AIR QUALITY MANAGEMENT IN THE YEAR 2020: AIRSHED EMISSION LIMITS FOR THE LOWER FRASER VALLEY

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SUMMARY

INTRODUCTION

The Greater Vancouver Regional District (GVRD) has developed an Air Quality Management Plan (AQMP) as part of its strategy to maintain the livability of the region. The AQMP includes measures that will reduce emissions of the five common air pollutants — carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxides (NO_x), sulphur oxides (SO_x) and total suspended particulate (TSP) — as well as those of greenhouse and toxic gases. Its overall objective is to ensure that regional air quality will be maintained and improved in the future.

One approach to air quality management in the GVRD and Lower Fraser Valley (LFV) would be to set Airshed Emission Limits (AELs) for appropriate atmospheric pollutants. The present work was undertaken as the first phase of setting such AELs for NO_x, VOC and inhalable particulate matter (PM_{10}), with consideration given to potential implications for emissions of carbon dioxide and other greenhouse gases.

The general scope of this work included:

- An analysis of the theoretical reasons for setting airshed emission limits and an assessment of the use of AELs against appropriate criteria;
- A discussion and evaluation of alternaytive conceptual approaches to setting AELs;
- A review of actual procedures used and results from setting AELs in other jurisdictions;
- Identification of information and data gaps that would require further study and research prior to the development of a final strategy and process for setting and implementing AELs for the LFV;
- Recommended project outlines and terms of reference for future phases of an overall process required to develop LFV AELs.

MANAGEMENT OF AN AIRSHED AS A NATURAL RESOURCE

Management of an airshed is similar to that of natural resources such as forests, fresh water and fisheries. These can all suffer from a "tragedy of the commons", whereby a resource that can be of continuing value is damaged because of use beyond sustainable limits, possibly to the extent of being of value to no one. Examples include the Canadian east coast cod fishery, and destruction of wildlife habitat because of excessive deforestation.

The use of limits or quotas in the management of these resources is appropriate under the following conditions:

1A. The resource is common property, open to use and/or exploitation by the public.

OR

1B. Access to the resource is controlled, but its use could detrimentally affect other valued resources.

2. The resource has a limited rate of regeneration, and as a result a rate of use above a critical level could lead to damage to the resource, or to other resources.

3. The current or projected rate of resource use is equal to or greater than the critical level defined above.

The use of an airshed for disposing of gaseous and suspended particulate wastes satisfies these conditions, and thus the use of airshed emission limits is an appropriate management tool.

APPROACHES TO SETTING AIRSHED EMISSION LIMITS

Approaches to establish AELs can be assessed against at least five objectives:

- effectiveness — ensuring good air quality for all dependent upon the airshed;
- efficiency — maximizing the excess of benefits over costs;
- equity — allocating emissions fairly;
- flexibility — allowing for uncertainty;
- acceptability — providing high probability of acceptance by stakeholders.

Traditionally, air quality management has used either implicit limits or targetted emission reductions in order to meet one or more of these objectives. However, emission limits can also be made explicit. Such limits can be developed using at least four different approaches:

- through achievement of ambient concentration objectives which are established to protect human health or some other receptor;
- through cost-benefit analysis;
- by determining the cumulative effect of specific emission control technologies;
- using consultation and negotiation.

Each alternative for setting AELs will satisfy the five objectives to different degrees, and Table S-1 provides a relative assessment of the five alternatives against the objectives.

TABLE S-1 RELATIVE ASSESSMENT OF THE FIVE ALTERNATIVES FOR SETTING AELS

Objective	Emission Limit Process				
	Traditional/ Implicit Limits	Achieving Concentration Objectives	Cost-Benefit Analysis	Technology Based Limits	Negotiated Limits
Good air quality	☒	☐	☒	☒	☒
Economic efficiency	■	■	☐	■	☒
Equitable allocation of the emissions	■	■	■	■	☐
Flexibility in the light of uncertainty	■	☐	☐	■	☐
Acceptability	■	☒	☒	■	☐

Legend ☐ Positive ☒ Neutral ■ Negative

AELs developed through concentration objectives provide the greatest assurance both of a healthy atmosphere and access to good air quality for those living in, and dependent upon, the airshed. Cost-benefit analysis on the other hand maximizes the net benefit of the AELs but does not assure the maximum protection of human health and dependent ecosystems.

Both traditional/implicit AELs and technology-based AELs are usually not equitable in the distribution of control costs or in the allocation of emissions among emission sources and emission sectors, and do not necessarily provide good air quality or economic efficiency.

Consultation and negotiation provides a process whereby the relative importance of each of the listed objectives (and possibly others) can be considered so as to identify the approach to setting AELs which will have the widest stakeholder support. Such a process could involve activities such as multiple account evaluation or multi-criteria analysis, but would always involve trade-offs through discussion and negotiation before the AEL process could be finalized.

The information base required by these five approaches for setting AELs is summarized below, together with comments on its current status and suitability.

- Information on the human health and other receptor impacts of air pollution:
  - the current information base is subject to ongoing research and investigation, which will influence current reviews of Canadian and U.S. air quality objectives for ozone and PM_{10};
  - although subject to change, current information can be used as a basis for setting AELs.
- Results from modelling LFV air quality:
  - results from detailed LFV ozone modelling should be available within a year, but similar PM_{10} modelling will take several years;
  - general models have been adapted for use in the LFV, thus providing a basis for initial AELs.

- Valuation of the damages caused by air pollution:

  — such valuations are dominated by valuation of increased risk of mortality, and therefore the value attributed to current and future statistical lives
  — there is a wide range in valuations, and therefore in AELs, depending upon the nature of the valuation process, but such processes are currently available for setting AELs.

- Identification and costs of emission reduction measures:

  — emission reduction measures have been identified and generic cost estimates summarized for LFV emission sources;
  — although these cost estimates will be refined with experience, they are currently in a suitable form for setting AELs.

PROCEDURES WHICH HAVE BEEN USED ELSEWHERE

Examples of procedures for setting AELs include the following:

- achievement of the air quality ozone objective in Canada through the NO_x/VOC Management Plan;

- protection of human and environmental health in the U.S. through achievement of air quality standards;

- prevention of damage to water bodies and ecosystems through limiting emissions of acid rain precursors in Canada, the U.S. and Europe;

- prevention of thinning of the ozone layer by elimination of ozone-depleting substances;

- limiting damage caused by global climate change by controlling greenhouse gas emissions.

In each of these cases, the conditions for limiting use of the natural resource in question have been satisfied. Specifically, in each case: there is common access to the atmosphere for disposal of the relevant pollutant; the atmosphere has a limited capacity to absorb or remove the pollutant and thus prevent damage to the atmosphere itself or other resources dependent upon the atmosphere; and, the current or potential future rate of emissions is above the critical level at which these damages will occur. Most of the pollutants in these cases are also the subject of the present report.

The general processes used to set AELs in these examples have used protection of human and/or environmental health as the prime consideration. However, public policy makers are now coming to the realization that human and/or environmental health objectives may have to integrate economic and social factors to establish achievable and acceptable limits.

In general, the technical procedures used for setting these limits have varied depending upon the level of understanding of the relationship between emissions and resulting effects. Where this understanding is limited, then general emission reduction targets have been used. As the level of understanding improves, then more explicit emission limits have been set, including sectoral limits and geographical limits.

The emission limits necessary for achievement of U.S. air quality standards are being phased in over a period of time, with a requirement that long-term planning for growth and transportation be appropriately integrated. For ozone depleting substances (ODS), the emission limit allowed for impacts on economic growth in only a small way, and the rate of implementation reflects primarily on the availability of ODS substitutes.

Changes in regulatory structure (where necessary) have typically been concerned with the control of new emission sources. New sources have not been given air emission permits unless they could obtain a more than equivalent emission reduction from another source, and thus keep total emissions below the emission limit.

It is noteworthy that when models for the relationships between emissions and resulting impacts are reliable and widely accepted, then the resulting emission-limit-setting process tends to be more successful. This results from wider stakeholder support and also more reliable inputs into supporting work such as cost-benefit analysis.

AIRSHED EMISSION LIMITS FOR THE LOWER FRASER VALLEY

AELS are an appropriate air quality management tool for the LFV because the LFV airshed satisfies the conditions for limiting use of a natural resource given above. In particular:

- the LFV airshed is common property, available for the disposal of gaseous and particulate wastes;
- the LFV airshed has a limited rate of regeneration, and there is therefore a critical rate of gaseous and particulate waste disposal above which there is damage to the airshed and associated, dependent resources;
- there have been periods when rates of emissions into the LFV airshed have been above the critical level defined above, and future emission rates could also exceed this level.

Thus, the evolution of air quality management in the LFV so as to incorporate the use of AELs would parallel the management of other natural resources. Moreover, comparison with other emission-limit-setting processes suggests that preliminary AELs should be developed with currently available data and information provided these are in a suitable form. Evaluation of this data and information show that it is subject to ongoing change and revision because of associated research and investigation, but is nevertheless currently suitable to set preliminary AELs for the LFV.

Thus, AELs for the LFV could be developed in two phases:

Phase I:

- choose an initial AEL-setting process and establish preliminary AELs using the currently available data and information;

Phase II:

- fully evaluate the alternative emission-limit-setting processes followed by selection based upon agreed objectives;
- assemble data and information to establish refined AELs using the selected process.

There will be two further overall requirements in order to ensure that this work proceeds effectively:

- address the data and information gaps to the extent necessary to support the selected Phase II process;
- provide for a consultation process that will allow appropriate input and feedback from public and stakeholder groups and individuals.

These phases are incorporated in an overall plan provided in Figure S-1, and associated projects have been identified in the body of the report. The overall plan includes a periodic review of the refined AELs, thus allowing for ongoing developments in the supporting information and data bases.

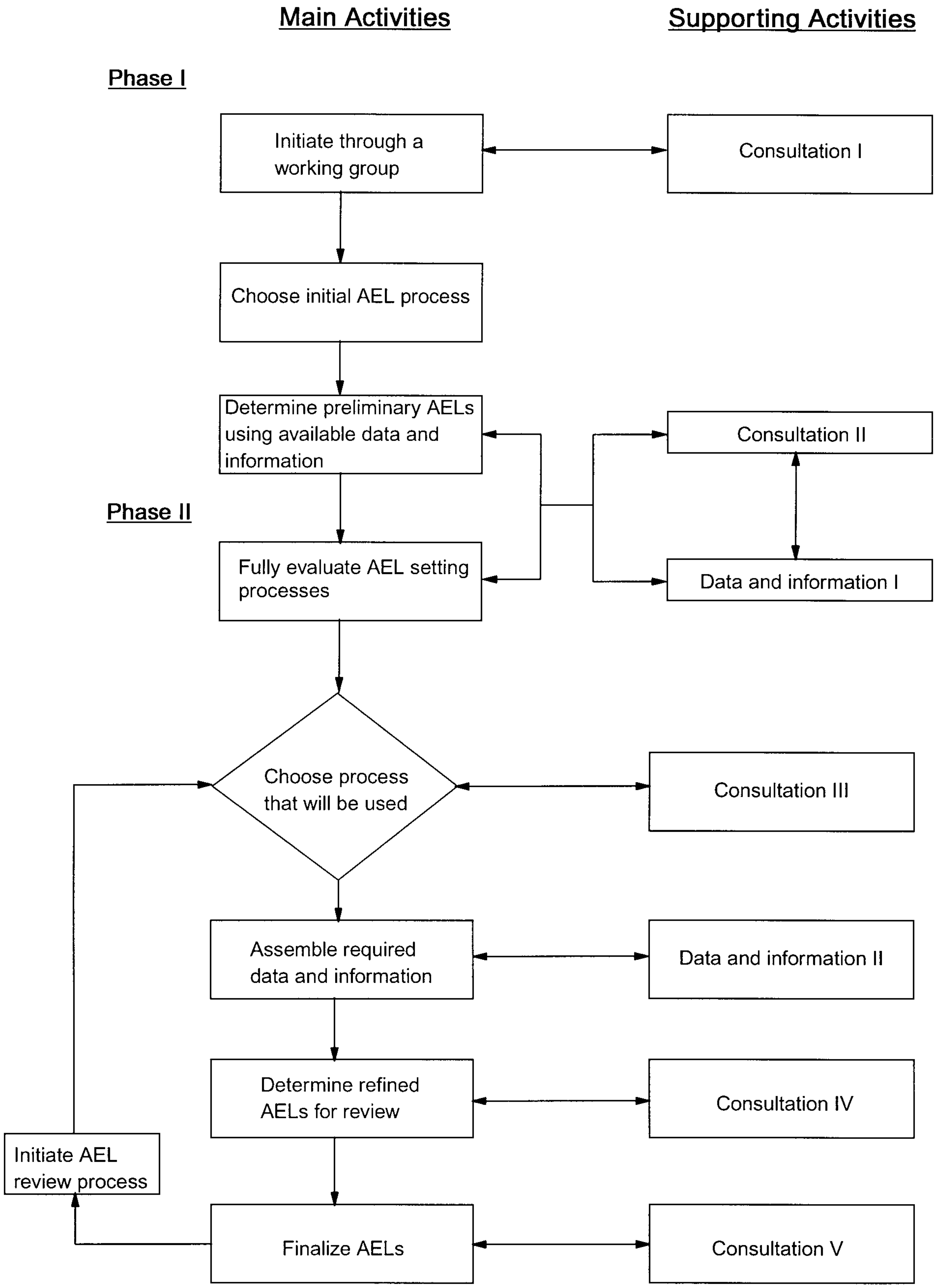

FIGURE S-1

PLAN FOR SETTING AIRSHED EMISSION LIMITS FOR THE LOWER FRASER VALLEY

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1. INTRODUCTION

1.1 BACKGROUND

Ambient air quality affects human health and vitality, and the well being of animals, plants and ecosystems. It also affects visibility, buildings, surface coatings and artwork. As a result, management of air quality has become a key issue in many parts of the world.

Ambient air quality in any region is determined by a number of factors, including:

- local emissions of primary pollutants (e.g. carbon monoxide, nitrogen oxides, sulphur oxides, total suspended particulate including PM_{10}, and volatile organic compounds);
- transport of pollutants from other areas;
- climate and meteorology;
- atmospheric chemistry and the formation of secondary pollutants such as ozone, secondary particulate and acidic aerosols (acid rain).

In addition, local geography and topography influence the magnitude of the effect that these factors have on air quality within an airshed.

Economic and population growth within the Lower Fraser Valley (LFV) have been, and will continue to be, very important in determining local emissions of primary pollutants and hence air qualtiy within this airshed. The geography and meteorology of the LFV provide additional reasons why any plan to ensure long-term sustainability of air quality within the region must be integrated into the strategy for managing regional economic and population growth.

To reduce the potential for adverse impacts, objectives have been developed for air quality management within the Lower Fraser Valley (GVRD, 1994a), with emphasis on emissions of the five common air pollutants: carbon monoxide (CO), nitrogen oxides (NO_x), sulphur oxides (SO_x), volatile organic compounds (VOC) and total suspended particulate (TSP). Relevant emission control measures for these pollutants have been identified for point, area and mobile sources, and their cumulative effect will be to reduce or limit ambient atmospheric concentrations of these five contaminants as well as related high-priority pollutants such as ozone and inhalable particulate (PM_{10}).

A further component of the GVRD Air Quality Management Plan (AQMP) is the development of a coordinated approach to another atmospheric emissions issue: climate change induced by increased levels of carbon dioxide and other greenhouse gases. Accordingly, the impact of the AQMP on emissions of these gases has been subject to some analysis (GVRD, 1994b).

The Air Quality Management Cost Benefit/Economic Instruments (CBEI) Committee, a joint committee of federal, British Columbia and GVRD representatives, is currently studying the role for airshed emission limits in the management of air quality. Accordingly, the CBEI

Committee commissioned this study to examine the feasibility and process for setting Lower Fraser Valley airshed emission limits.

1.2 SCOPE OF WORK

This report presents the findings of a project whose scope of work covered the first phase of setting airshed emission limits for the LFV, and providing the following:

- An analysis of the theoretical reasons for setting airshed emission limits, including parallels with natural resource management, and assessment of the use of AELs against appropriate criteria.

- Discussion of conceptual processes that can be used for setting airshed emission limits.

- A review of actual procedures used and results from setting airshed emission limits in other jurisdictions.

- Identification of information and data gaps that would require further study and research before the development of a final strategy and process for setting and implementing LFV airshed emission limits.

- Recommended project outlines and terms of reference for future phases required to develop recommended LFV emission limits.

This would be done by fulfilling the work requirements reproduced in Appendix C.

The contaminants identified as priority management issues in the GVRD AQMP which are the focus of this report are:

- CO_2 — carbon dioxide and greenhouse gas equivalents.

- PM_{10}— inhalable particulate.

- NO_x — nitrogen oxides.

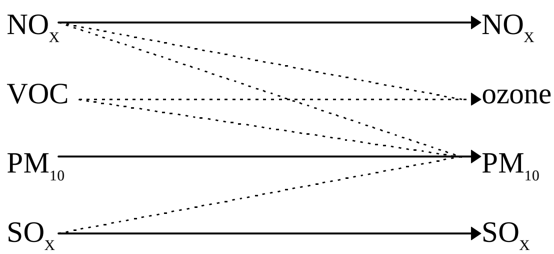
- VOC — volatile organic compounds.

