Columbia

Visibility was first explored as an issue in British Columbia in the late 1980's. Anecdotes indicate that at that time, the BC Ministry of Environment (herein referred to as 'the Ministry') fielded more public complaints about haze and smog than other air quality issues combined. Beehive burners in small Interior resource towns, and slash burning smoke in the Okanagan generated numerous inquiries to the Ministry. People in BC undoubtedly value good visibility and disparage poor visibility, especially in areas that attract tourists and residents from other provinces and countries.

Earlier efforts by the Province addressed air pollution from facilities discharging smoke into communities (e.g. foundries in Vancouver or sawmills in the Cariboo region). These efforts concentrated on visibility as an indirect benefit of reducing visible smoke and eliminating soiling effects through rudimentary emission controls. While reducing the potential for human health effects was a strong policy driver, the science linking fine particulate pollution and human health was not well developed at that time.

Since the 1980s a number of visibility initiatives and research studies have taken place in Canada and British Columbia. These studies are described briefly in the following section. Detailed information can be found in the annotated bibliography (available from the Steering Committee).

Source: Greater Vancouver Regional District

Figure 1 False Creek, Vancouver, in 1939 and Today

One of the first documents to directly address regional visibility issues was BC Environment (now BC Ministry of Environment) Issue Paper "Smoke Management for the 90's" (BC MELP, 1992). At the time, the Ministry was leading the development of a policy to manage smoke from prescribed fires, sawmill residue burning, urban and agricultural burning, and residential wood burning. Since the early 1990s, advances have been made in all of these areas. The prevention of adverse health effects and the protection of visibility were cited as the main benefits of a comprehensive smoke management program.

As a part of this smoke management work, the Ministry undertook thrice-daily photographic measurements of visual range from 1988-1990 at two southern Interior BC locations: Kamloops and Vernon. Light extinction was determined through photo densitometry. This represents the first quantitative measures of visual range in BC, and the data collected represents a legacy collection of spatial and temporal visibility measurements (ARS, 1889; ARS 1990, ARS, 1991).

Following the Smoke Management discussion paper, the Ministry released "Visibility Protection for British Columbia: An Issue Paper" (BC MELP, 1993). This paper introduced the concept of visibility protection, described light scattering by fine particles, provided an overview of visibility regimes in North America, described visibility measurement and modelling systems, and examined the level of protection afforded by particulate air quality objectives (TSP and proposed PM_{10} Objectives). As well, recommendations were presented (including for example, the creation of a task force to further address visibility protection).

The Ministry created the Visibility Task Force in February 1993. After a series of meetings, in 1994 the Task force submitted a final report ("Final Report of the BC Visibility Task Force"). Chaired by the Ministry of Environment, Lands and Parks (now "ministry"), members included: Parks Canada, BC Parks, the BC Ministry of Forests, the BC Ministry of Tourism, the Greater Vancouver Regional District, and Environment Canada. The Task Force was allowed to participate in the US IMPROVE (Integrated Monitoring of Protected Visual Environments) Steering Committee meetings, and developed relationships with visibility experts in the United States (BC MELP, 1994).

The Task Force report included a synopsis of key issues and notes from each meeting. It encapsulated the concerns of the participating agencies and contained a number of recommendations. Chief among these was the creation of a Visibility Management Steering Group to champion visibility science, policy development, and visibility management.

Soon after the Visibility Task Force was struck, an international visibility workshop was organized in Harrison Hot Springs, BC ("Protecting Visibility in Western Canada and the Pacific Northwest", (BC MELP, 1993b). This workshop began with an introduction to visibility science and perception, followed by a description of the US visibility protection programs (Federal and State perspective). The Canadian Federal and BC Provincial Legislative Framework were described, as were the challenges inherent in establishing a visibility protection program in BC. The workshop ended with a session on developing urban and regional haze strategies in Western Canada.

Following this work the BC Ministry of Ministry of Environment, Lands and Parks (now "ministry") conducted a study of episodic summertime haze events in the Chilliwack – Abbotsford area, 50 to 80 km west of Vancouver. This study included a network of scene, optical and IMPROVE samplers located in various locations in south western BC (Sakiyama, 1994). Entitled the 'Regional Visibility Experimental Assessment in the Lower Fraser Valley' (REVEAL), this study represented the first comprehensive assessment of visibility in Canada (July and August of 1993). From this work, a series of papers on visibility, $PM_{2.5}$ and source apportionment were published (Pryor et al., 1994; Lowenthal et al., 1997).

In 1994-1995, REVEAL was followed by REVEAL II, a program designed to: i) characterize aerosol and visibility conditions in the Lower Fraser Valley (LFV) over an entire year, and ii) provide public information regarding the sources and effects of existing aerosol concentrations. Both studies involved monitoring the three chief elements of atmospheric visibility: aerosol, optical, and scene characteristics. A visibility and source apportionment analysis are found in Pryor and Barthelmie (2000).

Triggered by the 1991 Canada/US Air Quality Agreement, in June 1995, an *International Air Issues Workshop* was co-sponsored by Parks Canada and the US National Park Service (US DOI, 1995). While the bulk of this workshop revolved around the issue of transboundary SO_2 and NOx, considerable attention was paid to visibility. Some recommendations focused on visibility science and policy, with the US National Park Service offering to assist Parks Canada in the monitoring of scene information and aerosols.

In 1994-1995 Environment Canada conducted a year-long visibility study entitled the *Kootenay National Park Visibility Project* (Pottier, 1996). This study investigated visibility in Kootenay National Park by measuring light scattering through photographic means. It discriminated both local effects and impairment originating from greater distances away.

In the post-REVEAL II period, the science studies focused on $PM_{2.5}$ through measurements taken at various locations in the province to determine the nature and sources of $PM_{2.5}$. Although no visibility-specific studies were conducted in this period, visibility-related work on monitoring and modelling continued.

The Greater Vancouver Regional District (GVRD) routinely collects air quality data in an effort to assess visibility and haze in the Lower Fraser Valley (LFV). Monitoring includes continuous measurements of $PM_{2.5}$, particulate nitrate and particulate sulphate, light scattering, and scene information. Two stations in the network (one in each of the GVRD and FVRD) collect $PM_{2.5}$ – the data of which is later analyzed in a federal laboratory to determine the various species that form the particles. Continuous fine particulate nitrate and fine particulate sulphate monitors are also operated at the Abbotsford Airport.

To continuously measure light scattering by both fine particles ($PM_{2.5}$) and gases, integrating nephelometers are operated at four air quality stations in the LFV (Vancouver Airport, Pitt Meadows, Abbotsford, and Chilliwack). Three continuous carbon analyzers are operated within the network to measure elemental carbon and organic carbon, the chemical constituents which absorb light. Six automated digital cameras are also operated throughout the LFV to record views along specific lines-of-sight with recognizable topographical features at known distances. When these photographs are examined alongside the pollutant measurements, visual range can be related to the concentrations of various $PM_{2.5}$ particles and provide insight to the sources of visibility degradation.

The visibility-component of the LFV monitoring network represents a substantial investment and commitment to understanding visibility – perhaps the most determined effort in a Canadian urban region. This work contributes quite substantially to the visibility management efforts of the Lower Fraser Valley Air Quality Coordinating Committee (LFVAQCC) and the Georgia Basin/Puget Sound

International Airshed Strategy (GB-PS IAS). Further details and data can be found in the LFV ambient air quality reports at http://www.gvrd.bc.ca/air/.

In addition to the six automated digital cameras located in the Lower Fraser Valley, three other sites outside the valley are operated by Environment Canada. All digital camera site data (both current and historical) are available from http://visibility.pyr.ec.gc.ca.

Environment Canada is currently reviewing and synthesizing recent visibility literature as well as performing an analysis of the GVRDs 2001-2006 LFV visibility data as part of the 2008 Smog Assessment document. This involves updating a previous analysis of speciated NAPS data across Canada at 42 sites and changing the IMPROVE light extinction formula to reflect Canadian data. Speciated $PM_{2.5}$ data in BC are collected at several locations in BC, including: Saturna Island, Victoria, Burnaby South, Abbotsford, Port Moody, Kelowna, Golden, and Prince George. Environment Canada is also installing a pilot / proof of concept measurement site in Alberta (digital camera plus $PM_{2.5}$ speciation). Results from this work are expected to be published and/or presented in the 2008 - 2010 time period.

In an effort to control the spread of the avian virus in poultry, 19 million birds in the Fraser Valley were culled between February and May 2004. The cull provided Environment Canada with an opportunity to study the effects of poultry farming shutdown on ammonia, $PM_{2.5}$ and visibility in the LFV. Ammonia sampling occurred at barns and in a network of 43 locations in agricultural areas through the cull period and the re-population period which concluded in the fall of 2005. Visibility and $PM_{2.5}$ data were collected from four air quality stations in an effort to characterize the effect of significant ammonia emission reductions on air quality. The data are currently in the process of being analyzed, and results are expected to be published in early 2008.

