APPLICATION OF CRITICAL, TARGET, AND MONITORING LOADS

FOR THE

EVALUATION AND MANAGEMENT

OF

ACID DEPOSITION

Clean Air Strategic Alliance

Alberta
ENVIRONMENT

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Report entitled *Application of Critical, Target, and Monitoring Loads for the Evaluation and Management of Acid Deposition*

In the captions for Figures 1 (pg 6) and 2 (pg 7) the units for emissions of SO_2 and NOx are given as “tonnes/yr”, when in fact they should be “ktonnes/yr”.

Corrections will be made to the second printing of this report.

PREFACE

A framework for management of acid deposition in Alberta, based upon the application of critical, target and monitoring loads is described within this document. The framework is the culmination of four years work by stakeholders brought together in the Target Loading Subgroup within Alberta's Clean Air Strategic Alliance (CASA). Members of the Target Loading Subgroup reached consensus on this framework (see Appendix I). In June, 1999, the CASA Board of Directors accepted the framework, and in so doing, recommended that Alberta Environment implement the framework as a component of the provincial environmental management process.

This document is based upon the document produced by the Target Loading Subgroup. Several changes in style and format have been made to conform with Departmental standards. There have been few changes in content, and no change in the framework itself. The Department extends its appreciation to all CASA stakeholders who contributed to the development of the framework.

Due to the complexity of the framework, and the level of detail required to adequately describe it, an Executive Summary has not been provided. Simplifying and condensing the material within this document into an Executive Summary would potentially lead to an incorrect understanding of the framework and its intended applications.

While divided into 12 chapters, this document is essentially presented in three parts. Chapters 1 through 6 present the information regarding the mandate of the Target Loading Subgroup and the consultation processes used to derive the framework, a review of the data that were used to both develop the framework, and an evaluation of the current state of acid deposition in Alberta.

The second part is contained in Chapter 7. In this chapter, the framework and the processes for its application in both long-term, long-range management of emissions and deposition, as well as the use of the framework in evaluating the effects of proposed new projects are discussed in detail.

The third part, containing the remaining chapters (8 through 12), provides additional information regarding inter-jurisdictional issues, monitoring, and future research and development, the list of references, and a glossary of terms used in this document.

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1 INTRODUCTION

Many industrial and personal activities result in the emission of compounds containing sulphur and nitrogen, which when deposited to terrestrial and aquatic systems may result in acidification of the recipient systems. Production and refining of oil and natural gas, coal- and natural gas-fired utility generation, transportation, agricultural operations, and other industrial and personal activities lead to the emission of compounds containing sulphur and nitrogen, the primary causes of acid deposition and environmental acidification. All of these activities are present in the Province of Alberta, along with ecosystems which are known or suspected to be sensitive to acid deposition.

Changes in the chemical properties of the soil or water occur when acid deposition exceeds the buffering capacity of the receiving system. Such chemical changes may modify the cycling o chemicals and nutrients within the system, the biological composition of the system, and the overall ability of the system to function. These changes may be subtle or dramatic within the affected area.

World-wide, management of acid deposition is shifting from a source-based approach (emission limits on facilities) to an integrated source- and receptor-based approach. This shift has come about from the recognition that emissions in one geographic area may have more or less o an effect than the same quantity of emissions in a different geographic area. Long-range transpor of emissions from an area that is not sensitive to acid input may contribute to acidification in distant areas that are sensitive to acid input. Thus, a source-based approach alone may not protec sensitive systems, or may be unduly restrictive in areas which are less sensitive.

Integrated acid deposition management requires an approach which includes measurement and estimation of emissions and deposition, and evaluation of effects of deposition on recipient systems. The critical load approach has been developed to meet this need. A critical load is defined as "the highest load that will not cause chemical changes leading to long-term harmfu effects on the most sensitive ecological systems" (Nilsson, 1986; cited in Bull, 1991). Other definitions have been derived for application to different receptors (water, soil), or for use in management of specific pollutants, however, the basic premise of Nilsson’s definition remains (Bull, 1991, 1992). The critical load concept has been widely accepted and is now applied in man countries. It is applied across national boundaries on a continental scale in Europe (Posch et al., 1995). In Alberta, the critical load definition provided by Nilsson (1986; cited in Bull 1991) has been accepted for use in Alberta (Target Loading Subgroup, 1996; SO_2 Management Projec Team, 1997).

In some areas in the world, current acid deposition exceeds the critical load and strategies have been developed to reduce emissions such that deposition is reduced to the critical load. In some jurisdictions, these strategies have included the establishment of a target load. Henriksen and Braake (1988) defined the target load as “the load determined by political agreement”. The definition accepted for application in Alberta by the Target Loading Subgroup (1996), the SO_2 Management Project Team (1997) and ultimately by the CASA Board is “the maximum level o acidic atmospheric deposition that affords long-term protection from adverse ecologica consequences, and that is politically[1] and practically achievable" (Target Loading Subgroup, 1996). Where current levels of deposition exceed the critical load, the target load may be set at or above the critical load, or a series of diminishing target loads may be applied over time in order to reduce deposition to levels equal to or less than the critical load. Establishment of a target load lower than the critical load can provide an additional measure of protection to ensure tha ecosystems are not subjected to acid deposition at sustained levels that may cause long-ter damage.

This document presents the framework for managing acidifying emissions and acid deposition in Alberta. The framework is based on the application of critical and target loads. Derivation of this framework included scientific assessment of acid deposition and effects, and stakeholder consultation to integrate the scientific aspects regarding acid deposition with economic, social and technological considerations.

1 In the context of the target load definition, "politically" encompasses social, economic, and technological considerations.

2 PROCESS TO ESTABLISH CRITICAL, TARGET, AND MONITORING LOADS

A multi-stakeholder consultation process, consistent with the requirements for consultation specified under the Environmental Protection and Enhancement Act (EPEA), has been used to ensure that stakeholders in Alberta were involved in the development of the acid deposition management framework. This framework meets the needs of Albertans to ensure that a high level of environmental protection is maintained while at the same time allowing environmentally-sustainable economic development.

2.1 Environmental Protection and Enhancement Act (EPEA)

Section 14 of the *Alberta Environmental Protection and Enhancement Act* (1995) states that:

(1) *…the Minister* [of Alberta Environment] *shall, after having complied with any applicable regulations regarding public input or, in the absence of regulations, after having engaged in such public consultation as the Minister considers appropriate, develop ambient environmental quality objectives in qualitative or quantitative terms for all or part of Alberta,*

(2) *In developing objectives under subsection (1), the Minister shall give due consideration to public input that he has received,*

(3) *Objectives developed under subsection (1) shall be made available to the public in accordance with the regulations,* and

(4) *The minister may develop other guidelines and objectives to meet goals or purposes toward which the Government's environmental protection efforts are directed, including without limitation, procedures, practices and methods for monitoring, analysis and predictive assessment*.

Section 14 clearly stipulates that the Minister is responsible for the development of environmental objectives, and also, that in developing environmental objectives, the Minister is to ensure that public input is sought and incorporated into the development process. The mechanism for public input is not stipulated, allowing the process to evolve in a manner that is suitable to the Minister, stakeholders and members of the public.

2.2 The Clean Air Strategic Alliance (CASA)

In 1994, the Clean Air Strategic Alliance (CASA) was formed in Alberta. The Alliance Board of Directors includes representation from the three main sectors: government (federal, provincial, municipal), industry (oil and gas, utility, coal) and non-governmental organizations (representing constituencies of health, wildlife, and environment). The CASA Board addresses air quality issues in the province, and strikes committees (with representation from each of the three stakeholder groups) to work towards resolution of complex air quality issues.

CASA struck the SO_2 Management Project Team in 1994 to re-evaluate the process used to manage SO_2 emissions and effects in Alberta. One component in this re-evaluation was a review of current advances in the calculation and application of critical loads for use in medium- and long-term management of acid deposition. A subcommittee of the Acidifying Emissions Management Implementation Team (formerly the SO_2 Management Implementation Coordination Team[2]), the Target Loading Subgroup, conducted this review.

The Target Loading Subgroup (1996) recommended to the SO_2 Management Project Team that a critical load approach be developed and implemented for medium- and long-term management of acid-forming emissions in Alberta. Recognizing that acidification may occur due to deposition of both sulphur- and nitrogen-containing compounds, it was recommended that the critical load approach include both types of substances. Based on a review of the scientific literature (Maynard, 1996), the Target Loading Subgroup also recommended that interim critical loads of 0.25, 0.50, and 1.00 kiloequivalents[3] of hydrogen ion deposition per hectare, per year (keq H^+ ha^{-1} yr^{-1}) be adopted for use in Alberta on an interim basis (3 to 5 years) for mineral soils which are sensitive, moderately sensitive, and of low sensitivity, respectively. A scientific review of the sensitivity of aquatic systems to acid input concluded that these interim critical loads would be protective of these systems as well (Schindler, 1996). During the interim period, further work to validate or adjust the interim critical loads would be conducted. The SO_2 Management Project Team (1997), and ultimately, the CASA Board of Directors accepted this recommendation. Following the established CASA process, this recommendation was forwarded to the responsible provincial government department, Alberta Environment, for implementation.

Implementing the recommendations from the SO_2 Management Project Team and Target Loading Subgroup is a complex process. To facilitate this process, the CASA Board struck the SO_2 Management Implementation Coordination Team (now the Acidifying Emissions Management Implementation Team), and the Target Loading Subgroup was reconstituted. The mandate set out for the renewed Target Loading Subgroup was to ensure that all perspectives related to development and implementation of the interim critical loads were considered in the development of a framework for acid deposition management. Membership on the Target Loading Subgroup evolved to include government [provincial (Alberta, Saskatchewan), federal], non-governmental organizations (environment), and industry (oil and gas, oil sands, utility). Members of the Target Loading Subgroup have indicated their support for the Acid Deposition Management Framework as described in this document by signing a consensus agreement (Appendix I – reproduced from the Target Loading Subgroup 1999 report). Thus, under the leadership of Alberta Environment, and with the active support and participation of stakeholders, the process used to develop critical and target loads and the framework for their application is consistent with the requirements set out in Section 14 of EPEA.

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2 On March 18, 1999, the CASA Board of Directors approved a change in name from the SO_2 Management Implementation Coordination Team to the Acidifying Emissions Management Implementation Team.

3 Kiloequivalents = kilomoles of hydrogen ion produced from compounds containing sulphur and nitrogen deposited to the soil surface.

3 ESTIMATING ACID DEPOSITION

While monitoring is the best method to estimate the amount of acid deposition, there are insufficient monitoring data available upon which to evaluate the level of acid deposition occurring over large geographic areas. This is due to the limited number of monitors that are deployed in the province, and the technical difficulties associated with monitoring all forms of acid deposition (especially dry deposition). Therefore, mathematical dispersion and deposition modelling is the most cost-effective way of linking emissions to deposition over large areas. Mathematical models take into account complex meteorology, chemical reactions among substances in the air, and wet and dry deposition. Model calculations are based upon our current state of knowledge regarding all of these processes, however, it must be recognized that our knowledge is imperfect. As a result, many of the model calculations are based upon assumptions and estimations regarding the processes that the model was derived to emulate. Thus, the results derived from mathematical modelling must be considered as best estimates.

3.1 Acidifying Emissions in Alberta

Evaluation and management of acid deposition relies upon the availability of a complete, current emission inventory. The most recent emission inventory is the 1990 Environment Canada Emissions Inventory (Deslauriers, 1995). Along with meteorological data, this inventory is used as input into a dispersion and deposition model which predicts the distribution of acidifying emissions and the subsequent deposition of compounds containing sulphur and nitrogen. Emissions of acidifying substances from 1° latitude x 1° longitude grid cells in western Canada are shown in Figures 1 (SO_2) and 2 (NO_x).

3.2 The REgional Lagrangian Acid Deposition (RELAD) Model

A detailed description of the RELAD model is provided in McDonald et al. (1996), and in Cheng et al. (1995). Only the key features of the model are presented here.

RELAD is a three-layer mass-conserving regional scale Lagrangian model that simulates ground-level ambient concentrations, and wet and dry deposition of SO_2, H_2SO_4, $(NH_4)_2SO_4$, NO_x (NO_2 + NO), HNO_3, and NH_4NO_3. The boundaries selected for the RELAD model domain are from 47°N to 62°N latitude and from 100°W to 130°W longitude, respectively (British Columbia, Alberta, Saskatchewan and portions of Manitoba, the northern Canadian territories and the north-western U.S. states), with a resolution of 1° latitude x 1° longitude. These 1° x 1° grid cells measure approximately 111 km by 60 km.

In order to run the RELAD model, three data sets are required. The first is an emissions inventory, a database of SO_2 and NO_x emissions from within each of the 1° x 1° grid cells in the model domain. Ideally, the emissions should be categorized as arising from large point sources (tall stacks), area sources (e.g. urban centres), and linear sources (e.g. highways) within the individual grid cells. The emissions inventory from 1990 for British Columbia and Alberta (Deslauriers, 1995) and from 1985 (Saskatchewan) (Figures 1 and 2) was divided into these categories for the model runs presented in this document.

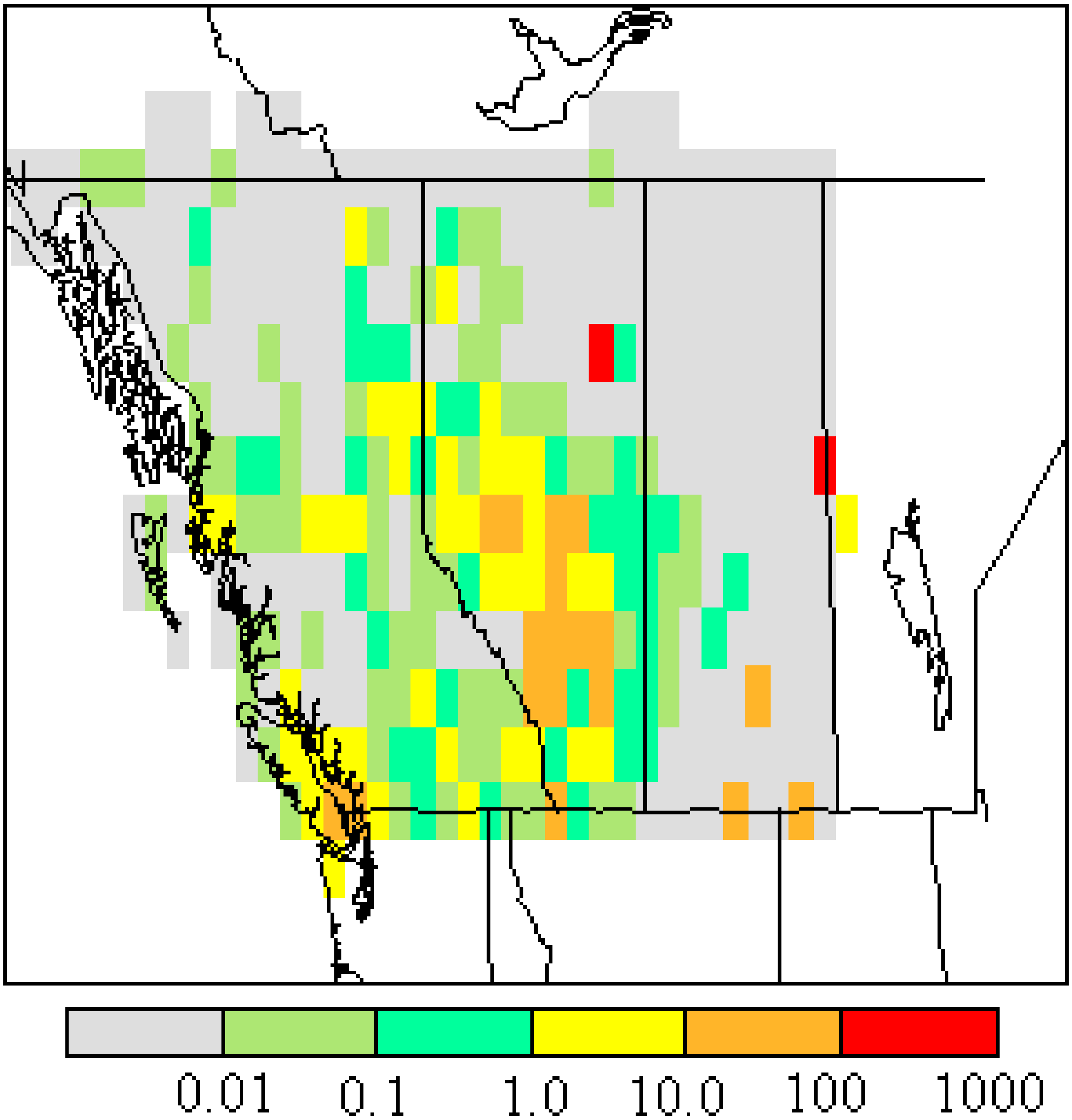

Figure 1. SO_2 emissions (tonnes yr^{-1}) in western Canada. Emissions of SO_2 from each grid cell (1° latitude x 1° longitude) used as input into the acid deposition model are shown for Alberta (1990), British Columbia (1990) and Saskatchewan (1985).