The report is primarily concerned with the process for setting the emission limits, and only addresses administration and achievement of the limits in so far as such factors have affected the feasibility and operability of an emission limit in other regions. As is discussed later in the report, emissions of carbon dioxide (and equivalents) from sources in the LFV have impacts which are global in nature, rather than being restricted to the local airshed. The concept of airshed emissions for these gases has therefore only been addressed with respect to how the emissions would respond to limits on the other pollutants and how this could be incorporated into the long-term emission limiting plan.

1.3 AIR QUALITY AND EMISSIONS IN THE LOWER FRASER VALLEY

The general relationships between primary emissions of pollutants and resulting atmospheric contaminants are shown below.

Primary Emissions | Contaminants



The atmospheric reactions involving NO_x and VOC that lead to ground-level ozone are significant during conditions of temperature and sunlight that are typically only found in the LFV from May to September. There have historically been numerous episodes where ozone concentrations in the LFV have risen above the relevant Canadian acceptable air quality objective of 82 ppb (1-hour basis). Since elevated ozone concentrations are associated with effects on human and plant health, control of ground-level ozone will be a prime consideration in setting NO_x and VOC emission limits in the LFV.

PM_{10}, or particulate matter with a diameter of 10 microns or less, is present in the atmosphere both because of direct PM_{10} emissions and also because of secondary formation from other atmospheric pollutants such as SO_x, NO_x and VOC. Atmospheric PM_{10} is not homogeneous, but is typically made up of particles falling within two distinct size ranges: 0 - 2.5 microns and 2.5 - 10 microns (fine and coarse PM_{10}). These two fractions of PM_{10} tend to have different composition and origin: fine PM_{10} typically contains higher proportions of material formed from secondary reactions of SO_x, NO_x and VOC, as well as combustion byproduct material. Available data indicates that PM_{10} samples collected in the GVRD are primarily derived from direct PM_{10} emissions.

Measured PM_{10} concentrations in the GVRD have declined over the last 10 years, with average 24-hour concentrations now below 20 micrograms per cubic metre ($\mu g/m^3$). The prime concern regarding PM_{10} is its effect on human health and vitality, and as a result of the indication that ambient PM_{10} in the GVRD originates largely from direct emissions, control of ambient PM_{10} concentrations will be the main factor in setting LFV PM_{10} emission limits. Similarly, control of secondary PM_{10} would be a factor in setting SO_x, NO_x and VOC limits, although for the latter two pollutants, their role in ground-level ozone formation may be the more significant consideration in setting their respective emission limits.

GVRD levels of NO_x and SO_x have historically been well below air quality objectives. Since the direct harmful effects at these levels are relatively low, emission limits for NO_x and SO_x in the LFV are unlikely to be set on the basis of controlling the respective concentrations.

The LFV airshed comprises the area bounded by the Straight of Georgia to the west, the Coast Mountains to the north and the Cascade Mountains to the south and east. Relevant emissions of NO_X, VOC and PM_{10} therefore occur in both the U.S. and Canadian sides of the LFV, and emission limits must cover all of this area in order to be a totally effective control on air quality.

2. PARALLELS BETWEEN NATURAL RESOURCE MANAGEMENT AND AIRSHED MANAGEMENT

2.1 NATURAL RESOURCE MANAGEMENT

Many natural resources, including the atmosphere, suffer from a phenomenon known as the "tragedy of the commons." During the 18th century villages often had a commons where any resident could keep livestock. In many villages the number of animals grazing on the commons increased to the point that the pasture was destroyed and was no longer able to support any livestock. Hardin (1968) describes the phenomenon as follows (a more complete extract is provided in Appendix A):

> "The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons....As a rational being, each herdsman seeks to maximize his gain....(and he) concludes that the only sensible course for him to pursue is to add another animal to his herd. And another... But this is the conclusion reached by each and every rational herdsman sharing the commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit - in a world that is limited."

The tragedy of the commons is that a resource that can be a benefit to all is abused to the point where it is of value to no one.

Economic analyses of this phenomenon indicate that since there is no charge for the use of the commons, livestock owners benefit from grazing their animals on the commons as long as there is some nutrition available. Furthermore, livestock owners who do not graze their animals on the commons are at a competitive disadvantage relative to those who use the commons as a free source of food. These incentives cause owners to increase the number of animals grazing on the commons until the available nutrition has been exhausted.

This phenomenon is characteristic of a variety of natural resources that economists refer to as "common property resources." Forests, fisheries, animal species, water supplies and some mineral resources have suffered from excessive use where access was not controlled.

The problem is more common for renewable resources such as forests, grazing lands, fisheries, animal species, and water than for non-renewable resources such as minerals because access to renewable resources is typically more difficult to control. However, where access to mineral resources is difficult to control, such as placer gold and sand, similar problems have occurred. During the early days of the oil industry, when it was not uncommon for several producers to be drawing oil from the same reservoir, each would try to obtain the maximum output from his well at the expense of the production of the other wells and the overall recovery from the reservoir. The same principle can be observed on public highways. As the traffic volume grows beyond the design capacity of the highway, the average speed declines. For any individual driver, using the highway may be faster than the best alternative route or mode, but this reduces the average speed for all other users.

Where demand for the resource is small relative to the stock, free access is not a problem. Where the timber harvest or the fish catch is far less than the natural growth, free access does not damage the resource. However, as the demand approaches the sustainable supply of the resource, access must be limited to avoid irreparable damage.

Management of forests typically includes an allowable harvest that is intended to be less than the net growth of merchantable timber. A timber license may also involve reforestation obligations to ensure that the forest resource is protected. In such cases, the allowable cut and/or the amount of reforestation are based upon a model of the natural ability of forests to regenerate, with due allowance for the impact of timber harvesting and uncertainty in the inputs into the model. This is illustrated in the recently revised annual allowable cut for the Fraser Timber Supply Area (B.C. Ministry of Forests, 1995). Forest areas that are particularly valuable for other uses, such as habitats for particular species, watershed protection, or recreation, may have much more stringent limits on logging activities or ban harvesting altogether.

Many fish stocks are also managed by setting quotas on the allowable catch. The allowable catch is based on the natural growth of the stock taking account of factors such as disease, predators, and by-catch harvesting by other fisheries. The age-sex composition of the stock is also considered when setting the allowable catch. The allowable catch is then allocated as quotas for licensed fishermen. Fisheries licenses regulate who can fish for particular species and when they can fish. Similar mechanisms are used to manage wild animal stocks.

The quantity of the resource consumed may also be regulated indirectly, for example, through restrictions on hunting and fishing seasons, or restrictions on the types of equipment that can be used. For example, restrictions on the type of fishing gear are often intended to limit the catch to mature fish. Direct restrictions typically provide more accurate control over total consumption of the resource than do indirect restrictions.

The mechanisms for managing natural resources are all intended to limit exploitation of the resource to sustainable levels and so to prevent irreparable damage.[1] The mechanisms have two components: one to regulate access to the resource and the second to limit overall consumption of the resource.

Timber licenses and fishing licenses are examples of devices for limiting access to the resource. These rights have to be allocated; timber license fees, fishing license fees, and grazing fees use price as an allocation device. Such rights can also be allocated on the basis of historical participation. Some commercial fishing licenses, for example, are allocated to fishermen who have historically participated in the particular fishery.

The above discussion abstracts from many of the complexities encountered in managing natural resources. Fish and animals, for example, may migrate from one regulatory jurisdiction to another making limits on harvesting the resource much more

[1] The *intention* is to limit exploitation to sustainable levels. That is not always achieved. The net growth of the stock may not be accurately known and/or may follow a cyclical pattern causing the allowable harvest to be set at unsustainable levels. Weather conditions, disease, or other factors may cause the net growth to be much lower than expected during a particular year. Stocks may straddle two or more jurisdictions and may not be optimally managed as a result. Enforcement may not effectively limit the harvest to allowable levels.

difficult to establish and enforce. Forests serve a number of purposes in addition to serving as a source of timber. Managing forest resources to serve all of the uses can be extremely complex and controversial (Healey, 1995). Complexities such as these, however, do not diminish the need to regulate consumption of the resource to avoid irreparable damage.

In economic terms limiting overall consumption of the resource is a question of efficiency — how best to use the available resources. In deciding upon an overall consumption limit, alternative commercial and non-commercial uses must be balanced and the temporal pattern of resource use must be considered.

The question of access to the resource is one of equity. A common property resource belongs to all members of society. When access is limited, some members of society continue to have access to the resource while others have more limited, or no, access to the resource. This raises questions of equity.

One way to deal with the equity issue is to impose fees for access to the resource, e.g., timber licenses, and using the revenue for general government purposes.[2] Then the members of society to whom access to the resource is most valuable will pay the fees. Other members of society will benefit through lower taxes and can use the added income in ways they prefer.

2.2 PARALLELS WITH AIRSHED MANAGEMENT

Hardin (1968) recognised that the "Tragedy of the Commons" applies to pollution as well as natural resource management. He notes that:

> "In a reverse way, the tragedy of the commons reappears in problems of pollution....The rational man finds that his share of the cost of the wastes he discharges into the commons is less than the cost of purifying his wastes before releasing them....The tragedy of the commons as a cesspool must be prevented....by....laws....or....devices that made it cheaper for the polluter to treat his pollutants than to discharge them untreated."

An airshed is a common property resource. It is a very special resource because all members of society need continuous access to a clean atmosphere for healthy survival. Access for this purpose cannot be restricted. The atmosphere can also be used to dispose of airborne wastes. Access for this use can be restricted, and indeed must be restricted if the atmosphere is to serve its purpose in sustaining health and environment. In this sense, setting emission limits for an airshed is similar to setting quotas on harvesting fish and forests.

The atmosphere has a finite capacity to absorb pollution. Some pollutants, such as particulates, precipitate out of the atmosphere within relatively short periods of time. Others, such as volatile organic compounds, are removed from the atmosphere through chemical

[2] Licenses could be auctioned in an effort to raise the maximum amount of revenue or the resource manager could establish a fee structure on some other basis, such as the costs of managing the resource. In the latter case the fees may not be high enough to ration the demand to the desired level, in which case they will need to be complemented by other rationing devices. Some hunting licenses, for example, are allocated by lottery.

reactions. Several greenhouse gases, such as carbon dioxide and nitrous oxide, remain in the atmosphere for decades or centuries. As long as the rates of emission discharge are small relative to the rates of removal from an airshed atmosphere, the overall impact on atmospheric concentrations is negligible. However, when the rates of emissions approach the rates of removal, concentrations of the primary pollutants, and possibly associated secondary pollutants, can rise to unacceptable levels.

The relevant airshed differs for each pollutant depending upon rates of dispersion and removal from the atmosphere. For example, small amounts of toxic air pollutants may only be of concern in a small, localized airshed, while greenhouse gases and ozone-depleting substances have long atmospheric lives so the relevant airshed is the global atmosphere. Due to weather conditions and the processes by which pollutants are removed from the atmosphere, concentrations may vary within the relevant airshed. Dealing with variations in concentrations further complicates the air quality management problem.

In addition to the removal of pollutants by precipitation or chemical reaction, meteorology can result in the rapid purging or regeneration of an airshed such as the Lower Fraser Valley. However, removal of pollutants from one local airshed merely means their effect is felt elsewhere (e.g. acid rain). In addition, pollutants with long atmospheric lifetimes, such as greenhouse gases and ozone-depleting substances, accumulate in the atmosphere. They change the characteristics of the atmosphere and so can be said to damage the resource.

Short or episodic periods of heightened air pollution can lead to effects which are not necessarily quickly reversed. This would apply to effects on human or plant health, as well as to the general perception of regional air quality that results from an episode of poor visibility. It can thus be seen that "the tragedy of the commons" can equally befall an airshed, and that airshed planning and management should be done in a manner that is consistent with that of other natural resources, and that considers long term impacts on other resources and valued attributes.

Thus, when access to the atmosphere as a means for waste disposal results in pollutant levels that might detract from its ability to provide environmental health, human health and aesthetic values, access for pollution disposal uses must be controlled. Under those circumstances, total emissions must be limited, either explicitly or implicitly.

Air quality management faces many of the same challenges as managing other natural resources. In addition, each of the common property natural resources gives rise to its own set of challenges. In the case of air quality these include: administrative jurisdictions that do not match airshed boundaries; chemical reactions in the atmosphere; the diversity of sources for different pollutants; limited scientific knowledge of the impacts of exposures to different concentrations of atmospheric pollutants. These difficulties affect the approach adopted to managing various pollutants as will be seen in later sections of the report.

In parallel with other common property resources, the management issues for limiting emissions into an airshed are:

- setting the overall level of emissions, or the best and most efficient use of the available resource;

- allocation of emissions, or equity of access to the atmosphere for waste disposal;
- assurance of good air quality, or equity of access to a healthy and healthful atmosphere.

As in the case of common property natural resources, the overall level of emissions can be explicit or implicit, but implicit levels have been much more common in air quality management.

Air quality regulations typically seek to achieve a reduction from current emissions sufficiently large to reduce peak concentrations to acceptable levels. Concentrations, however, can be very difficult to relate to emissions because concentrations are affected by chemical reactions, transport of pollutants, weather conditions and other factors. In addition the actual emissions by all sources during the periods that would contribute to peak concentrations are often not available in sufficient detail. This type of regulatory approach implicitly sets an emissions limit, although that limit may not be accurately known. Recently, however, some jurisdictions have established explicit emissions caps for particular sources. Some of the best known examples are the national SO_2 allowance program for electric utility sources in the United States and the RECLAIM program for SO_2 and NO_x emissions by large point sources in the South Coast Air Quality Management District of California.

Implementation of emissions reductions under an implicit approach typically proceeds by identifying technologies or processes capable of reducing emissions from particular sources and requiring those sources to implement the identified measures. These efforts tend to focus on large point sources. In many jurisdictions emission reductions for point sources have been offset, at least partially, by increased emissions by mobile and area sources[3] which now account for a significant share of total emissions. Thus, although national emission standards for new motor vehicles have become significantly more stringent over time, and emissions per vehicle kilometer much lower, total emissions from automobiles have fallen more slowly because the number of vehicle kilometers travelled has increased.

2.3 SUMMARY

In light of the discussion and examples given above, it is useful to summarize the criteria which would indicate when limits on the use of a natural resource are appropriate. Such a summary is provided below, together with relevant examples, including examples relating to atmopsheric emissions.

[3] Area sources are small dispersed sources, such as residential furnaces.

1A. **The resource is common property, open to use and/or exploitation by the public.**

examples: harvesting of fish stocks, use of fresh water, emitting to the atmosphere

OR

1B. **Access to the resource is controlled, but exploitation or use could potentially affect associated and publicly-valued resources.**

examples: development of mineral and oil rights in sensitive areas, inappropriate land use, deforestation affecting wildlife habitats.

2. **The resource has a limited rate of regeneration, and as a result use, or a rate of use, above a critical level could lead to damage to the resource, or to an associated resource.**

examples: forestry, removal of water from subsurface aquifers, depletion of the stratospheric ozone layer.

3. **The current or projected rate of resource use is equal to or greater than the critical level defined above.**

examples: cod fishing in Atlantic Canada, increasing emissions in a confined airshed.

These criteria for limiting resource use are applicable not only to resources which are of direct, tangible value, but also those whose intrinsic value lies in the support they provide to human health, ecosystems and other resources, as well as in their aesthetic properties. In particular, the use of an airshed for disposing of gaseous and suspended particulate wastes falls in this latter category. This leads to the conclusion that management of an airshed parallels that of other natural resources, and the use of airshed emission limits is an appropriate management tool.

The method used to establish airshed emission limits must address at least three issues:

- achieving economic efficiency, or setting the overall level of emissions;
- allocation of the emissions, or providing equity of access to the atmosphere for waste disposal;
- assurance of good air quality, or providing equity of access to an unpolluted atmosphere.

Approaches to setting emission limits are discussed at greater length in Section 3. These include a cost-benefit approach which focuses on economic efficiency, together with a process focusing on equitable access to a healthy and healthful atmosphere through acheivement of air quality objectives. Since economic efficiency and equity issues are all important, an approach that focuses on only one of these may not be acceptable as the basis for setting an AEL. An alternative approach is therefore to develop AELs and air quality management strategies through discussion and negotiation where all of the efficiency and equity issues can be balanced.

3. SETTING AIRSHED EMISSION LIMITS

As use of the atmosphere for disposal of gaseous wastes rises to the point where it can cause irreparable or unacceptable damage to human health, ecosystems, or other resources, total emissions must be limited. This chapter discusses conceptual approaches to setting emission limits and the suitability of the current information base for using each approach.

3.1 TRADITIONAL APPROACH TO AIR QUALITY MANAGEMENT

Before reviewing the conceptual approaches to establishing airshed limits it is useful to review the traditional approach to air quality management. It seeks to reduce or limit total emissions, but does not define an explicit emission limit.