With respect to recent modelling efforts, Environment Canada has used the photochemical models CMAQ and AURAMS (traditionally used for O_3 and $PM_{2.5}$ predictions) to model visibility. Various maps of light extinction changes under varying emission scenarios were created for south western BC. Such advances in modelling provide a tool to link emissions and visibility under select episode situations.

Future visibility related work planned by Environment Canada includes a visibility monitoring equipment inter-comparison study (anticipated during the summer of 2007). The equipment tested and compared will include: different types of nephelometers (open chamber, two different drier types), aethalometer, transmissometer, speciation measures and a digital camera.

Finally, in 2006, the Ministry of Environment, Environment Canada, FVRD and the GVRD began discussions on the issue of visibility management and identified the need to begin a process to identify: interests of stakeholders, scientific and policy needs, and a path forward (given public interest and policy drivers regarding visibility). These discussions have led to this reports production and a planned workshop (June 2007) to explore potential options for managing visibility in British Columbia.

3.0 VISIBILITY MANAGEMENT IN OTHER JURISDICTIONS

The measurement and management of visual air quality is nowhere better expressed than in the United States (Tombach and McDonald, 2006). A 'critical review' of the history of the American visibility management program is described in the June 2002 edition of the Journal of the Air and Waste Management Association (Watson, 2002). Watson's review contains an extensive review of visibility science and policy, as well as over 1,000 references. Although other jurisdictions have conducted research and regulated sources with visibility in mind, the regulatory structures and means of verification are not nearly as well developed as in the United States. The US program is described in Section 3.1, followed by a description of visibility management and protection efforts in Europe, Australasia, and Asia (Section 3.2).

3.1 The United States

Although the United States passed the Air Pollution Control Act in 1955 and the Clean Air Act in 1963, it was the 1970 Clean Air Act (CAA) that placed the United States on the path to regulating visual air quality in the 156 mandatory Class I Federal areas. Class 1 areas include national parks, wilderness areas, national memorial parks and international parks.

The 1970 Clean Air Act delegated authority to the newly-formed Environmental Protection Agency to formulate national ambient air quality standards (NAAQS), emission standards for new sources, and reduce emissions from road and non-road vehicles. This Act named visibility as part of secondary welfare effects that were to protect against the non-health effects of air pollution. The 1970 CAA also required State Implementation Plans (SIPs) that outlined responsibilities and deadlines, as well as methods for citizens to seek legal redress when ambient or emission standards were exceeded (Watson, 2002).

The 1977 CAA amendments addressed visibility in non-urban areas through the Prevention of Significant Deterioration of Air Quality (PSD) Provisions. These were intended to protect relatively pollution-free areas from becoming more polluted. One purpose of the PSD provisions is "… to preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural recreational, scenic, or historic value." The word 'scenic' is a direct reference to visibility (Watson, 2002).

Section 169A of the 1977 amendment to the CAA set a national goal for visibility as "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from man made air pollution". In 1990 the CAA was amended to include a section entitled 'Visibility' (Section 169B) that required the expansion of visibility networks, assessment of source contributions, and studies of haze formation and transport. It also authorized the establishment of visibility transport regions and commissions to address interstate transport of pollution affecting regional haze (Watson, 2002).

The Clean Air Act directly addresses visibility only in mandatory Class I Federal areas. Two primary mechanisms are the 1980 'Plume Blight Rule' and the 1999 'Regional Haze Rule'.

The 1980 ‘Plume Blight Rule’ defines plume blight and regional haze. Only plume blight was to be controlled because of the scientific limitations in attributing the contribution of multiple sources to regional haze. This was rectified nearly two decades later by advances in science and the establishment the 1999 ‘Regional Haze Rule’ (Watson, 2002).

It is the 1980 plume blight rule that defined visibility impairment as “… humanly perceptible change in visibility (visual range, contrast, coloration) from that which would have existed under natural conditions”. It allowed for the application of emission reduction measure on stationery sources that could be found to be impairing visibility in a mandatory Class I Federal area “through visual observation or any other technique the state deemed appropriate”. This inclusion of the phrase “*any other technique”* opened the door to techniques such as time-lapse photography, chemical tracer studies, and complex source attribution studies. It helped develop the modern science that led to the establishment of the Regional Haze Rule (Watson, 2002).

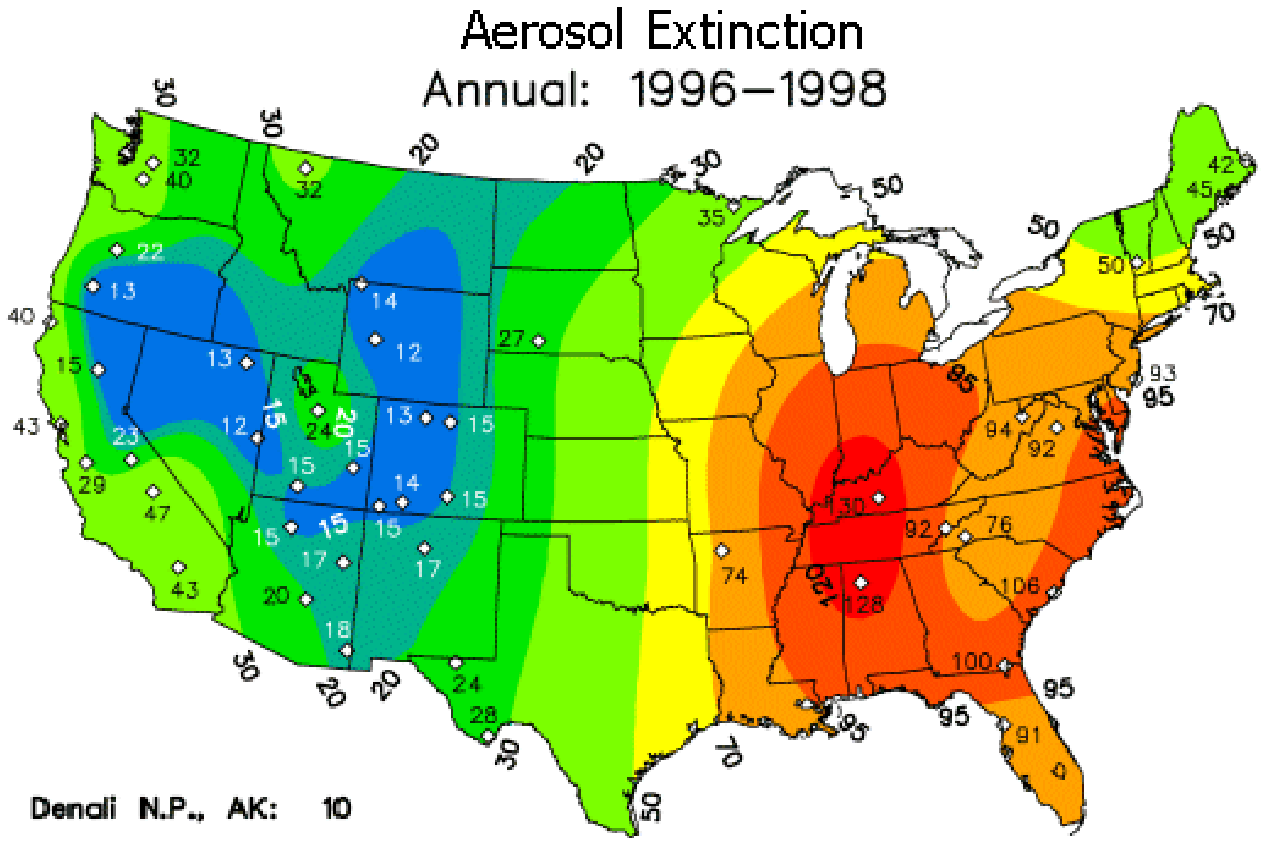
The right of citizens to seek legal redress under the Clean Air Act has been exercised several times with respect to visibility. Most famously, the Environmental Defence Fund sued the EPA in 1982 for not creating visibility SIPs for the States of Arizona and Utah, among others. This litigation was settled in 1984 when the EPA set a schedule for completing the visibility SIPs – setting in motion a variety of visibility studies and the advancement of visibility science.

To reduce haze, and to meet requirements of the Clean Air Act, the US EPA issued a Regional Haze rule aimed at protecting visibility in mandatory Class I Federal areas (April 1999). The rule seeks to reduce the visibility impairment caused by many sources over a wide area. Under the 1999 Regional Haze rule, states are required to set periodic goals for improving visibility in the 156 mandatory Class I Federal areas. As they work to reach these goals states must develop implementation plans (SIPs) that contain enforceable measures and strategies for reducing visibility-impairing pollution (Watson, 2002).