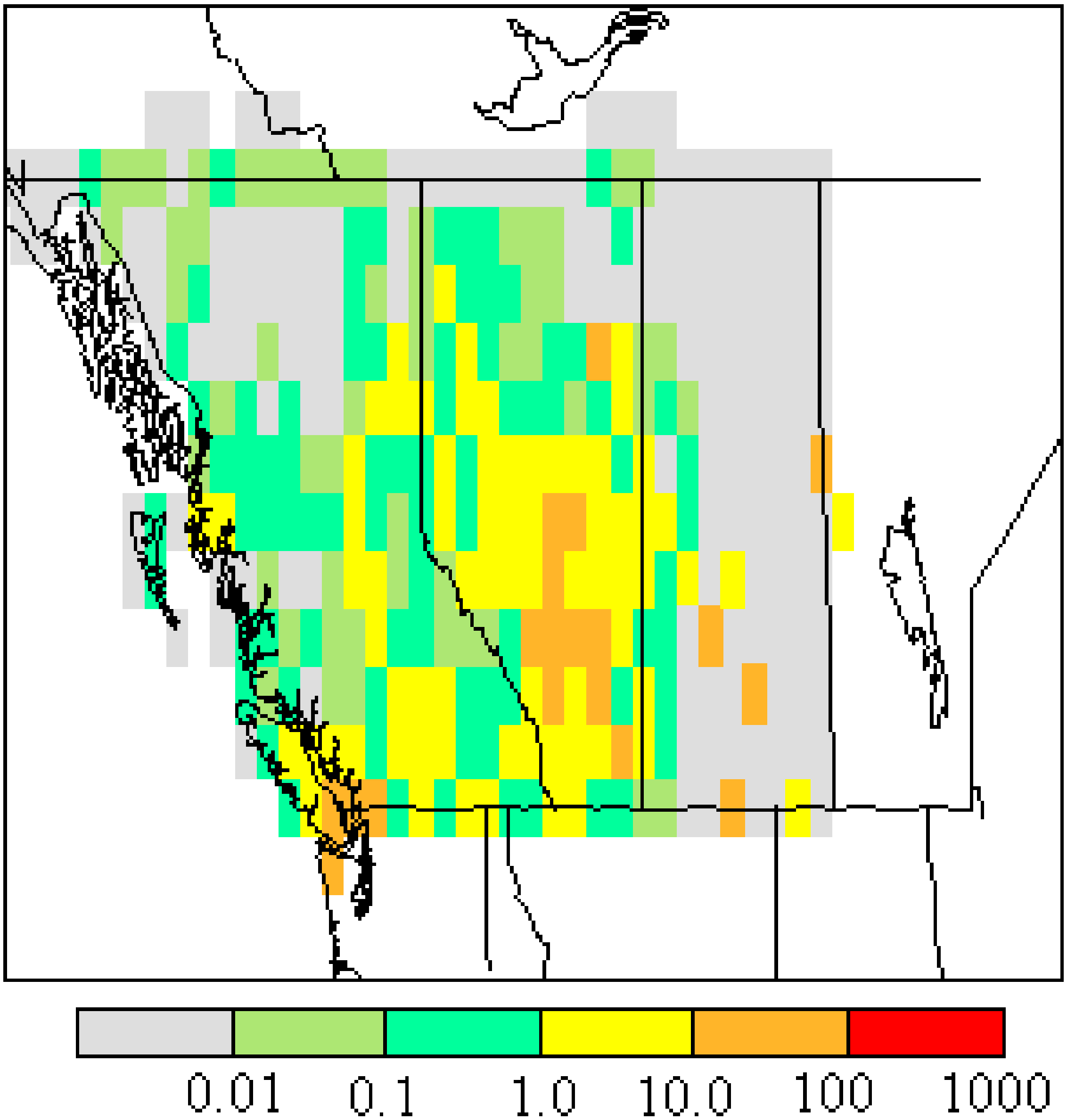

Figure 2. NO_x emissions (tonnes yr^{-1}) in western Canada. Emissions of NO_x from each grid cell (1º latitude x 1º longitude) used as input into the acid deposition model are shown for Alberta (1990), British Columbia (1990) and Saskatchewan (1985).

The second data requirement is an estimate of each of the various chemical reactions, and rates of reactions, that occur among the acid-forming substances emitted into the atmosphere. As research continues to provide information, the RELAD model code may be updated, such that the estimates of acid deposition continue to improve.

The third required data set contains meteorological data. Based on our understanding of atmospheric chemistry, RELAD estimates the dispersion of emitted substances, the chemical reactions among them in the atmosphere, and the rates of deposition of sulphur- and nitrogen-containing compounds, on the basis of meteorology (wind direction, wind speed, air temperature, relative humidity, etc.). A pre-processing step whereby the meteorological data is converted to a form acceptable as input into RELAD is needed. This requires substantial resources, both in personnel and in computer access and processing time. For this reason, a selected meteorological data set is usually used as the input for a number of RELAD model runs. For the runs presented in this document, meteorological data from 1990 has been used. This year was judged to be the most representative of the 10-year period from 1981 to 1990 (Cheng and Angle, 1993).

The output from the RELAD model is the deposition of acidity, in units of keq H^+ ha^{-1} yr^{-1}.

3.3 Potential Acid Input

RELAD provides an estimate of the total amount of acidity deposited in each 1° x 1° grid cell. Co-deposition of base cations (Na^+, Mg^{2+}, Ca^{2+} and K^+) results in a reduction of the amount of deposited acidity, as these substances reduce the acidity of compounds containing sulphur and nitrogen. Subtraction of this neutralizing capacity from the estimated deposition of acidic substances results in an estimation of Potential Acid Input (PAI), in units of keq H^+ ha^{-1} yr^{-1}. Wet deposition of base cations is estimated on the basis of precipitation chemistry monitoring data obtained from a few locations in western Canada. Base cation dry deposition is estimated from ambient air concentrations of the base cations, and the deposition velocity for base cations derived from research studies. A more detailed description of the calculation of PAI can be found in Cheng et al. (1997).

The PAI method does not include an estimation of any process that removes acidity within the recipient system (leaching, runoff, etc.) – it is an estimation of the total Potential Acid Input into the system. In reality, a portion of the deposited potentially acidifying substances will not be available to contribute to acidification. These processes are included in some methods to estimate critical loads (e.g. ForSust), which are discussed in sections 5.1.2.4.3, 5.1.2.4.4, and 10.2.1.1.

3.4 Acid Deposition in Alberta

Using RELAD and the base cation deposition data, an estimate of acid deposition in the grid cells in Alberta has been made (Figure 3). This map indicates the total PAI currently estimated in each cell.

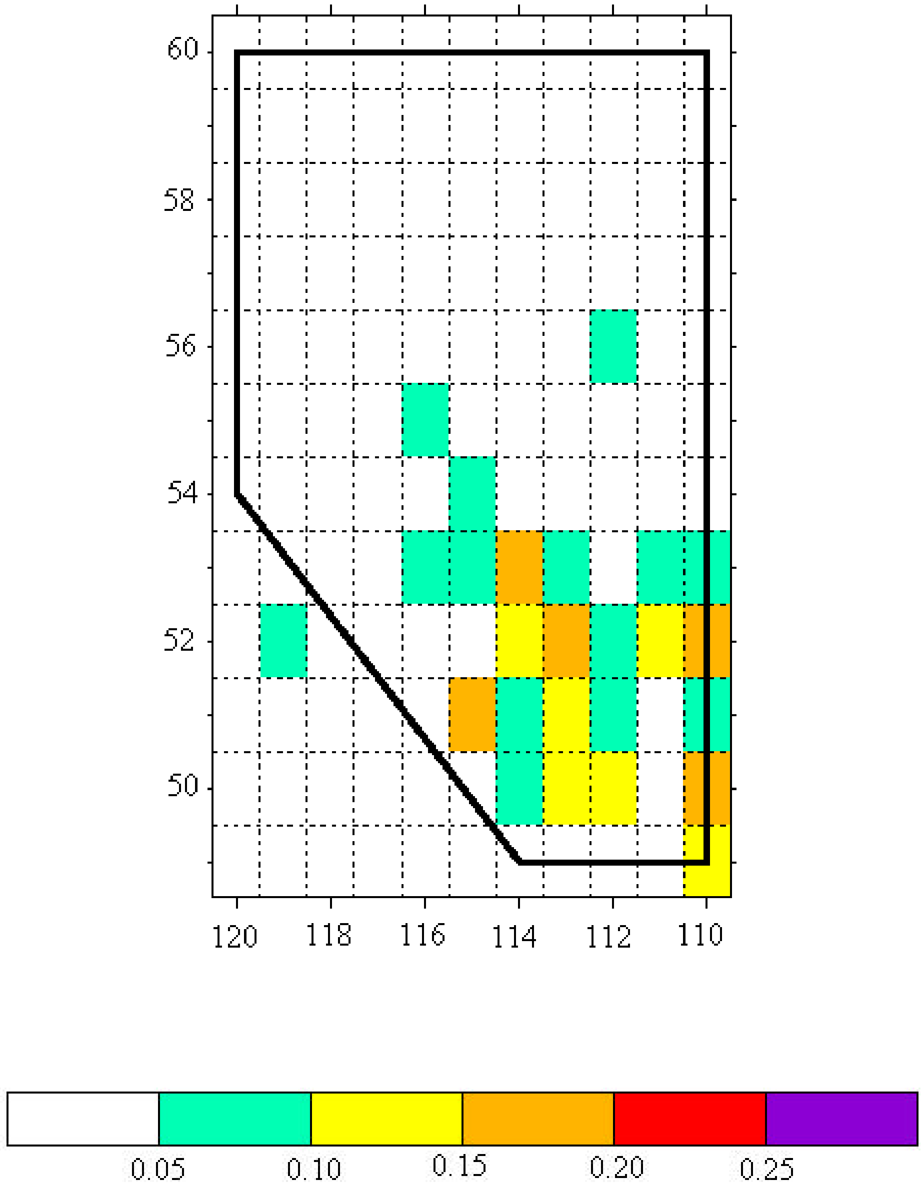

Figure 3. Current levels of acid deposition in Alberta. Potential Acid Input (PAI; in units of keq H^+ ha^{-1} yr^{-1}) in grid cells measuring 1° latitude x 1° longitude in Alberta.

4 Sensitivity of Receptors to Acid Deposition

The primary receptors of acid deposition are soil and aquatic systems. For this reason, most of the effort in deriving critical loads for acid deposition have focussed on soil systems and water bodies.

Soils may be of mineral or organic origin. Aquatic systems located in watersheds composed of mainly mineral soils will differ substantially from those located in watersheds containing mostly organic soils. Wetlands (marshes, bogs, fens) may be intermediate between organic soil and aquatic systems, having properties of both.

Terrestrial and aquatic vegetation is sometimes considered to be a receptor in the analysis of acid deposition effects. However, vegetation is typically exposed either directly to pollutants in ambient air ("fumigation events"), or indirectly to an altered soil and/or water chemical profile which has occurred as a result of acid input. Thus, the response of vegetation to acid deposition is considered to be mainly a secondary effect.

4.1 Mineral Soils

The Target Loading Subgroup's recommendation to use the critical load approach was based on the use of critical loads in Europe for the management of acid emissions and deposition (Target Loading Subgroup, 1996). In Europe, soils of a coarse texture having parent materials of sandstone, gravel, granite, quatzine, and gneiss are categorized as being highly sensitive to acid input, and a critical load of 0.25 keq H^+ ha^{-1} yr^{-1} is applied to these soil types (WHO Working Group on Ecotoxic Effects, 1995). Other soils were deemed to be sensitive (0.50 keq H^+ ha^{-1} yr^{-1}), moderately sensitive (1.00 keq H^+ ha^{-1} yr^{-1}), or not sensitive (1.5 keq H^+ ha^{-1} yr^{-1}) to acid input. The three lower critical loads were recommended for application in Alberta; 0.25 keq H^+ ha^{-1} yr^{-1} for sensitive soils, 0.50 keq H^+ ha^{-1} yr^{-1} for moderately sensitive soils, and 1.00 keq H^+ ha^{-1} yr^{-1} for soils of low sensitivity (Target Loading Subgroup, 1996).

Holowaychuk and Fessenden (1987) presented a compilation of data regarding soil sensitivities to acidic deposition in Alberta, and from this database a map showing the location and sensitivity rating of each of the 215 soil units in Alberta was produced. Soils were classified on the basis of the characteristics of the soil, specifically soil texture, organic material content, pH, and cation exchange capacity. Based upon these characteristics, the sensitivity of each soil type to base cation loss, acidification, and aluminum mobilization was rated as low, medium or high, and from these ratings the overall sensitivity rating for the soil type was derived (Figure 4).

4.2 Wetlands

4.2.1 Organic (Peat) Soil Sensitivity to Acid Deposition

Organic soil systems are defined as soils having 30% or more organic material content. The vast majority of organic soils are present in wetland systems, where the organic material (peat) is in constant or nearly constant contact with water.

Based upon the same criteria used to classify mineral soil systems, Holowaychuk and Fessenden (1987) classified organic soils into the same three classes (high, moderate and low sensitivity to acid

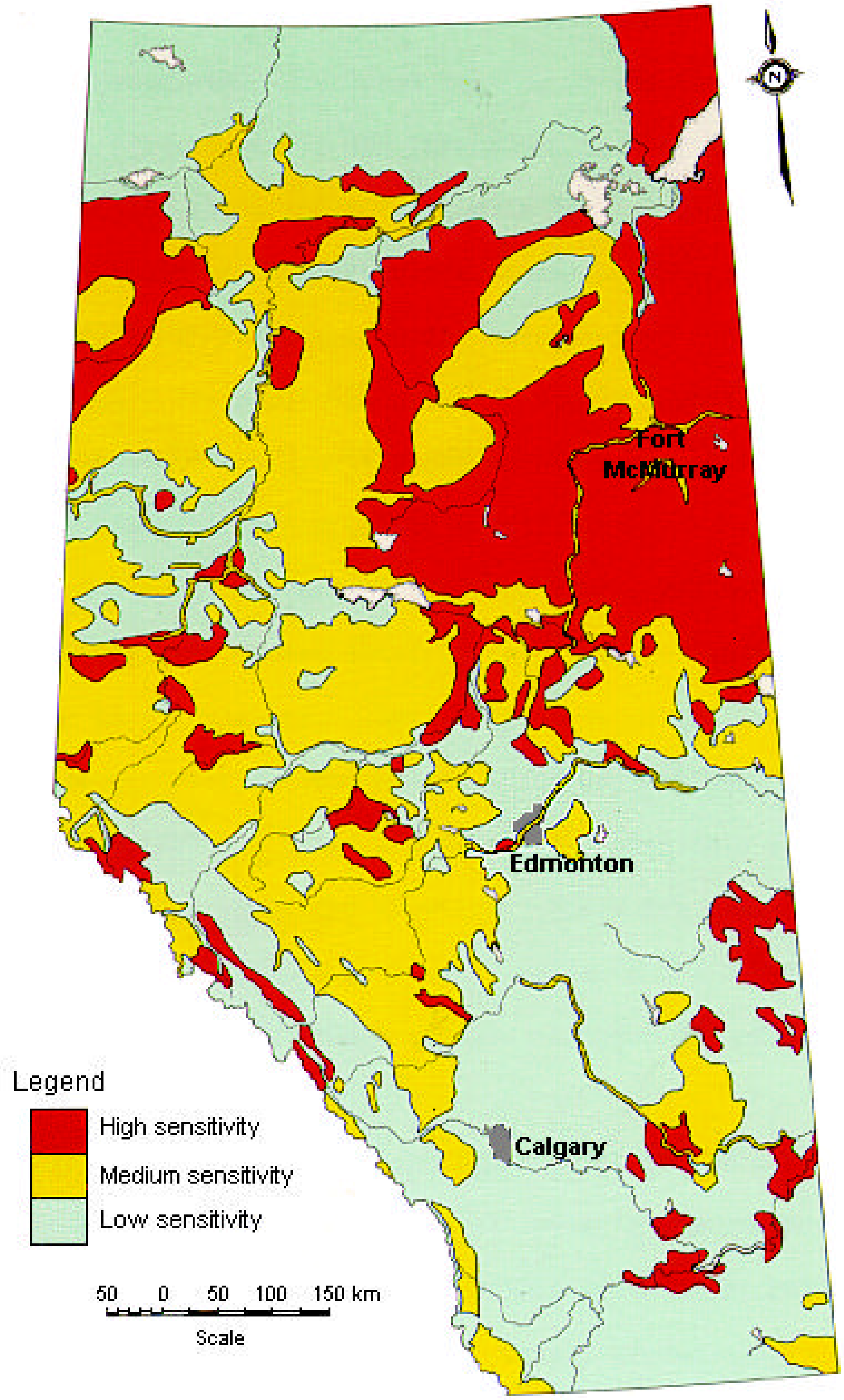

Figure 4. Soil sensitivity to acid input. The sensitivity of the rooting zone of soils to acid deposition categorized as sensitive (red), moderately sensitive (yellow) or of low sensitivity (green). Adapted from Holowaychuk and Fessenden (1987)

deposition). However, there was a high level of uncertainty in the classification of organic soils due to the limited availability of data on organic soil chemistry and processes. Holowaychuk and Fessenden (1987) pointed out the weaknesses in the database and classification, and recommended that organic soil sensitivity to acid input be more thoroughly investigated and that their classification be re-evaluated.

Turchenek et al. (1998) reviewed the international literature on the responses and sensitivity of organic (peat) soils to acid input, and proposed a revision of the Holowaychuk and Fessenden (1987) sensitivity classification of peat systems. Eutrophic wetland systems (extremely rich fens) should continue to be classified as being of low sensitivity to acid input due to the high levels of acid-consuming capacity in the peat-water complex. Mesotrophic systems (moderately rich fens) should be downgraded from a rating of high sensitivity (Holowaychuk and Fessenden, 1987) to moderate sensitivity (Turchenek et al., 1998) based upon a re-evaluation and interpretation of the data on cation exchange capacity and buffering capacity of peat.

Turchenek et al. (1998) proposed that oligotrophic systems (bogs and poor fens) be reclassified from a low sensitivity rating (Holowaychuk and Fessenden, 1987) to a rating of moderate sensitivity. This proposed change is primarily due to the uncertainty regarding the role of aluminum buffering in poor fens and bogs. Holowaychuk and Fessenden (1987) believed that aluminum buffering would be sufficient to protect oligotrophic systems from acidification, while Turchenek et al. (1998) believe that this assumption is unproven. The mechanisms that produce and consume protons (acid) in bogs and poor fens are limited in capacity and activity in comparison to eutrophic and mesotrophic systems. However, buffering and other proton removal processes do exist in oligotrophic peat systems, and these mechanisms are believed (Turchenek et al., 1998) to have sufficient buffering capacity to classify oligotrophic systems as moderately sensitive to acid deposition.

The review and interpretation of the literature on organic soil responses to acid input (Turchenek et al., 1998) was commissioned by the Target Loading Subgroup in order to better understand organic soil processes and potential changes in organic systems that may result from acid deposition. It was hoped that this review would allow the Target Loading Subgroup to validate or reassign the organic soil sensitivity classifications provided by Holowaychuk and Fessenden (1987). However, the organic soil classification system currently in use in Alberta and for which soil maps are available (Holowaychuk and Fessenden,1987) does not fully correspond with the chemical and biological classification system proposed by Turchenek et al. (1998). The organic soil classification system on which currently available Alberta soil maps are based is not compatible with the wetland types (eutrophic, mesotrophic, oligotrophic), on which the Turchenek et al. (1998) sensitivity rating is based.