Traditionally, air quality management seeks to ensure that ambient concentrations averaged over specified periods do not exceed levels that are believed to pose an unacceptable risk to human health, ecosystems, or other resources. For example, Canada has an acceptable ground-level ozone objective of 82 parts per billion (ppb), and similar objectives have been set for total suspended particulate, NO_2 and SO_2. Additional air quality objectives for PM_{10} have been set in British Columbia and the GVRD.

Table 1 gives the ambient air quality objectives and standards for ozone, PM_{10} and nitrogen oxides (NO_x) in selected Canadian and U.S. jurisdictions.

When concentrations approach or exceed these air quality objectives, actions are proposed to reduce emissions by amounts estimated to be sufficient to prevent exceedence. The magnitude of the required emission reduction may be calculated using models that relate emissions to concentrations or may be based largely on judgement. Actions to achieve the target reduction in emissions are then identified and implemented.

Proposed emission controls affect some sources more than others. This is inherent in the nature of emission controls: they are readily available for some sources, but not for others. It also reflects the regulatory jurisdiction. The air quality management agency may lack jurisdiction over some sources, especially mobile or area sources, so it must impose larger emission reductions on the sources over which it has authority, typically large point sources.

The proposed emission reduction measures are also influenced by technological and political considerations. Some emission reduction actions are more cost-effective than others. The most cost-effective measures would preferably be implemented first. However, it may be difficult politically to impose emission reductions requirements on mobile and area sources because such actions affect voters. It may also be difficult to impose emission reductions on large point sources if this causes economic hardship and leads to reduced economic activity.

The traditional approach to airshed management, then, establishes an **implicit** airshed emission limit. This is the emission level believed to be consistent with attainment of the ambient concentration objective and achievable through identified emission reduction measures. Each individual source must bear the costs of the emission reduction actions it is required to implement. Thus the mandated actions affect each source differently.

TABLE 1
AMBIENT AIR QUALITY OBJECTIVES AND STANDARDS FOR OZONE, PM_{10} AND NO_X IN CANADIAN AND U.S. JURISDICTIONS

	Ozone (ppb)			PM_{10} ($\mu g/m^3$)			NOx (ppm)		
	1-hour	**24-hour**	**Annual**	**1-hour**	**24-hour**	**Annual**	**1-hour**	**24-hour**	**Annual**
Canadian national objectives:									
desirable	50	15	-	-	-	-	-	-	0.03
acceptable	82	25	-	-	-	-	0.21	0.11	0.05
tolerable	150	-	-	-	-	-	0.53	0.16	-
U.S. primary standard	121	-	-	-	150	-	-	-	0.05
British Columbia					50	-			
GVRD	-	-	-	-	50	30	-	-	-
California	90	-	-	-	50	30	0.25	-	-

When a few categories of large point sources account for most of the emissions, this approach can work reasonably well. In the case of SO_2 emissions, for example, requiring coal-fired generating stations and metal smelters to reduce their emissions has had a major impact on total emissions in eastern Canada.

The traditional approach has been less successful when mobile and area sources account for a significant share of total emissions of a pollutant. While mobile and area sources are small individually, collectively they are a significant contributor to total emissions. In many cases these small sources have not been regulated to a level commensurate with their contribution to overall emissions. Emission reductions achieved by large point sources have been offset, at least in part, by growth in emissions from mobile and area sources. As a result, neither total emissions nor access to the resource have been limited.

A similar situation is common in water quality management. Point source dischargers have been regulated. Non-point sources have not been regulated, or only lightly regulated, and now dominate total discharges of phosphorous or nitrogen in many watersheds. Water quality regulators are considering caps on total discharges to address these situations.

3.2 CONCEPTUAL APPROACHES TO SETTING AIRSHED EMISSION LIMITS

Conceptually, at least four approaches can be used to set an airshed emission limit for a particular pollutant. These approaches are to set limits based upon:

- achieving ambient concentration objectives which are established to protect human health or some other receptor;
- ensuring economic efficiency through cost-benefit analysis;
- determining the cumulative effect of specific emission control technologies;
- using consultation and negotiation.

Each of these approaches is described below together with a discussion of the suitability of the current information base for using each approach for the LFV. To keep the discussion simple it assumes a self-contained airshed which is managed by a single regulatory authority. In practice, it is rarely the case that a single regulatory authority is responsible for an entire airshed, so transport into and out of the regulatory jurisdiction may be a significant factor.

3.2.1 Achieving Ambient Concentration Objectives

3.2.1.1 Description

Achievement of ambient concentration objectives as a basis to set airshed emission limits is similar to the traditional approach to airshed management described above. To be successful however, all relevant emission sources must be covered by the emission limit: point, area and mobile sources in all jurisdictions that affect air quality in the airshed. In addition, the limit would preferably be explicitly stated.

An ambient concentration objective is usually based on human health considerations, but it could also be based on avoiding damage to specific ecosystems or other resources, such as crops. An ambient concentration objective based on human health considerations can be interpreted as meeting the equity objective of ensuring access to a healthy and healthful atmosphere.

There are two prerequisites to using this approach:

- the availability of established or accepted relationships between ambient atmospheric concentrations of the pollutant(s) and human health;

- an understanding of both pollutant and precursor emissions and their effect on atmospheric concentrations.

Our knowledge of these relationships will change as results from medical research, emission inventories and atmospheric modelling become available. As a result, emission limits developed using this approach would be subject to ongoing review.

Ideally, the relationship between atmospheric concentrations and health effects will provide two pieces of information:

- whether or not there is a threshold concentration below which there are no health effects;
- a description of how the nature and magnitude of the health effects change as concentrations rise (above any threshold).

The existence of a threshold concentration makes the setting of a completely "safe" air quality objective straightforward. However, in the absence of a threshold or when the threshold is not felt to provide a reasonable or practical air quality target, it is necessary to choose an objective which provides adequate but not complete protection of human health, and which can be realistically used as a basis for air quality and emission management plans. This then requires the second type of information described above.

Once the ambient concentration objective has been chosen, a relationship between emissions and concentrations is used to derive the corresponding emission limit. As noted above, it is possible that this emission limit may not be felt to be realistically achievable, in which case the ambient objective could be revised, or an alternative or second objective specified and the corresponding emission limit determined.

The setting of emission limits using this approach generally involves the use of complex models, particularly for control of ozone and PM_{10}. Since an air quality objective is expressed as an average over a specific period, such as one, eight or twenty-four hours, the models need to relate concentrations to emissions over the corresponding period. An emission limit, however, cannot easily be set in terms of emissions during a particular hour or day with less stringent limits during other periods. In practice an emissions limit must be a seasonal and/or annual limit since most sources require the ability to emit to the atmosphere at the same rate over a sustained period. In any case virtually all actions to reduce emissions apply to a source on a year-round basis, although some notable exceptions do exist, for example B.C. Hydro's Burrard Thermal Plant.

Thus the challenge is to determine the annual or seasonal emission limit that will ensure achievement of the short term concentration objective, even under the most adverse conditions (temperature, wind speed and direction, etc.). Assuming a suitable model is available, several strategies for achieving the concentration objective may be possible, including:

- a large reduction in annual or seasonal emissions is implemented to ensure that the short-term concentration objective will be achieved at all times; or

- a smaller reduction in annual or seasonal emissions is implemented which will achieve the concentration objective for all but a few days, and additional temporary emission reductions can be invoked during those periods to achieve the objective.

If the second strategy is feasible and less costly than the first, it may be the more appropriate basis for the emission limit.

3.2.1.2 Suitability of Information Base

Human Health and Other Receptor Impacts of Air Pollution

Information relative to the impact of air pollution on human health, ecosystems and other receptors continues to expand as a result of pertinent research and investigation. The effects of ozone and particulate matter are of specific relevance to the present work, and their impacts on human health and vitality are of particular importance as this is the main consideration when using at least three of the approaches to setting AELs described in this chapter.

The information on health and other effects of air pollution must be quantitative in order to provide a reasonable basis for setting AELs. The degree of quantification and the associated level of confidence currently varies significantly between different studies, but nevertheless the necessary quantitative relationships are available. Indeed, such relationships have been used to carry out related studies (Bovar, 1995).

Thus, it must be concluded that the currently available information in the areas of health effects of air pollution are in a suitable form for setting AELs. It should be noted, however, that the correctness or accuracy of these relationships cannot be evaluated herein. Nevertheless, the following provides a summary of areas where these relationships could be further investigated and developed, particularly with regard to conditions as they exist in the LFV, and thus increase the level of confidence in subsequent AELs.

- relationships between PM_{10} (and other sizes of particle) concentrations and health effects:

  - quantification of the relationships at PM_{10} levels typical of the LFV (15 – 25 $\mu g/m^3$);
  - resolution of whether a threshold concentration exists;
  - evaluation of potential dependency upon particle chemical composition and upon emission source;
  - resolution of the magnitude of concentration change required to produce an observable or real change in health effects;
  - resolution of actual human exposure levels versus ambient concentrations;

- determination of whether exposure to an alternative particle size such as $PM_{2.5}$ or PM_1, may be a better predictor of health effects, and therefore should be used as the basis for AELs;
- resolution of whether repeated short-term exposure to high particulate levels is more influential on health effects than a long-term or annual exposure to a lower level.

- relationships between ozone concentrations and health effects:

  - evaluation of whether the results from available epidemiological studies are directly applicable to the LFV, where the levels of ozone and other atmospheric pollutants are not always comparable;
  - resolution of whether a threshold ozone concentration exists;
  - resolution of actual human exposure levels versus ambient concentrations.

- resolution of whether any synergy exists between ozone, PM10 and other pollutants such as SO_2 with regard to their effect on human health, vegetation and the environment.

With regard to non-health effects of air pollution, such as those on agricultural crops and buildings, relationships are subject to similar uncertainties. There are some areas, such as visibility, where the understanding of the relationships between emissions and unwanted effects may still be insufficient for use in the setting of AELs for the LFV.

Modelling of LFV Air Quality

The required modelling of LFV air quality modelling would focus on atmospheric concentrations of ozone and PM_{10}, and would be used to provide at least two kinds of information:

- quantitative relationships between emissions of precursors (NO_X, VOC, PM_{10} and SO_X) and ambient ozone and PM_{10} levels, taking into account local emission profiles as well as local geography, climate and meteorology;

- an analysis of the variability or range in atmospheric ozone and PM_{10} concentrations that would result upon achievement of AELs, and therefore an indication of whether 100% compliance with air quality objectives can be reasonably expected.

It is possible to satisfy these two information requirements using models which vary in their complexity and specificity to the LFV. Thus, general models exist which have been adapted to reflect some aspects of the LFV (Bovar, 1995), and these could be used in setting the AELs. However, it is likely that wide support for any emission limits will result only when models have been used that more fully reflect LFV characteristics and which are based on a satisfactory understanding of local conditions.

Activities that will provide this improved specificity to LFV conditions have thus far focused on modelling ozone. This latter work has been progressing for approximately five years, and will likely provide some of the required information within the next year (Steyn, 1995). However, modelling of PM_{10} concentrations in the LFV is still in its infancy, and is unlikely to provide similar results to the ozone work for several years.

The suitability of currently available LFV air quality models for setting AELs is thus suggested to be less than satisfactory, albeit that these models can be used to provide some initial indication of what the eventual emission limits might be.

Some specific areas where additional or improved data may be beneficial in support of the modelling activities are given below.

- Ozone modelling:
  - expansion or redesign of the ozone monitoring network to give more data in the Port Coquitlam to Maple Ridge area;
  - expansion of the number of VOC monitors and an increase in sampling frequency;
  - resolution of uncertainties in the amount of VOC emitted from biogenic sources;
  - more detail regarding the physical aspects of industrial point sources (stack height, gas velocity and temperature, specific operating cycles and upset conditions, etc.);
  - evaluation of whether U.S. LFV emissions are adequately represented in the overall emission inventory, especially as these are a significant part of the total LFV inventory;
  - use of AirCare data to reduce uncertainty in the motor vehicle emissions inventory;
  - establishment of routine acoustic sounding to detect atmospheric mixed layer depths in the LFV during summertime.

- PM_{10} modelling:
  - improvement in the source apportionment of atmospheric PM_{10} including characterization by size and chemical analysis;
  - evaluation of whether all significant primary PM_{10} emission sources are reliable quantified in current LFV emission inventories, especially fugitive sources such as wind-blown dust from agricultural areas and road dust;
  - expansion and review of the current LFV emissions inventories to ensure satisfactory data on secondary PM_{10} precursor emissions, for example sources of SO_x (including biogenic sulphur), biogenic VOCs and ammonia;
  - improved understanding of related chemistry: gas to particle modelling; effects of temperature and humidity; and chemical reactions within particles; together with monitoring of relevant parameters in the LFV.

3.2.2 Using Cost-Benefit Analysis

3.2.2.1 Description

In its pure sense, cost-benefit analysis focuses on economic efficiency and seeks the emission limit where the benefits of additional emission reductions equal the costs of achieving these additional reductions. This approach would maximize the overall net benefits of an emission limit.

The cost side of the analysis is relatively simple. The information needed is the lowest cost emission control option for each source for various levels of emission control. Generic cost estimates for emission control options for various sources are available; these may be too high or too low in any specific situation. In addition, it is sometimes possible for a source to develop a non-standard emission reduction approach which is cheaper than the conventional emission reduction option.

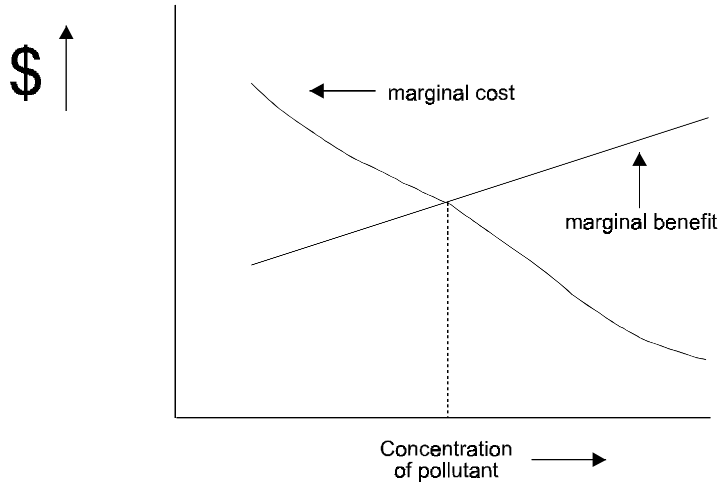
The benefit side of the calculation requires three types of inputs:

- relationships between exposure to atmospheric concentrations and impacts on human health, ecosystems and other resources;
- relationships between emissions of pollutants or precursors and ambient concentrations;
- valuation of the benefit of avoiding and/or mitigating the impacts caused by elevated atmospheric concentrations.

The first two of these requirements are similar to the prerequisites for using ambient concentration objectives described in the previous section. However, cost-benefit analysis requires much more information on relationships between concentrations and impacts than does the ambient concentration approach. The ambient concentration approach focuses on a single impact, usually human health. Cost-benefit analysis incorporates all impacts, thus it requires knowledge of the relationship between concentrations and impacts for all resources affected by the pollutant. There may be multiple health effects, as well as deleterious impacts on forests, crops, water bodies, visibility, and materials.

In practice, the links between specific pollutants and various impacts are known in a general sense. However, quantitative relationships between concentrations and impacts are subject to varying degrees of uncertainty or are not available.

The final step in calculating the benefits is to assign monetary values to the various deleterious impacts that will be avoided. For impacts that affect marketed products, such as crops, this is relatively straightforward. However, the principal impacts often are those that affect non-marketed products such as human health, visibility, and ecosystems. While various approaches are available to determine values for the avoided impacts in those cases, the estimates have wide ranges of uncertainty and may be contentious. Assuming that all of the relationships are known, acceptable and monetary values assigned, cost-benefit analysis finds the concentration where the marginal costs and marginal benefits are equal (Ce in diagram below).



Thus, cost-benefit analysis avoids the problem encountered in the ambient concentration approach of having to choose a particular point on the concentration-impact relationship as the air quality objective.

It should be noted that other benefits and costs could be included in the analysis. Thus, there may be improvements in industry efficiency as a result of implementing some emission reduction measures, which in turn lead to increased levels of trade and business activity. Quantification of the net value to society of these possible benefits and attributing this strictly to the establishment of an emission limit will be difficult.

An emission limit determined through cost-benefit analysis is unlikely to remain constant over time. Changes in control technologies will affect the costs. Changes in the number and/or mix of sources will also affect the costs. Population growth will affect the number of people exposed to the pollutant and so increase the benefits of further control. Increased incomes will tend to lead to higher values for avoiding damages to non-market resources. Such developments will cause the optimal emission limit to change in unpredictable ways over time.

Cost-benefit analysis focuses only on efficient use of resources for emission control. It does not address the equity issues of distribution of the control costs nor the distribution of damages to the people and resources affected. Mechanisms for sharing the costs of implementing control measures are relatively easy to design, but getting agreement on what constitutes an equitable distribution of these costs can be very difficult. Linking specific damages to atmospheric concentrations of a pollutant is extremely difficult if not impossible. Thus, addressing an inequitable distribution of damages through compensation is virtually impossible and may be unacceptable to those affected.