The new regional haze regulations require ambient monitoring (representative of each of the Class I areas) to track progress toward the US national visibility goal. Required regional haze trend assessments will be based on changes in visibility (expressed in “deciviews” – see Appendix A). To facilitate these assessments, the aerosol portion of the Interagency Monitoring of Protected Visual Environments (IMPROVE) visibility network was expanded from 30 to 110 sites in 2001. This dense a network, situated in remote regions, allows for spatial and temporal studies of visibility largely unaffected by interference from nearby urban sources (Watson, 2002).

Figure 2 below is a spatial interpolation of average particle light extinction ($b_{ext,p}$) from 1996 to 1998 based on IMPROVE measurements (in inverse megametres or 1/Mm or Mm^{-1}). Higher values of light extinction mean poorer visibility (e.g. lower visual range). Note the four-fold disparity between east and west, the region of good visibility in the Great Basin, and the region of poor visibility in Appalachia.

Looking at the map one can deduce that this pattern of east-west disparity extends into Canada. Unfortunately, measurements comparable to those taken in rural areas by the IMPROVE network are not available in Canada. Considerable work is needed to develop this comprehensive a delineation of visibility regimes in Canada.



Source: http://vista.cira.colostate.edu/improve/Data/Graphic_Viewer/seasonal.htm

Figure 2 Distribution of average light extinction (inverse Megameters) in National Parks and Wilderness areas of the United States

States are now working together in five regional planning organizations to develop strategies to address haze. Individual states will then develop implementation plans designed to achieve "reasonable progress" toward the national visibility goal of no human-caused impairment in the 156 Class I areas across the country.

Specifically, the regional haze rule requires that States establish goals to improve visibility on the 20% worst days and to allow no degradation on the 20% best days for each Class I area in the state. In establishing progress goals, states must analyze the rate of progress for the next 10-to-15-year implementation period that, if maintained, would achieve natural visibility conditions within 60 years from the baseline period of 2000 through 2004 (by 2065) (Watson, 2002).

Many urban regions suffer visibility impairment resulting from man-made and natural sources. This type of visibility impairment is not addressed specifically by the Clean Air Act. However, local and regional air pollution control authorities in the United States have raised the profile of visibility impairment as an issue. Several studies have focussed on urban visibility – notably the San Joaquin Valley air quality and visibility studies; the Metro Denver Brown Cloud Study, and the Phoenix and Tucson Urban Haze and PM_{10} Studies. The main goals of these studies were to determine the origin and means of remedying local visibility impairment.

3.2 Europe, Australasia, and Asia

In Europe visibility is not the issue it is in the US. The European Commission indicates that, while tourism is an important industry, it is generally reliant on cultural amenities and not the appreciation of scenic vistas (as in the US mid-West). Despite this, the Clean Air for Europe (CAFE) program may soon consider the economic benefits of improved visibility due to EU policy action. Many European countries are well advanced in studying their air quality, determining patterns of acidic deposition, discerning the potential health effects of fine particulate, and measuring toxic air pollutants. There is no strong interest at present in studying regional haze, and there are no plans to develop mechanisms to protect visibility in the EU.

New Zealand's position with respect to visibility management and protection is very similar to that of Canada's. They acknowledge that adoption of a US style 'Visibility Goal' is not practical, given the responsibility for air quality management lies with regional and district councils (MfE, 2002). They acknowledge the difficulty in setting a national guideline for visibility lies in determining the level of visibility degradation that is acceptable to communities based on amenity (or welfare) values. Going forward they are following up on recommended actions such as raising awareness, forming a visibility working group, and setting long-term objectives.

Similarly, in Australia the effects of poor visibility are judged to be minor compared to potential health effects of air pollution (welfare vs health effects). Visibility is not considered separately in Australia's study of the total value of air quality improvements. They note that perceived health improvements and perceived visibility improvements are inseparably related in people's minds, resulting in super-additivity (double counting).

In Asia, visibility concerns are related to forest and agricultural burning only. The Association of South East Asian Nations have an Agreement on Transboundary Haze Pollution (ASEAN, 2002) that considers reducing the effect of smoke, mainly owing to severe economic effects suffered during the 1997 burning season (visibility was impaired to the extent that it hampered air, marine, and road transportation). Health and other effects are considered, however the effects of industrial and transportation-related emissions on visibility are not.

Hong Kong differs from this model in that they consider visibility effects from a broad range of emission sources (le Clue, 2004). It is understood that there are very real costs and benefits associated with changes in visibility. Poor visibility and the perceived health effects may result in tourists reducing their length of stay, or divert their vacations entirely to perceived cleaner destinations. Given the residential and tourism implications, emphasis is on researching the extent to which residents are willing to pay for improvements.

A synopsis of visibility management and visibility protection efforts in Europe, Australasia and Asia is provided in the annotated bibliography. This includes two comprehensive works on visibility internationally; one from the New Zealand Ministry for the Environment (MfE, 2002), and another from Hong Kong (le Clue, 2004) respectively. The latter provides an international summary, followed by recommendation for Hong Kong. The former describes the situation in New Zealand, which in many respects resembles the British Columbia situation.

While there may be other regions where visibility science has progressed, or where aerosol, optical, and scene data have been collected (e.g. the Arctic and Antarctic), it is believed that the above-mentioned areas represent the bulk of regions where visibility is studied, and where policy issues related to the regulation of visibility have been explored.

4.0 POTENTIAL VISIBILITY MANAGEMENT OPTIONS FOR BC

A management option for visibility is defined as the use of a particular policy mechanism by an air management agency to achieve visibility protection or improvement. One management option, for example, might be to establish targets and develop mechanisms to achieve those targets. Following a brief summary of visibility policy drivers for clean air agencies in BC, this section considers a range of potential management options developed in consultation with the Steering Committee.

4.1 Preamble

The Canadian government obligations to address transboundary air pollution, and specifically to protect visibility, is found in Annex I, Part 4 of the 1991 Canada / US Air Quality Agreement (Prevention of Air Quality Deterioration and Visibility Protection). In recognition of the "importance of preventing significant air quality deterioration and protecting visibility, particularly for international parks, national, state, and provincial parks, and designated wilderness areas" the signatories are obliged to:

> A. For the United States:
>
> Requirement that the United States maintain means for preventing significant air quality deterioration and protecting visibility, to the extent required by Part C of Title I of the Clean Air Act, with respect to sources that could cause significant transboundary air pollution.
>
> B. For Canada:
>
> Requirement that Canada, by January 1, 1995, develop and implement means affording levels of prevention of significant air quality deterioration and protection of visibility comparable to those in paragraph A above, with respect to sources that could cause significant transboundary air pollution.

A progress report issued by Environment Canada (2006) notes that the US is fulfilling their obligations through the "Prevention of Significant Air Quality Deterioration" (PSD) program. This program is designed to protect public health from any adverse effects that might occur from the addition of new sources of air pollution, even at levels lower than the National Ambient Air Quality Standards (NAAQS).

While the US is directly addressing visibility, Canada is addressing this commitment through the implementation of Canada-wide Standards for PM and Ozone and the Canada-Wide Acid Rain Strategy Post-2000. However, since the current CWSs relate primarily to the protection of human health, their adequacy for the protection of vegetation, visibility impairment, material damage or other adverse effects may need to be assessed (CCME, 2000). Specifically, Tombach and McDonald, (2006) note:

> "In Canada, the management of visibility is not as closely coordinated with the management of PM. Environment Canada has the responsibility to ensure that transboundary issues, including both PM and visibility, are addressed under the Canadian Environmental Protection Act. Heritage Canada's Parks Service shares responsibility for managing visibility issues within the National Parks system, while the provincial governments are generally responsible for other air issues under the Canadian Environmental Assessment Act. Coordination with regard to visibility issues, similar to that in the United States, is not available nationally, but has taken place in localized settings, such as Kejimkujik National Park and the Lower Fraser Valley around Vancouver, British Columbia."
>
> "In Canada, most locales experience 24-hour mass concentrations at or above the 30 µg/m3 Canada-Wide Standard level only occasionally. The 98th percentile of mass measurements has potential to exceed the standard only in urban centers of the Golden Triangle and Upper Canada. Therefore, meeting the Canada-Wide Standard at these sites will improve local visibility to a small degree. However, for the rest Canada, including all of the west and the Maritimes, maintaining the Canada-Wide Standard allows increasing the current PM mass concentrations could produce a degradation in visibility (McDonald, 2002). Therefore, the Canada-Wide Standard $PM_{2.5}$ does not promote the protection improvement of visibility over much of the country. This is especially so for the most pristine regions, including national parks and wilderness areas."