4.2.2 Wetland Vegetation Sensitivity to Acid Deposition

Vitt (1994) and Kuhry et al. (1993) have observed that there are very few wetlands having a pH between 5.0 and 5.6. Vitt (1994) and Kuhry et al. (1993) suggest that this pH range represents a transition zone; wetlands in this zone may rapidly become more acidic. The causal agent which initiates transition of a rich fen to a bog is not identified, however, the characteristics of this transition were provided. The transition is marked by a loss of alkalinity, and an acidic system is formed. Climactic factors are possibly involved. Brown moss species disappear, and *Sphagnum* becomes the predominant moss species. *Sphagnum*, as a normal growth process, acidify their environment. Shifts from fens to bogs are indicated in the chemical and biological record contained within the peat accumulated during the past 10,000 years.

Acid deposition may participate in this process by tipping the balance away from an alkaline system towards an acidic system. These changes may be accompanied by a change in moss species present in the wetland. It is conceivable that a small change in wetland chemistry that results in an environment more favourable to *Sphagnum* species will enhance the transition, given the acidifying nature of *Sphagnum*. Thus, acid deposition may play a part in the biological and chemical transition from a fen to a bog that occurs on a natural timeline (Vitt, 1994; Kuhry et al., 1993). It is conceivable that deposition of acidic substances to a fen may trigger the transition to a bog, or may accelerate the process if it has already begun. Nutrient availability does affect the establishment of a number of moss species (Li and Vitt, 1994), and nitrogen deposition to a wetland may alter nutrient abundance. This is an area requiring further investigation (section 10.2.1.4).

Wetlands in the lower pH range of 4.0 to 5.5 may be susceptible to further chemical change in the peat and water due to acid input. However, as species in this vegetation system tend to be acid-tolerant or acid-requiring, it is possible that no changes in vegetation composition will occur despite a reduction in pH and/or base cation content in the peat and associated water.

The sensitivity rating of organic soils provided by Holowaychuk and Fessenden (1987) is therefore accepted as the basis for assigning organic soil (wetland) sensitivity for the application of critical and target loads in Alberta at this time.

4.3 Water

Saffran and Trew (1996) assembled available data on lake sensitivity to acid input, including data from a recent sampling program involving 109 northern Alberta lakes. A lake was classified as sensitive if total alkalinity in the lake was between 0 and 10 mg of $CaCO_3$ equivalents per litre (National Research Council of Canada, 1981). The location and sensitivity rating of each of the sampled lakes in Alberta is shown in Figure 5. Three main clusters of sensitive lakes are apparent: one in the Rocky Mountains (Jasper National Park, Wilmore Wilderness Provincial Park), a second in the northeastern corner of the province (near Lake Athabasca), and a third in the northern upland regions (Caribou and Birch Mountains).

In addition to the assessment of soil sensitivity to acid deposition (section 4.1), Holowaychuk and Fessenden (1987) also assessed the soil system's ability to reduce acid input, and presented a sensitivity map based on the ability of the soil to reduce acidic input (Figure 6). A low potential to reduce acid input means that the soil column has a limited ability to neutralize acid deposited to the soil prior to the acid entering into a stream, creek, river, or lake through the groundwater system. A low potential to buffer acid input (Figure 6) may be different from high soil sensitivity to acid input (Figure 4), because soil sensitivity considers the upper soil layers and the potential effect of acid input on changes to the chemistry in these layers (the rooting zone), and subsequent effects on vegetation. The classification of sensitivity based on the potential to reduce the acidity of acid input resulted in some of the soil units having a different sensitivity rating than those assigned on the basis of soil sensitivity (the surface soil layers) to acid input.

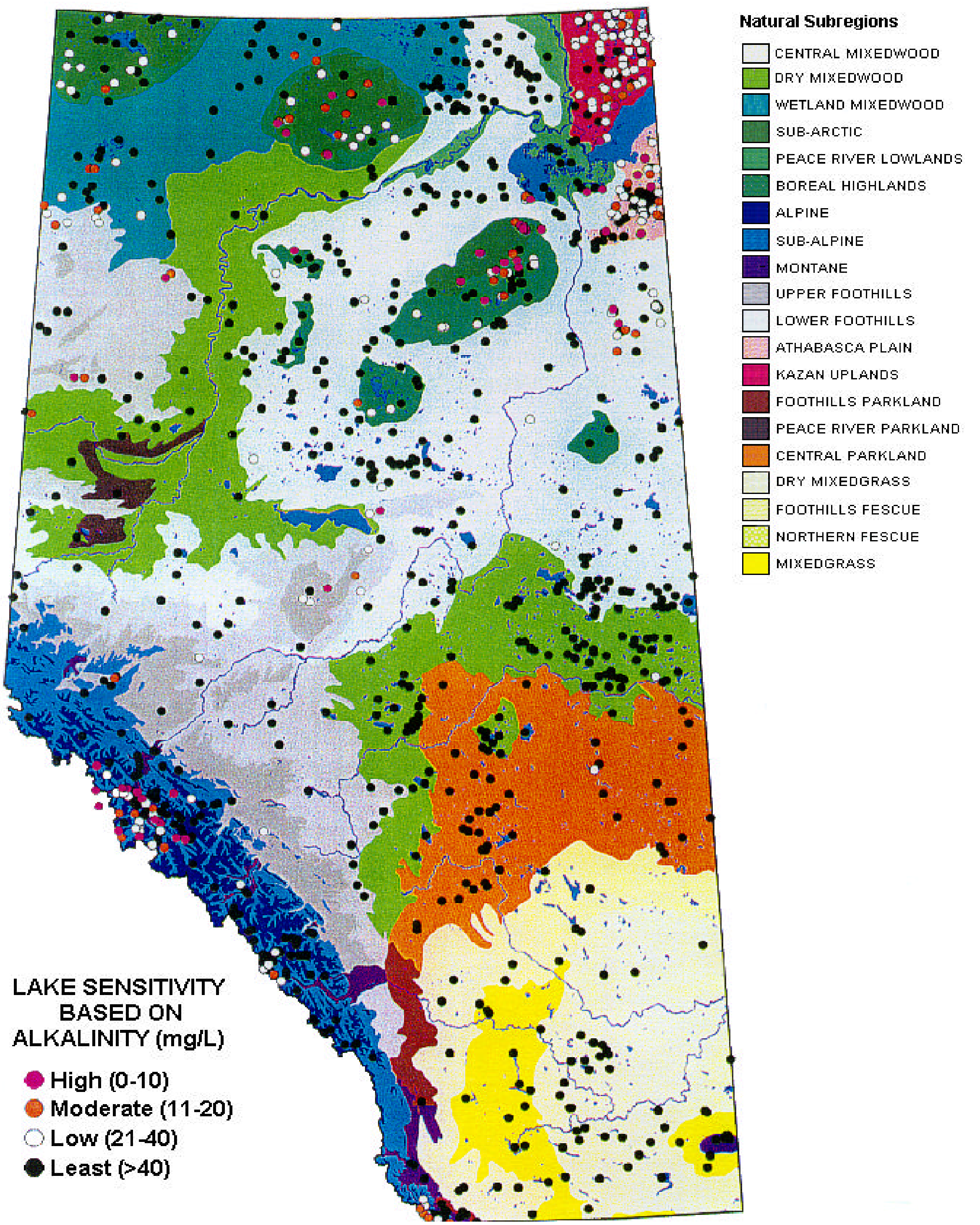

Figure 5. Sensitivity of Alberta lakes to acidic deposition. Lake sensitivity is based upon alkalinity (mg l^{-1}). Sensitive lakes are represented by a pink dots, moderately sensitive lakes by orange dots, lakes of low sensitivity by white dots, and lakes that are the least sensitive with black dots. Reproduced from Saffran and Trew (1996)

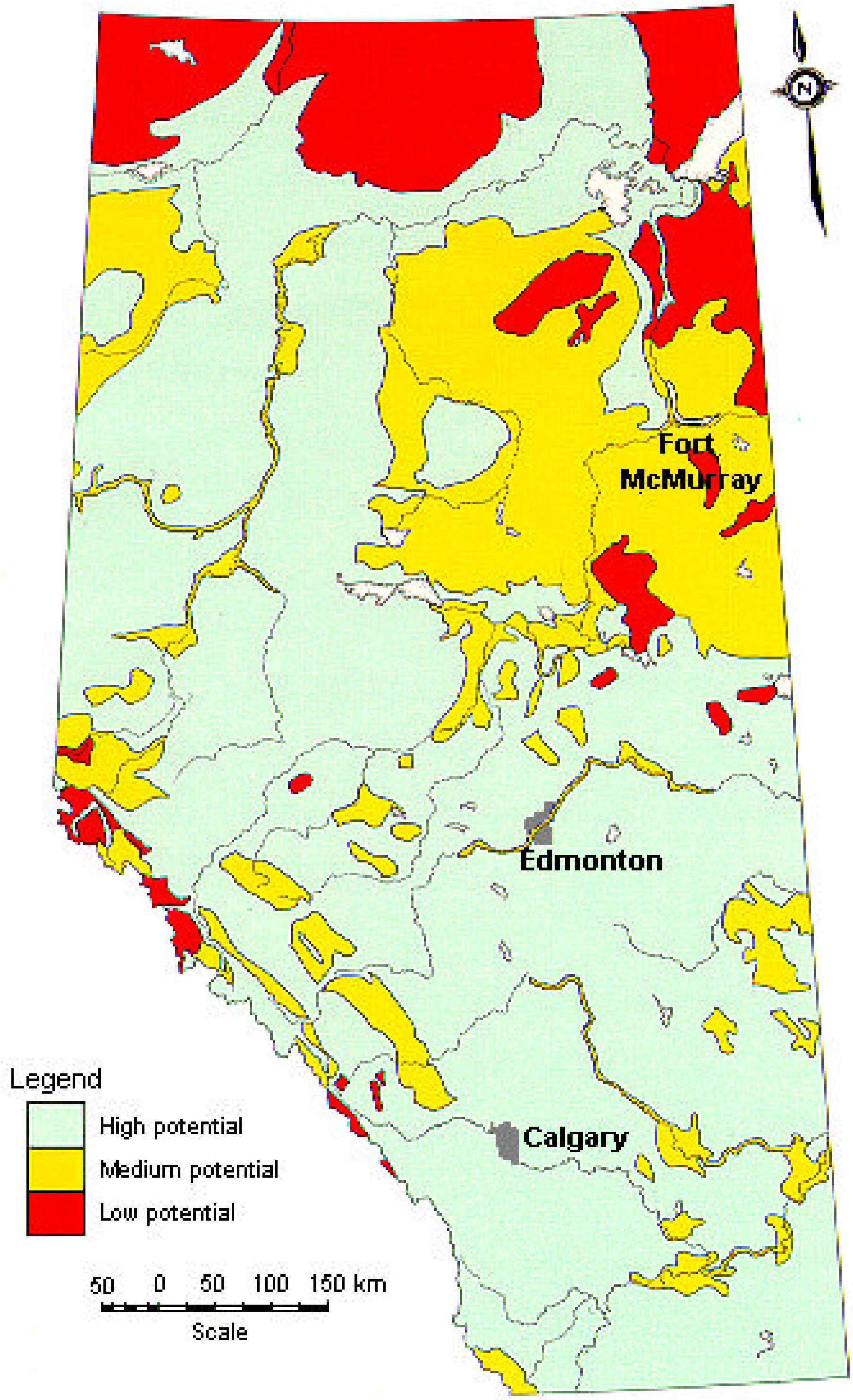

Figure 6. Potential of soil and geology to reduce acidity of incoming acidic deposition. This is a measure of the buffering ability of the soil beneath the rooting zone to reduce acidity of deposited acidic substances. Ability to reduce acidity is categorized as low (red), moderate (yellow) and high (green). Adapted from Holowaychuk and Fessenden (1987)

Comparison of the distribution of sensitive lakes provided by Saffran and Trew (1996; Figure 5) with the map describing the soil's potential to reduce acid input (Figure 6; Holowaychuk and Fessenden, 1987), shows that sensitive lakes are generally associated with the areas identified as having a low potential to reduce acid input. Since water in streams and lakes is dependent upon the groundwater flow from within the watershed, the correlation of sensitive lakes with the chemical parameters associated with subsurface soils is likely due to the dependence of lake chemistry and sensitivity on catchment (watershed) properties (Koski et al., 1988). A similar correlation has been observed by Devito (1995) for wetlands in Canadian shield catchments.

Alkalinity is an expression of inorganic buffering capacity, with carbonate/bicarbonate buffering being the dominant buffering mechanism. A more correct measurement of the buffering capacity of aquatic systems is the determination of Acid Neutralizing Capacity (ANC), since ANC includes the buffering provided by organic compounds and metals dissolved in the water. These substances can play a major role in lake pH responses to acid input (Sullivan et al., 1996). This is an area that requires further investigation (section 10.2.1.3).

Schindler (1996) provided a review of aquatic responses and sensitivity to acid deposition, and concluded that the interim critical load adopted by the original Target Loading Subgroup (1996) for the protection of sensitive soils (0.25 keq H^+ ha^{-1} yr^{-1}) would also be protective of sensitive aquatic systems in Alberta.

Because of the close correlation of ability of subsurface soil to reduce acid input (Figure 6) with the location of sensitive lakes (Figure 5), the Target Loading Subgroup has chosen to use the Holowaychuk and Fessenden (1987) map of the soils ability to reduce acid input (Figure 6) as a surrogate for the description of areas containing lakes sensitive to acid deposition.

4.4 Vegetation

With the exception of the possible effects of acid deposition on wetland vegetation discussed earlier (section 4.4), the majority of the effects on vegetation that result from acidic input are secondary effects. Accumulation of metals (mainly aluminum) in leaves, decreased vigour and reproduction, and increased incidence of disease are examples of vegetation effects which may follow changes in soil and/or water chemistry. Vegetation effects are generally not considered in the derivation of critical loads, since soil and water effects occur earlier, are more readily measured, and are more definitive, than are effects on vegetation.

4.5 Receptor Sensitivity in Alberta

As discussed in the preceding sections, the maps which are currently available that best describe the distribution and extent of receptors sensitive to acid deposition are Figures 4 (soil sensitivity), and 6 (ability to reduce acid input as a surrogate for lake sensitivity). For each soil unit, the more sensitive classification of the two is applied. Combining the receptor sensitivity data in this way represents the best integration of aquatic and soil sensitivity knowledge that is possible at this time, and is therefore used as the database for the application of the critical, target and monitoring loads. Use of the integrated receptor sensitivity map is discussed in section 6.

5 CRITICAL, TARGET, AND MONITORING LOADS

5.1 Critical Loads

Receptor-based management of acid deposition is based upon the critical load. This is a numerical expression of the level of deposition that does not lead to long-term, harmful changes to a receptor.

5.1.1 Critical Load Concept

The critical load concept is based upon two fundamental principles. First, societal values must be considered and certain value judgements are required. Guidance from society is required regarding the level of protection desired. Does society expect that 99% of all receptors will be protected, or is 90% sufficient? While it is possible to empirically determine the changes in chemical parameters in soil and water which result from acid deposition, and to assign a critical load based on these calculations, it is not possible to scientifically determine if these changes are "harmful", and represent the type and magnitude of change that society is willing to accept. Thus, the degree of risk (or level of protection) and magnitude of change (the definition of "harmful") are to be defined by society at large.

The second fundamental principle is that the calculation of a critical load is a scientific exercise, conducted within the constraints of society's desire for protection and definition of "harmful". The work of the scientist is therefore guided by society. The result of this process is a scientific understanding of the causes (emissions, dispersion, atmospheric chemistry, deposition) and effects (changes in soil and water chemistry, vegetation responses) of acid deposition, interpreted and applied in the context of society's values regarding the importance of their natural resources and the quality of the environment.

5.1.2 Methods of Calculation and Application of Critical Loads

Critical loads may be calculated and applied in a variety of ways. The primary differences among methods are with respect to the chemical compounds included in the calculation, assumptions regarding receptor processing (e.g. leaching, nitrogen assimilation), and the mathematical methods used to derive critical loads for a specific receptor and/or region. In some cases, an estimation of the amount of deposition of sulphur and/or nitrogen may be included as part of the calculation of critical loads. In these instances, deposition of acidic substances and receptor properties and processes are not considered to be mutually exclusive.

5.1.2.1 Critical Loads in Europe

The European method of determining critical loads is more comprehensive than methods used elsewhere. Oxides of sulphur and nitrogen and reduced nitrogen are included in the calculation. Furthermore, since co-deposition of base cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) reduces the amount of acid deposited (chemical neutralization), base cation deposition is also included in the calculation. Although sulphur, nitrogen and base cation deposition is included in the calculation of critical loads by countries in Europe, different forms of the calculation are used. In most instances, these differences are based upon the types of receptor processes measured or assumed to be present in the receiving terrestrial or aquatic ecosystem.

Individual countries within Europe conduct activities designed to estimate the critical load for acid deposition in selected receptor systems. Receptor systems are chosen by the individual country, and vary from grasslands to forests, with distinctions between general forest types (coniferous or deciduous), or even specific forest types (oak, beech, pine, etc.) being made in some countries. In Europe, soil and water samples are collected from a variety of ecosystems and land use areas, and the critical load for nitrogen and sulphur deposition is determined using laboratory methods. These data are then submitted to the Effects Program of the UN/ECE Convention on Long-Range Transboundary Air Pollution, and integrated into the continental critical load program (Posch et al., 1995).

The Effects Program has divided Europe into grid cells measuring 150 km x 150 km. Data submitted by the individual countries are placed within the appropriate cell. From these data critical loads protective of 95% and 50% of the receptors within each cell are calculated, and maps showing the distribution of critical loads relative to deposition are produced. The wide variety of national sampling programs results in a disproportionate number of sample locations within the various grid cells. In some cells more than 10,000 samples have been obtained. In others, one sample has been analysed, and the critical load is based on this single sample. For countries that do not submit critical load data, a European background database is used to estimate critical loads.