3.2.2.2 Suitability of Information Base

Human Health and Other Receptor Impacts of Air Pollution

As noted earlier, the use of cost-benefit analysis for setting AELs requires similar information regarding the impacts of air pollution as does using the achievement of air quality objectives. However, cost benefit analysis requires this information for all impacts (instead of only the major impacts), and it needs this information for the complete range of atmospheric concentrations that will be evaluated.

Thus, similar comments to those provided in Section 3.2.1.2 apply, in that the current information base is in a suitable form for proceeding with this approach, but the information base would benefit from further research and development.

Modelling of LFV Air Quality

Comments made in Section 3.2.1.2 on this subject are also applicable here.

Valuation of the Damages Caused by Air Pollution

Valuations should be available for at least the most significant damages of ozone and PM_{10} air pollution. These damages tend to be dominated by the increased risk of mortality and other human health effects. As a result, valuation of the damages is sensitive to the values attributed to the avoidance of health impacts and, especially, the value assigned to avoiding increased risk of mortality. This latter benefit is quantified by first determining the increased number of statistical lives, where a statistical life is defined as 70 person-years, and the number of statistical lives is calculated as follows:

$$S = \frac{I*N}{70}$$

where S = number of statistical lives
I = average increase in life span in years
N = number of people benefiting from the improvement in air quality

The range of values that can be assigned to a statistical life, however, creates a difficulty in that different emission limits will result depending upon the value chosen. For example, a range of $ 2.4 to $ 7.9 million 1994 Canadian dollars has recently been reported for the age-weighted value of a statistical life (Hagler Bailley, 1995). The future value of a statistical life is also uncertain. The theoretically preferred values for a statistical life are based on the concept of the "willingness-to-pay" for a reduction of the risk of mortality. Such estimates are constrained by income. As incomes rise the value of a statistical life can be expected to rise as well. The value of a statistical life may rise faster than the per capita income (net of inflation) since individuals may decide to assign more of their extra income to reducing the risks of mortality.

Since impacts on mortality predominantly occur in the future, questions arise when discounting future benefits of reduced air pollution to a present value. If the current value (allowing for inflation) of a statistical life is used to calculate the value of future reductions in the risk of mortality, the present value will be lower than that of a corresponding reduction in risk achieved today due to the discounting process. As long as the present value of the future benefits can be invested today at a rate of return equal to the discount rate, and the proceeds used in the future to reduce the risk of mortality, the same real benefit can be realized in the future. However, the institutional mechanisms to implement this may not be available.

However, if the value of a statistical life (net of inflation) rises in the interim, the funds available in the future may not be sufficient to produce the socially optimal benefit in reduced future mortality. Changes in the future costs of reducing the risk of mortality will also affect the analysis. It can also be argued that the current generation need not incur additional costs to reduce risks for future generations who will be better off. Thus, the future value of a statistical life involves a choice of what is equitable for current and future generations.

In practice there appear to be three options:

- Assume that the value of a statistical life remains constant in real terms and discount the future benefits using the social discount rate.

- Increase the value of a statistical life at the same rate as per capita real income and discount the future benefits using the social discount rate.

- Assume that the value of a statistical life rises faster than per capita real income. Since data on the relationship between income and the value of a statistical life is not available, assume that the value of a statistical life rises at the same rate as the social discount rate. Future benefits are then discounted at the social discount rate, and the present value of a statistical life for any future date is the same as it is today.

The first option assumes that future generations are treated in the same manner as today's generation. The last option leads to decisions that are economically efficient for future generations.

Further discussion of discount rates applicable to the costs and benefits of air quality management is provided in Appendix B.

It is thus indicated that the current information base with regard to valuing the damages caused by air pollution is suitable for use in a cost-benefit approach to setting AELs, but that a wide range in AELs will be possible depending upon valuation and treatment of avoided damages.

Costs of Emission Reductions

The GVRD AQMP has summarized from the literature generic costs for reducing emissions from a wide range of point, area and mobile sources. These emission reduction measures, however, have not been subject to sufficient analysis so as to allow full prioritization and comparison of their individual costs and benefits specific to the GVRD or LFV.

The actual costs incurred in the LFV may be higher or lower than the generic cost estimates that have been used for many of the emission reduction measures. The true costs may not be actually known until available emission reduction options are fully evaluated for each individual source or source type.

The choice of an appropriate discount rate also applies to the treatment of future costs (Appendix B).

It must be concluded, therefore, that the current information with regard to the costs of emission reductions may only be appropriate for use in cost-benefit analysis used to give general evaluation of the AQMP, and is not sufficient to allow the setting of AELs for the LFV using the cost-benefit approach described herein.

3.2.3 Setting Technology Based Limits

3.2.3.1 Description

Technology based limits identify the emission controls that can be used by each source and limit emissions to the level that would exist after all of those controls have been implemented. It can thus be seen that technology-based limits are similar to the traditional approach to air quality management discussed in Section 3.1.

Implementing emission controls costs money. Increased degrees of emission control are generally possible, but at rising cost. Selection of the control technologies to be implemented, then, cannot be divorced from consideration of the attendant costs. This is generally done judgmentally in light of the severity of the air quality problem.

If the air quality problem is deemed to be serious, the control technologies that provide the maximum degree of emission reduction can be prescribed.[4] If the air quality problem is less severe, less stringent control technologies which are considered to be affordable for the sources to which they apply, and still provide a satisfactory level of emission reduction, can be prescribed.

Generally each source is responsible for the cost of the technologies it is expected to implement. The technologies may imply different levels of control for different types of sources, possibly including no control for some sources. It may also imply very different costs per tonne of reduced emissions for different sources.[5] Thus, a technology-based limit may not lead to an efficient use of society's resources nor to an equitable distribution of the costs of control.

A potential alternative to the use of emission control technology is application of pollution prevention. Pollution prevention is also typically technology based but seeks to reduce or eliminate pollutant emissions by avoiding their generation, thus obviating the need for emission controls. Where feasible, pollution prevention can have relatively low costs.

Having identified the technologically achievable emission reductions, these are applied to a baseline level of emissions to calculate the emission limit. Future growth in the number and type of emission sources would have to be accommodated within this limit.

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[4] The ultimate level of control is zero emissions. Some products have been banned or are being phased out to achieve zero emissions. However, bans have not been suggested for the pollutants that are the focus of this report.

[5] Sources tend to be concerned about the **total** cost they will be expected to incur. The **average** cost per tonne of emissions reduced at various sources is sometimes used as an indicator of the equity of the proposed control measures. The **marginal** cost per tonne of emissions reduced at various sources is an indicator of economic efficiency. An efficient use of resources leads to the same marginal cost of emissions reduction for all sources.

3.2.3.2 Suitability of Information Base

As noted in Section 3.2.3.2, the GVRD AQMP has identified potential emission reduction measures for point, area and mobile sources, and their cumulative effect on total emissions can be calculated. Thus, a technology-based set of AELs can be established once a base year of emissions is decided.

Since the identified AQMP emission reduction measures are in some cases generic, the estimated emission reductions could be subject to upward or downward revisions, depending upon actual experience gained from implementation.

3.2.4 Using Consultation and Negotiation

3.2.4.1 Description

An emission limit must address three issues: economic efficiency (wise use of society's resources), equitable access to a healthy atmosphere, and equitable access to the limited waste disposal capacity of the atmosphere. No analytical process is able to balance these issues, and therefore a procedure is required which enables stakeholders or decision makers to rank options that reflect different trade-offs between these, and possibly additional, objectives. Two such procedures are outlined below.

Multiple Account Evaluation

Multiple account evaluation is similar to cost-benefit analysis, except that the intention is to evaluate alternatives against a set of objectives or "accounts". The evaluation of an alternative might indicate that it makes a positive contribution toward some objectives, while detracting from achievement of others.

Even in the rare cases where performance against all of the objectives can be measured in monetary terms, it is usually not correct to sum the amounts for the accounts to get an overall assessment. Rather, multiple account evaluation helps to illustrate the advantages and disadvantages of alternatives and the trade-offs they entail. This information may allow revisions to one or more of the alternatives so as to minimize the adverse impacts while retaining most of the benefits.

The evaluation accounts suggested for B.C. Crown Corporations are (Crown Corporations Secretariat, 1993):

- financial performance
- customer service
- environment
- economic development
- social.

These objectives can be refined further. For example, environment could be divided into solid, liquid and gaseous wastes. Obviously, judgment is required in deciding which accounts to analyze and at what level of detail.

In the case of choosing between AELs, multiple account evaluation could consider health and environmental benefits, costs to affected parties, economic development impacts and social concerns. This would show that the health of the general population benefitted while costs were imposed on sources and that there were other economic and social effects. In order to choose a final set of AELs it would be necessary to decide on an appropriate weighting or balance to each of the positive and negative accounts.

Multi-Criteria Analysis

Multi-Criteria Analysis is also known as Multi-Criteria Decision Making, Multi-Attribute Trade-Off Analysis and Goals Achievement Matrix (B.C.U.C., 1996). This type of process can be used for rating or ranking alternatives using specified criteria, and in principle provides a mechanism whereby a representative set of stakeholders can reach agreement on how available options should be ranked. This should lead to broad support for the preferred option. However, the probability of reaching concensus is reduced as the number of stakeholders is increased.

A convenient way to describe multi-criteria analysis is as a scoring system. Having defined a set of objectives, each option is scored against each objective and an overall score computed. Variations include giving different weights to each objective, assigning a simple pass/fail mark against objectives, and using non-linear scoring systems. The choice of scoring system to be used in any given application can have a significant effect on the eventual outcome, and can be revised when the initial results of an analysis are reviewed.

Experience suggests that the chances of achieving concensus on a preferred option among a group of stakeholders are low. This is true even if the participants have an opportunity to compare and discuss each other's evaluations of the options and revise their own scores. Neither B.C. Gas or B.C. Hydro was able to achieve concensus among stakeholders in a consultation process undertaken as part of their planning processes (Hobbs, 1994; B.C. Hydro, 1995). Even if the stakeholders are able to agree on a preferred option, the public may not accept the choice as they may not be aware of the reasons for the choice made by the stakeholder representatives.

Thus, multi-criteria analysis provides a technique that can be used to facilitate making a negotiated choice between options. Different objectives such as environmental benefits, equity, economic efficiency and economic development can be included in the analysis so as to develop a balanced evaluation. However, concensus among participants or stakeholders is unlikely to be fully achieved, even though understanding of the options and the potential trade-offs is improved.

Other approaches are possible to the setting of negotiated AELs, but they will all face the same problem of achieving universal support. This would indicate that negotiation and discussion would be required in order to agree on trade-offs and establish the most-widely accepted criteria which will be used in setting the AELs.

3.2.4.2 Suitability of the Information Base

It can be seen that a negotiated or political process for setting AELs will require the information that is used in all of the processes described in Sections 3.2.1 to 3.2.3, and therefore the respective comments apply.

The information base required for multiple account evaluation is similar to that required for cost-benefit analysis, except that it is not necessary to monetize the benefits in the same way. Thus, many of the comments of Section 3.2.2.2 are relevant to those accounts which use a financial measure, but multiple account evaluation may alleviate some of the problems where there is a potential range in the valuation of air pollution damages. The problems, however, would not be completely resolved as it would still be necessary to assign relative importance or weightings to the various accounts.

3.3 RISK MANAGEMENT, POLICY DEVELOPMENT AND UNCERTAINTY

The discussion in the preceding sections has indicated that the inputs used in the various approaches to setting airshed emission limits each have associated degrees of uncertainty. As a result, the values of the AELs which result will have potential errors and can therefore be associated with at least two potential risks:

- risk that the emission limits have been set too high, and therefore that adverse health and environmental effects have not been adequately reduced;

- risk that the emission limits have been set too low, and that the associated costs to individuals, society and industry are therefore inappropriately high, albeit that the level of health and environmental protection is very good.

It can be appreciated that the outcome of a negotiation or political process could be AELs which balances these risks, and as a result does not guarantee achievement of the ambient air quality objectives at all times. Indeed, it could be argued that no reasonably achievable emissions limit could be set with such a guarantee, given the levels of uncertainty and variability in the factors that influence atmospheric concentrations.

Moreover, short-term and year-to-year variability in the level of emissions and in local meteorology mean that fluctuations in ambient pollutant concentrations are inevitable, and therefore that complete compliance with an air quality objective will require **average** concentrations significantly below the objective. Indeed, it has been estimated that long-term compliance with U.S. ozone attainment criteria in California's San Francisco Bay Area would require annual mean concentrations to approach those of rural background levels (Chock, 1993). This would imply that a realistic health-based AEL cannot be set, at least for this area, and therefore that a political or negotiated AEL would have to be established. It should be noted however that the Bay Area has now been designated as in attainment against the U.S. ozone standard, and therefore effective NO_x and VOC limits can be achieved in that area, at least under recent meteorological conditions.

Scientific and economic uncertainties are inherent in the process of establishing an emission limit, regardless of the process used to set the limit. Current data and scientific knowledge are uncertain, although research may reduce those uncertainties. However, an emission limit must also consider future developments, and research cannot remove uncertainties inherent in the future.

Faced with uncertainties, at least some of which can never be reduced, two basic strategies are possible. Uncertainty can be incorporated into the analysis of policy options to provide a better information base for decisions. Secondly, policies can be designed to be robust in the face of uncertainty, recognizing that uncertainty can not be eliminated. These strategies are not mutually exclusive.

3.3.1 Incorporating Uncertainty into the Analyses

Assuming that the necessary information is available, uncertainty can be incorporated into analysis of airshed emission limits in various ways. To base an ambient standard on health risks, for example, the analysis could consider the distribution of risks, the risks for different segments of the population, the risks to persons voluntarily and involuntarily exposed, the risks of different health impacts, etc. The standard could then be based on an "acceptable" risk to a particularly vulnerable segment of the population.

Uncertainties in the relationship between emissions and ambient concentrations could be addressed through modelling different scenarios. Assuming that probabilities could be assigned to the different scenarios, a probability distribution for the emission limit could be developed. Linking that distribution to the health impacts would provide the basis for selecting a human-health based emission limit.

If a cost-benefit approach is used, distributions on the values assigned to different damages and the costs of mitigation options can also be factored into the analysis. The sensitivity of the results to the choice of the discount rate can also be analysed. Published cost-benefit studies of climate change indicate that the resulting distribution spans everything from minimal action to aggressive controls on emissions.

Under a technology-based approach, distributions on the costs and effectiveness of different control technologies can be incorporated into the analysis. Probabilities can also be assigned to the likelihood that every source will implement the specified measure(s).

All of these, and other, adjustments to the analysis of policy options to incorporate uncertainty presuppose that the necessary information is available. In fact, a principal source of uncertainty often is that the information is not available. Not only are the probability distributions for many variables not known, the basic relationships are often only imperfectly understood.

Another aspect of uncertainty is human reactions to the unknown. The public, or policy makers, may prefer some degree of risk aversion to avoid unknown consequences of air pollution. A risk aversion premium can be explicitly introduced in analyses of a possible emission limit. For example, risk aversion can be incorporated into the selection of a health-based criterion by focusing on the risks to vulnerable segments of the population. In a cost-benefit analysis risk aversion can be introduced by giving greater weight to extreme events. This approach is similar to the "precautionary principle" used in British Columbia which ensures that regulators err on the conservative side.

Incorporating uncertainty into analyses provides stakeholders with better information. However, much of the information needed to do this rigorously is not available. And, in any event, some uncertainty will always remain.

3.3.2 Adopt Policies that are Robust in the Face of Uncertainty

Some policies are more robust to changing circumstances than others. Waiting until the uncertainties associated with establishing an emission limit are resolved is pointless; that will never happen. Rather decisions must be made despite the uncertainty, recognizing that they may need to be modified in the light of changing circumstances.

Firms and individuals use a variety of methods to cope with uncertainty. It is possible to buy insurance, futures contracts, or options to protect against unfavourable outcomes. There is a cost, but it also reduces the potential adverse consequences of uncertainty. Similarly, investors often acquire a portfolio of assets. This reduces the probability of very low or very high returns, but provides better protection of the existing asset.

These methods respond to better information on the risks and individuals/firms react accordingly. Insurance premiums change in response to claims experience and individuals adjust their coverage accordingly. Prices of commodity futures change with expectations for supply and demand and individuals adjust their holdings to reflect their expectations and exposures. Portfolios are adjusted to reflect experience and expectations concerning different types of assets.

Environmental policies can be designed to embody some of these methods of coping with uncertainty. For example, an emission limit that can be adjusted in the light of new information is better able to cope with uncertainty than no emission limit. Similarly, an emission limit for specific sources that can be adjusted relatively quickly is better able to cope with uncertainty than technology based regulations. And strategies to regulate emissions from the broadest possible range of sources and to increase the range of control options for the future are preferable to a strategy of limiting emissions from the largest or most easily regulated sources.