Canada is relying on the implementation of principles such as pollution prevention, continuous improvement (CI), and keeping clean areas clean (KCAC) to prevent the deterioration of air quality and address the pollutants involved in impairment of visibility (Environment Canada, 2006). The KCAC principle recognizes that polluting "up to a limit" is not acceptable and that the best strategy to avoid future problems is to keep clean areas clean (Tombach and McDonald, 2006). Continuous improvement applies in areas with ambient levels below the levels of the standards but still above the levels associated with observable health effects. Keeping clean areas clean (KCAC) may prevent the deterioration of air quality and address the pollutants involved.

Provinces are encouraged to take remedial and preventive actions to reduce emissions from anthropogenic sources. The Federal Government is taking actions such as revising emission limits for SO_2, NO_x, and total PM to be consistent with the performance capability of current economically feasible best available technologies. Proposed revisions are intended to align with US standards and best available control technology (BACT) determinations (Environment Canada, 2006).

As recently as April 13, 2007, US EPA Administrator Stephen L. Johnson and the Honorable John Baird, Canada's Minister of the Environment, announced that Canada and the United States will begin negotiation of an annex to the US-Canada Air Quality Agreement aimed at reducing the cross-border flow of air pollution and its impact on the health and ecosystems of Canadians and Americans. The annex will result in reductions in PM as well as many of the chemicals that contribute to other air quality issues of concern such as acid rain, regional haze and visibility in the communities along the US-Canada border.

The following two sections lay out both the potential options for managing visibility in British Columbia (4.2) and the elements common to effective visibility management programs (4.3). The Steering Committee discussed both of these topics at length. The former can be thought of as "How can we make this happen?", while the latter is "What needs to be done next?". While the five options are presented as distinct choices, this grouping of policy and regulatory actions is not meant to be restrictive or all-inclusive. It was developed in the knowledge that the final result will be a synthesis of many elements.

4.2 Potential Options for Managing Visibility in British Columbia

Potential options for managing visibility in British Columbia are influenced by the overarching Federal and Provincial responses to obligations under the Canada / US Air Quality Agreement. The United States is directly regulating visibility in 156 Class I areas and obliging states to develop plans to achieve a visibility goal in these areas. Canada is managing visibility as a co-benefit of measures designed to protect human health from the effects of $PM_{2.5}$. The Canadian approach to visibility protection is less specific to parks and wilderness areas, and does not explicitly create or employ regional visibility-focused planning groups.

In both countries however, point source emissions are controlled by essentially the same instruments: discharge objectives, and a regulatory process that requires state-of-the-art, proven control technology (in the U.S. the terms 'best available control technology' and occasionally 'best available retrofit technology' are used). Also common to both jurisdictions are controls on transportation-related emissions (technology and fuel), and policies covering forestry, land-clearing, and agricultural burning.

Visibility, and the specific physical qualities of fine aerosols that impair visibility, are routinely measured at 110 rural / remote sites across the Unites States. In Canada, $PM_{2.5}$ is measured across the country, largely at urban sites. The aerosol chemistry data required to perform back-trajectory analyses and reconstruct light extinction are available, but limited in their applicability. Visible range is measured at airports across Canada, however detailed scene information and atmospheric extinction measurements are limited.

Regardless, in British Columbia, the historical momentum of these earlier visibility related studies has served to overcome these limitations, and provided a foundation to develop a program to directly address visibility. This is attributable to the initiative of BC's air management agencies, and the constant reminder of the importance of visibility given the scenic vistas, and evidence that the costs of visibility impairment to tourism are considerable ($9 million in the Lower Fraser Valley: McNeill and Roberge, 2000),

British Columbia lies in a region where the background visual range is very high, and it has a physiographic makeup that allows for the appreciation of distant views. In the late 1990s, the Interior Plateau was shown to have annual average visual ranges in excess of 110 km - comparable to the cleanest areas in the US Midwest (ARS, 1999; ARS, 2000; ARS, 2001). BC's physiographic makeup also ensures that during regional haze episodes, people recognize their loss.

For this reason, a growing number of stakeholders inside and outside of the air quality community deem visibility as deserving of attention in its own right - not to be managed as a co-benefit of an air quality program that solely addresses health effects. Current science indicates that without directly addressing visibility, and despite increasingly stringent fine particulate criteria, visibility will worsen in the future (Tombach and McDonald, 2006).

4.2.1 Policy Drivers

On October 26, 2006, air management agencies met to identify outstanding questions and knowledge gaps with respect to visibility science and policy in British Columbia. This included representatives of the Greater Vancouver Regional District, the Fraser Valley Regional District, the BC Ministry of Environment, and Environment Canada. Current visibility policy drivers for air management agencies in BC were identified, and are described below and in Table 1.

The Greater Vancouver Regional District (GVRD) is a partnership of 21 municipalities and one electoral area that make up the metropolitan area of Greater Vancouver. The GVRD has been delegated authority under the BC Environmental Management Act and the 1971 GVRD Letters Patent to manage Greater Vancouver's air quality. The GVRD was the first regional district in Canada to develop and adopt an Air Quality Management Plan (AQMP) in 1994. Implementation of several AQMP initiatives, the AirCare program and improvements in vehicle technology reduced emissions by 38% from 1985 to 2000. In October 2005 the GVRD adopted a new AQMP. Goal #2 of the 2005 AQMP is to "improve visibility". The GVRD has a continuing interest in visibility and has been conducting monitoring of aerosol, optical, and scene data since the early 1990s. They wish to respond to the needs of residents respecting air quality, and reduce $PM_{2.5}$ emissions and ambient concentrations with the understanding that visibility protection will also be achieved as a co-benefit.

The Fraser Valley Regional District was amalgamated from three former regions (Central Fraser Valley Regional District, Dewdney Alouette Regional District, and Fraser Cheam Regional District) in December 1995. The Fraser Valley Regional District's role is to provide their resident population with good government, services, stewardship, and economic and environmental well-being. The FVRD Regional Growth Strategy outlines their plans for carrying out these responsibilities. Visibility is a concern of the FVRD residents, especially following the emergence of a 'white haze' in the last decade. Their interest in visibility protection policy is publicly and politically supported, and they are mindful that reduced $PM_{2.5}$.is a co-benefit.

The BC Ministry of Environment (BC MoE) has a broad mandate to protect the quality and integrity of water and air resources in the province. The Environmental Protection Division (EPD) of the Ministry of Environment works to protect human and environmental health. The EPD's main goals are to: improve air quality; reduce greenhouse gas emissions; reduce and remove wastes that contaminate the land, air and water; and, respond to high-risk environmental emergencies. The BC Premier's Great Goal #4 calls for BC to "Lead the world in sustainable environmental management, with the best air… quality… bar none." Furthermore, the BC Environmental Management Act specifically defines an air contaminant as a substance "that is introduced into the air and that (c) interferes with or is capable of interfering with visibility". As such a visibility impairing substance could cause "pollution" (defined under the Act as contaminants that substantially alters or impairs the usefulness of the environment) and the emitter subject to legal action.

The BC MoE has an obligation to plan and execute an implementation strategy for the Canada-wide Standards for $PM_{2.5}$ and Ozone by 2010, and develop the concepts of KCAC and CI. The Ministry has a continuing interest in visibility, and was primarily responsible for REVEAL and provided technical support for the REVEAL II program.

Environment Canada coordinates environmental policies and programs for the federal government. They have a mandate to preserve and enhance the quality of the natural environment, conserve Canada's renewable and water resources, forecast weather and environmental change, as well as enforce rules relating to boundary waters. Environment Canada has made international commitments with the United States to prevent significant air quality deterioration and visibility protection. Through provisions for continuous improvement (CI) and keeping clean areas clean (KCAC), there is recognition that the Canada-wide Standards are not intended as allowable pollution limits. Together with US Environmental Protection Agency (Region 10), Environment Canada co-leads the *Georgia Basin-Puget Sound International Airshed Strategy (GB-PS IAS)* - a multi-agency, international co-operative effort to address shared air quality management concerns. One of the two goals of the GB-PS IAS is increasing visibility and reducing regional haze. Environment Canada is also responsive to the needs of Canadians and understands that visibility protection carries the co-benefit of reduced $PM_{2.5}$ and the preservation of culturally significant viewscapes of aboriginal groups.