While individual European countries include sulphur, nitrogen and base cation species in their calculations of acid deposition, there are some differences in the equations used to calculate the critical load. Thus, there may be grid cells that span national borders which include estimates of critical loads which were derived using different methods. Where possible, the data are transformed to a common format. While critical loads that are determined using different methods may not be directly comparable, it is assumed that the critical loads determined using different approaches reasonably estimate the true critical load. Based upon this assumption, critical load estimates within the grid cells that span national borders are deemed valid, and are included in the analysis. Critical loads determined using this empirical method are reasonably accurate, as long as sufficient sampling occurs within each grid cell.

While the process of derivation and application of critical loads is most advanced in Europe, critical loads have been calculated and proposed for use in China (Xie et al., 1995). In this study, a reduction in emissions which would lead to reduced sulphur deposition by 50 to 90% was suggested in order to bring deposition to or below the critical load, which for sand and silt yellow red earth soils were estimated to be as low as 0.70 keq H^+ ha^{-1} yr^{-1}.

5.1.2.2 Critical Loads in the United States

The United States Environmental Protection Agency (USEPA) reviewed the critical load approach (United States Environmental Protection Agency, 1995), and recommended that the United States not calculate and apply an acid deposition standard such as a critical or target load. This recommendation was based on a lack of congressional guidance on desired goals for protecting sensitive resources (i.e. an absence of societal guidance), the high level of scientific uncertainty regarding the role of nitrogen in acidification and watershed nitrogen saturation, the requirement for extensive monitoring that would be needed to determine if the standard was being met, and the management approach used to implement the standard (state-by-state implementation) would all likely negatively affect the effectiveness of the standard. Although the USEPA did recognize the important role of sulphur and nitrogen compounds in causing, or having the ability to cause, acidification in terrestrial and aquatic systems, it was decided that the uncertainties were too large to allow proceeding with the development of deposition standards. This decision was made in spite of a large body of scientific evidence that acidification in some areas of the United States has occurred (Fenn et al., 1998; Likens et al., 1996; Sullivan and Eilers, 1994; United States Environmental Protection Agency, 1995). This is due to the loss of large amounts of cations (calcium and magnesium) from the soil, as well as reductions in the atmospheric deposition of base cations (Likens et al., 1996).

Increased watershed nitrogen content has also been demonstrated in areas in the United States which have been and are being subjected to deposition of nitrogen-containing chemical species (Adams et al., 1997; McNulty et al., 1996. Newell and Skjelkvåle (1997) describe similar effects in Canada, mainland Europe, and Scandinavia as well as in the United States. This is indicative of watershed saturation, which indicates that deposited nitrogen may be a more important factor in environmental acidification than in watersheds that are not nitrogen-saturated. In the Hubbard Brook Experimental Forest, recovery from acidification will require further reductions in acidifying emissions and deposition (Likens et al., 1996).

5.1.2.3 Critical Loads in Eastern Canada

Acid deposition in eastern Canada, and the resulting effects, have been of concern for several years. In 1990, the Federal/Provincial Research and Monitoring Co-ordinating Committee (1990) summarized the critical loads for lakes in various areas. These loads varied from wet deposition of 8 kg SO_4^{2-} ha^{-1} yr^{-1} to more than 20 kg SO_4^{2-} ha^{-1} yr^{-1}. This method of calculation included only the sulphate anion (SO_4^{2-}), in wet deposition (i.e. in rain and snow).

The assessment has recently been updated and presented in the 1997 Canadian Acid Rain Assessment (Environment Canada, 1997). In the 1997 assessment, the Integrated Assessment Model (Jeffries, 1997) was used to estimate the pH for each lake in six separate clusters at specific levels of wet sulphate deposition over the range of 6 to 30 kg SO_4^{2-} ha^{-1} yr^{-1}. The clusters analysed were Kejimkujik (Nova Scotia - New Brunswick), Montmorency (Quebec), Algoma and Sudbury (Ontario), Adirondack (New York), and Fort McMurray (Alberta). Recognizing that deposition of sulphur may occur in both wet and dry forms, model input included an estimate for dry deposition. However, as the custom in previous eastern Canadian assessments has been to express deposition in terms of wet SO_4^{2-} deposition, for consistency and comparison the model results were transformed and presented in terms of kilograms of wet SO_4^{2-} deposition per hectare per year. As in the 1990 assessment, emissions, deposition, and effects of nitrogen on lake acidification were not addressed. Estimates of atmospheric deposition of base cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+; these ions neutralize co-deposited acidic substances, see section 3.3) were included in the 1997 assessment, however, deposition was assumed to be constant. Recent evidence suggests that the deposition of base cations is decreasing in some locations in Canada (Couture, 1995), a phenomenon also observed elsewhere (Likens et al., 1996).

Gaps and uncertainties exist in a number of aspects of the 1997 federal analysis. Nitrogen deposition was not included, base cation deposition was estimated based on a limited database, validation of critical load estimates through sample collection and analysis was not included, and knowledge regarding the actual number and location of lakes which are extremely sensitive to acid deposition is lacking.

It is important to note that management of acidifying emissions and acid deposition in eastern Canada was initiated in response to the environmental damage that was occurring in that part of the country due to the high levels of sulphur emissions. The management actions that have been taken to reduce acid deposition have resulted in chemical and biological recovery in some systems, indications that recovery is possible in other systems, and a reduction in the overall area subjected to damaging (above the critical load) levels of acid input (Couture, 1995; Gunn et al., 1995; Mallory et al., 1998). However, in some areas, deposition still exceeds the critical load (Arp et al., 1996), and recovery in these areas may not be possible until further reductions in emissions and deposition occur.

5.1.2.4 Critical Loads in Alberta

Alberta Environment (1990) reviewed two approaches for deriving critical loads. The first is the Effective Acidity model, which incorporates hydrogen ion deposition, the amount of hydrogen ions generated by receptor processing of acid-producing substances in deposition, and the loss of hydrogen ions due to receptor processing (consumption) of acid (hydrogen ions) and acid-forming substances. The second is the Acidifying Potential model, which estimates acid input as the sum of deposited sulphate less co-deposited base cations in wet deposition only.

Recently, a soil receptor model (ForSust) has been applied in Alberta to estimate the critical loads for some soils (Syncrude Canada Ltd., 1998). This, and other receptor models, can be used to derive site-specific critical loads for soils on the basis of measured soil chemical parameters.

5.1.2.4.1 Effective Acidity

Peake (1992) presented a discussion of the different methods of calculation of effective acidity (EA); each method includes different assumptions regarding the form of deposition and the types of chemical reactions and transformations which occur in soil and the uptake of these compounds by plants. In the most simple form (Coote, 1981; cited in Peake, 1992), effective acidity (expressed as keq H^+ ha^{-1} yr^{-1}) in wet deposition is calculated by:

$$EA = [H^+]_{wet} + 1.15[NH_4^+] - 0.7[NO_3^-] \qquad \text{(Eq. \#1)}$$

The ammonium coefficient was to account for the production of H^+ as a result of plant uptake and nitrification of NH_4^+. Similarly, the nitrate coefficient is to account for removal of H^+ due to denitrification, uptake and leaching. Refinements of this calculation have been made to make the effective acidity calculation more applicable to Alberta. Dry deposition of sulphur and nitrogen, modification of the coefficients for dry deposition of ammonia gas and nitrate, deposition of wet alkaline species (Ca^{2+} and Mg^{2+}), and dry deposition of alkaline species are some of the factors included in the various methods of calculation. Other, more complete forms of the effective acidity calculation are:

$$EA = ([H^+] + 1.15[NH_4^+] - 0.7[NO_3^-])_{wet} + ([SO_4^{2-}] + [SO_2] - [Ca^{2+}] - [Mg^{2+}])_{dry} \qquad \text{(Eq. \#2)}$$

which includes wet deposition of nitrogen (equation #1 above), plus dry sulphur deposition, less the neutralizing capacity of dry base cation (calcium and magnesium) deposition, and

$$EA = ([H^+] + 1.15[NH_4^+] - 0.7[NO_3^-] - [Ca^{2+}] - [Mg^{2+}])_{wet} + ([SO_4^{2-}] + [SO_2])_{dry} \qquad \text{(Eq. \#3)}$$

which is similar to equation #2, except that wet alkaline deposition is included while deposition of dry base cations is not.

Peake (1992) used several different equations for effective acidity to estimate acid deposition using data from the Alberta Acid Deposition Research Program (Legge, 1988). Estimates of deposition depended upon the equation used, with sulphur dioxide and gaseous ammonia dominating the effective acidity values in agricultural areas and in areas where processing of sour (contains hydrogen sulphide) natural gas is a major industry. Peake (1992) also concluded that the assumptions on rates of nitrification, denitrification, leaching and plant uptake of nitrogen species need to be examined and refined for Alberta soils. The coefficients applied to account for these processes greatly affected the value determined for effective acidity.

5.1.2.4.2 Acidifying Potential

Brydges and Summers (1989) defined Acidifying Potential (AP) as:

$$AP = ([SO_4^{2-}] - [Ca^{2+} + Mg^{2+}])_{wet} \qquad \text{(Eq. \#4)}$$

in rainfall (wet deposition). Nitrogen is assumed to have no acidifying effect if taken up by vegetation. However, once a watershed is saturated with nitrogen, excess nitrogen is believed to contribute to acidification. In this case, the acidifying potential calculation becomes the net acidifying potential equation (NAP):

$$NAP = ([SO_4^{2-}] - [Ca^{2+} + Mg^{2+}])_{wet} + [NO_3^-]_{leached} \qquad \text{(Eq. \#5)}$$

where $[NO_3^-]_{leached}$ represents the amount of nitrate leached from a nitrogen-saturated watershed.

5.1.2.4.3 ForSust Model

ForSust is a steady-state mass balance model that uses a simple means of assessing soil weathering rates and plant nutrient uptake (Bhatti et al., 1998; Syncrude Canada Ltd., 1998). Critical loads for soil acidification for jack pine forest communities in northeastern Alberta have been calculated in terms of acid equivalents per hectare per year in three ways:

- Actual critical loads (ACL) were calculated from (i) the rate of soil weathering, which depends on the nature (mineralogy) of the soil substrate, the soil temperature, rooting zone depth, extent of coarse fragment content and internal soil surface area, and (ii) the rate of tolerable acid leaching loss from the soil;
- Potential critical loads (PCL) included the actual critical load plus the rate of acid neutralization or acidification as afforded by the vegetation through net nutrient uptake; and
- Overall critical loads (OCL) included atmospheric base deposition as part of the acid neutralization process in the impacted ecosystem.

The calculated critical loads are then compared to the rates of atmospheric acid deposition. A soil acidification exceedance is said to occur once the atmospheric acid deposition rate exceeds the overall critical load. As with the Effective Acidity and Acidifying Potential models, the overall critical load derived by the ForSust model includes both deposition and receptor processing of deposited substances.

An early version of this model was also used to calculate exceedances of the sulphur and nitrogen critical loads in upland forests in southern Ontario (Arp et al., 1996). Based upon the selection of acceptable aluminum concentrations in soil or upon acceptable Al:BC (aluminum to base cation ratio, molar concentrations in solution), critical loads for each of sulphur and nitrogen were estimated for southern Ontario, and areas of exceedance determined. Exceedances of both the nitrogen critical loads (eutrophication) and acid deposition critical loads (sulphur plus nitrogen) continue to occur in some areas of southern Ontario (Arp et al., 1996).

5.1.2.4.4 Other Critical Load Models

In addition to ForSust, there are other models available and in use elsewhere in the world to estimate critical loads for soil systems (de Vries et al., 1995; see also discussion in Maynard, 1996). A key feature of all models is that key chemical criteria must be selected in order to apply the model. These criteria define limits for certain chemical values used by the model; these limits generally reflect the degree of change acceptable due to acid input. For example, de Vries used the values of 0.1 mol_c NO_3^- m^{-3}, 0.2 mol_c Al m^{-3}, and an Al:BC ratio of 1.0 (mol mol^{-1}) as the key chemical criteria representing the limits of acceptable vegetation changes, damage to root systems, and inhibition of vegetation base cation uptake, respectively. In this way, the definition of "harmful effect" (see section 5.1.1) is quantified and applied in the scientific determination of a critical load for a soil type. The type of critical chemical value (Al:BC ratio, NO_3^- concentration, avoiding magnesium deficiency, etc.) and the magnitude of the value have major effects on the model estimation of critical loads (de Vries et al., 1995). de Vries (1993) and de Vries et al. (1994, 1995) correctly point out that many of the critical chemical values are based upon assumptions regarding forest ecosystem processes, tree growth, and tree health, and that altering these values may cause significant changes in model prediction of critical loads, and the areal extent of critical load exceedances. Additional knowledge regarding the links between the critical chemical values and tree (or other receptor) physiology and growth is required in order to refine and improve the ability to estimate site-specific critical loads using ForSust or other similar models.

Models can be generally categorized as steady state or dynamic. Steady state models are less complex, and are used more widely than the dynamic models. Dynamic models require data from intensive soil monitoring programs, and are generally applied on a regional basis (e.g. a watershed). For this reason, Maynard (1996) states that dynamic models are not appropriate for application in Alberta at this time.

5.1.2.5 Calculated Critical Loads for Alberta

Several attempts have been made to establish critical loads for Alberta in the past decade. These critical loads are presented in Table 1. In 1990, the Interim Acid Deposition Critical Loadings Task Group presented an interim critical load for western and northern Canada. This critical load was based on the Acidifying Potential calculation, and was described as a range of 0.12 to 0.31 keq H^+ ha^{-1} yr^{-1}.

Jeffries (1997) recently evaluated acid deposition in five regions of Canada, including northeastern Alberta. The Integrated Assessment Model (IAM) model predicts that there are a small number of lakes in the Fort McMurray region (≤ 5% of the total) that are extremely sensitive to acid deposition. The deposition at which 95% of the lakes in the Fort McMurray

Table 1. Summary of critical loads for sensitive ecosystems derived for application in Alberta.

Reference	Critical Load Estimate	Sensitive Receptor	Calculation Method/Model
Interim Acid Deposition Critical Loadings Task Group (1990)	12 to 31 meq H^+ m^{-2} yr^{-1} [= 0.12 to 0.31 keq H^+ ha^{-1} yr^{-1}]	Soil and water	Acidifying Potential (Eq. #4 in text)
Alberta Environment (1990)	0.1 to 0.3 keq H^+ ha^{-1} yr^{-1}	Soil and water	Effective Acidity
Jeffries (1997)	<6.0 kg SO_4^{2-} ha^{-1} yr^{-1} (≈0.13 keq H^+ ha^{-1} yr^{-1}]	Water	Integrated Assessment Model
Syncrude Canada Ltd. (1998)	0.21 to 0.69 keq H^+ ha^{-1} yr^{-1} (mean of 0.44 keq H^+ ha^{-1} yr^{-1})	Soil	ForSust Model (Overall Critical Loads)
Target Loading Subgroup (1996)	0.25 keq H^+ ha^{-1} yr^{-1}	Soil	Adoption of European critical load for sensitive soil

region would remain above a pH of 6.0 was accepted as a reasonable estimate of the regional critical load. Since protection of 95% of the lakes in the region would be achieved by a critical load of < 6 kg SO_4^{2-} ha^{-1} yr^{-1} (wet deposition equivalent), this value was judged to be representative of the estimated critical load for the protection of sensitive lakes in the Fort McMurray area. Additional analysis suggests that protection of 90% of the lakes would occur at a wet deposition limit of 16.0 kg SO_4^{2-} ha^{-1} yr^{-1}, while a wet deposition limit of 30 kg SO_4^{2-} ha^{-1} yr^{-1} would protect 85% of the lakes. A wet sulphate critical load of 6 kg SO_4^{2-} ha^{-1} yr^{-1} is approximately equivalent to 0.13 keq H^+ ha^{-1} yr^{-1}.

The range of 0.12 to 0.31 keq H^+ ha^{-1} yr^{-1} (Acidifying Potential) is approximately equivalent to a wet deposition of 4.8 to 13.9 kg SO_4^{2-} ha^{-1} yr^{-1} (Jeffries, 1997). The critical load for the protection of 90% to 95% of the lakes in the Fort McMurray falls within this range (≤ 6.0 kg SO_4^{2-} ha^{-1} yr^{-1}, protection of 95% of the lakes from acidification below a pH of 6.0). Use of the Effective Acidity approach resulted in an estimated critical load in the range of 0.1 to 0.3 H^+ ha^{-1} yr^{-1} (Alberta Environment, 1990). The critical loads estimated by Alberta Environment (1990), Interim Acid Deposition Critical Loadings Task Group (1992), and Jeffries (1997) are all within the range of 0.10 to 0.31 keq H^+ ha^{-1} yr^{-1}, despite the different methods used to arrive at the estimates. The interim critical load recommended by the Target Loading Subgroup (1996) for the protection of sensitive soils and aquatic systems (0.25 keq H^+ ha^{-1} yr^{-1}) also falls within this range despite the use of yet another different method of determination (adopted on the basis that Alberta soils were unlikely to be more sensitive than those in Europe) and application (based upon potential acid input).

Critical loads for the most sensitive mineral soils in the Fort McMurray area (sandy soils supporting a jack pine forest) were calculated using the ForSust model. This is a Canadian version of the simple mass balance model which is widely used in Europe (Arp et al., 1996; Posch, 1995). In the estimation of site-specific critical loads, the value for the base cation to aluminum (BC:Al) ratio used was 6.0. This is a more conservative approach than the BC:Al ratio of 1.0 used in Europe and will result in lower calculated critical load and a higher degree of protection for forests. Critical loads have been estimated using the ForSust model for 110 ARNEWS (the national Acid Rain Network Early Warning System) plots that range from Newfoundland to Alberta (Moayeri and Arp, 1997). See section 10.2.1.1 for further discussion of the BC:Al ratio.

The ForSust model calculations of the critical load for sandy soils (jack pine forest) in the Fort McMurray area of Alberta are somewhat higher than previous estimates (Table I). ForSust accounts for the effect of nitrogen uptake by vegetation, and loss of N and S from the system as a result of leaching, harvest (forestry) and forest fires. It was assumed that nearly all nitrogen in vegetation would be lost during a forest fire (on a 50-year burn cycle), and that 50% of the base cation content of the aboveground forest biomass was assumed to be lost as fly ash. An overall critical load in the range of 0.21 to 0.69 keq H^+ ha^{-1} yr^{-1}, with a median of 0.44 keq ha^{-1} yr^{-1}, was calculated for the jack pine sites.