3.3.3 Allowing for Uncertainty When Setting Airshed Emission Limits for the Lower Fraser Valley

Section 3.2 indicated that the only approach to setting airshed emission limits that considers all of the efficiency and equity issues is negotiation or a political process. Other approaches provide useful information on the implications of different criteria, but can focus on one criterion while ignoring the others. Allowing for uncertainty in these approaches where possible will provide better information for the negotiation/political process. However, it will not change the need for that process.

Fundamentally, air quality management policies, including airshed emission limits, must recognize the reality that uncertainty can not be eliminated. Policies that are robust in the face of uncertainty incorporate flexibility and are easy to adjust as circumstances change. For example:

- an explicit limit would be better than an implicit limit, since it is easier to adjust an explicit limit in light of new information regarding factors such as actual versus predicted changes in air quality, as well as other new knowledge and changing circumstances;

- the overall emission limit should cover all sources, even those not yet included in emission estimates, thus allowing for changes in the relative importance of different source categories;

- flexibility should be incorporated into any allocation of the overall limit between source sectors and/or groups of sources, thus allowing for potential redistribution of emissions as a result of future emission reduction initiatives and other changing circumstances.

3.4 RELATIVE STRENGTHS AND WEAKNESSES

Having reviewed the approaches to setting AELs, it is possible to review their strengths and weaknesses against relevant objectives. This is done in Table 2, where the objectives used are as follows:

- effectiveness — ensuring good air quality;
- efficiency — maximizing the excess of benefits over costs;
- equity — allocating emissions fairly;
- flexibility — allowing for uncertainty;
- acceptability — providing high probability of acceptance by stakeholders.

It should be noted that Table 2 is based on relative strengths and weaknesses, not absolute indicators against each criterion.

It is not anticipated that Table 2 will change significantly when applied to emissions of any one particular contaminant or precursor. However, this cannot be fully evaluated until the size of the emission limits are determined under each approach and the implications against each objective more fully assessed.

TABLE 2

RELATIVE ASSESSMENT OF THE FIVE ALTERNATIVES FOR SETTING AELS

Objective	Emission Limit Process				
	Traditional/ Implicit Limits	Achieving Concentration Objectives	Cost-Benefit Analysis	Technology Based Limits	Negotiated Limits
Good air quality	☒	☐	☒	☒	☒
Economic efficiency	■	■	☐	■	☒
Equitable allocation of the emissions	■	■	■	■	☐
Flexibility in the light of uncertainty	■	☐	☐	■	☐
Acceptability	■	☒	☒	■	☐

Legend ☐ Positive ☒ Neutral ■ Negative

4. PROCEDURES WHICH HAVE BEEN USED ELSEWHERE

Having reviewed the conceptual approaches to setting AELs, it is worthwhile to review procedures which have actually been used for setting emission limits, so that a basis is available for assessing factors which will be important in setting AELs for the Lower Fraser Valley.

4.1 ACHIEVEMENT OF CANADIAN AMBIENT AIR QUALITY OBJECTIVES

4.1.1 Ambient Air Quality Objectives in Canada

The current Canadian National Ambient Air Quality Objectives (NAAQOs) were published in 1976 with some revisions in 1989. As shown in Table 1 (Section 3.1), there are up to three levels of NAAQOs: desirable, acceptable and tolerble. These levels are successively less stringent, and can be defined as follows:

- desirable: the long-term goal for air quality and provides a basis for anti-degradation policy for unpolluted parts of the country and for continuing development of control technology;

- acceptable: provides adequate protection against adverse effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well being; and

- tolerable: a concentration of an air contaminant that requires abatement without delay to avoid further deterioration to an air quality that endangers the prevailing Canadian lifestyle or, ultimately, to an air quality that poses a substantial risk to public health.

Objectives are not set for all of the pollutants relevant to this report, and in particular, there are presently no Canadian objectives for PM_{10}. There are Canadian objectives for total particulate, or TSP, and these can be used to infer effective PM_{10} objectives, although the relationship between PM_{10} and TSP concentrations is not the same in all areas of Canada.

Achievement of the air quality objectives is not mandatory for any Canadian region or airshed, in that there is no requirement to limit current emissions so that these objectives will be met. However, the objectives can be used in assessing the impact of a new emission source, and an environmental assessment process would typically require that a large new emission source would not result in significant deterioration in air quality. This is particularly true in sensitive rural areas, where the desirable objectives would apply.

British Columbia has established a parallel set of air quality objectives, designated as levels A, B and C. Some of these are more stringent than the Canadian national objectives, and in particular British Columbia has a PM_{10} objective. Similarly, the GVRD has established 24-hour and annual PM_{10} objectives.

Since 1992 the Working Group on Air Quality Objectives and Guidelines (WGAQOG) has been reviewing the framework of the NAAQOs as well as the implications of increasing information on the effects of air pollution on human health and other receptors. The working group has made recommendations to the Canadian Environmental Protection Act/Federal Provincial Advisory Committee (CEPA/FPAC) that the current three-level system of air quality objectives be replaced with a two-level system, defined as follows:

> **The Reference Level** — A level above which there are demonstrated effects on human health and the environment. It provides a basis for establishing goals for long term air quality management.
>
> **The Air Quality Objective** — A level selected based upon consideration of scientific, social, economic and technological factors. It provides a basis for air quality management and is intended to provide protection for the general population and the environment.

This two-level system thus allows for a thorough and scientifically credible basis for setting the Reference Level, and the selection of an Air Quality Objective through an approach which would be transparent, balancing the need to protect receptors with society's willingness to achieve air quality improvements. As a result, the potential problems arising from a zero- or low-level threshold effect of an air pollutant can be recognized (Section 3.2.1.1) and an air quality objective set above this level.

There is presently no fixed schedule for implementing either the two-level system or designating actual numeric values for air pollutant levels (Jessieman, 1996). However, it is possible that a reference level for PM_{10} will be agreed by mid-1996 and the second level for PM_{10} at a later date in 1996/97. No dates for setting similar levels for ozone are available.

As noted above, British Columbia has established an interim PM_{10} objective, pending the outcome of the NAAQOs review, and has also developed a two-tiered air quality objective for formaldehyde: an action level of 60 $\mu g/m^3$ for air quality management, and an episode level of 370 $\mu g/m^3$ for triggering immediate emission reduction measures.

There are parallels between the proposed two-level system of NAAQOS and the management of substances evaluated as toxic under the Canadian Environmental Protection Act (CEPA). Thus, substances from the initial Priority Substances List (PSL1) which have been assessed as "CEPA-toxic" have been placed in one of two categories: Track 1 for the substances with proven health and environmental effects and which are persistent and bioaccumulative, and Track 2 for those substances with smaller or not-fully-proven effects. Management strategies for each CEPA-toxic substance are being developed through a Strategic Options Process in consulation with stakeholders. For Track 1 substances the goal is virtual elimination of the substance in Canada, while for Track 2 the goal is minimization of consumption and release to the environment. A second Priority Substances List, PSL2, has been recommended for assessment under CEPA, and PM_{10} is included on this list.

4.1.2 The NO_x/VOC Management Plan

Perhaps the most comprehensive Canadian program to control emissions and ensure achievement of a Canadian air quality objective is the NO_x/VOC Management Plan. This program arose from the frequent exceedance of the Canadian acceptable objective for ozone in several areas in Canada, as well as Canada being a signatory to UNECE protocols on NO_x and VOC. The current Phase I of the plan includes a series of studies and initiatives intended to enable a better understanding of the factors that influence ground-level ozone in Canada, in particular emissions of NO_x and VOC, and to recommend strategies and policies to reduce these emissions.

With regard to emission limits, the NO_x/VOC Plan has not yet set explicit limits for overall or airshed emissions, although Canada has agreed to stabilization and reductions in NO_x and VOC emissions through related international protocols. The general methodology used to date in the NO_x/VOC plan is that described earlier as the traditional approach to air quality management: identifying and requiring specific emission control technology for specific source types, and developing the optimum strategy for achieving targeted emission reductions from source sectors. Thus, NO_x emissions from industrial and utility boilers would be reduced by prescribing control technologies, whereas VOC emissions from commercial and industrial solvent use would be reduced by focusing on solvent uses where the most cost-effective and practical solvent reduction measures can be implemented, consistent with achieving a targetted reduction.

However, it should be noted that although Phase I of the Plan does not as yet include explicit limits on NO_x and VOC emissions, there has recently been some analysis of the cumulative effects of the identified measures (Pinault, 1995), and estimates of total emission reductions have been calculated. When combined with the results from associated atmospheric modelling (e.g. using the Urban Airshed Model or UAM) this will allow the need for further emission reductions to be evaluated. Thus, it is possible that explicit emission limits will be developed during the conclusion of Phase I, or as part of Phase II of the Plan. In particular, NO_x and VOC explicit emission limits or well-defined emission reductions will be essential to ensure the success of programs developed in support of the NO_x/VOC Plan. To this end, emission limits for the Lower Fraser Valley and the Windsor-Quebec City corridor are part of the approaches planned for dealing with ground-level ozone.

In summary, Canada's NO_x/VOC Management Plan has not yet set explicit emission limits, either nationally or for specific airsheds, although such limits are planned once the results from ozone modelling are available.

4.2 ACHIEVEMENT OF U.S. AMBIENT AIR QUALITY STANDARDS

4.2.1 National Ambient Air Quality Standards

The United States' Environmental Protection Agency has established national ambient air quality standards (NAAQS), which every air basin in the United States is expected to achieve. These standards, which limit ambient pollutant concentrations in the atmosphere, are designed to protect the public health and welfare from the adverse effects of air pollution. The standards are not to be influenced by the cost or technical feasibility of realizing them, and are to include an adequate margin of safety. Thus far, EPA has established NAAQS for CO, NO_x, SO_2, ozone, PM_{10}, and lead. Areas that attain the NAAQS are termed "attainment areas" — those that do not attain the NAAQS are called "non-attainment areas."

In addition to the federal NAAQS, states and regional air quality administrators may promulgate additional or more stringent requirements. Currently only the State of California has established state ambient air quality standards (SAAQS) that are more stringent than the federal standards. The California SAAQS are also based on protecting the public health and welfare from the effects of air pollution.

As noted above, EPA is responsible for setting the NAAQS and the process for promulgating and reviewing the NAAQS begins with a review of relevant research on the health impacts of air pollution. This research is reviewed by the EPA Clean Air Science Advisory Committee for its relevance and EPA develops a report recommending either a specific value or a range of values for the standard under review. The EPA administrator will then formally adopt a standard, which has to be reviewed every five years.

Currently, both the U.S. PM_{10} and ozone standards are being reviewed. These review processes are both faced with two problems: the absence of an apparent threshold level, and insufficinet scientific evidence to choose between or set new air quality standards (EMa and EMb, 1996). As a result, the PM_{10} standard review and a possible new $PM_{2.5}$ standard may be delayed beyond the original 1997 deadline, and the expected mid-1996 decision on a new ozone standard may be based on other than scientific evidence.

State Implementation Plans (SIP)

Although NAAQS are not guidelines they are also not directly enforceable. However, each state must develop a State Implementation Plan (SIP) that details the emission reduction strategies that are to be implemented to maintain or realize NAAQS. States must develop and gain EPA approval for SIPs. Further, once adopted, States must adhere to the SIPs.

SIPs must include the development of a detailed emissions inventory, define stationary source control measures, and address the transportation planning that is required to manage mobile source emissions. Depending on an area's non-attainment status, a State may also be required to implement mandatory emission reduction programs, such as vehicle inspection and maintenance programs and require alternative fuel use (i.e. oxygenated gasoline).

States are given a great deal of discretion in designing and developing their SIPs.[6] EPA will approve a State-submitted SIP if EPA concludes that it contains control measures that are sufficient to achieve the NAAQS. SIPs may contain measures that are more stringent than are required by EPA. EPA is specifically prohibited from taking into account cost and feasibility considerations. As such, EPA may not reject a SIP because the SIP is thought to impose unreasonable costs on industry and/or because it includes measures that are not technologically feasible.

[6] Some argue that states have little discretion in the area of controls that are required for new sources. Under the Clean Air Act EPA is required to develop new source performance standards (NSPS) which apply to specified categories of new sources. NSPS reflect an emission limitation/percentage reduction that can be achieved through the application of the best technological system of continuous emission reduction which EPA determines is demonstrated for each category. As such, new sources are required to utilize controls that achieve the highest level of control that is technologically achievable and that are economically feasible.

If EPA is unable to approve a SIP, it must develop and implement a Federal Implementation Plan (FIP). The FIP puts the EPA in the role of developing and implementing (sometimes with the State's assistance) emission reduction strategies for the State. EPA's many responsibilities, the awkwardness of implementing a program from the federal level, and State resentment of federal involvement in day-to-day management has made the FIP development process difficult.

EPA has also developed measures and programs that can be used in the SIPs. These measures, if adopted, will be "pre-approved" as part of a state's plan. These may include Economic Incentive Plans (EIP), which allow for the creation of emission trading markets.

It is as yet too early to judge the success of any SIP.

Mobile Sources

One notable area where State's have more limited discretion is in matters relating to the transportation sector. The Clean Air Act required EPA to "maintain a continuous transportation-air quality planning process...and publish guidance on the development and implementation of transportation and other measures necessary to demonstrate and maintain attainment of [NAAQS]." That is, an ongoing dialogue is required to ensure that transportation planning takes into account potential effects on achieving or maintaining the air quality standards.

Additionally, EPA maintains control over many aspects of motor vehicle emission standards. With some exceptions, this control effectively precludes certain aspects of what a State can do to control such emissions.[7]

Attainment and Non-Attainment SIP Requirements

As noted above, an area's attainment/non-attainment status is based on the ambient concentration of each pollutant in the atmosphere. However, an area does not have to show 100% compliance with the NAAQS in order to be in attainment. Rather, each area determines a "design value" for each of the relevant air contaminants, and compares this with the appropriate NAAQS. The design values are determined in slightly different ways for each pollutant, and for ozone and PM_{10} these can be summarized as:

- Ozone: greatest of the second highest 1-hour concentrations from each monitoring station over a three year period.
- PM_{10}: greatest of the fourth highest 24-hour concentrations from each monitoring station over a three year period.

These definitions of the design values are ostensibly intended to give those concentrations of ozone and PM_{10} which on average would be exceeded one or three times per year respectively. It has been suggested, however, that these definitions of the design values are

[7] One exception is that states with approved SIPs may impose California-equivalent motor vehicle standards. Also, states may impose tailpipe emission standards applicable to automobile resale and re-registrations.

much more stringent than they appear, and that the ozone design value is not an appropriate way to calculate the "average second highest" concentration (Chock, 1995).[8]

The goal for attainment areas is to ensure that air quality does not deteriorate to the point where a violation of the NAAQS is registered. The underlying goal of all non-attainment areas is to reduce emissions such that the area attains the NAAQS. The SIPs for attainment and non-attainment areas are constructed to ensure that these goals are realized.

States with attainment areas are required to develop Prevention of Significant Deterioration (PSD) programs to ensure the State maintains its acceptable air quality. PSD programs must meet a number of objectives including the following:

(1) Preserve, protect, and enhance the air quality in national parks, wilderness areas, monuments, seashores, and other areas of special national or regional natural, recreational, scenic, or historic value;

(2) Ensure economic growth consistent with the preservation of existing clean air resources;

(3) Assure that emissions from one state will not interfere with the PSD in another; and

(4) Assure that any decision to permit increased air pollution in attainment areas will be made only after public participation.

PSD programs may be implemented by either the EPA or by the State if it has garnered EPA approval.

EPA has designated five levels of non-attainment, ranging from marginal to extreme. As of November of 1995 there were 33 non-attainment areas within the United States. These non-attainment areas are required to develop SIPs that provide for the attainment of the primary NAAQS. Required SIP elements for all non-attainment areas include the following:

(1) New or modified major stationary sources must go through new source review, obtain permits, utilize stringent control technologies to reduce emissions, and obtain compensating emission reductions (or offsets) to mitigate the impact of significant new emission increases.

(2) Certain emission categories must utilize reasonably available control technology.

(3) The State must develop a comprehensive emissions inventory that includes emissions from all sources of pollutants for which the area is non-attainment.

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8 Note: EPA must go through a formal process to change the attainment status of an area. As such, an area that has previously been determined by EPA to be an attainment area will not automatically be redesignated as a non-attainment area. The redesignation process can take a number of years to play out.

The deadlines for compliance with the NAAQS and the type of other requirements that are imposed on non-attainment areas are based on the severity of the non-attainment problem and the classification of the area. The table below gives the ozone attainment designations, the number of areas currently at each designation, and the required time frames to achieve compliance.[9]

Level of Non-Attainment	Deadline for Compliance
Marginal (4 areas)	1993
Moderate (7 areas)	1996
Serious (12 areas)	1999
Severe (9 areas)	2005
Extreme (1 area)	2010

The Clean Air Act establishes sanctions that may be imposed on States that fail to meet the attainment deadlines. EPA may, among other things, prohibit the awarding of highway grants and withhold approval of highway projects.