Table 1 Visibility Policy Drivers for BC Clean Air Agencies

Policy Drivers	Greater Vancouver Regional District	Fraser Valley Regional District	BC Ministry of Environment	Environment Canada	Transboundary Issues
Regulatory or Formal Agreements	2005 Air Quality Management Plan Goal #2 "Improve Visibility"	Could play role in new Air Quality Management Plan	Canada-wide Standards: Continuous Improvement and Keeping Clean Areas Clean (CI & KCAC) Environmental Management Act (visibility could as cause "pollution") Airshed Planning	Canada-wide Standards: CI & KCAC Georgia Basin - Puget Sound International Airshed (GB-PSIA) Canada/US Air Quality Agreement (Annex 1, #4)	Canada/US Air Quality Agreement (Annex 1, #4) GB-PSIA Goal: "Reduce the impacts of air pollution to human health, ecosystem, and visibility in the GB-PS Airshed"
Political	Politically adopted as one of GVRD's goals	Politically supported and a concern of residents.	No. 4 of the Premier's Five Great Goals: "Lead the world in sustainable environmental management, with the best air… quality… bar none."		
Desired Public Perception	Being responsive to public needs (improve quality of life)	Public perception (especially the emergence of the white haze)	Being responsive to public needs	Being responsive to public needs	
Co-benefits and Air Quality Management	Adopted new PM2.5, NO2, SO2, CO and O3 objectives with the 2005 AQMP Interested in reducing $PM_{2.5}$ and precursors	Interested in reducing $PM_{2.5}$ and precursors	Development of new BC $PM_{2.5}$ Objective Interested in reducing $PM_{2.5}$ and precursors	Canada-wide Standards for $PM_{2.5}$ and CI & KCAC.	US concern re: transboundary pollutant flows from Canada / BC and impacts on US visibility (US Regional Haze Rule)

Source: Visibility Meeting Summary – Oct. 26th, 2006, held at the GVRD offices.

All of BC's clean air agencies have concerns respecting transboundary issues. The Georgia Basin - Puget Sound International Airshed (GB-PSIA) was created, in part, to "reduce the impacts of air pollution to… visibility". The membership of the Lower Fraser Valley Air Quality Coordinating Committee (LFVAQCC) also includes BC's clean air agencies. The LFVAQCC is aware that the LFV airshed already suffers from significant air quality and visibility issues. Through these agencies, there is a clear commitment to improve air quality in the LFV – including visual air quality.

4.2.2 Policy Options

The five broad policy options presented in this section range from a Status Quo model to the development of a National Visibility Management Program. Potential options are described in a short written summary that expands on aspects such as: i) public perception and acceptability; ii) ease of integration within and among clean air agencies; iii) the interests of other agencies (e.g., tourism, forestry), iv) economic costs and benefits; and v) the geography and demographics in BC. Following this discussion they are summarized in Table 2, with the potential positive outcomes and other considerations listed in bullet form.

The very process of considering the various options for protecting visibility illustrates the complexities and challenges involved. It is important to remember that these potential policy options were developed as a starting point for discussions. They are intended to be expanded upon, consolidated, changed and refined.

Option 1: Status Quo – No New Efforts for Visibility Protection

This option relies on achieving visibility protection through existing air quality management programs that are designed to manage ambient air quality. As these programs are implemented and air quality goals are achieved, it is assumed that visibility protection (and improvements) will follow without any additional effort in new visibility science, policy and programs. For example, the Canada-wide Standards for $PM_{2.5}$ and Ozone, and in particular the concepts of Keeping Clean Areas Clean and Continuous Improvement is cited in the 'Canada / US Air Quality Agreement' as the method to achieve parity with US visibility protection programs.

The Status Quo option may be quite attractive especially if visibility is not a priority relative to the other environmental and human health effects of air pollution. The downside to this option is the real possibility that only a limited measure of success would be achieved, and a risk that a steady deterioration in visibility could occur where remediation, and not simply protection, becomes necessary.

Option 2: Include Visibility Considerations in the Implementation of Canada-Wide Standards, Continuous Improvement - Keeping Clean Areas Clean

This option builds on the Canada-Wide Standards for $PM_{2.5}$ and O_3 by including visibility considerations in the implementation Continuous Improvement - Keeping Clean Areas Clean.

Given that there is no apparent threshold for the effects of these two pollutants on human health, under CI-KCAC, jurisdictions are expected to work with stakeholders and the public to establish programs that apply pollution prevention and best management practices in order to avoid polluting up to the CWS, and thereby avoiding future problems (Caton et. al., 2003). Although the specifics of CI-KCAC are not defined, they can include a number of approaches including best available emission control technologies and local airshed management planning processes.

As noted earlier, this approach is cited in the Canada/US Air Quality Agreement as the method to achieve parity with US visibility protection programs. However, unlike Option 1 (Status Quo), this Option goes further in that specific visibility considerations are incorporated into the implementation of

CI-KCAC. Although it falls short of a specific visibility protection and improvement program, visibility "piggy backs" on a National framework which Provinces are expected to apply.

British Columbia, under the umbrella of KCAC and CI, could develop an implementation of the CWS that facilitates the protection of visibility. A comprehensive implementation could involve the development of new ambient air quality and discharge objectives for criteria air contaminants (and even their precursors) that would include visibility considerations. Most of the existing air quality objectives were developed along with the BC Pollution Control Objectives nearly 30 years ago. The AAQO are in need of updating – a process that would require a substantial and sustained effort. The Canada-wide Standard setting process and the latest recommended options for a BC $PM_{2.5}$ objective (discussed later) speak to these complexities.

Specifically, this effort would involve updating objectives for oxides of sulphur and nitrogen, fine particulate matter, ozone, carbon monoxide, and other substances such as ammonia and volatile organic carbon species (VOCs). A multi-pollutant strategy is preferred to targeting contaminants separately. This is especially relevant for visibility protection, given the multi-pollutant nature of visibility impairment. The goal is to efficiently achieve meaningful reductions in particles and gases that impair visibility and minimize negative outcomes.

The province is currently developing an objective for respirable particulate matter ($PM_{2.5}$). The recently published options for BC's ambient $PM_{2.5}$ objective recommends a flexible approach to respond to local and regional issues (BC Lung Association, 2005). These were developed in part to enable a day-to-day management approach; something not achievable through the CWS (which imposes a three consecutive year rolling average for the 98^{th} percentile value). Applying different $PM_{2.5}$ objectives for urban, rural and remote regions may lead to visibility improvements. The BC Lung report recognizes that what works in the Lower Fraser Valley (LFV) may not work in Fort Nelson – and this is a key consideration for the management of visual air quality. A $PM_{2.5}$ objective may lead to visibility improvements as a co-benefit in the LFV, but not in northeast BC.

Ambient objectives are a familiar air quality management approach and more stringent objectives are acceptable to the public and some stakeholders. More stringent AAQO would achieve a number of potential positive outcomes with respect to health as well. New objectives which reflect visibility considerations may also be implemented such as to be compatible with the KCAC and CI provisions of the CWS.

Another CWS CI-KCAC implementation approach is through the establishment of emission criteria on the basis of state-of-the-art, proven emission control technology. Increasingly stringent discharge -objectives will ultimately lead to improvements in ambient air quality (and visibility) as they are phased in. Currently the Ministry does not have a formal policy on defining state-of-the-art, proven emissions control technology (analogous to the US EPA policy on Best Available Control Technology (BACT) or Best Available Retrofit Technology (BART)). Such determinations are case-by-case specific and rely on factors such as recent technology used for similar facilities in other jurisdictions, as well as technological feasibility.

Emission criteria for specific permits are based on technology review determination as well as an assessment of the air quality impacts of the emission on the receiving environment. Predicting visibility impacts could be included in such assessments. If the air quality impacts (including visibility) are not acceptable, more stringent emission levels are warranted. More stringent, new, ambient air quality objectives will drive cleaner emission control technology through new permits, approvals and registrations of industrial facilities regulated by the Ministry, the BC Oil and Gas Commission (OGC) and the GVRD. Industry may be challenged to achieve compliance with the new AAQO, and will require long lead-times to adapt with new technology. Consideration will have to be given such that industry is not compelled to strand assets that are productive, relatively clean, and not fully depreciated. It may well take upwards of a decade to amend existing permits. As permit amendments are submitted, the permit review process will determine if the new, existing or expanded facility will meet the AAQO.

In keeping with the CI-KCAC approach, in many areas of the province, there are active air quality management ("airshed") processes (nine in BC, including the GVRD, Quesnel, and the Bulkley Valley) where there has been a history of multi-stakeholder and public consultation and participation at a local level. These airshed management processes are currently recognized as an implementation measure of CI-KCAC. In some of these processes, visibility has been identified as a key issue (Sea-to-Sky, GVRD).