5.1.3 Level of Protection

An essential component in the application of critical loads is the level of protection to be applied. Selection of a 100% level of protection would mean that the selected critical load would be protective of every ecosystem component, while a 90% level of protection would infer that 10% of the ecosystems in a defined area may be subjected to acid deposition in excess of their critical loads, and hence, may be at risk due to acid deposition. In Europe, countries are divided into grid cells, and from each cell soil and/or water samples are collected and analysed to determine the site-specific critical load. The critical load for each cell is then set at the 95th percentile of the analysed samples. The critical load is therefore considered to be protective of 95% of the sampled receptor systems.

Conceptually, the 95% level of protection is acceptable to stakeholders and members of the public (government, industry, non-governmental organizations) that are represented through Alberta's Clean Air Strategic Alliance. This selection is consistent with the need for society to define a level of protection, and with the requirement for public input and consultation as stated in Section 14 of the Alberta Environmental Protection and Enhancement Act.

However, the interpretation and application of this level of protection in Alberta differs from that applied in Europe. For application in Alberta, the 95% level of protection is to be interpreted as follows. A grid is superimposed upon the combined receptor sensitivity map presented in Figure 6. The grids are defined by the intersection of whole degrees of latitude and longitude such that the intersection occurs in the centre of the each cell. Grid cells measure 1° latitude x 1° longitude (approximately 111 km x 60 km). If 5% or more of the area contained within a grid cell is rated as sensitive to acid deposition, then the entire grid cell is classified as sensitive. If less than 5% of the area is sensitive, but the total of sensitive and moderately sensitive areas equals or exceeds 5% of the grid cell area, the grid cell is classified as moderately sensitive. All remaining grid cells are of low sensitivity. The grid cell sensitivity assignments that are to be used as the basis for application of critical and target loads are shown in

Figure 7.

5.1.4 The Critical Loads for Alberta

Based upon a review and evaluation of the critical loads applied in other jurisdictions, the Target Loading Subgroup (1996) recommended the adoption of the generic critical load classification system used for soils in Europe (WHO Working Group on Ecotoxic Effects, 1995). [On an ongoing basis, European countries revise these generic critical loads based upon the collection and analysis of soil and water samples.] The selection of critical loads was based upon the assumption that sensitive mineral soils in Alberta are no more sensitive than the most sensitive European mineral soils. The recommended critical loads were 0.25 keq H^+ ha^{-1} yr^{-1} for sensitive soils, 0.50 keq H^+ ha^{-1} yr^{-1} for moderately sensitive soils, and 1.00 keq H^+ ha^{-1} yr^{-1} for soils of low sensitivity. A review of aquatic receptor sensitivity concluded that these critical loads were also sufficient to protect sensitive water systems from long-term harmful change (Schindler, 1996).

Further examination of deposition and receptor sensitivity as part of the work described in this document reaffirms the conclusion that at the current level of understanding, the interim critical loads recommended by the Target Loading Subgroup (1996) are protective of Alberta's ecosystems. Therefore, these critical loads are to no longer be considered "interim".

5.2 Target Loads

In the effects-based management of acid deposition, the first requirement is to establish the critical load or loads. The critical load represents the level of sustained acid deposition that will not cause long-term harmful change to the ecosystem; it is a property of the ecosystem. Acidifying emissions may be managed using the critical load as the management objective, or other levels may be established which are different from, but based upon, the critical loads. These other levels may then be used as the management objectives. Stakeholders in Alberta have chosen this latter approach.

By definition, acid deposition in excess of the critical load will lead to long-term environmental harm. In some areas of the world (Eastern Canada, northeastern United States, and regions in Europe and Scandinavia), current deposition exceeds the critical load for the receptors in these regions. In order to minimize further degradation, and to begin mitigation, reductions in emissions and deposition have been required.

A target load is defined as a level of deposition that considers the critical load, and that is practically and politically4 achievable (Target Loading Subgroup, 1996). When used to manage emission reductions, target loads are typically established between the levels of current deposition and the critical load. This process may include mandated emission reductions according to a defined schedule, a process that has been employed in Eastern Canada and the northeastern United States (International Joint Commission, 1996, 1998).

Since current deposition in the majority of grid cells in Alberta is estimated (on the basis of model prediction) to be well below the critical load, Alberta is in the enviable position of being

4 See definition of "politically" in footnote 1 on page 1.

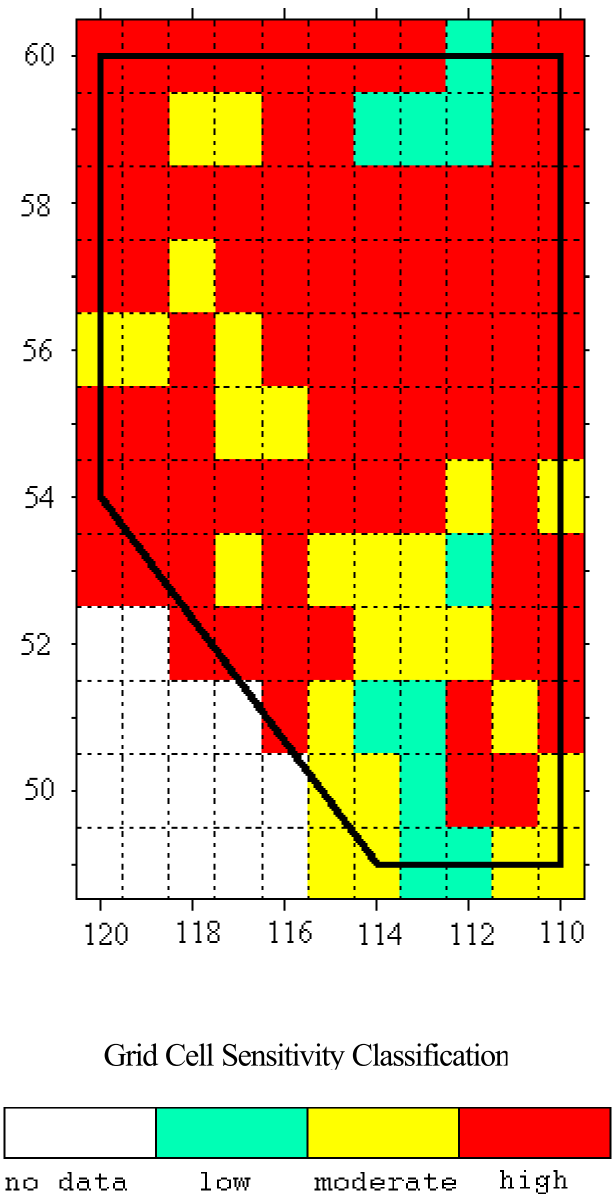

Figure 7. Receptor sensitivity in Alberta. Grid cell sensitivity based upon the combination of soil sensitivity (Figure 4) and the ability of soil to reduce incoming acidity (Figure 6), which has been used as a surrogate for lake sensitivity (Figure 5). This combined sensitivity classification is used as the basis of application of critical, target and monitoring loads, and for the assessment of acid deposition in Alberta.

able to manage development and emissions in a manner that will ensure that the levels o deposition remain below the critical loads. Stakeholders and the public in Alberta have agreed to the establishment of a target load below the critical load, as this confers an additional level o assurance that receptors in each grid cell are protected given the level of uncertainty currently associated with model predictions and the receptor sensitivity databases. The target load sets the boundaries upon which a management framework can be built, and is consistent with the principle of environmental non-degradation and with the national Keeping Clean Areas Clean initiative (Acidifying Emissions Task Group, 1997).

As in the derivation of the critical loads, three target loads have been selected: one for application in grid cells classified as sensitive (0.22 keq H^+ ha^{-1} yr^{-1}), the second for the cells classified as moderately sensitive (0.45 keq H^+ ha^{-1} yr^{-1}), and a third for the grid cells of low sensitivity (0.90 keq H^+ ha^{-1} yr^{-1}).

The target loads applied to grid cells in Alberta are established at approximately 90% of the critical loads; however, this does not mean that the target loads are linked to the critical loads by a factor of 90%. Should the critical loads be adjusted on the basis of new information at some future date, the target loads may be set at 90% of the new critical loads, or at some other value. This decision will be made in consultation with stakeholders.

5.3 Monitoring Loads

At this time, there is little available data upon which to validate the model deposition predictions on a provincial scale. In developing the management framework for the application of critical and target loads, stakeholders indicated that management based on model estimation was less desirable than management based on data obtained from monitoring and the study of receptor sensitivity. It is to fill this need that the Target Loading Subgroup has established monitoring loads.

The concept of monitoring loads has not been presented in the environmental management or scientific literature. In this respect, monitoring loads are a new concept. Monitoring loads are levels of deposition predicted or estimated by a dispersion and deposition model (e.g. RELAD) that trigger monitoring and/or research actions. Monitoring loads are different from target loads, since the only actions that take place once deposition at or above the monitoring load has been reached are to collect additional data. No actions regarding emissions reductions are initiated a the monitoring load. Therefore, monitoring loads are not to be considered as environmental management objectives, as are the target loads.

For each of the three grid cell sensitivity classes, a monitoring load has been chosen. These are 0.17 keq H^+ ha^{-1} yr^{-1}, 0.35 keq H^+ ha^{-1} yr^{-1}, and 0.70 keq H^+ ha^{-1} yr^{-1} for sensitive, moderately sensitive, and low sensitivity grid cells, respectively. The time that passes between deposition reaching the monitoring load and deposition reaching the target load is dependent upon the rate o increase in emissions. At current rates of emission increases, the Target Loading Subgroup believes that the difference between the monitoring and target loads provides sufficient time to collect deposition and receptor sensitivity data before emissions and deposition increase to the point that the target load is reached or exceeded. This timeframe ensures that both deposition data and receptor sensitivity data are available should deposition exceed the target load, and management of emissions becomes necessary.

6 ASSESSMENT OF CURRENT ACID DEPOSITION IN ALBERTA

The available data on Alberta receptor (soil and water) sensitivity to acid input has been compiled, and broad classifications of receptor sensitivity have been derived (Figure 7). The leve of deposition of acid-forming substances has been estimated using RELAD and the 1990 emissions inventory (Figures 1 and 2) and base cation deposition to derive an estimate of PAI in Alberta (Figure 3). Sensitivity and deposition have been compared in each of the grid cells, and the percent of critical, target and monitoring loads now being deposited in each grid cell has been calculated (Figure 8). The conclusions drawn by the Target Loading Subgroup from this analysis are that on a provincial scale:

(i) based upon the current level of understanding regarding receptor sensitivities to acid deposition, the critical loads and the level of protection (95%) to be applied to each cell are protective of the receptors within each grid cell,

(ii) there is one grid cell spanning the Alberta-Saskatchewan border (between 51.5º and 52.5º N. latitude) that is currently estimated (RELAD model prediction) to be receiving acid deposition (0.18 keq H^+ ha^{-1} yr^{-1}) in excess of the monitoring load (0.17 keq H^+ ha^{-1} yr^{-1}) (Figure 8), and

(iii) there are two additional grid cells in southern Alberta that warrant observation during the next few years, as deposition is estimated to be approaching 80% of the monitoring loads for these cells (Figure 8).

Actions that are to occur in the event of an exceedance of the monitoring, target or critical loads are discussed in the following section (section 7). The remaining grid cells are currently estimated to be receiving less than 40% of their designated critical loads.

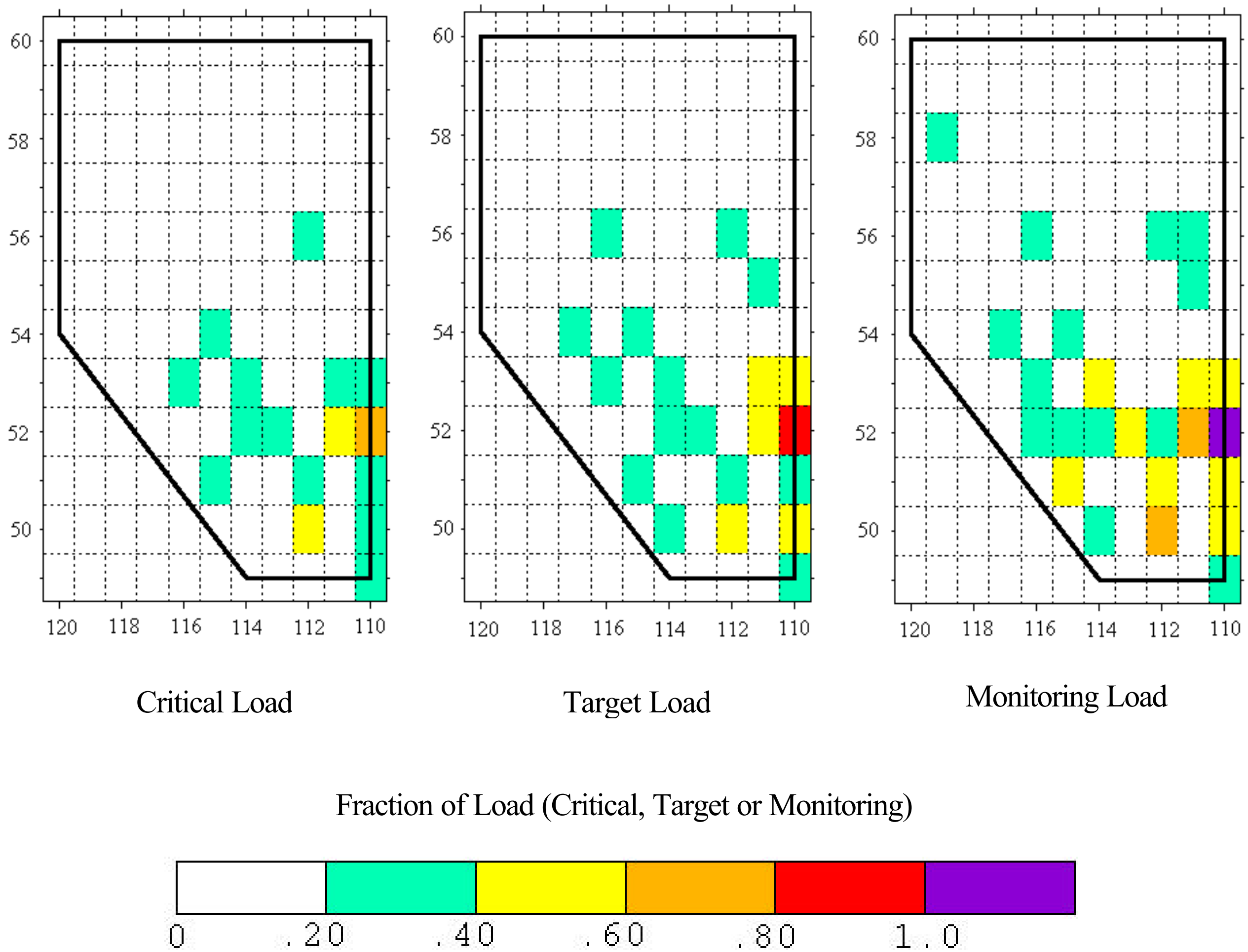

Figure 8. Acid deposition as a fraction of the critical, target and monitoring loads for Alberta grid cells. The fraction of the load for each cell is calculated by dividing acid input (PAI) (Figure 3) by the critical, target or monitoring load assigned to the cell on the basis of the grid cell sensitivity classification (Figure 7).

7 APPLICATION OF CRITICAL, TARGET, AND MONITORING LOADS

The derivation and application of critical and target loads was initiated as a consequence of an evaluation of the SO_2 management system in Alberta (SO_2 Management Project Team, 1997). This evaluation identified gaps in the current system, one of which was management based upon the environmental effects of acidifying emissions and deposition.

The management framework includes two uses of critical, target, and monitoring loads, one of which fills a gap identified in the existing management process (section 7.2). The second application is within the processes which currently exist for the review and approval of proposed developments (section 7.3).

7.1 The Acid Deposition Management Framework

The management framework is based upon four defined levels of acid deposition: pre-industrial deposition (background), the current level of deposition, the target load, and the critical load. These four levels define three management zones (Figure 9).

In the lower zone, defined by background deposition (pre-industrial deposition) on the bottom and current deposition levels on the top, management practices which reflect continuous improvement are to be employed. Thus, current emissions are not deemed as being simply acceptable, rather, methods of reducing current levels of emissions, and hence deposition, should constantly be sought and pursued.

The second management zone, bounded by current deposition levels on the bottom and the target load on the top (Figure 9), defines an area within which management of new and expanding emission sources occurs and the focus is on emission minimization. The primary management tools applied in this zone include voluntary measures employed by industry[5], application of best available demonstrated technology (BADT) for emission minimization, and regulatory operating approval conditions. The processes directed towards continuous improvement (as described in the lower zone) are to be applied in this zone as well, such that there is a constant effort to maximize efficiency and minimize emissions and acid deposition.

The monitoring load divides the emissions minimization zone into two sub-zones. Emissions management opportunities and actions do not differ between the sub-zones, however, in the upper sub-zone, additional activities related to monitoring and the study of receptor sensitivity are to be conducted.

Above the monitoring load within the emissions minimization zone, activities related to deposition monitoring and the study of receptor sensitivity are to be implemented. These actions are initiated by Alberta Environment, and include an announcement that such monitoring and/or receptor studies are being implemented, an invitation to stakeholders to participate, and a reporting function to stakeholders and the public. Reporting may possibly occur through the Clean Air Strategic Alliance.

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5 A recent example of a collaborative effort is the agreement among stakeholders to reduce the number of sour gas flares in Alberta, and to reduce the volume of gas flared from the remaining flares (Flaring Project Team, 1998).