Multi-Jurisdiction Regulation

In multi-state areas where the EPA concludes that interstate transport of air pollutants contributes significantly to a violation of a NAAQS, EPA may establish a transport region for such pollutants and a transport commission which consists of representatives from each state. These commissions are charged with developing region-wide emission reduction strategies. Strategies that fail to garner majority support will not be implemented. This effectively guarantees that the only strategies that will be approved will be those that are acceptable to a majority of the commission members, even if there are no alternatives for achievement of the NAAQS.

The Ozone Transport Region (OTR), which includes the 12 northeastern States and the District of Columbia, is an example of such a region. The Ozone Transport Commission (OTC) is charged with the responsibility of developing a region-wide air quality strategy for the OTR. The OTR has labored for the last five years with mixed success to meet this goal. For example, while the broad outlines of a NOx trading program have been developed, Virginia and the District of Columbia have not signed onto the plan.

California

California has air quality standards for its own jurisdiction. According to California law, these SAAQS are to be established by the California Air Resources Board (CARB) "in consideration of the public health, safety, and welfare including, but not limited to, health, illness, irritation of the senses, aesthetic value, interference with visibility and effects on the economy." CARB has stated that it does not consider compliance costs when developing

[9] CO and PM_{10} non-attainment areas are classifed as either moderate or serious.

standards. Similar to the NAAQS, California standards are regulations, and not approved by any legislative body. The standards, presented in Table 1, are stricter than federal standards, and are to be reviewed approximately every five years. California delegates the implementation of the federal and state requirements to local air districts.[10]

4.2.2 Examples of United States Emission Limiting Programs

There are three basic approaches to limiting emissions in the US in order to achieve compliance with the NAAQS. Below is a general outline of these three types of programs, and following are some specific examples.

First, a Gross Emissions Cap limits the total quantity of emissions without restricting any individual emitter to the rate of emission. If, based on air quality modeling, an acceptable level of emissions from a population of emission sources can be stated, then emissions from these sources can be capped at that level. Programs using a gross emissions cap can allocate total allowable emissions to affected sources. A cap may be designed to limit emissions in a given time period. For example, areas with a summer ozone problem may choose to cap total emissions only during the ozone season, without capping total annual emissions. If the pollutant is a year-round problem, an annual emissions cap may be applied. Trading programs used in conjunction with an emission cap allows for the redistribution of allowable emissions without exceeding the cap. Examples of this type of limit are the EPA SO_2 emission program and the SCAQMD Regional Clean Air Incentives Market or RECLAIM program.

Second, an Emission Rate Cap limits emissions with respect to a given period of time or unit of output (per hour, day, mmBTU etc.) but does not place a limit on total emissions. If the rate of emissions equating to the desired ambient concentration can be determined (through air quality modeling), sources can be restricted to a maximum allowable emission rate.

Finally, a Percentage Reduction can be set if an emission reduction target has been established. This target, while reducing total emissions, may or may not be based on achieving a certain level of air quality. An example of this type of program is the OTC NOx program.

Example 1 — South Coast Air Quality Management District (SCAQMD) Regional Clean Air Incentives Market (RECLAIM)

The South Coast Air Quality Management District (SCAQMD) is unique in several aspects. It is the only area in the US designated by the EPA as an extreme non-attainment area for ozone, and is in non-attainment status for NO_X, Reactive Organic Gas (ROG), SO_2, and PM_{10}. Federal law requires the SCAQMD demonstrate attainment with all Federal standards by year 2010. Additionally, it is situated in an geographically defined air basin, with virtually no emission transport into the area. Beyond federal air quality standards, the

10 California has been granted authority to develop and implement motor vehicle emission standards that are more stringent than the federally imposed standards. Additionally, Title II of the Clean Air Act establishes a clean fuel vehicle pilot program in California that mandates the production of a specified number of such vehicles by 1999.

State of California has adopted standards with which the SCAQMD must also comply.

The SCAQMD employs many programs to reduce emissions from a range of sources, most of which are traditional "command and control" regulations based on technological feasibility to reduce emissions. The SCAQMD is best known, however, for its RECLAIM program.

RECLAIM, which began in 1994, represents an innovative market-based emission reduction program that will require reductions in NO_x and SO_2 emissions by imposing emission limits that decline over time. The program currently covers only NO_x and SO_2 emissions, but a VOC RECLAIM program is planned for implementation in January of 1997. The NO_x and SO_2 programs cover only major emitting facilities, which are defined as those emitting greater than four tons of either gas per year. This represents approximately 17% of all stationary source emissions in the SCAQMD air basin, or approximately 5% of all NOx and SO2 emissions in the SCAQMD. Smaller emission sources were concerned with reporting requirements of RECLAIM, and so were excluded. These smaller sources can opt-in to RECLAIM, and consideration is being given to lowering the limit to two tonnes per year.

RECLAIM is a "cap and trade" emissions market program. Based on airshed modelling, the SCAQMD determined that, compared to 1990, a 73% reduction in NOx emissions and a 65% reduction in SO2 emissions is required from RECLAIM facilities, in addition to other emission reduction requirements from non-RECLAIM emitting sources, in order to demonstrate attainment with Federal and State air quality standards. The SCAQMD capped emissions from this group of point sources at a base year level of actual emissions (for most sources this year was 1990). Additionally, to achieve the needed emission reductions, the cap declines each year until the year 2003 and then stays constant to 2010.

Previously scheduled future emission reduction requirements for NO_x and SO_2 at the RECLAIM sources were removed (facilities must still comply with other criteria pollutant reductions that are not covered by RECLAIM). RECLAIM facilities in existence at the beginning of the program were given annual NO_x and SO_2 credit allocations, which the facility may use or sell. All RECLAIM facilities must surrender credits at the end of each year equal to their actual emissions. Credits are issued in annual vintages, and may not be banked for future compliance or used prematurely. Excess credits may be sold on the market, and additional credits required must be purchased on the open market. The SCAQMD does not control, manage, or influence the RECLAIM market.

New or expanding emission sources with annual NO_x or SO_2 emissions greater than four tons are also included in the RECLAIM program. These sources still must comply with all New Source Review (NSR) standards and install emissions controls to meet NSR requirements. They receive no additional RECLAIM allocation, and must purchase required emission credits in the open market equivalent to their annual SO_2 and/or NO_x emissions.

Example 2 — Ozone Transport Commission (OTC)

The Ozone Transport Commission (OTC) is a multi-jurisdictional entity established by EPA in 1990 to coordinate ozone pre-cursor emission reduction efforts of 12 states, and the District of Columbia, located in the Northeast and Mid-Atlantic areas of the US.[11] OTC states have signed a joint Memorandum of Understanding (MOU) that it will implement consistent rules to implement an emission reduction program region-wide.

The OTC has established a percentage reduction goal and an emission rate cap to achieve emission reductions in the region. OTC members believe a 75% reduction in NO_x emissions from electric generators during the ozone season is necessary to improve the air quality of the region. This percentage reduction goal is not based on air quality modeling, nor has it been demonstrated that the region will be in attainment for the ozone standards when this reduction has been achieved. The Commission believes, however, this is an achievable reduction target. While the OTC has established seasonal limits, it has not established annual emission limits, as the region has demonstrated that it is in attainment with the NAAQS during the remainder of the year. The OTC has not, to date, considered enacting any emission reduction requirements or emission limits on other emission sources.

In addition to the percentage reduction requirement, the OTC has also implemented an emission rate cap on affected sources. This rate limit requires electric power utilities, depending on their individual location within the OTC region (zones), to limit emission rates (in pounds per mmBTU of energy input). The three zones, inner, outer, and northern, have different emission rate caps and percentage reductions. The limits for each zone:

- inner - 65% (or less than 0.2 lb./mmBTU) by 5/1/99, 75% (or less than 0.15 lb./mmBTU) by 5/1/03
- outer - 55% (or less than 0.2 lb./mmBTU) by 5/1/99, 75% (or less than 0.2 lb./mmBTU) by 5/1/03
- northern - 55% (or less than 0.2 lb./mmBTU) by 5/1/03.

The OTC has determined the historical amount of emissions and the reduction it seeks to achieve (an "emission budget"). Each member State of the OTC has been granted its portion of the budget, and it is left to each state to determine how the budget will be allocated among its individual affected sources. Allocation methodologies could differ by state, and may include simply allocating to sources based on their historical emission, or reserving a portion of the allocation for new sources and allocating the remainder. Alternatively, states could conceivably auction their allocations on an open market. As of December 1995, OTC states were undertaking their individual processes to implement the OTC emission rate cap and percentage reductions.

4.3 CONTROL OF ACID RAIN

Acid rain results from the wet and dry deposition of acidic aerosols. These acidic aerosols are formed in the atmosphere by the transformation of SO_x and NO_x into sulphates and nitrates, and can be transported several hundreds of kilometres before being deposited on the earth's surface. The effects of acid rain are seen in acidification of lakes, damage to

[11] The OTC is composed of members of the Northeast States Coordinated Air Use Management (NESCAUM), an association of state air quality managers from each state in New England, New York and New Jersey, and members of the Mid-Atlantic Regional Air Management Association (MARAMA), an association of state air quality directors from Pennsylvania, New Jersey, Delaware, Maryland, Virginia, North Carolina, and the District of Columbia.

tree growth, and stress on related ecosystems. As a result of the widespread occurrence of these effects, programs to reduce acid rain have been in place since at least the 1980s in Canada, the U.S. and Europe.

Ideally, a program to reduce acid rain would be based upon the following:

- an established relationship between the amount of acid rain and the resulting effects in the receiving environment;

- an understanding both of relevant sources of NO_x and SO_x emissions and of the relationships between the size of these emisisons and the amount of acid rain.

If these two prerequisites are available, then it would be possible to set limits for NO_x and SO_x emissions such that the resulting levels of acid rain would have no (or acceptably low) environmental impact. This is then very similar to the establishment of emission limits based on health-based air quality objectives as described in Section 3.2.1. Moreover, there are potentially similar problems for the two processes, which for acid rain emission limits include the following:

- difficulty in establishing a target level of acid rain deposition – either a zero-effect level or a compromise using inputs such as a cost-benefit analysis;

- inter-jurisdictional issues, especially because acid rain can impact areas over a thousand kilometres from the relevant emission sources;

- inclusion of all significant sources in the emission limit;

- allowing for uncertainty in the various inputs, as well as for new information and data as it becomes available.

Examples of these problems, and approaches to their resolution, can be found in the processes used to establish acid rain emission limits in Canada, the U.S. and Europe. Some of these are summarized below:

<u>Canada</u>

The Eastern Canada Acid Rain Control Program was initiated in 1985 and resulted in SO_x emission reduction targets for the seven eastern provinces. These targets were based upon a maximum sulphate deposition rate of 20 kilogams per hectare per year (kg/ha/y), which was felt to provide acceptable protection for moderately sensitive aquatic systems. As an initial step, SO_x emissions in eastern Canadian provinces were limited to a total of 2,300 kilotonnes by the year 1994.

By 1994 all of the relevant provinces had exceeded their emission reduction targets, with total SO_x emissions estimated at 1,700 kilotonnes. Significant SO_x emission reductions were seen from the major sources of metal smelting and power generation as well as from smaller sources.

The reasons for the success of this SO_x emissions limit-setting and reduction program in eastern Canada cannot be stated categorically, but are felt to include the fact that the methods of achieving the emission reductions were not prescribed. Once it was accepted that the emission limits were necessary, then innovative and cost-effective emission reduction strategies were developed, especially at the larger point sources.

In addition, setting emission limits for each province and not as a total for all of eastern Canada, has ensured that the benefits of emission reductions have been felt widely, and not localized to specific regions or provinces.

Two potential problems have arisen subsequent to the implementation of this program which are both relevant to the uncertainty in some of the original assumptions. Firstly, it is possible that the significance of NO_x emissions to acid rain may have been underestimated (Renner, 1995). Secondly, it is recognized that a sulphate deposition rate below 20 kg/ha/y may be required to provide adequate environmental protection, especially for the more sensitive receptors (Jeffries, 1995). That is, the "critical load" required to protect any given water body may be significantly lower than the "target load" established for general protection.

This critical load approach has been used in the development of the United Nations Economic Commission for Europe (UNECE) 1994 Oslo Protocol, which focuses on not harming the environment as opposed to specifying overall target loads. As a result, the protocol establishes a Sulphur Oxide Management Area in southeastern Canada, and limits emissions there to 1.75 million tons of SO_2 as a follow up to the Eastern Canada Acid Rain Control Program.

United States

Emissions of SO_x and NO_x in the U.S. contribute to acid rain in both Canada and the U.S., and when Canada was developing its acid rain emission reduction program, a parallel approach was developed for SO_2 emissions in the U.S. However, the SO_2 emission reduction plan in the U.S. differed from that in Canada in several significant ways.

Firstly, the only sources that are initially covered by the U.S. SO_2 emission limit are electrical utility plants, with other sources to be included later. These utility plants accounted for the major portion of U.S. SO_2 emissions, which totalled approximately 18,000 kilotonnes in 1980, primarily originating from the sulphur content of coal.

Secondly, the U.S. SO_2 emission limit is not specifically based upon health, environmental impact or economic criteria. It is understood that the limit is related to an achievable rate of SO_2 emissions, expressed as lbs SO_2/MMBtu of energy output. Thus, achievement of the emission target will not necessarily guarantee that the harmful effects of acid rain will be reduced to an acceptable level.

Thirdly, the total emission limit will be achieved in two stages, with the initial reduction applying to only the top 13% of SO_2 emitters. While this does not detract from the eventual achievement of the overall reductions, it has had a potential adverse effect on the efficiency of the process used to achieve the reductions (GAO, 1994). Thus, it is suggested that emissions trading would be much more effective if all emission sources are included from the outset.

Fourthly, the U.S. utility SO_2 emissions cap is a national limit on SO_2 emissions, with no regional or airshed limits. This means that localized "hot spots" of SO_2 emissions may persist, and high levels of acid rain continue to fall on sensitive areas. It should be noted, however, that compliance with the Air Quality Standard for SO_2 is still required, which will place a restriction on regional SO_2 emissions.

Europe

The development of programs to reduce acid rain in Europe has paralleled those in North America. Recent developments are also much more focused on determining the critical load of acid rain above which ecosystems show harmful effects, and using appropriate models to determine where SO_x emissions would optimally be limited to reduce exceedances of these critical loads (Gough, 1994).

The Helsinki Protocol, adopted in 1985, required signatories to reduce sulphur emissions by 30% by 1993 relative to 1980 levels. As noted earlier, subsequent work that resulted in the 1994 Oslo Protocol was based upon the development of a critical load approach using assessment models and analysis of cost-effective strategies.

In addition, the recognition of NO_x emissions as a significant precursor of acid rain has resulted in the expectation that the UNECE will issue a further protocol to cover these pollutants (Freemantle, 1995).

It will also be appreciated that many of the emission reduction costs in Europe will be borne by countries that will not necessarily receive the majority of the benefits (Pearce, 1993). This has led to the need for the international protocols discussed above.

4.4 OZONE-DEPLETING SUBSTANCES

The current thinning of earth's protective ozone layer is caused by emissions of several man-made substances from the earth's surface. These ozone-depleting substances (ODS) include chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and other halogenated organics. The significance of methyl chloroform and carbon tetrachloride as ODS was only established after the original 1987 Montreal protocol, and these were added to the list of ODS in 1990. As a result, all ODS with high ozone-depleting potential are subject to a complete ban on import and manufacture in Canada as of January 1, 1996. In addition, Canadian provinces are regulating the recovery of ODS.

The timetable for implementing this ODS ban had to take into account the urgent need for elimination of high-potential ODS and the availability of substitutes.

HCFCs have a generally lower ozone-depleting potential than the other substances listed above, and accordingly their complete phase-out has been set for 2030, with many countries committing to an earlier date of 2020. This timetable is felt to be warranted because scientific modelling has shown the ozone layer will still be able to recover, and it also allows for the longer lifetime of HCFC equipment and the fact that replacements for HCFCs in some applications still have to be developed.

It is also understood that the phase-out of CFCs in some countries with developing economies and low CFC consumption has been extended by up to 10 years (Made, 1995).

It can thus be seen that the approach to controlling ODS included an initial action plan (the 1987 Montreal protocol), which was subsequently modified to allow for new scientific information and the results from economic and technical evaluations.

4.5 GREENHOUSE GASES

Greenhouse gases have relatively long atmospheric lives -- decades to centuries. This means that they are thoroughly mixed throughout the global atmosphere. Emissions have the same effect on global climate change no matter where they originate. The impacts of climate change in a particular region are due to the atmospheric concentrations of greenhouse gases rather than local emissions. Thus the notion of a regional airshed is meaningless in the case of greenhouse gases.

Atmospheric concentrations of greenhouse gases affect climate and sea level. The impacts depend upon the **concentrations** (stock) of greenhouse gases in the atmosphere, and less on the **emissions** during a given period. The potential impacts of climate change are numerous and varied, affecting several sectors of the economy, almost every ecosystem, coastal areas and human health. It is not possible to identify a single impact, such as human health risk, that could be used to define an ambient concentration limit.

Actions to limit emissions of greenhouse gases will be negotiated internationally under the provisions of the Framework Convention on Climate Change (FCCC) which came into force in 1994 and has now been ratified by over 135 countries. The ultimate objective of the FCCC is to stabilize "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." Thus, the FCCC establishes an ambient objective for greenhouse gas concentrations.