The airshed planning processes have the advantage of including familiar means of implementing air quality improvement initiatives. There is already buy-in at the agency level, and a good measure of acceptability with the public and stakeholders. Stakeholders with in interest in visibility such as the Ministry of Tourism, the Ministry of Energy, Mines and Petroleum Resources, and the Ministry of Forests & Range may already be engaged on a local level, even if they are minimally engaged on the visibility issue on an agency-to-agency level. Inclusion of these stakeholders in these local airshed management planning processes is crucial in any effort to implement visibility protection.

These airshed plans are key to the control of non-industrial (i.e. non-permitted) emissions of visibility-reducing aerosols and their precursors. Activities examined under this process could include open burning (all forms), fugitive emission sources (land disturbances), agriculture, and transportation. Through these local stakeholder efforts, these substances can be better controlled, leading to improved visibility and reduced $PM_{2.5}$ as a co-benefit.

Some of the challenges associated with this option are:

- Relying on air quality management approaches designed to achieve pollutant specific ambient goals ($PM_{2.5}$ and ozone for example) may fail to protect visibility, especially regional haze in remote, pristine settings. In other words, it may well not be robust and specific enough to achieve the desired co-benefit of improved visibility. This option may also fail to achieve a nuanced solution - policies that will address the reality that protecting visibility will require the control of emissions of different chemical species in different geographic areas. For example, AAQO do not address transportation emissions or emissions associated with burning.

- The level of effort needed to achieve a reasonable measure of visibility protection through this option is considerable. It must be supported by good science, thoughtful policy development, consultation, and drafting of new regulations and / or the establishment of new air quality objectives. Buy in at all levels would require extensive consultations, and the resolution of various agency concerns respecting implementation, grandfathering, and the equitable distribution of costs. Details are presented in Section 4.3 (Elements Common to Effective Visibility Management Programs).

- If specific and rigorous visibility protection concepts are not fully integrated into existing air quality management activities, (BC's implementation of CI-KCAC mechanisms, establishment of AAQO's, determination of BACT, and local airshed, multi-stakeholder processes) this will default to Option 1 (Status Quo) with the attendant downsides already described.

- This is not a visibility specific program, so no overall visibility goal or achievement criteria (which would drive the program) are declared. Visibility protection would be a by-product through "tweaking" of components in the CI-KCAC implementation.

Option 3: Leverage Existing Policy Directives and Establish Visibility as a Protected Value

This option involves the Province and the GVRD to leverage existing broad policy directives ("the best air…quality…bar none") by defining visibility as an important value and establishing a visibility goal, then directing the management of visibility using existing mechanisms to meet the goal – with no new legislation or land designations (i.e. visually important areas). It has the benefit of immediacy, and perhaps some of the potential positive outcomes of the more complex "visually important areas" option (Option 4). The main benefit is that there is a greater likelihood that visibility protection would actually be achieved given that efforts would be directed to protecting visibility as an air quality value through the achievement of visibility specific goals.

This approach would require the declaration of a visibility goal (similar to the US Goal: "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from manmade air pollution".), establishment of a visibility standard, and/or by having BC join the Western Regional Air Partnership (WRAP http://www.wrapair.org). The declaration of a visibility goal would of necessity be followed by other actions, such as setting a visibility standard, adopting some equivalent to the US Regional Haze Rule, and taking steps to protect visibility (resolving to protect the upper quartile of days with the best visibility, and resolving to remedy the lower quartile of days with the poorest visibility).

A visibility standard, like the ambient air quality objectives mentioned in Options 2, can allow for a flexible approach to respond to local and regional issues. The benefit of course will be that airshed management options will have to include measures that specifically protect visibility rather than relying on air quality objectives or CWS implementation to achieve the goal. Effectively implementing this approach may be as costly and complex as Options 2 and 4. The collection of aerosol, optical, and scene data representative of a variety of rural and remote regions in the province will be required. Decision makers will also need to use visibility models as a tool used to link emissions to visibility impacts and to understand the implications of control measures on the visual environment. Details are presented in Section 4.3 (Elements Common to Effective Visibility Management Programs).

Requesting and exercising membership in the Western Regional Air Partnership (WRAP), the Integrated Monitoring of Protected Visual Environments (IMPROVE) Steering Committee, and the Western States Air Resources Council (WESTAR) may be desirable. Membership in some capacity would likely be welcomed by the US, and a great deal may be learned through participating. A good BC model for this type of collaboration is the West Coast Collaborative Marine/Port Work Group. It involves BC air quality agencies (all levels), ports, carriers, transportation interests, vendors, ENGOs and an informal steering group composed of the US EPA, Environment Canada, Puget Sound Clean Air Agency (PSCAA).

Some of the challenges associated with this option are:

- As it is driven by broad direction and implemented quickly to respond to this direction, it may have little legislative backstop and could be subject to shifting priorities. In other words, it lacks the resolve and permanence of a legislated change – a potentially fatal flaw given the long-term commitment required of visibility management efforts.

- There can be inconsistency between BC and other provinces (which do not have a specific visibility protection program) unless a WRAP-like partnership is developed. Inconsistency can be a disincentive to industry (more regulatory requirements in BC). On the other hand, visibility protection and clean vistas may be seen to be a benefit by other sectors of industry (tourism, knowledge based industry).

- Developing and implementing this approach will take a concerted and co-ordinated multi-agency approach with sustained new funding. Achieving buy in by other Ministries, and integration within and among them will be much more challenging than developing and implementing new AAQO. The level of effort to achieve a reasonable measure of visibility protection with this approach is considerable. It must be supported by good science and policy. Details are presented in Section 4.3 (Elements Common to Effective Visibility Management Programs).

- Without strong and lasting commitments enshrined in law, this less forceful approach may not protect visibility, address regional haze in remote, pristine settings, or carry a health co-benefit. The lack of a legislative backstop almost certainly ensures that lasting parity with the American system will not be achieved.

Option 4: Visibility Protection by Establishing Visually Important Areas in BC through Legislation

This option differs from Option 3 in that visually important areas are specifically protected by law, and the accompanying visibility protection program would have to be developed to fulfill obligations under the law. Visibility protection would be a legal requirement, and thus will be less prone to shifting government priorities.

The protection of visibility values in non-urban regions may be achieved through an internally-driven amendment of the BC Environmental Management Act, the Forest Act, and the Park Act to mandate protection of visually important areas. This approach carries substantial air quality co-benefits. It will lessen ecosystem effects from chronic, low-level exposure to sulphates and nitrates, and indirectly address human health. Amending key pieces of existing legislation to protect visually important areas is to mimic the American approach of protecting Class 1 lands.

The Ministry of Forests has long embraced the concept of ‘smoke sensitive areas’, however this applies to the application of prescribed fire as a policy. These areas have no legal standing, and there are few consequences for impacting on a smoke sensitive area. However more recent efforts have focused on the creation of burn plans under the Open Burning Smoke Control Regulation, where smoke sensitive areas are identified and efforts are taken to minimize smoke impacts in these areas. Mandating visually important areas would be similar in concept, but will require the full weight of legislated changes to be effective. A measure such as BC Parks designating selected large parks (e.g., Bowron lakes, Tweedsmuir, Wells Gray) and wilderness parks (e.g., Spatsizi Plateau, Northern Rocky Mountains Park) as visually important areas may be sufficient. The Ministry of Parks could embrace the task of monitoring, and the BC Ministry of Environment, the Ministry of Forests and Range, and other Ministries could coordinate the regulatory compliance aspects.

This option may be fairly easy to sell to the public and stakeholders as it is appealing and simple in concept. This nuanced approach will protect visibility, and address regional haze in remote, pristine settings, plus it carries health and ecosystem co-benefits. This approach has the province achieving some level of parity with the American system, and potentially satisfies transboundary concerns respecting visibility protection.

Some of the challenges associated with this option are:

- Integrating this solution among clean air agencies will be a substantial effort that requires a great deal of support. Implementing this approach requires the collection of aerosol, optical, and scene data representative of a variety of rural and remote regions in the province. It will take a concerted and co-ordinated multi-agency, approach with sustained new funding. Details are presented in Section 4.3 (Elements Common to Effective Visibility Management Programs). This approach will require the concept of airshed management to expand from an urban base to encompassing broad regions.

- Achieving buy in by other Ministries, and integration within and among them will be much more challenging than developing and implementing new air quality or discharge objectives (e.g., it may require the revision of many existing land and resource management plans). As adjoining Canadian jurisdictions are not compelled to embrace this concept, it may create economic disincentives for certain activities (e.g., mining, oil and gas, manufacturing), resulting in their developing elsewhere. On the other hand, it may create incentives to other industry sectors (tourism, health services).