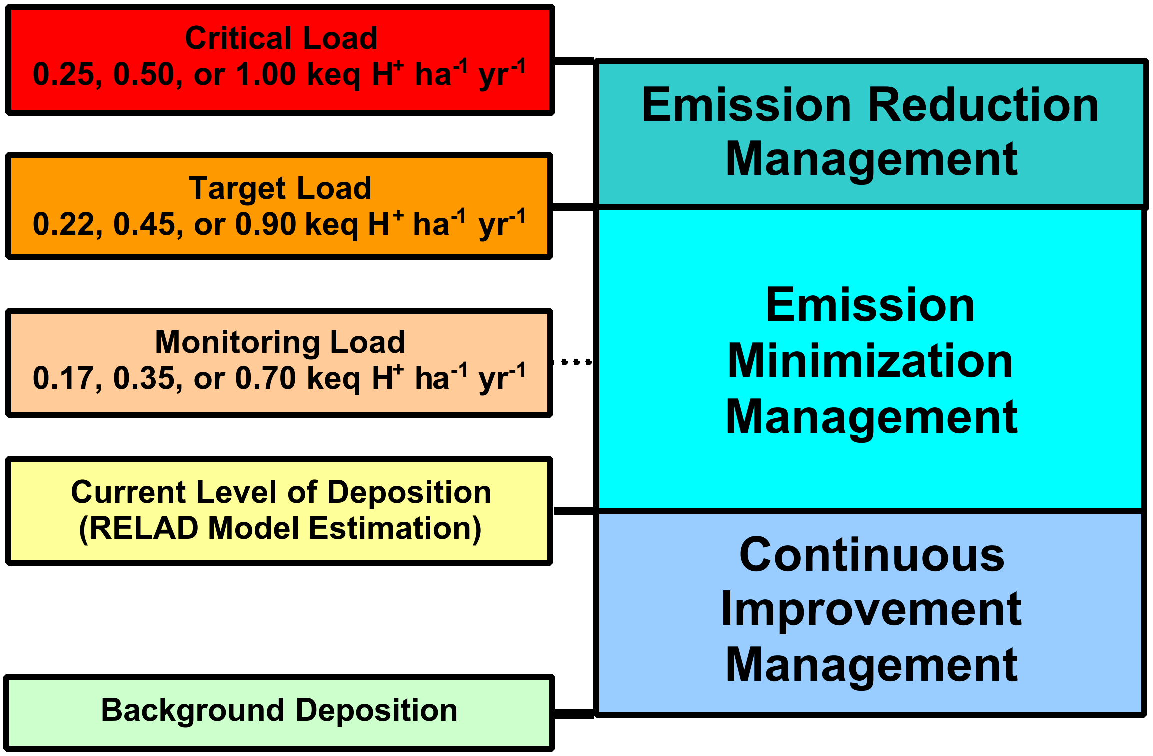

Figure 9. Acidifying emissions and deposition management framework.

The upper management zone is defined by the target load on the bottom. Entry into this zone results in implementation of more restrictive management processes. Once deposition in a grid cell exceeds the target load, a strategy to reduce deposition to below the target load is to be developed. Used in this manner, the target load becomes an environmental objective (as defined in EPEA 14.1; see section 2.0) for the management of acidifying emissions and acid deposition.

7.2 Application of the Acid Deposition Management Framework

The critical, target and monitoring loads can be used in more than one way. The primary application is in the management of acidifying emissions and acid deposition on a long-term, large-scale basis. Although not intended for regulatory use on a local scale, these loads may be used as a guide in the review of the proposed construction of a facility that will emit acidifying substances. These applications are discussed below.

7.2.1 Evaluation of Provincial Acidifying Emissions and Resulting Acid Deposition Levels and Effects – A 5-Year Assessment Cycle

As presented in the preceding sections, the Target Loading Subgroup has evaluated the current status of acid deposition relative to receptor sensitivity. However, the system for the management of acidifying emissions does not at present include a mechanism to conduct such evaluations on an on-going basis. Questions such as:

- what is the current situation regarding acid deposition?
- are large areas being put at risk due to deposition of acidifying substances?
- are there changes in acid deposition patterns over the long-term that indicate that harmful effects may occur in some areas in the foreseeable future?
- are activities in Alberta negatively impacting the environment in neighbouring jurisdictions?

can not be routinely answered within the existing management framework. The critical, target and monitoring loads are tools to be used to evaluate the effects of acidifying emissions, and to detect trends in deposition levels in areas where effects may become apparent in the future.

The evaluation of acid emissions and subsequent deposition relative to receptor sensitivity will be repeated on a regular basis in order for critical, target and monitoring loads to be effective management tools. Alberta Environment will conduct these regular assessments.

Assessments are to be completed at 5-year intervals. The databases will not change substantially (receptor sensitivity) or be available (emission inventory) on an annual basis, or even on a 2 to 3 year cycle, therefore, more frequent assessments will not be useful.

Each 5-year assessment will include:

1. An estimation of PAI in each grid cell in Alberta. Based upon the most recent available emissions inventory, base cation deposition data, and meteorological data, an estimation of deposition in each grid cell will be made using the RELAD model. The model will be used as described in this document to predict deposition in 1° latitude x 1° longitude grid cells. As stated in section 5.1.3, the grid cells are defined by the intersection of whole degrees of longitude and latitude, where the intersection occurs in the centre of the cell.

2. Validation of the model predictions. Any ambient and/or deposition monitoring data that has become available since the previous assessment will be used to validate predictions by the deposition model. Actual deposition data should be available from grid cells that exceeded the monitoring load (from previous assessment(s), see section 7.2.2 below). In these cases, a detailed evaluation of monitoring data from these cells should be conducted.

3. Revision of the receptor sensitivity database. New data regarding receptor sensitivity will be incorporated into the database, and receptor sensitivity in the grid cells will be updated as required to reflect the new data. Receptor sensitivity data may come from a number of sources, including Environmental Impact Assessments for new facilities, environmental (ecological, biological) effects monitoring programs, research projects, and sampling surveys. Cells which have been predicted to receive acid deposition above the monitoring load should have been evaluated for receptor sensitivity during the period since the previous assessment (section 7.2.2 below). Data obtained between assessments may lead to a revision of the critical load (and therefore the target and/or monitoring load) for individual grid cells, should the data indicate that receptor sensitivity is different from that assigned in this document (Figure 7).

4. Compare deposition to receptor sensitivity. Comparison of estimated (and if available, measured) PAI to receptor sensitivity in each grid cell is most easily done by calculating deposition as the proportion of the critical, target, and monitoring loads for each grid cell.

5. Public and stakeholder input, and generation of a report describing the results of the assessment. Public and stakeholder input will be included as part of each assessment. Public and stakeholder involvement may continue to be facilitated by the Clean Air Strategic Alliance. The results of each 5-year assessment will be presented in a report that will be available to stakeholders and to the public.

   The next assessment will take place in 2004.

This framework is built upon the use of the RELAD model. At present, the RELAD model is the standard for estimating acid deposition on a provincial scale. It is recognized that models such as RELAD are continuously improving, and that new models may become available in the future. If RELAD is substantially changed, if the basis for application of the RELAD results is changed (i.e. application of the results to grid cells of a size other than 1º latitude x 1º longitude), or if a different model is used for the estimation of acid deposition, the management system described in this document will be re-evaluated to ensure that it is compatible with the revised or alternate model. This re-evaluation will be conducted as part of the 5-year assessment, and will include stakeholder consultation.

In addition to an adjustment of the framework to include a substantially altered, or new, deposition model, the framework itself will be evaluated. Should modification of the framework be appropriate, and lead to more effective management of acid deposition, adjustments will be made. Public involvement will be included, and the refined framework will be documented within the 5-year acid deposition assessment report.

Should the assessment indicate that deposition in one or more grid cells exceeds one of the assigned loads for the cell(s), certain actions are to be taken. These actions will be outlined in the assessment report, and will be initiated by Alberta Environment. Stakeholders will be expected to participate in the activities that are undertaken to address the exceedance; the nature of the activities will be dependent upon the nature of the exceedance.

7.2.2 Exceedance of the Monitoring Load

The best management decisions are based upon data obtained from monitoring programs and research studies that include the collection of empirical data. In the absence of such data, dispersion and deposition models are used. By establishing a mechanism that provides for the initiation of scientific data collection prior to deriving and implementing management decisions that may have significant economic implications, the needs of regulators, environmental managers, and the general public are satisfied.

The monitoring loads are established below the target loads, at 0.17 keq H^+ ha^{-1} yr^{-1}, 0.35 keq H^+ ha^{-1} yr^{-1}, and 0.70 keq H^+ ha^{-1} yr^{-1}, for sensitive, moderately sensitive and low sensitivity cells, respectively. If, as the result of a 5-year evaluation, deposition is predicted to occur in a grid cell that is in excess of the assigned monitoring load, Alberta Environment will take the following actions:

(i) as part of the assessment report, a notice announcing the implementation of monitoring and receptor sensitivity studies in the affected cell(s) will be made.

(ii) to the extent possible using the RELAD model, grid cells which contain sources of acidifying emissions that contribute to deposition above the monitoring load in the grid cell of concern will be identified.

(iii) representatives from organizations which are the major emission sources that contribute to acid deposition in the affected cell(s) will be brought together to discuss the best approach to monitoring and research studies, and to discuss the funding of these studies. An equally important purpose for these stakeholder discussions is to ensure that all parties understand the process used to manage acid deposition, and their responsibilities in contributing to the management of emissions and deposition.

(iv) stakeholders representing other interests (e.g. environmental non-governmental organizations, residents in the affected grid cell(s)) will be invited to participate in the design and implementation of monitoring and/or research projects for the cell(s).

(v) Alberta Environment will ensure that the participation of stakeholders is meaningful, and that consultation is not used to delay action. Alberta Environment remains the authority for ensuring that actions necessary for the protection of the environment are taken, including actions related to monitoring and research.

The monitoring loads have been set at levels that are substantially below the target loads. The difference between them allows time to collect data regarding trends in emissions and deposition and the sensitivity of the recipient system, before the need to take emission management actions arises. The larger the difference, the more time that is available to ensure that management actions are based upon data obtained by scientific measurement and study, and not solely on model results. Alberta Environment has initiated a study of receptor sensitivity in the cell predicted by RELAD to be receiving acid deposition above the assigned monitoring load for this cell (Figure 8, section 6).

Given the current and projected rate of increase in acid emissions, the Target Loading Subgroup believes that the difference between the monitoring and target loads represents at least 5 years, the period of time between assessments. Thus, data regarding deposition and receptor sensitivity should be available for at least a 5-year period before active emissions management is required.

7.2.3 Exceedance of the Target Load

Given the activities that occur following an exceedance of the monitoring load, exceedance of a target load coincident with an absence of monitoring and research data should be a rare occurrence. However, with increasing development and urbanization, deposition in excess of a target load within a grid cell or cells is a possible future event.

Used in the manner described in the remainder of this section, **the target load becomes the environmental objective, a regulatory instrument**, as defined in EPEA, Section 14. If applied other than as described here (section 7.2.2), the target load is not to be considered as a regulatory instrument. Other non-regulatory uses are outlined in section 7.3.

7.2.3.1 Development of an Acid Deposition Management Plan

As structured, the management framework (Figure 9) maximizes the potential for management on the basis of measurement (monitoring and receptor measurement), and minimizes the reliance on model prediction. Thus, should emission reductions be required, stakeholders should already be aware of, and participating in, activities related to monitoring of deposition and examination of receptor sensitivity in grid cells that have exceeded the monitoring load in previous assessments (section 7.2.2). For the most part, it is the same group of stakeholders that will be given the task of deriving a management plan to reduce emissions to below the target load. Thus, there should be little delay in responding to an exceedance of the target load.

For each cell that is predicted (model result), or observed (monitoring result) to exceed the assigned target load, an Acid Deposition Management Zone (ADMZ) will be established. Establishment of this zone will be the responsibility of Alberta Environment and the Energy Utilities Board. The ADMZ will include all grid cells which substantially contribute to deposition in the exceedance cell. There may be some cells that do not include acidifying emissions that contribute to the exceedance, but are located between cells that do, and that if development were to occur within them, would be a contributor. These cells would be included in the ADMZ. The boundaries of the ADMZ would be described within the 5-year assessment report. A general public notice, in an appropriate forum(s), will be made to ensure that stakeholders affected by, and interested in, the establishment of the ADMZ are notified. The notice will be provided directly to all facilities with EPEA and/or EUB approvals for SO_2 and NO_x emissions within the ADMZ. Additionally, industrial associations, environmental advocacy groups, municipalities, and other government agencies will receive copies of the announcement. This process is to ensure that proponents of facilities (small and large), and potential investors in activities in the ADMZ (e.g. acquisition of sour gas leases, investment in small facilities) are aware of potential future management actions that could affect the value of their investment(s)[6].

Stakeholders brought together to develop the management plan that will result in emission

6 Should more than one cell be identified as being in exceedance of its assigned target load, this procedure will be implemented for each exceedance. Each exceedance will be addressed; depending upon the location of the exceeding cells, there may be one, or more than one, stakeholder group formed to derive appropriate emissions management strategy(ies).

reductions and decreases in acid deposition to below the target load(s) will have a 2-year period to derive an emissions-reduction plan. Alberta Environment will participate in, and should it become necessary, facilitate this process. At the end of this period, Alberta Environment will receive from stakeholders a written description of the ADMZ management plan; this submission will include the following elements:

(i) a program to evaluate overall emissions reductions necessary to eliminate the target load exceedance and to establish related long-term emissions management objectives for the Acid Deposition Management Zone. The management plan must provide for sufficient reduction in ADMZ acidifying emissions to reduce deposition to, or below, the target load. Alberta Environment and the Energy and Utilities Board will support this work by providing technical assistance and expertise.

(ii) an allocation scheme for emissions reductions and procedures for creating allowances for major new emissions sources in the ADMZ. This will include recommendations to Alberta Environment and to the EUB, as appropriate, on necessary revisions to facility approvals in the ADMZ.

(iii) an implementation schedule for realizing the necessary emission reductions on a timely basis. Implementation will begin immediately upon acceptance of the plan, and implementation should be essentially complete within 3 years. For those instances where major changes in design and/or operation of a facility are necessary, required emission reductions will be achieved within 10 years, unless mitigating circumstances are brought forward by the multi-stakeholder ADMZ committee.

(iv) a process to evaluate and verify the results of the ADMZ management plan, and to revise the plan based upon the findings.

In deriving the ADMZ management plan, all options are open for consideration by stakeholders, and include, but are not limited to, installation of pollution abatement equipment, emissions trading, and mandated implementation of offsets. Offsets may occur among industries, or between industries and urban residents (e.g. old vehicle scrappage programs).

Resolution by stakeholders is the preferred solution. However, in the event that stakeholders are unable to derive a management plan, or if emission reductions under such a plan are not achieved, Alberta Environment in consultation with other Alberta regulatory bodies will develop and impose a management plan. This plan will include:

(i) an evaluation of required emission reductions and derivation of an emissions reduction schedule. The goal will be based upon achieving measurable reductions within 5 years, and achieving all necessary reductions to reduce deposition to no greater than the target load in the exceedance cell within 10 years (taking into account the economic and social impact of mandated emission reductions).

(ii) a process to allocate emission reduction targets to regulated emission sources in the ADMZ and to modify facility approvals (EPEA, EUB) accordingly.

(iii) a process to facilitate approval of new emission sources in the ADMZ in a manner that will not result in increased deposition in the exceeding grid cell , and that will meet overall emission reduction targets for the ADMZ.

(iv) emission inventory and acid deposition monitoring programs to verify progress of the management plan. The program will include processes for adjusting emission reduction targets based on actual performance of the management system.

(v) measures to reduce urban emissions where these emissions contribute substantially to the exceedance cell(s).

In reviewing applications for significant new sources of acidifying emissions within the ADMZ, it will be a regulatory objective to avoid approving significant incremental acidifying emissions, until a suitable management strategy for the ADMZ is in place.

The Target Loading Subgroup recognizes that the management of acidifying emissions arising from urban centres will be a challenging task. This is due to the multitude of sources in an urban environment, and the dependence that society places on vehicles. In the long-term, changes in public attitudes and actions will likely be the only successful solution leading to effective, sustained reductions in acidifying (NO_x) emissions from urban areas. Public input is a key feature of the Clean Air Strategic Alliance, and the Alliance provides a structure and opportunity for exchange of information among all stakeholder groups in the province. Provincial and municipal governments, motor associations, and public advocacy groups (non-governmental organizations) participate in the Alliance, and therefore, this unique body provides an excellent forum within which to address an acid deposition issue where the origin of acidifying emissions is the public at large. It is not the desire of the Target Loading Subgroup to impose emission reductions on industrial facilities alone, when urban centres are responsible for a portion of the deposition in a cell which exceeds its target load. It is expected that representatives from municipalities within an ADMZ will fully participate in the stakeholder consultation process, and will work collaboratively with other participating stakeholders to minimize and reduce emissions from within each municipality in the ADMZ.

At this time, no cells are in exceedance of their assigned target load (Figure 8). Thus, establishment of an ADMZ, and derivation of a management plan, is not required at this time. Stakeholders should continue to be aware of receptor sensitivity studies that are commencing in the cell identified as exceeding the monitoring load (Figure 8, section 6).

7.2.3.2 Approval of Facilities within the Acid Deposition Management Zone

If either measured or modelled (in the absence of measured) deposition exceeds the target load, and in the absence of an acid deposition management plan, a new licensed source within the ADMZ which will contribute more than 10 tonnes per day (t/d) of SO_2 equivalents (sum of SO_2 + NO_x, expressed as SO_2 equivalents), will be required to offset these emissions in one of two ways:

1. an offset equivalent to the emissions from the new source may be garnered from other emission sources within the grid cell containing the new source. The offset is to be determined on the basis of SO_2 equivalents, thus, offsets may include SO_2, NO_x, or some combination thereof.
2. an offset which will achieve deposition neutrality (no increase in deposition) in the affected cell

may be garnered from emission sources from other grid cells within the ADMZ. The proponent of the new facility must clearly demonstrate that these offsets satisfy the requirement for deposition neutrality in the exceedance cell.

These options provide flexibility for new development in the event that a target load is exceeded. The first option represents a relatively easy way to achieve offsets: a one-to-one offset can be obtained from within the cell containing the new development. No modelling or other analysis is required. The second option provides the opportunity for a less than one-to-one offset, however, the proponent must demonstrate through the use of dispersion and deposition models that the offsets will not lead to increased deposition in the exceedance cell following development and commissioning of the new facility.