The precise level at which concentrations should be stabilized and the date by which concentrations should be stabilized have not yet been defined. The FCCC provides that the time frame should allow ecosystems to adapt naturally, ensure that food supplies are not threatened, and enable economic development to proceed in a sustainable manner. Given the long atmospheric lives of greenhouse gases and the extent to which current emissions exceed the rate of removal of the gases from the atmosphere, it is unlikely that atmospheric concentrations can be stabilized in much less than a century (IPCC, 1995).

Several researchers have published cost-benefit studies of climate change. A cost-benefit analysis generally does not find a stable concentration to be the most efficient outcome. Rather, the optimum atmospheric concentration would vary in response to changes in projected damages and mitigation costs. However, applying cost-benefit analysis to climate change is problematic. The benefits of limiting greenhouse gas emissions occur well into the future and are dominated by reduced damages to non-market goods, such as ecosystems. Mitigation costs are dominated by assumptions concerning the costs of non-fossil energy sources. And due to the long time horizons involved in the analysis, the discount rate plays a crucial role. As a result, almost any conclusion can be obtained by making the appropriate assumptions.

Since the parties to the FCCC are countries, definition of the level and date at which atmospheric concentrations should be stabilized will be a political and negotiating process. Canada, like other developed country parties to the FCCC, has undertaken to reduce its greenhouse gas emissions to 1990 levels by 2000. As required by the FCCC a National Action Plan has been prepared. It relies heavily on voluntary actions and is not expected to achieve the goal for 2000. British Columbia has developed a provincial greenhouse action plan (B.C. MEMPR, 1995) which sets out over 50 initiatives that will be implemented or developed in order to support the achievement of the 2000 goal.

The first meeting of the Parties to the Convention in the spring of 1995 approved the Berlin Mandate to negotiate a legally binding instrument by 1997 for further reductions of greenhouse gas emissions, particularly by developed countries, for the period to 2020. Negotiations on the Berlin Mandate have just begun. Equity concerns -- the relative responsibilities of developed and developing countries and comparable treatment of countries responsible for emissions reductions -- dominate efficiency considerations in the proposals currently under consideration.

The dominant source of greenhouse gas emissions in Canada is fossil fuel combustion. At present, energy efficiency and fuel switching measures are the most cost-effective approaches to reducing greenhouse gas emissions. Technologies to remove CO_2 from emissions streams and to store it so that it never escapes to the atmosphere are uneconomic.

Actions to reduce emissions of greenhouse gases often reduce emissions of other air pollutants as well. That is because actions to improve the efficiency of fossil fuel use also reduce emissions of other air pollutants created by combustion of fossil fuels -- such as NOx, VOCs, SO_2, hazardous air pollutants.

Reductions in emissions of non-greenhouse gases may reduce or increase emissions of greenhouse gases. This is because emissions are often reduced through installation of control systems. Control systems may increase energy use and so lead to higher greenhouse gas emissions due to fossil fuel combustion. A scrubber to reduce SO_2 emissions from a coal-fired generating station, for example, generally increases fuel consumption by a few percent.

Greenhouse gas emissions in the Lower Fraser Valley will be affected by measures adopted for Canada's and British Columbia'a action plans. LFV residents may disagree with the nature and scale of these emission reduction measures. However, establishing a separate regional emissions limit will yield no local benefits and will have negligible effect on global impacts. The size of the global impacts could be increased by supporting emission reduction measures in other parts of the world.

Sources in the Lower Fraser Valley will be affected by national and provincial initiatives to limit greenhouse gas emissions. The Greater Vancouver Regional District may wish to analyse how those greenhouse gas reduction initiatives will contribute to its other air quality objectives. It is possible that some emission control options yield multiple benefits that are not evident when each issue is analysed independently.

4.6 SUMMARY

The five emission limiting procedures which have been discussed in the previous sections are summarized in Table 3. In particular, wherever possible, six aspects are addressed:

- Which pollutants were addressed and why?
- What technical aspects and criteria were used and what were the operational limits?
- What integration was done with long-term planning for growth and transportation, and were sectoral limits set?
- Were there any changes in regulatory structure and permitting?
- What were the success and failure factors?
- Where available, what were supporting and opposing arguments with regard to whether emission limits should be set?

It can be seen that the circumstances of setting these emission limits have satisfied the criteria for limiting use of a natural resource as summarized in Section 2.3. Thus, in each case there is common access to the atmosphere for disposal of the relevant pollutant. In addition, the atmosphere has a limited capacity to absorb or remove the pollutant and thus prevent damage to the atmosphere itself or other resources dependent upon the atmosphere. Finally, the current or potential rate of emissions is above the critical level at which these damages will occur. Most of the pollutants covered by these emission limiting processes are also the subject of the present report.

The general processes used to set these emission limits have used protection of human and/or environmental health as the prime consideration. In the case of setting and achieving air quality standards and objectives, however, there is now realization that the objectives may have to take into account economic and social factors when establishing achievable and practical limits.

In general, the technical procedures used for setting these limits have varied depending upon the level of understanding of the relationship between emissions and resulting effects. Where this understanding is limited, then general emission reduction targets have been used. As the level of understanding improves, then more explicit emission limits have been set, including sectoral limits and geographical limits.

For achievement of U.S. air quality standards, the emission limits are being phased in over a period of time, with a requirement that long-term planning for growth and transportation be appropriately integrated. For ozone depleting substances, the emission limit allowed for impacts on economic growth is only a small way, and the rate of implementation was based primarily on the availability of substances.

TABLE 3

SUMMARY OF EMISSION LIMIT SETTING PROCEDURES

Limit Setting Process	Which Pollutants and Why	Technical Procedures, Criteria and Operational Values	Integration into Long-Term Planning; Sectoral Limits	Regulatory Structure and Permitting	Success and Failure Factors	Supporting and Opposing Arguments
Canadian NO_x/VOC Management Plan	• NO_x and VOC • protection of human health through achievement of health-based ozone objective	• "traditional" approach used to date, i.e. technology-based implicit limits • explicit limits possible in stage II after improved modelling and emission inventories	• some economic analysis • as yet, little integration into other planning • no sectoral limits (yet)	• not relevant to this process • has provided information for provincial permitting activities	• success: – wide recognition of need to control ozone levels • failure: – modelling results not yet available for setting explicit limits	• opposing: – high costs
Achievement of U.S. and California State Air Quality Standards	• NO_x, VOC, CO, PM_{10} and SO_2 • required in regions not in compliance against standards • required to prevent significant deterioration in air quality • protection of human and environmental health and welfare	• combination of explicit and implicit limits • technology requirements for some sources, emission caps for some groups of large sources • based on modelling • absolute limits and rate limits • annual and seasonal limits	• requirement that transportation planning be integrated into regional air quality strategies • emission budgets have been set for certain sectors (e.g. stationary sources) in some regions	• certain sources must off-set new emissions • control technology requirements	• success: – mandatory air quality target – limits based on air quality modelling	• supporting: – ensures healthy atmosphere and protects environ-ment – allows flexibility in achieving emission reductions • opposing: – no consultation – timetable too aggressive – inappropriate averaging period for air quality standards
Acid Rain	• SO_x • prevention of damage to water bodies and ecosystems	• Canada: based on achieving a targeted level of sulphate deposition and modelling • U.S.: based on emission rate that can be achieved from major contributing sector • Europe: initial approach of a % reduction now being replaced by critical loads and modelling	• Canada: no integration, no sectoral limits • U.S.: no detailed planning for future economic effects; only one sector initially, additional sectors would be added by raising overall limit • Europe: beginning to use models that give costs to emission sources required to achieve significant reductions in deposition	• Canada: set provincial limits and used a wide range of methods to achieve limits • U.S.: emission trading and requirement for off-sets for a new source • Europe: unknown	Success factors: • Canada: – acceptance of need for limit – modelling available – no presciption of how to achieve limit • U.S.: – based upon reasonably achievable emission rate • Europe: – use of critical loads and transportation models Failure factors: • modelling did not allow for importance of NO_x emissions	• opposing – high costs

TABLE 3 (CONT'D)

SUMMARY OF EMISSION LIMIT SETTING PROCEDURES

Limit Setting Process	Which Pollutants and Why	Technical Procedures, Criteria and Operational Values	Integration into Long-Term Planning; Sectoral Limits	Regulatory Structure and Permitting	Success and Failure Factors	Supporting and Opposing Arguments
Ozone-Depleting Substances (ODS)	• CFCs, HCFCs, halons, some specific organo-chlorines • protecting worldwide human and environ-mental health by preventing thinning of ozone layer	• timetable for phase-out based upon ozone-depleting potential and modelling of effect on stratospheric ozone • allowance made for availability of substitutes	• some allowance for effect in developing countries, based upon amounts of ODS used • longer phase-out for HCFCs included allowance for longer life of equipment using HCFCs	• production, consumption, import/ export and recovery all regulated	• success: – wide acceptance of need for limits and phase-out – availability of alternatives	
Greenhouse Gases	• CO_2, N_2O, methane • prevention of damage to human and natural resources caused by global climate change	• explicit limits being set which will be reduced in future • atmospheric modelling	• limits are voluntary • no sectoral limits (yet)	• voluntary approach used in Canada	• success: – international conven-tion negotiated and ratified relatively quickly – convention targets the largest contribu-tors to emissions - developed countries	• opposing: – not enough understanding of potential effects – high costs and economic impacts • supporting: – must err on the side of caution

Changes in regulatory structure (where necessary) have typically been in the control of new emission sources. These have not been given air emission permits unless they can obtain a more than equivalent emission reduction from another source, and thus keep total emissions below the emission limit.

It is noteworthy that when models for the relationships between emissions and resulting impacts are reliable and widely accepted, then the resulting emission-limit-setting process tends to be more successful. This results from wider stakeholder support and also more reliable inputs into supporting work such as cost-benefit analysis.

5. SETTING AIRSHED EMISSION LIMITS FOR THE LOWER FRASER VALLEY

5.1 APPROACH

The current GVRD Air Quality Management Plan (AQMP) can be characterized as primarily using the traditional approach to air quality management described in Section 3.1. Thus, the AQMP is working towards a 50% reduction in the combined emissions of the five common pollutants (SO_x, NO_x, VOC, CO and TSP), and it is felt that this is appropriate for achieving and/or maintaining good air quality in the GVRD and LFV. This target reduction in total emissions, however, is not stated as explicit emission limits for each pollutant, and therefore cannot be used to state target atmospheric concentrations through the use of appropriate models. As a result, it is not possible to state what level of air quality will result from achieving the overall AQMP objective, nor is it possible to carry out the previously described cost benefit analysis.

The AQMP does include several elements which require use of specific emission control technology and techniques, which can be used to infer emission limits for individual sources and groups of sources. However, such limits are not stated explicitly, nor are they integrated into airshed limits, either on a sectoral or an overall basis. Thus, the assurance of equity of access to the waste disposal capacity of the LFV airshed cannot be evaluated.

It can be seen from the examples of emission-limit-setting processes described in Chapter 4, however, that it is common for air quality and air emissions management to progress from a traditional approach to a method which is based on a more thorough understanding of contributing factors. This typically involves setting explicit emission limits for targetted pollutants, and often results in wide stakeholder support for the limits.

Moreover, the criteria developed in Chapter 2 with regard to the appropriateness of emission limits as tools for the management of air quality within an airshed would apply to the Lower Fraser Valley. Thus:

- the Lower Fraser Valley airshed is common property available for the disposal of gaseous and particulate wastes;
- the LFV airshed has a limited rate of regeneration, and there is therefore a critical rate of gaseous and particulate waste disposal above which there is damage to the airshed and associated dependent resources;
- current and projected rates of emissions into the LFV airshed can be above the critical level defined above.

The evolution of the AQMP into a management plan that includes airshed emission limits would involve the following three elements:

- choosing an appropriate AEL - setting process (possibly for each contaminant) based upon a full evaluation of the alternatives;

- addressing relevant gaps and deficiencies in the required data and information base;

- calculating the resulting emission limits.

The timing and timetable for initiating and completing these is dependent on two factors: the optimum time for having AELs available as a management tool within the AQMP, and the availability of sufficient data, information and other inputs so as to allow each element to proceed.

With regard to the optimum timing for setting AELs, the examples provided in Chapter 4 in general show that emission limits have been set soon after a problem has been identified with an atmospheric contaminant and the means have been available to calculate the corresponding emission limit(s). Thus, emission limits required for achievement of ground-level ozone air quality objectives and standards in Canada and the U.S. have been set, or are planned, subject to the availability of appropriate atmospheric modelling. Similarly, as soon as the nature and size of depletion of the ozone layer was determined, the need for a zero emission limit on ODS was quickly identified. Emission targets for acid-rain precursors and greenhouse gases were developed once the magnitude of the associate effects were apparent and these could be related to emission sources. It should be noted that some of these limits have been subsequently refined (e.g. acid rain precursors), or will be specified further (greenhouse gases), subject to additional information and inputs into the emission-limit-setting processes.

Given that ozone and PM_{10} have been identified as contaminants of concern to the LFV, it is therefore consistent that relevant AELs would be set once the required data and information is in a suitable form. It was indicated in Chapter 4 that although this data and information is subject to ongoing development and refinement, the current data and information bases could be used to set AELs. These preliminary AELs would then be refined as new or improved inputs become available.

Thus, the setting of AELs for the LFV would involve two phases:

Phase I:

- choosing an initial AEL setting process, and calculating preliminary AELs using the currently available data and information

Phase II:

- comprehensive evaluation of possible emission-limit-setting processes, leading to selection of the process to be used for the LFV;

- assembly and use of data and information to calculate refined AELs using the chosen process.

There are two further areas of work that will need to be undertaken in order to ensure that these activities will proceed effectively:

- addressing the data and information gaps to the extent necessary to support the chosen Phase II process;

- provision of a consultation process that will allow appropriate input and feedback from public and stakeholder groups and individuals.

5.2 DESCRIPTION OF REQUIRED ACTIVITIES

5.2.1 Overall Work Plan

Resolution of data and information gaps together with stakeholder consulation can be viewed as ongoing requirements throughout an entire AEL process, which will each be associated with several critical points on the schedule to setting emission limits. As has been previously indicated, many of the data and information gaps are common to two or three of the possible AEL processes, and it is therefore not necessary that the choice of process be made before addressing these. Moreover, relevant data and information will continue to become available after AELs have been set, which should be accommodated by regular reviews and adjustment of the AELs as appropriate.

Thus, setting of AELs for the LFV could proceed according to the following overall plan:

Phase I:

- initiate through a working group;
- choose initial process and determine preliminary AELs;

Phase II:

- fully evaluate AEL setting processes;
- choose AEL process that will be used;
- assemble required data and information;
- determine refined AELs for the LFV;
- finalize the AELs;
- review the AELs on a regular basis.

This is shown in Figure 1, together with the provision of consultation and data and information as supporting activities. These supporting activities are identified as Consultation I, II, III, IV and V and Data and Information I and II, and their respective contents are outlined below.

Consultation

I 1. Ensure appropriate representation on the working group:

- Canadian and U.S. LFV agencies?
- B.C. provincial agencies?
- Canadian federal agencies?
- International Joint Commission?
- other?