- The level of effort to implement this solution is considerable. Affected stakeholders in Provincial and joint Federal/Provincial processes will be challenged to adapt to a new layer of complexity, and processes unfamiliar in Canada. Substantial new investment in science, monitoring, and policy/procedure development will challenge Provincial Ministries. Details are presented in Section 4.3 (Elements Common to Effective Visibility Management Programs).

- This approach may be difficult to implement. Some regions upwind of protected areas may be subject to increasingly stringent controls; not only on industry, but a wide variety of non-permitted activities that emit air contaminants (open burning, transportation). Certain development areas could be off limits, or are much less economic to develop. The science behind visibility management could become highly politicised, with various interests contesting scientific measurements, analyses, and visibility modelling results.

Visibility protection concepts are more likely to be fully considered and addressed in this process. If implemented prudently, considerable success in protecting visibility and preventing future deterioration may be enjoyed. As air quality improves new activities (e.g., information and knowledge-based industries) may locate in BC owing to the improved quality of life. Only Option 5 (a National program) more effectively ensures this outcome.

Option 5: Develop a National Visibility Management Program

The opposite of the Status Quo option is the development of a National visibility management program through Environment Canada and the CCME, in cooperation with the Provinces. This approach requires a complete policy reversal with respect to Canada's achievement of Annex I, Part 4 of the 1991 Canada / US Air Quality Agreement. Achieving buy in by other agencies and integration within and among clean air agencies will be as challenging as the CWS process. This option involves abandoning reliance on the Canada-wide Standards and CI/KCAC to achieve the Visibility Protection commitments in the Canada / US Air Quality Agreement.

During the Visibility Task Force discussions, this option was dismissed as inconsistent with the current sharing of powers respecting air quality between the Canadian government and the provinces. This may or may not be the case.

This option could be implemented through the development of legislation through the proposed Federal Clean Air Act if it mimics the US Visibility Goal and PSD-like visibility protection. It may require the establishment of nation-wide equivalent to "Class 1 lands" (e.g., National Parks and large provincial parks with wilderness values) and mechanisms like the Regional Haze Rule. It may need to include mechanisms such as mandatory Implementation Plans.

Another regulatory option would be to add projects capable of impairing visibility in a National Park or large Provincial Parks to the list of projects reviewable under the Canadian Environmental Protection Act (CEAA). This may be possible to impose this requirement under the Law List Regulations trigger in paragraph 5(1)(d) of the CEAA (under a provision prescribed pursuant to paragraph 59(f), issues a permit or licence, grants an approval or takes any other action for the purpose of enabling the project to be carried out in whole).

These types of approaches would be sweeping in scope, and ground breaking in nature. It would be the most costly to implement, requiring the establishment of supporting programs across the country (see Section 4.3 Elements Common to Effective Visibility Management Programs). Planning and implementing this approach would require a great deal of resolve. As with many of the other options, affected stakeholders will be challenged to adapt to new layers of complexity, and there will be resistance.

Depending on the implementation, a nuanced approach that will protect visibility, and address regional haze in remote, pristine settings, could be achieved. It would satisfy the transboundary aspects of the Canada / US Accord. There would be health and ecosystems co-benefits. Adjoining Canadian jurisdictions will be compelled to embrace this concept, thereby avoiding economic disincentives for activities in BC. Considerable success in protecting visibility and preventing future deterioration nation wide may be enjoyed under this option.

Table 2 Potential Policy Options for Visibility Protection in BC

Potential Policy Option	Potential Positive Outcomes	Other Considerations
1.Status Quo – No New Efforts for Visibility Protection - Rely on current existing air management activities which are focussed on air pollutants	- No new efforts, resources required	- Visibility protection is assumed to be by-product of pollutant specific air quality management actions - Does not directly address visibility, therefore visibility benefits are not ensured
2. Include Visibility Considerations in the Implementation of Canada-wide Standards, Continuous Improvement - Keeping Clean Areas Clean - Implementation through local & regional airshed plans that include visibility measures - Implement more stringent Provincial AAQO for Criteria Air Contaminants that consider visibility - (e.g. $PM_{2.5}$, SO_2, NO_2, and Ozone). - Establish BACT and include visibility assessment in setting permit emission limits	- Cited in the 'Agreement' as the method to achieve parity with US visibility protection programs. - Regulatory mechanisms are well understood. - Buy-in Nationally and across Provincial boundaries - Provides additional protection of visibility and human health. - Potential competitive advantage with other Provinces for industrial facilities and sectors (such as tourism) as quality of life improves. - Encourages application of BACT and consideration of BART. - Fulfills BC's commitment under CWS CI/KCAC.	- Does not directly address visibility, therefore visibility benefits are not ensured, except perhaps locally. - No means of addressing regional haze and impairment of visibility in large remote regions (Airshed Plans tend to be locally focussed). - Potential competitive disadvantage with other Provinces for industrial facilities as start-up costs increase. - Introduces new complexities in the Permitting and EIA Process. - Resources and time required.
3. Leverage Existing Policy Directives and Establish Visibility as a Protected Value - The Province and the GVRD define visibility as an important value, and direct their Agencies to protect visibility using existing mechanisms	- Requires less bottom-up effort to achieve, and is almost immediate. - Does not require passage of Regulations or changes to legislation. - Establishes visibility as a value to be protected, rather than a by-product of other programs. - Sets a visibility goal. - Includes some benefits of Option 4.	- Requires visibility monitoring and assessment tools (models). - Requires new program funding. - Does not address trans-provincial / territorial issues. - Regional disparities in the identification of visibility issues, and response to them. - Introduces complexity is Permitting and EIA Process. - May be subject to shifting priorities
4. Visibility Protection by Establishing Visually Important Areas in BC through Legislation - Internally driven amendment of the BC Environmental Management Act, Forestry Act, and Parks Act to mandate protection of visually important areas	- Directly addresses visibility, ensuring achievement of visibility benefits. - Indirectly addresses human health - Directly protects tourism and park values. - Lessens ecosystem effects from chronic, low-level exposure (e.g.: SO_4) - Potential competitive advantage with other Provinces for industrial facilities or other sectors (tourism, knowledge based industry) as quality of life improves. - Results in collection of scene, concentration and extinction data representative of background.	- Requires effort to coordinate - Politically difficult - Requires visibility monitoring and assessment tools (models). - Does not address trans-provincial / territorial issues. - Regional disparities in the identification of visibility issues, and response. - Potential competitive disadvantage with other Provinces for industrial facilities as start-up costs increase. - Introduces complexity is Permitting and EIA Process.

Table 2 Potential Policy Options for Visibility Protection in BC (cont'd)

Potential Policy Option	Potential Positive Outcomes	Other Considerations
5. **Develop a National Visibility Management Program** - Encourage / participate in the development of a National Visibility Protection Program through Environment Canada and the CCME	- Directly addresses visibility. - Will address trans-provincial / territorial issues. - Will include a broad visibility goal and uniform metrics country-wide.	- Requires fundamental shift at the Federal level on how Visibility Protection is achieved as per the 'Agreement'. - Requires new program support and funding (science and policy)

4.3 Elements Common to Effective Visibility Management Programs

Regardless of the policy direction taken, experience indicates that effective visibility management programs share a number of common elements. A mature, effective program in British Columbia will include the elements below. These broadly include: a strong basis in visibility and air quality science, support for related socioeconomic studies, agency efforts to develop visibility standards, advocacy for regulatory change, and legal requirements. The challenge will be to build a visibility management framework that both supports and nurtures this activity.

Visibility and Air Quality Science

Well-developed visibility management programs have at their core a strong basis in science. The issues and potential solutions are identified through the collection of aerosol, optical, and scene data. Scientists and technologists support this work through data collection, quality assurance, analysis, peer review and publication. There is a strong connection to the existing air quality community where research focuses on atmospheric dispersion, inventories of emissions, chemical processes in the atmosphere, and effects assessment. Visibility research includes scientific disciplines such as physics, chemistry, biology, and meteorology. A strong community of government, university, industry, and consultants support visibility research in the United States.

Related Socioeconomic Studies

A necessary adjunct to visibility science is strong support to determine both the costs and benefits of visibility management. This includes studies focussed on the willingness to pay for improvements, or the tolerance of deterioration. These studies consider social factors, economics, achievable changes in visibility, and health co-benefits. Visibility standards, the determination of visually important areas, and the establishment of visibility goals are strongly supported by this work.

Development of Visibility Standards

The development of standards for visibility is where the scientific and social science communities intersect. Scene and other information are used to establish the existing visibility regime plus the causes of visibility degradation. Social and economic studies determine the appetite for change, and the value placed on that change. The established standard will reflect what is possible and desirable to achieve, be it an overall net improvement, fewer 'bad' days, or more 'good' days (e.g., the Denver

Visibility Standard of 76 Mm^{-1} http://apcd.state.co.us/psi/brochure.html#D). These values are then reflected in whatever policies, laws or regulations are developed by local, regional or national governments.