Development of facilities within an ADMZ that emit less than 10 tonnes of SO_2 equivalents per day (t SO_2 eq. day^{-1}) will also be affected by the target load exceedance. The Energy and Utilities Board (EUB) is responsible for regulating, including the approval of, small energy resource facilities that emit acidifying emissions (primarily SO_2). It is recognized that without guidelines regarding these sources, a proliferation of small sources within a grid cell contained in the ADMZ could result in emissions at or above 10 t SO_2 eq. day^{-1}, the level requiring offsets. Thus, at the time of establishment of an ADMZ, the EUB will begin tracking small developments in each grid cell within the ADMZ. Should the cumulative emissions from these small facilities achieve or exceed 10 t SO_2 eq. day^{-1}, the operators of these small facilities will be required to obtain and implement the offsets as described above. These offsets may be achieved by either of the two options described above. The offsets must be sufficient to achieve deposition neutrality, defined in this instance as the level of deposition at the time that the grid cell was determined to be in exceedance of its assigned target load.

In order to ensure that the operators of small (less than 10 t SO_2 eq. day^{-1}) facilities are aware that emission reductions, or emission offsets, may be required of them in the future, an approval for a facility in an ADMZ (the zone contributing to a target load exceedance in one or more grid cells) will contain an approval condition specifying that emission reductions may be required at some future date. These reductions may be stipulated in a revised approval issued to the operator.

It is important to reiterate that the emission offsets, approval conditions, and revised approvals are tools that will be utilized only in the instance of a target load exceedance in one or more grid cells. Concurrent with these activities will be the derivation of a management plan by stakeholders within the ADMZ that will, once implemented, reduce deposition in the exceedance cell to no more than the target load. Operators of new facilities will have the opportunity to participate in the development of the plan, in collaboration with operators of existing facilities and other stakeholders.

7.2.4 Exceedance of the Critical Load

As structured and applied, the management framework should all but eliminate the possibility that the critical load will be exceeded within any grid cell. Measurement of deposition and receptor sensitivity based upon the use of the monitoring load, and management of emissions and deposition based upon the use of the target load as the environmental objective, should ensure that emission reductions are implemented prior to acid deposition increasing to above the critical load for any grid cell.

In the event that a critical load exceedance is predicted or observed, the emission reduction strategies derived by the stakeholders will be implemented on an accelerated schedule, if possible. It is important to note, however, that even in the event of a critical load exceedance, environmental damage is not necessarily imminent. Damage will occur should deposition above the critical load be sustained over many years. Thus, management strategies to reduce emissions and deposition to below the critical (and target) load will preserve environmental integrity and sustainability.

7.3 Assessment of Acid Deposition Amounts and Effects on a Local Scale

The critical, target and monitoring loads may also be used on a local scale to evaluate the potential for adverse effects arising from the development of single or multiple projects. This is not intended to be a primary use of the critical, target and monitoring load values. Nevertheless, these values may be used as a benchmark to trigger further investigation of potential effects on a local scale, and/or emission management activities. **In this case, the target load is not to be applied as an environmental objective** as defined in EPEA, Section 14.

The processes of review and evaluation of a proposed industrial facility are well established in Alberta. The SO_2 Management Team agreed that current review processes are adequate and do not require modification. Therefore, the processes outlined in this section are not intended to supersede established practices, rather, this section describes how the critical, target and monitoring loads can be used within established review and approval processes.

The Environmental Protection and Enhancement Act designates the types of facilities and operations that require an environmental review. Most major projects are classified as "mandatory activities" (EPEA, Part 2), and, therefore require the preparation of an Environmental Impact Assessment (EIA). However, certain types of development not classified as mandatory activities under EPEA may be subject to an EIA at the discretion of the Director of the Environmental Assessment and Strategy Division. An approval to construct and operate an industrial facility in Alberta may be granted following a review of the application and the EIA by Alberta Environment, the Energy and Utilities Board (EUB) and/or the Natural Resources Conservation Board (NRCB), and if appropriate, other departments of the provincial (e.g. Community Development and Agriculture, Food and Rural Development) and Federal (e.g. Environment Canada, Fisheries and Oceans) governments. Section 38(d) of EPEA stipulates that public consultation is to be included throughout the review process.

The EUB or the NRCB (depending upon the type of project) hold the responsibility and authority (e.g. Alberta Energy and Utilities Board, 1995) to approve or reject an application on the basis of whether or not the proposed development is in the public interest. This decision takes into account social, environmental, technical/scientific, and economic considerations. Included in this process may be a public hearing, during which members of the public, stakeholders, and government agencies may express their position regarding the acceptability of the project. The hearing is a quasi-judicial process with the goal of ensuring that the EUB and/or NRCB understands the concerns and positions of all parties. The EUB and/or NRCB then responds to these concerns in its decision document. Should the project receive EUB and/or NRCB approval, specific conditions that the proponent must abide by through construction, operation, and/or decommissioning of the facility may be stipulated.

An evaluation of the entire suite of emissions and an assessment of their effects is presented in the EIA. Assessment of acidifying emissions and acid deposition in the vicinity of the proposed facility may be one aspect of an environmental impact assessment. Prediction of acid deposition in a local or sub-regional area in excess of the monitoring, target and/or critical loads is not in itself sufficient to deny approval to build and operate a facility which emits acid-forming substances. In the context of the project review and approval process, critical, target and monitoring loads provide benchmarks for comparison against which local issues regarding acid deposition can be assessed. Should the results of the assessment indicate that a receptor or suite of receptors are likely to be at risk as a result of the proposed development, regulators may decide to not approve the project, or may require the proponent to take certain actions (monitoring, development of contingency plans, mitigation) to minimize environmental risk and harm in the potentially affected areas.

Management of acid deposition on a regional scale (smaller than the grid cell approach used for provincial management) will likely require a refinement of derivation and application of critical and target loads. Hettelingh et al. (1992) and Selçuk et al. (1996) discuss approaches that may be useful in evaluating the sensitivity of a diverse number and types of receptors within one or a few grid cells, and a means of deriving emissions abatement strategies on the basis of receptor chemical properties. Stoddard et al. (1998) discuss the benefits and problems associated with extrapolating site-specific trends in acidification, and recovery from acidification, to a regional scale. Should such methods be viewed as potentially useful, the data necessary to use these methods must be collected during the monitoring implemented following the prediction of a monitoring load exceedance.

When a proposed project includes acidifying emissions that may be subject to long-range transport, and deposition of acidifying substances in jurisdictions beyond Alberta, an evaluation of deposition and potential effects at these distant sites may be required as part of the EIA process. Evaluation of long-range transport and distant effects has not been included in recent EIA's, and this is viewed as a gap in Alberta's management system. An assessment of the potential for long-range transport of acidifying emissions, and evaluation of the potential effects resulting from acid deposition distant from the emission point(s) may be needed in the event that a large facility is proposed. At present, the ability of proponents to conduct the required modelling is limited. Alberta Environment is currently investigating options that would allow such an analysis to be conducted.

8 INTERPROVINCIAL AND NATIONAL LINKAGES

Acidifying emissions are subject to long-range transport and, therefore, deposition of acidifying species may occur in a province, territory or state distant from the emission sources. Depending upon receptor sensitivity in the recipient jurisdiction, harmful effects of acid deposition may be a concern. As a result of the Long-Range Transport of Air Pollutants program (Interim Acid Deposition Critical Loadings Task Group, 1990), each province in western Canada agreed that no activities in their province would negatively affect the environment in another province. The Government of Alberta reaffirms this commitment.

Model estimates suggest that as much as 70% of the sulphur emitted from sources in Alberta is transported beyond its borders (McDonald et al., 1996). The majority of this enters into Saskatchewan due to the predominant wind directions. In addition, the model suggests that Alberta is the recipient of acid-forming emissions from sources in British Columbia (< 12% of acidifying emissions from within British Columbia) (McDonald et al., 1996). Because of the potential for emission transport into Saskatchewan, the Target Loading Subgroup broadened membership to include representation from Saskatchewan Environment and Resource Management.

8.1 Assessment of Acid Deposition in Saskatchewan

Although the Government of Saskatchewan has participated on the Target Loading Subgroup, it is clearly recognized that recommendations from the Subgroup are to the Acidifying Emissions Management Implementation Team, the CASA Board of Directors, and the Province of Alberta. At this time, Saskatchewan has not chosen the target load approach to managing acidifying emissions and deposition, has not assigned critical, target or monitoring loads (or any other deposition load or limit) to areas in Saskatchewan, nor has Saskatchewan chosen to use the grid cell approach. However, as a preliminary attempt to evaluate deposition and identify possible areas of concern in Saskatchewan due to emissions from British Columbia, Alberta, and Saskatchewan (Figures 1 and 2), and in the absence of other options, the Subgroup elected to extend the analysis and evaluation into Saskatchewan using the values for the critical, target and monitoring loads selected for application in Alberta, applied on grid cells of the same size as used in Alberta.

Saskatchewan Environment and Resource Management indicated that soil sensitivity may not be as high a concern within Saskatchewan as is surface water sensitivity. This is especially true for the northern shield region. Saskatchewan Environment and Resource Management provided maps of lake sensitivity to the Target Loading Subgroup and Environment Canada, and based on these maps grid cell sensitivities were assigned (sensitive, moderately sensitive, and low sensitivity). On the basis of these maps, and using the deposition loads that are to be applied in Alberta, an analysis of deposition in Saskatchewan was conducted (McDonald et al., 1999); the results are presented in Figure 10.

With the emissions considered in this analysis, there are two areas in Saskatchewan that are predicted to be receiving between 40% to 60% of the assigned monitoring loads: an area in north central Saskatchewan (near Cree Lake) and an area in the southwest (Sand Hills region). The remaining areas are predicted to be receiving less than 40% of the assigned monitoring loads.

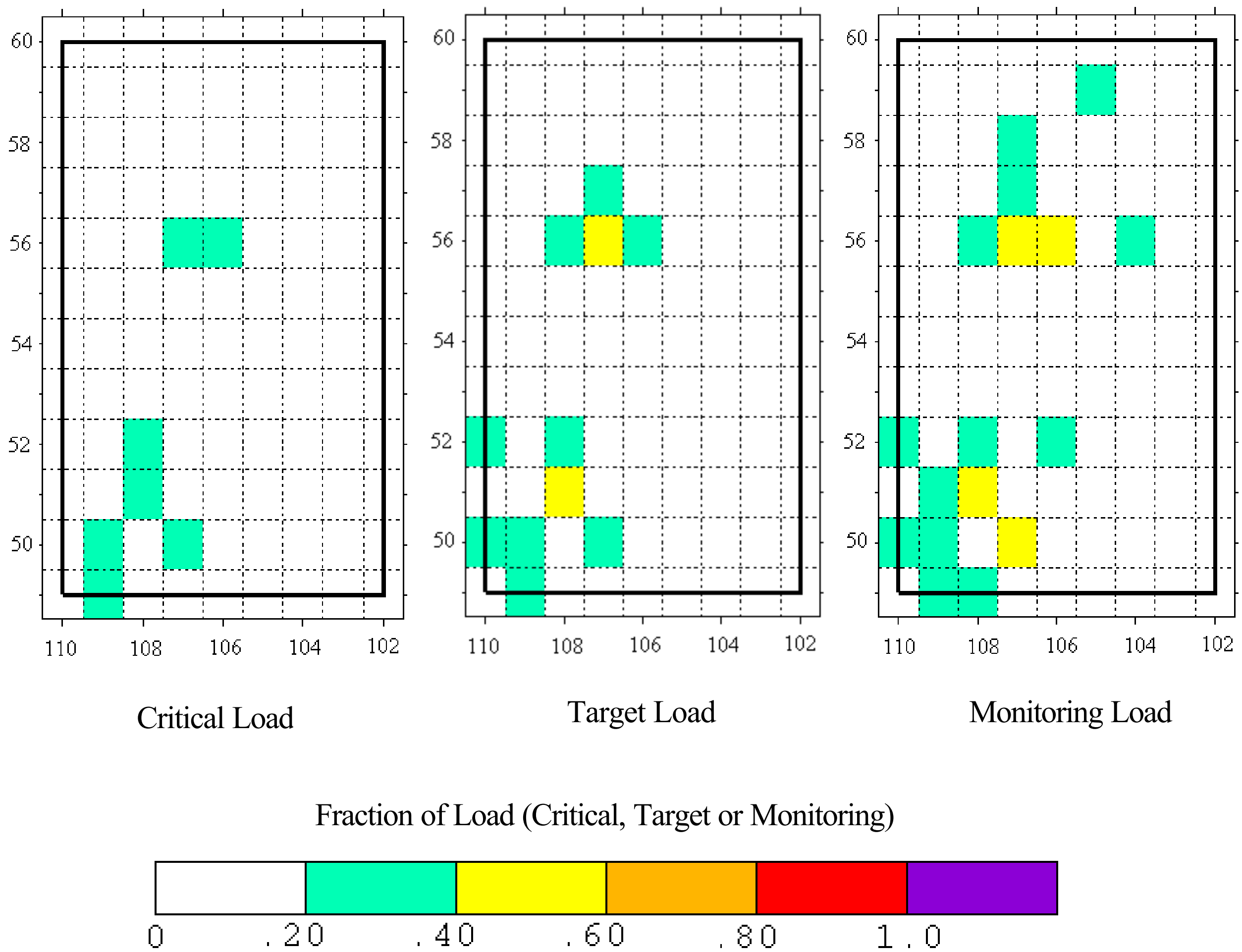

Figure 10. Acid deposition as a fraction of the critical, target and monitoring loads for Saskatchewan grid cells. The fraction of the load for each cell is calculated by dividing acid input (PAI) by the critical, target or monitoring load assigned to the cell on the basis of water sensitivity data.

Validation of deposition through monitoring and examination of actual receptor sensitivity in these regions is the responsibility of the Government of Saskatchewan. Alberta Environment and Environment Canada are willing to assist, where possible and desired by the Province of Saskatchewan by providing advice, information and expertise.

Because of the differences between the two provinces with respect to the receptor(s) selected as the basis for assigning sensitivity, results presented for grid cells spanning the border are inconsistent (Figure 8 vs. Figure 10). The Alberta analysis (Figure 8) is based upon an integrated receptor database (soil and lake sensitivity), whereas the analysis of deposition in Saskatchewan is based upon aquatic sensitivity only. Thus, the grid cell spanning the Alberta-Saskatchewan border that is predicted to be receiving acid deposition in excess of the monitoring load in the Alberta analysis (Figure 8) is due to the assignment of this grid cell as sensitive, a consequence of the presence of sensitive soils. In the analysis of deposition in Saskatchewan (Figure 10), this same grid cell is identified as receiving deposition well below the monitoring load, as the sensitivity of this cell is low on the basis of surface water sensitivity.

As stated above, this preliminary attempt to evaluate deposition was conducted to identify possible areas of concern in Saskatchewan, and that the focus of this analysis was on water sensitivity in the Canadian Shield region of Saskatchewan. Concerns regarding receptor sensitivity, such as soil sensitivity, in the southern portions of Saskatchewan are not addressed in this analysis. Due to the limitations associated with this analysis, no direct, quantitative, comparison between the results of the Alberta and Saskatchewan analyses is valid.

Alberta Environment will invite Saskatchewan Environment and Resource Management as well as Environment Canada to participate in the 5-year assessments outlined in Chapter 7 of this document. In order for the framework developed in this document to be effective as an inter-provincial environmental management tool, participation by all agencies is desired. This will ensure the maximum amount of information-sharing and will provide a forum for discussion of complementary management actions across jurisdictions.

8.2 Acid Deposition in Saskatchewan Arising from a Proposed Development in Alberta

The process of project review in Alberta is inclusive. All stakeholders are invited to participate; this includes stakeholders representing interests outside of the Province of Alberta. Should inter-provincial consultation (e.g. with Saskatchewan) be required as part of the review process for a proposed project, Alberta Environment will ensure that such consultation occurs. Federal agencies also participate in the review of major projects within Alberta.

8.3 Consistency with the Canada-Wide Acid Rain Strategy

This framework, and the critical, target and monitoring loads associated with it, were developed for use in Alberta. Saskatchewan Environment and Resource Management has been a part of this process, and is evaluating the framework for possible application in Saskatchewan. Although derived for acid deposition management in one, or possibly two, provinces, this framework does meet the "Keeping Clean Areas Clean" philosophy outlined in the National Acid Rain Strategy first formulated in 1997

(Acidifying Emissions Task Group, 1997), and recently reaffirmed by the Federal/Provincial/Territorial Ministers of Energy and Environment (1998). In applying the framework and critical, target and monitoring loads described in this document, Alberta is ensuring that the clean areas are kept clean, consistent with the recent agreement among ministers.

9 MONITORING REQUIREMENTS

This section describes the types of monitoring that are required to improve our understanding of the dispersion of acidifying emissions, the deposition of acidifying substances, and their effects on the environment.

9.1 Meteorological Monitoring

Models used for prediction of dispersion and deposition of acidifying emissions require a data set which describes the meteorological conditions that occur within the domain of the model. Environment Canada compiles a comprehensive set of meteorological data from a large number of monitoring stations on an annual basis. For the evaluation of acid deposition presented in this report, the meteorological data set from 1990 was used (Cheng and Angle, 1993). Future evaluations will require the use of data sets from other years, or perhaps a data set containing the average meteorological conditions representative of the long-term meteorology.

Because meteorological data is used for many different purposes, including weather forecasting, collection of the data required to run deposition models is expected to continue.

9.2 Deposition Monitoring

In order to measure potential acid input (PAI), wet and dry deposition of each acidifying compound and base cation must be monitored. Monitoring of wet deposition of acidifying substances and base cations is relatively simple, requiring only a mechanism for the collection of precipitation (rain, snow), and a laboratory equipped for the analysis of the collected precipitation samples.

Direct monitoring of dry deposition to a natural environment is not possible at this time. At present, only highly specialized equipment is available for the continuous monitoring of low concentrations of acidifying substances in air. Estimation of dry deposition is then based upon these ambient measurements multiplied by the deposition velocity for each substance.

Multiplication of the ambient air concentration by a deposition velocity for each substance provides an estimate of dry deposition of that substance in the vicinity of the ambient air monitor. Deposition velocities have been determined for most of the substances of interest (acid-forming, base cation), however, it is now becoming recognized that deposition velocities change with environmental conditions (Hofschreuder et al., 1997; Ruijgrok et al., 1997; Wyers and Duyzer, 1997). Damp or wet leaves are more efficient at “scrubbing” the air of pollutants, and therefore, when leaves are wet the deposition velocity (or rate) is higher. Similarly, conifer needles are more efficient at removing substances from the air than are deciduous leaves, and therefore, different deposition velocities for conifer, deciduous and mixed wood forests are needed. While it is the best tool available at present, ambient monitoring and the use of deposition velocities can only provide an estimate of dry deposition. Section 10.2.1.2 provides a more complete discussion of the need to improve our methods of dry deposition estimation and measurement.