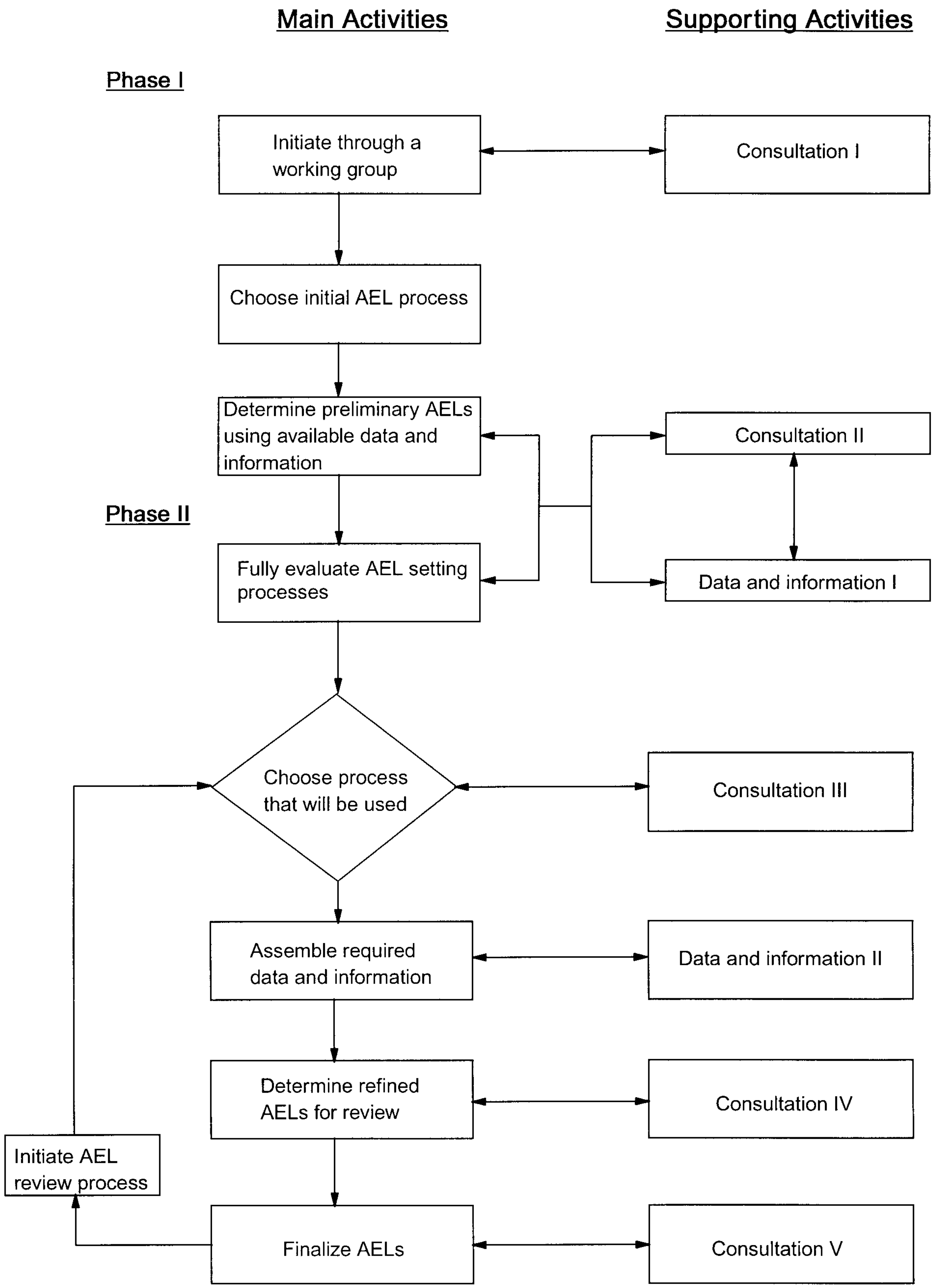

FIGURE 1

PLAN FOR SETTING AIRSHED EMISSION LIMITS FOR THE LOWER FRASER VALLEY

II 1. Public awareness and information regarding reasons for AELs.

2. Comments and feedback from stakeholders on the possible AEL processes.

3. Communicate and receive comments on preliminary AELs

4. Develop criteria and approach for choosing AEL process.

III 1. Communicate results of detailed evaluation of AEL-setting processes.

2. Opportunity for public and stakeholder feedback on the chosen AEL process.

IV 1. Communicate refined AELs.

2. Opportunity for public and stakeholder feedback on refined AELs.

V 1. Communicate "final" AELs.

Data and Information

I 1. Indicate data and information gaps as well as areas of uncertainty.

- can use the present report as initial reference
- assemble data and information for preliminary analysis

II 1. Review ambient air quality standards for ozone and particulate (PM_{10} and possibly $PM_{2.5}$ and PM_1), and revise or institute new standards as appropriate.

- Canadian system of air quality objectives currently under review; new PM_{10} and possibly ozone objectives expected 1996/97.
- EPA is currently reviewing U.S. standards for $PM_{10}/PM_{2.5}$ and ozone; expected in 1996/97.

2. Ozone modelling and monitoring

2.1 Improve monitoring data for ozone and VOCs.

2.2 Develop 1995 emission inventory with improved methodology and information, and backcast to 1990 and forecast to 2010

- biogenics
- source details for Canadian and U.S. LFV (physical aspects and selective upgrades to methodologies)
- use AirCare data to improve motor vehicle emission estimates

2.3 Determine summertime mixing layer depths in the LFV.

2.4 Incorporate results into ozone modelling.

3. Suspended particulate (PM_{10} and possibly $PM_{2.5}$ and PM_1) modelling.

3.1 Upgrade primary particulate inventory.

3.2 Upgrade secondary particulate inventory, including gas-to-particle modelling.

3.3 Conduct improved source apportionment study.

4. Valuation of the damages caused by air pollution

- continue to refine existing damage functions and discount rates

5. Costs of emission reductions

- review and upgrade costs and prioritize emission reductions for use in cost-benefit analysis (as appropriate to updated emission inventory)

6. Refine cost-benefit analysis, if appropriate to process chosen (consider effect of upgraded emission inventory and cost data).

Much of the work required for satisfying Data and Information II could be carried out through specific projects. Accordingly, Table 4 lists these projects, together with suggested time frame, estimated budget and responsible agency. Also given in Table 4 is other relevant work, including the setting of preliminary and refined AELs. It is suggested that the responsible agencies for these projects be finalised through discussions of the working group, with consideration of the mandate of the agencies and the most effective means of participation.

As has been indicated earlier in this report, recent work has already established a basis for some of these future projects. Results from other recent studies will also provide appropriate starting points (Levelton, 1995a, 1995b; Bovar, 1995).

Table 5 provides the suggested principal tasks associated with the projects identified in Table 4. However, these should be reviewed before initiating the relevant work since the present study could not provide a complete review of the current status in each area, and therefore the suggested tasks may not be fully appropriate.

5.3 TIMING AND COORDINATION ISSUES

Ideally, airshed emission limits for the LFV must be set on an overall basis, covering all sources and source types. In addition, it is preferable that the implementation of these AELs should not create perceived inequities between emission sectors or individual sources. Potential inequities include the following:

- different timetables for achieving the AELs for different sectors or individual sources;

- allocation of the total AELs to different sectors and individual sources on a basis that is not felt to reflect historical contributions to overall emissions, or to recognize the requirements for future emissions.

TABLE 4

LIST OF POTENTIALLY CONTRACTED PROJECTS AND OTHER DATA GATHERING ACTIVITIES

Project	Time Frame	Budget	Responsible Agency
Phase I:			
1. Select initial process and determine tentative AELs	1996	$30 - 50K	GVRD/MELP/Environment Canada
Phase II:			
1. Review and possibly revise or set new ambient air quality standards (for ozone and particulate)	Depends on completion of reviews by Canadian and U.S. agencies (expected by 1997).	Assumed done by government agencies with outside support at $ 30K.	B.C. MELP and Environment Canada
2. Ozone modelling and monitoring			
2.1 Review and improve ozone and VOC monitoring data as needed	Begin in 1996	Refer to GVRD historical costs	GVRD
2.2 Develop 1995 emission inventory and backcast/forecast with improved methodologies and information: • biogenics • source details and methodologies • use AirCare data for motor vehicle emissions	1996/97	$ 120 - 150K	GVRD/MELP
2.3 Determine summertime mixing layer depths	1996	Assumed by government agency	Environment Canada/AES
2.4 Refine ozone modelling results	1996/97	Assumed by Environment Canada/UBC	Environment Canada/AES

continued/

TABLE 4

LIST OF POTENTIALLY CONTRACTED PROJECTS AND OTHER DATA GATHERING ACTIVITIES (CONTINUED)

Project	Time Frame	Budget	Responsible Agency
3. Suspended particulate (PM_{10}, $PM_{2.5}$ and PM_1) modelling			
3.1 Upgrade primary particulate inventory	1996/97	$ 20 - 30K	GVRD
3.2 Upgrade secondary particulate inventory, including gas-to-particle modelling	1996/97	$ 50 - 60K	GVRD
3.3 Conduct source apportionment study	1997	$ 80 - 100K	MELP/Environment Canada
4. Valuation of the damages caused by air pollution • continue to refine existing damage functions and discount rates	1996/97	$ 20 - 25K	MELP
5. Costs of emission reductions • review and upgrade costs and prioritize for use in cost-benefit analysis (consider effects of inventory upgrades)	1997	$ 50 - 75K	MELP/GVRD
6. Refine cost-benefit analysis, if appropriate to chosen AEL process (consider effects of upgrades to inventory and cost data)	1998	$ 60 - 75K	MELP
7. Fully evaluate AEL setting processes and calculate refined AELs	1998/99 (?)	$80K - 100K	GVRD/MELP/Environment Canada

TABLE 5

OUTLINE OF SCOPE OF PROJECTS

Project	Principal Tasks
Phase I 1. Select initial process and determine tentative AELs.	• Compile and review available information needed to support determination of AELs. • Select initial AEL setting process within constraints of available data. • Determine tentative AELs based on available information.
Phase II 1. Review ambient air quality standards for ozone and particulate.	• Monitor continuing reviews of air quality standards in the United States. • Participate in the reviews of air quality standards in Canada. • Assess the need for air quality standards specific to the LFV. • Develop air quality standards for the LFV (as deemed appropriate).
2. Ozone modelling and monitoring 2.1 Improve ozone and VOC monitoring data, as needed.	• Review available monitoring data to establish if it is sufficient for AEL setting processes. • Recommend improvements to monitoring, such as station locations, frequency and speciation of VOCs. • Develop specifications for recommended improvements to monitoring activities.
2.2 Develop 1995 emission inventory and prepare backcast/forecast of emissions.	• Develop 1995 inventory for point, area and mobile sources. • Upgrade emission inventory: biogenic emissions; source details (e.g. point sources); and use AirCare data to improve model estimates of emissions from motor vehicles. • Backcast the 1995 inventory to 1990 using latest methodologies. • Forecast the 1995 inventory to 2010 using socioeconomic data.
2.3 Determine summertime mixing layer depths.	• Monitor mixing layer depths over the period susceptible to ozone episodes. • Process this information for use in Urban Airshed Model.
2.4 Refine ozone modelling results.	• Prepare the 1995 emission inventory and forecast data for use in the Urban Airshed Model. • Update other inputs to UAM as data allows. • Conduct modelling runs to predict present and future ozone episodes. • Identify priority data gaps. • Identify priority emission source types and pollutants.

TABLE 5 (CONTINUED)

OUTLINE OF SCOPE OF PROJECTS

Project	Principal Tasks
Phase II (continued) 3. Suspended particulate modelling	
3.1 Upgrade primary particulate emission inventory.	• Ensure inclusion of all major source types and consistency with U.S. LFV inventory. • Upgrade methodologies for specific source sectors, especially fugitive dust.
3.2 Upgrade secondary particulate inventory.	• Review and upgrade SO_x and VOC inventory methodologies: biogenic sulphur, biogenic VOCs, ammonia.
3.3 Conduct Source Apportionment Study.	• Conduct selective sampling and analysis of fugitive dust sources and ambient dust. • Conduct source apportionment modelling. • Rationalize modelling results using primary and secondary particulate emission inventories. • Rank priority sources of particualte matter.
4. Valuation of the damages caused by air pollution.	• Identify the principal areas of uncertainty in the input data used for cost-benefit analysis. • Review recent literature to refine the existing damage estimating functions, focusing on the principal areas of uncertainty. • Update benefit valuations contingent on updates to damage functions.
5. Cost of emission reductions.	• Update list of priority sources for emission reduction using 1995 emission inventory and updated emission forecast. • Determine representative costs of emission reductions for priority sources, including fine particulate. • Update the cost of emission reductions for the priority emission sources.
6. Refine cost benefit analysis (if appropriate).	• This study need proceed only if it is needed for the AEL setting process that is chosen and would involve updating of the existing cost benefit study. The study should use the results of the studies described in 3., 4. and 5.
7. Fully evaluate AEL setting processes and calculate refined AELs.	• Review the initial process used to tentatively set AELs. • Conduct a rigorous evaluation of AEL setting processes. • Select the AEL setting processes. • Use the additional information made available from the work program and other sources to develop refined AELs using the process selected. • Incorporate the refined AELs in the air quality planning activity for the region.

The first of these can have potential adverse consequences in an emissions trading system, as has been observed elsewhere (GAO, 1994). The second requires that sectoral AELs be set with full appreciation of and interaction with urban, economic and transportation planning for the LFV.

It was indicated in Section 3.3.2.1 that there is a federal requirement in the U.S. that transportation planning be done in a way that does not detract from air quality management. Moreover, U.S. State Implementation Plans (for achievement of air quality standards) can include land use restrictions as a transportation emission control measure, and this has been the impetus for development of programs such as Oregon's LUTRAQ (Land Use, Transport and Air Quality) (Liebe, 1995). The implication is that air quality management and setting AELs must be integrated into other planning activities so that potential interactions can be anticipated and appropriately dealt with.

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APPENDIX A

EXTRACTS FROM "THE TRAGEDY OF THE COMMONS" (HARDIN, 1968)

Basic Concept

"The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work reasonably satisfactorily for centuries because tribal wars, poaching, and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning, that is the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the commons remorselessly generates tragedy.

"As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility to me of adding one more animal to my herd?" This utility has one negative and one positive component.

1) The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1.

2) The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of -1.

"Adding the component utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another... But this is the conclusion reached by each and every rational herdsman sharing the commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit - in a world that is limited. Ruin is the destiny toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all."

Applied to Pollution

"In a reverse way, the tragedy of the commons reappears in problems of pollution. Here it is not a case of taking something out of the commons, but of putting something in - sewage, or chemical, radioactive, and heat wastes into water; noxious and dangerous fumes into the air; and distracting and unpleasant advertising signs into the line of sight. The calculations of utility are much the same as before. The rational man finds that his share of the cost of the wastes he discharges into the commons is less than the cost of purifying his wastes before releasing them. Since this is true for everyone, we are locked into a system of "fouling our own nest," so long as we behave only as independent, rational, free-enterprisers.

"The tragedy of the commons as a food basket is averted by private property, or something formally like it. But the air and waters surrounding us cannot readily be fenced, and so the tragedy of the commons as a cesspool must be prevented by other means, by coercive laws or taxing devices that made it cheaper for the polluter to treat his pollutants than to discharge them untreated."

Coercion Needed

"the only kind of coercion I recommend is mutual coercion, mutually agreed upon by the majority of the people affected. An alternative to the commons need not be perfectly just to the preferable. ... The alternative of the commons is too horrifying to contemplate. Injustice is preferable to total ruin."

APPENDIX B

DISCOUNTING FUTURE COSTS AND BENEFITS

Since both the costs and benefits of emission limits are spread over time, a fair comparison requires that they be "discounted" to the same date. Funds invested in a savings account today earn interest and so are worth more next year. Conversely, a given amount of money at some future date is worth less today. The relationship between the future payment and its value today is the discount rate. In other words, discounting converts each future cost or benefit into an equivalent dollar amount on the specified date for the analysis.

The discount rate can have significant effects on the outcome of a cost benefit analysis, and it should be chosen and used with full recognition of this possible effect. The availability of an appropriately chosen discount rate is therefore an information requirement that must be addressed before using cost benefit analysis to set AELs. If a single acceptable discount rate cannot be specified, then the AELs that result will likely cover a wide range. For public policy analyses, such as air quality management, the social discount rate is the appropriate discount rate, which is the rate appropriate for society as a whole. The social discount rate is generally lower than the discount rate appropriate for an individual or firm. A firm or individual faces a risk that it will not enjoy the benefits over the full life of the project. This risk is much lower for society as a whole.

Two approaches have been used to estimate the social discount rate. One approach compares consumption today with future consumption. The social rate of time preference which establishes equivalence between consumption today and a different level of consumption in the future is one approach to estimating the social discount rate. The social rate of time preference can be expressed as $\rho + \theta g$, where ρ is the "pure" rate of time preference or utility discount rate, θ is the absolute value of the elasticity of marginal utility, and g is the growth rate of per capita consumption. The pure rate of time preference is a measure of the importance attached to consumption today versus consumption in the future. The elasticity of marginal utility is a measure of the relative effect of a change in income on welfare. Thus the social rate of time preference reflects both the "pure" rate of time preference and the welfare derived from future consumption given that per capita income has changed in the interim.

The second approach sets the social discount rate equal to the risk-adjusted opportunity cost of capital. This approach assumes that the government, on behalf of society, borrows the money for the project thus displacing other investments. Thus, government projects must earn a return, adjusted for risk, that is at least equal to the return the funds could earn if invested in other projects otherwise society is made worse off.

Neither the social rate of time preference nor the risk adjusted opportunity cost of capital can be observed. They must be estimated through adjustments to observed variables. Governments often have a discount rate that must be used in analyses of public investments or policies. In Canada these discount rates tend to be between 5% and 10% per year net of inflation. In the United States social discount rates between 3% and 7% are more common. The choice of discount rate is especially critical for climate change analyses due to the long atmospheric lives of greenhouse gases. The long lifetimes mean that emissions reductions today yield benefits for over a century into the future. The higher the discount rate, the less the weight given to the future benefits. Discount rates used in climate change analyses typically range between 1% and 5% net of inflation.

Since the discount rate often has a major impact on the results and because it is difficult to pick a single best estimate of the social discount rate, sensitivity analyses using different discount rates are often conducted. Higher discount rates are frequently assumed to compensate for uncertainty. While that is a common practice, it is technically incorrect. The correct procedure, which is very difficult to implement, is to convert each uncertain cost or benefit amount into its "certainty equivalent". This is the amount that a representative person would pay to receive the uncertain amount on the same day. The certainty equivalents should be very close to the expected values of the uncertain amounts. The certainty equivalents should be used in the benefit-cost analysis.

APPENDIX C

WORK REQUIREMENTS OF THE

PRESENT STUDY