Advocacy for Regulatory Change

None of these processes move forward without strong and sustained advocacy for change. In a jurisdiction with a mature visibility community, there will be both strong advocates for change and defenders of the status quo. The history of the United States visibility protection program is punctuated with litigation (Watson, 2002). While law suits are not preferred drivers for change, it is sometimes difficult to challenge their effectiveness. These extremes aside, most visibility protection advocacy is conducted in a reasonable manner by concerned individuals who are convinced that visibility is an important value that carries a wide variety of direct and indirect benefits.

Legal Requirements

The effectiveness of the U.S. visibility protection and improvement programs is largely due to the Clean Air Act that requires visibility protection in Class 1 areas, and requirements such as those associated with the Regional Haze Rule. These legal requirements require adjoining States into coordinated planning and assessment in order to achieve specific visibility protection goal.

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APPENDIX A

Definitions and Terminology

Definitions and Terminology

Air Quality Terminology:

Aerosols	Very fine airborne solid or liquid particles generally less than 2.5 micrometers or µm (10^{-6} m) in diameter
AAQO	Ambient Air Quality Objectives. See CAC's below.
AURAMS	"A Unified Regional Air-quality Modeling System" is an episodic, multi-pollutant, regional air-quality modelling system that predicts size-resolved and chemically-characterized particulate matter.
Back-Trajectory Analysis	This is a useful tool for analyzing source regions for haze and other transport-related pollution phenomena. This approach involves using meteorological data to track the prior "path" of parcels of air arriving at a particular monitoring site over a period of hours or days.
Best Available Control Technology (BACT)	For any specific source, the currently available technology producing the greatest reduction of air pollutant emissions, taking into account energy, environmental, economic and other costs.
CAA	The Clean Air Act (United States). Enacted in 1963 (Public Law 88-206) and subsequently amended (1967, 1970, 1977). A successor to the Air Pollution Control Act (1955).
CAC's	Criteria Air Contaminants. These are air contaminants for which the Federal and/or Provincial government have established air quality objectives, criteria, or standards.
CEAA	Canadian Environmental Assessment Act. A Canadian Act to establish a federal environmental assessment process http://laws.justice.gc.ca/en/C-15.2/.
CI/KCAC	Continuous Improvement / Keeping Clean Areas Clean. A conservation concept expressed in the Canada-wide Standards.
CMAQ	"Community Multiscale Air Quality Modeling system" is capable of simulating regional through urban patterns of ozone and photochemical oxidants, fine and coarse particulate matter, visibility, and acid deposition. It was developed by the US EPA and is driven by the MM5 meteorological model and the Sparse Matrix Operator Kernel Emissions (SMOKE) model.
CWS	Canada-wide Standards (for Ozone and $PM_{2.5}$). The Canada-wide Standards (http://www.ec.gc.ca/CEPARegistry/agreements/cws.cfm) are intergovernmental agreements developed under the Canadian Council of Ministers of the Environment (CCME).
NAPS	The Canadian National Air Pollution Surveillance Network.
PM_{10}	Inhalable particulate matter; airborne particles smaller than 10 micrometers in diameter.

$PM_{2.5}$	Respirable particulate matter; airborne particles smaller than 2.5 micrometers in diameter.
PSD	Prevention of Significant Deterioration of Air Quality (United States CAA, Title 1, Part C). A provision in the 1977 CAA amendments that addressed pollution (and visibility) in non-urban areas.
SO_2	Sulphur Dioxide
NAAQS	National Ambient Air Quality Standards (Untied States). See CAC's above.
NO_2	Nitrogen Dioxide
O_3	Ozone
VOCs	Volatile Organic Carbon species

Atmospheric Optics Terminology:

Absorption	The process by which incident radiant energy is retained by a substance by conversion to some other form of energy.
Light extinction	Light extinction (b_{ext}) The sum of the Rayleigh scattering coefficient (b_{Rg}) and the Mie scattering coefficient (b_{scat}). Or, $b_{ext} = b_{Rg} + b_{scat}$.
Meteorological Range (Mr)	Or visual range, as approximated by the Koschmieder formula where: $Mr = 3.92 / b_{scat}$, where $b_{scat} = b_{ext}$ (b_{Rg} ignored).
Photo Densitometry	A process whereby photographs are quantitatively analyzed to determine light extinction along a path of known length. It involves measuring the contrast between a known black target (e.g. a forested mountainside) and the adjacent sky.
Reflection	The process by which light changes direction when it strikes and rebounds from a surface or the boundary between two media.
Scattering	The process by which small particles in the atmosphere deflect radiation from its path into different directions. Rayleigh scattering (b_{Rg}) is the scattering and absorption of visible light by the component gases of the atmosphere (nitrogen and oxygen mainly). Mie scattering (b_{scat}) is the scattering of light by very fine airborne particles.
Solar radiation	Electromagnetic energy emitted by the sun with wavelengths ranging from approximately 200 to 2,000 nm or nanometers (10^{-9} m).
Terrestrial radiation	Electromagnetic energy emitted with wavelengths ranging from approximately 8 to 14 nm or nanometers (10^{-9} m).
Transmission	The fraction of radiant energy that passes through a substance.
Visible light	Electromagnetic energy with a wavelength between approximately 400 to 700 nm or nanometers (10^{-9} m). That which is visible to human eyes.

Visibility (visual range)	Visibility (or visual range) is generally taken to mean the horizontal distance one can see through the atmosphere.

Visibility Terminology and Measures:

Aethalometer	The Aethalometer is an optical transmission instrument that measures suspended carbonaceous particulates. Aerosol Black Carbon ("BC", or "EC" for **Elemental Carbon**) is a ubiquitous component of combustion emissions. It is most obvious in diesel exhaust, but it is emitted from all combustion sources together with other species such as toxic and carcinogenic organic compounds, and it can be found everywhere. See also **organic carbon** below.
Deciview (Dv)	A deciview (d_v) is a visibility index, the scale of which is linear to humanly-perceived changes in visual air quality. A one d_v change is approximately a 10% change in the extinction coefficient, which is a small, but usually perceptible scenic change. Expressed in terms of extinction coefficient (b_{ext}) and visual range (vr) it is defined: $d_v = 10 \ln (b_{ext}/0.01 \text{ km}^{-1}) = 10 \ln (391 \text{ km/vr})$ $d_v = 0$ for Rayleigh conditions at approximately 1.8 km elevation, and a just noticeable change is usually 1 or 2 d_v.
Mm^{-1}	Atmospheric extinction, given in units of inverse megameters (Mm^{-1}). $b_{ext,p}$ is an indicator of how much light is removed from a sight path by particle scattering and absorption. Higher values mean poorer visibility. B_{ext} values should include additional clear air scattering of ~10 Mm^{-1}.
Nephelometer	The Nephelometer is an instrument for measuring suspended particulates in a gas by employing a light beam, and a light detector set to one side of the source beam. Particle density is a function of the light reflected into the detector from the particles.
Organic Carbon	These are compounds where carbon is combined with hydrogen, oxygen, nitrogen, and other elements. **Organic carbon** differs from **elemental carbon** in that organic carbon has carbon-hydrogen bonds, while elemental or "inorganic carbon" does not.
Plume Blight	The US EPA defines plume blight as “smoke, dust, colored gas plumes, or layered haze emitted from stacks… relatable to a single source or small group of sources”.
Regional Haze	The US EPA defines regional haze as “widespread, regionally homogeneous haze from a multitude of sources”.
Speciation	Speciation analysis is the analytical activity of identifying / measuring the quantities of one or more individual chemical species in a sample. Species are specific forms of an element (unique isotopic composition, electronic or oxidation state, and/or complex, or molecular structure).

Transmissometer	The Transmissometer is a device for measuring transmission or beam attenuation as a measure of atmospheric turbidity. A narrow, collimated beam of light shines through the air and a receiver with a narrow field of view measures how much light arrives at the other end of a set distance.

Organization Acronyms:

AES	Atmospheric Environment Service
BC MoE	British Columbia Ministry of Environment
AWMA	the Air and Waste Management Association
FVRD	Fraser Valley Regional District
GVRD	Greater Vancouver Regional District
IMPROVE	Integrated Monitoring of Protected Visual Environments
NARTSO	North American Consortium for Atmospheric Research in Support of Air Quality Management
PSCAA	Puget Sound Clean Air Agency
US EPA	United States Environmental Protection Agency
WESTAR	Western States Air Resources Council
WCCM/PWG	West Coast Collaborative Marine/Port Work Group
WRAP	Western Regional Air Partnership