Passive monitoring devices have been recently developed to monitor ambient air concentrations of SO_2, NO_x, O_3 and volatile organic compounds (VOC's). Deployed for periods of weeks to months, these devices can provide an indication of the concentration of the target substance, integrated over time. These devices do not allow for a direct calculation of acid deposition; however, they can be used to provide some data that may be used for the validation of model predictions on a local to regional scale. Their use in the evaluation of acid deposition on a provincial scale has not yet been tested.

9.3 Ecological (Environmental, Biological) Monitoring

Ecological monitoring, also called environmental or biological monitoring, is the means by which the effects of acid deposition (or any other stress or combination of stresses) are measured. Because of the diversity of receptors, the variety of stresses, and the long time frames during which responses to acid deposition develop, it is an expensive and time-consuming process to monitor ecological processes. However, such monitoring is required in order to validate predictions of acid deposition and receptor responses. In the absence of environmental monitoring data, our understanding of how the environment responds to acid input will not advance, and the goals of responsible management of acidifying emissions for sustainable development while maintaining a high degree of environmental protection will not be achieved.

Ecological monitoring requires an understanding of the processes by which ecosystems function; it is upon this understanding that a program of measurement of key parameters and processes is designed in order to evaluate the effects of exposure to acid deposition stress (or any other stress). Ecological monitoring for acid deposition effects includes monitoring of soil chemistry, vegetation (lichen, moss, herbaceous plant and woody plants) growth and reproduction, and chemical composition of plant material. Other stresses, such as disease and insect infestation are also monitored, as these may increase due to acid deposition, or may be independent of any effects related to acid input. A large body of data on a wide number of ecological processes at a monitoring location may be required before a subtle change indicating the onset of acidification stress may be discerned from the noise in the data, or from changes due to stresses unrelated to acidification.

At present, there is one comprehensive ecological monitoring program for the detection of acid deposition effects operational in Alberta. The Terrestrial Environmental Effects Monitoring program of the Wood Buffalo Environmental Association is centred on the oil sands mining and processing facilities in northeastern Alberta, and is operated by the Wood Buffalo Environmental Association. A less intensive program is the Saskatoon and alfalfa monitoring program in the West Central Airshed Society (1997). The Acid Deposition Research Program (Legge, 1988) included measurement of acid deposition in some areas of the province; however, while this program evaluated potential effects of acid deposition on vegetation, it did not include an ecological monitoring program, and was terminated in 1988. Maynard et al. (1994) evaluated the effects of sulphur dusting (elemental sulphur) and sulphur dioxide on forests in west-central Alberta. This program is continuing, and additional reports are expected.

10 FUTURE WORK

The analysis conducted during the development of the critical, target and monitoring loads pointed to a number of uncertainties regarding the deposition of acid-forming substances and their effects. Some of these gaps and uncertainties may be addressed in the short-term (before the next assessment in 2004), while others will require a number of years within which to conduct the required research and field investigations.

A long-term goal is to establish critical loads for each of the grid cells in the province which fundamentally represents the actual critical loads for the receptor systems within individual grid cells. The critical loads (and hence the target and monitoring loads) established at this time are the result of the current understanding of the emissions, deposition, and soil and water sensitivities to acid input. This understanding is sure to improve, and therefore, there is a strong possibility that the assigned loads for some of the grid cells will change. Measurement of soil and water properties, and the use of increasingly sophisticated receptor models (e.g. ForSust), may provide better estimates of critical loads, and further development of these models and their application to Alberta is an area of promise.

10.1 Requirements for the 2004 Acid Deposition Assessment

In order to complete the assessment in 2004, an updated emissions inventory will be required. The inventory of 1995 emissions is currently being prepared, and the subsequent inventory is scheduled for 2002 (based on emissions in the year 2000). The most up-to-date inventory available will be used in the 2004 assessment.

The assessment conducted as part of the derivation of the critical, target and monitoring loads indicated that one grid cell is currently in exceedance of its assigned monitoring load (Figure 8). As a consequence, Alberta Environment is initiating a study to determine the critical load of receptors in the cell, and is compiling the data available to estimate wet and dry deposition in this area. These results will be available for incorporation into the next assessment. At this time, activities related to management of emissions are not required.

Efforts to further the understanding of receptor sensitivity and receptor responses to acid deposition are required. While some efforts are currently underway (monitoring programs, EIA preparation), most of the work required will take longer than 5 years, and as results become available, they will be integrated into each assessment at the earliest opportunity.

10.2 Uncertainties and Data Gaps

Data gaps and uncertainties can be addressed through research, monitoring, and survey initiatives. The boundaries among research, monitoring, and surveys are not clear. To be effective, integration among these activities is necessary, with the observations and findings obtained within one category being used to support and direct activities in the others. A description of the major areas and specific examples requiring attention within the broad categories of research, monitoring and survey, are provided below.

10.2.1 Research

The Target Loading Subgroup identified a number of specific issues requiring investigation from the research community. These issues are described below; however, the list is not intended to be exhaustive. The imagination and insight of the research community is welcome, and any research project which expands the understanding of acid deposition processes or effects would be a valuable contribution to the management of acid emissions and deposition.

10.2.1.1 Mineral Soil Sensitivity

Mineral soil sensitivity classification is based on the sensitivity of the soil to base cation loss, aluminum solubilization, and acidification (drop in pH). Soil acidification increases the levels of the toxic form of soluble aluminum (Al^{3+}) and/or reduces base cation (BC) levels, and the Al:BC concentration ratio increases. As calcium is often the predominant base cation in soil, some use a Ca:Al ratio (Cronan and Grigal, 1995). Based upon a comprehensive review of the literature, Cronan and Grigal (1995) conclude that a Ca:Al ratio (based on molar concentrations of calcium and aluminum in soil solution) of 1.0 represents a 50% risk of reduced tree growth or soil nutrition due to aluminum stress, and this increases to a 75% risk at a Ca:Al ratio of 0.5, and a 100% risk at a Ca:Al ratio of 0.2. Other factors may also help in determining whether or not a forest ecosystem is at risk from aluminum stress. These include a base saturation of less than 15% of effective cation exchange capacity, the ratio of Ca:Al in fine roots of trees (50% risk of adverse effects due to aluminum stress at a ratio of 0.2, 80% risk at a ratio of 0.1), and the ratio of Ca:Al in current year foliage (ratio of 12. 5 represents 50% risk of adverse effects due to aluminum stress, 6.2 represents 75% risk).

While conceptually simple, use of this ratio is difficult at present. Recent reports have called into question the use of the Al:BC in critical load determination (Løkke et al., 1996), since the concentration of toxic aluminum forms in soil are generally only a fraction of the total soluble aluminum concentration in soil (which is measured using standard methods). Freer-Smith and Read (1995) show that the poorest observed tree crown conditions in spruce stands were associated with low Al:BC ratios. The relationships among chemical criteria (e.g. Al:BC ratio) and biological processes (e.g. tree health, growth and reproduction) are uncertain. Furthermore, use of this ratio may not apply to organic soil systems. A key recommendation arising from the Target Loading Subgroup (1996) was that the basis for calculating this ratio, and its application in the determination of critical loads for Alberta soils, be thoroughly investigated. This recommendation is reiterated here.

Bedrock weathering rates are important model input values in the estimation of critical loads. Use of bedrock classification maps and the weathering rates assigned to various bedrock types is the usual method of estimating weathering. Empirical examination of weathering rates should improve the accuracy of model inputs (Johansson and Tarvainen, 1997).

Changes in soil chemistry are relatively easy to measure, and in some cases are correlated with changes in the growth and vigour of vegetation growing on the soil, making it possible to predict vegetation responses due to soil chemical changes that may result from acid input. However, between the soil and plant roots is a complex of soil microflora, collectively called the rhizosphere. Acid deposition may alter the species composition of the rhizosphere, and the metabolism of the organisms in the rhizosphere (Thirukkumaran and Morrison, 1996), leading to changes in plant growth that may not be predicted on the basis of soil chemistry analysis alone (Clegg et al., 1997), although acidification may have no effect on some soil microbes (Heijne et al., 1996). Physiological responses within the plants, such as redirected translocation of minerals within plants and alterations in foliar leaching of minerals in response to soil acidification (Gjengedal, 1996), may result in visual responses that differ from the responses predicted. Additionally, responses in soil biota may respond to the fertilization aspects of nitrogen deposition (Koopmans et al., 1996), rather than in a manner suggested if nitrogen is considered as an acidifying substance. These are areas of continuing research interest – areas that may provide data of relevance to effects-based management of acid deposition in Alberta at some future time.

10.2.1.2 Dry Deposition Monitoring

Measurement of wet deposition is relatively easy; however, monitoring for dry deposition is difficult. The common approach to dry deposition monitoring is to estimate dry deposition based upon the atmospheric concentration of each substance and the deposition velocity for each of the substances. The deposition velocity for many substances is assumed, inferred or estimated on the basis of limited data, although attempts at direct measurement of deposition velocity have been made (Hofschreuder et al., 1997; Ruijgrok et al., 1997; Wyers and Duyzer, 1997). Brook et al. (1997) discuss the difficulties associated with determining a deposition velocity for atmospheric substances. Determination of deposition velocity for individual substances under different environmental conditions (terrain, receptor surface, meteorology, time of day) continues to be a research question, and is a key requirement for accurate determination of acid deposition from ambient air quality monitoring data.

10.2.1.2.1 Deposition Collector Methods

Deposition collector and foliage washing techniques take advantage of surfaces as samplers which collect chemicals to be analyzed. Washing techniques take advantage of the availability of natural (e.g. leaves) and artificial surfaces to accumulate substances directly from the air.

Measurements of a chemical tracer (such as sulphur, iodine or lead) which has been added to the emissions from a release point, and subsequent measurement of the tracer and substance of interest obtained from a deposition collector (artificial or foliage) provides a means of estimating dry deposition. The difference between the amount of tracer detected and the amount of the substance of interest is a measure of dry deposition. With simultaneous meteorological and air concentration measurements, dry deposition velocities can be determined.

Collection and analysis of throughfall samples is another deposition collector technique. Throughfall is the precipitation which has passed through the forest canopy. During dry periods, trees filter the air as it moves through the canopy (some tree species are more efficient than others), with gaseous and fine particulate compounds being removed from the air and collected on the leaf or needle surfaces. Rainfall then washes these compounds off the leaves, and deposits them on the ground where they may contribute to soil acidification. Chemical analysis of the collected throughfall can be used to estimate the quantity of dry deposition since the previous rain. Thimonier (1998) has reviewed the various methods of throughfall collection, as well as many of the theoretical and operational issues associated with throughfall collection and analysis. Typically, throughfall is collected in buckets or specially designed collection vessels, or in a series of channels or troughs directed towards a collection vessel (Fenn and

Bytnerowicz, 1997; Hamburg and Lin, 1998; Kallio and Kauppi, 1990; Thimonier, 1998). Attempts to use artificial branches as collectors of dry deposition, and estimation of deposition during rainfall by washing the artificial collector have also been made (Draaijers et al., 1997; Hofschreuder et al., 1997). In a study of throughfall chemistry in California (Fenn and Bytnerowicz, 1997), the concentration of acidifying substances (containing sulphur and nitrogen) was highest in throughfall collected under spruce trees, the species with the highest foliar surface area. Concentrations were next highest in pine, followed by oak, and lastly, in rainfall (Fenn and Bytnerowicz, 1997). Similarly, throughfall concentrations of sulphur under pine trees was substantially higher than that observed under a species of evergreen oak (Singer et al., 1996).

Leaching of compounds (mostly cations) from vegetation into throughfall water, and uptake of deposited ions (usually nitrogen as NH_4^+ and NO_3^-) by vegetation may alter the chemical composition of the throughfall (Draaijers et al., 1997; Hansen, 1996; Kallio and Kauppi, 1990; Rao et al., 1995). Differential retention of wet-deposited cations and anions may occur, and this may also vary with species and leaf type (Hoffman et al., 1995); this may also be a factor in retention of dry-deposited compounds. Without taking these considerations account, errors in the estimation of dry deposition are likely to occur.

There are difficulties related to the collection of samples, and the maintenance of the collection equipment in distant locations. The reliability of throughfall measurement as a surrogate for dry deposition estimation in relatively open pine forest canopies and in broad-leaved deciduous tree communities, as well as those areas where nitrogen contributes substantially to dry acid deposition, is also questionable. Given the theoretical and practical considerations involved in throughfall collection and analysis (Thimonier, 1998), it is important to calibrate and validate this technique in Alberta's environments prior to recommending its use as a method for estimation of dry deposition to forests.

10.2.1.2.2 Estimation of Dry Deposition using Micrometeorological and Ambient Monitoring Methods

Throughfall, while receiving much recent attention, is one of several methods of estimating dry deposition. Most others rely on measurements of vertical distributions or fluxes of chemicals and micrometeorological parameters. Mathematical relationships are then used to infer dry deposition from the measured vertical flux through the use of deposition resistance methods (Gallagher et al., 1997; Hicks et al., 1980; Hunt et al., 1981; Sehmel, 1980). These methods are very briefly described below.

Eddy correlation and variance methods are well-accepted techniques to measure heat and water vapour fluxes. They can also be applied to the direct measure of vertical flux of chemical species under natural conditions by taking simultaneous measurements of vertical wind velocity and its standard deviation as well as instantaneous concentration at a given point. These methods are becoming more feasible as chemical response times are decreased as chemical monitoring technology improves.

Eddy accumulation methods measure two separate air samples: one for times associated with upwards air motion and one for downward air motion. Chemical flux is then determined as a function of the difference in mass between the two measurements. This method removes the need for fast-response chemical monitoring systems but increases uncertainty by determining differences of very similar concentrations (a small error can be magnified due to the very small differences between measurements). Gradient methods involve taking wind velocity and air concentration measurements at multiple heights to create a profile of concentration changes with height which can be used to infer the vertical flux of the chemical.

All of these methods provide vertical flux values which are used to calculate resistances to transfer of the chemical through the air to the underlying surface. Dry deposition velocities can be determined from flux measurements for use in calculating the dry deposition. Improvements in these methods, and their application in the field, are needed in order to allow routine dry deposition measurement (or estimation) on a wider scale.

10.2.1.3 Aquatic Sensitivity

To date, aquatic sensitivity has been determined by measuring alkalinity (mg $CaCO_3$ l^{-1}). However, this measurement excludes the buffering role played by organic substances and metals that are dissolved in the water. The contribution of organic compounds and metals is particularly important when evaluating the sensitivity of aquatic systems that contain high levels of dissolved organic compounds ("brown water" systems). Exclusion of buffering processes provided by organic acids (which are present in relatively large quantities in brown water systems) resulted in an overestimation of the response of lakewater pH to acid deposition (Sullivan et al., 1996). Determination of the Acid Neutralizing Capacity (ANC) of an aquatic system includes the processes of buffering by organic and metallic substances. It is important that these processes be understood, such that accurate calculations of ANC are possible for aquatic systems in Alberta.

Another aspect of aquatic acidification is the spring acid pulse, also known as a spring pH depression, which may occur during snowmelt. Accumulation of strong anions (SO_4^{2-}, NO_3^-) in the snow during the winter may cause a pulse of acidity in the spring, coincident with a dilution of base cations in the water due to increased water volumes. While a spring acid pulse has been observed in several streams in areas subjected to acid deposition (Allan, 1995; Jacks et al., 1986; Jeffries et al., 1979; Lynch et al., 1986; Molot et al., 1989; Sharpe and Demchik, 1998), the processes leading to a spring pulse (conditions in the fall at freeze-up, winter snowfall, spring melt conditions, etc.) are not well understood. The effects of a spring acid pulse on the organisms inhabiting the affected watercourse are also poorly understood. Alberta Environment, in collaboration with the University of Alberta and stakeholders in the oilsands area of northeastern Alberta are studying this phenomenon in medium-sized rivers in the northeast. The 5-year assessments will include an evaluation of the results of this study, as they become available.

10.2.1.4 Wetland (Organic Soil) Sensitivity

Wetlands are an intermediate between soil and aquatic systems, having properties of both. These are diverse systems, and our knowledge regarding fundamental ecological processes within wetlands is limited. As a result, it is difficult to determine if wetlands are at risk from acid deposition, and if so, the type and magnitude of the responses that may occur.

Turchenek et al. (1998) state that uncertainty regarding the role of chemical reduction reactions in organic soil systems is a key limitation in our understanding of organic soil responses to acid input. Chemically, reduction of deposited SO_4^{2-} (and other sulphur compounds) and oxides of nitrogen are acid-consuming processes, and may provide an organic system with some protection from acidification. However, the extent to which chemical reduction occurs in organic soils is unknown.

Further investigation into the possible role that acidic deposition may play in stimulating or accentuating the natural processes involved in the transition of a fen to a bog (Vitt, 1994) is warranted. If this further work suggests that acid deposition may enhance the colonization of wetlands by *Sphagnum* mosses, with subsequent further acidification of the wetland by the mosses, a re-evaluation of the sensitivity classification of organic systems, which is currently based upon chemical and physical properties of peat, would be required.

In any case, mapping of wetlands at much finer resolution than that provided by Holowaychuk and Fessenden (1987) is needed in order to apply the organic (peat, wetland) sensitivity classification proposed by Turchenek et al. (1998). As a long-term goal, the classification and fine resolution mapping of wetlands (Zoltai and Vitt, 1995) would greatly enhance the ability to evaluate potential effects of acid deposition to sensitive receptors.

10.2.1.5 Nitrogen Fertilization

Deposition of nitrogen to an ecosystem may result in acidification of that system; however, as nitrogen is also a nutrient, nitrogen deposition may result in effects independent of acidification, or may interact with the processes of acidification to produce effects that can not be predicted by independent examination of these processes. Some ecosystems in Alberta that are considered to be acid-sensitive are also nitrogen-deficient. In these cases, the bulk of deposited nitrogen will be taken up by vegetation (Fenn et al., 1998; Hurd et al., 1998) and will not contribute to acidification in the ecosystem. In systems where nitrogen is abundant, deposition of nitrogen may lead to nitrogen saturation (eutrophication), and in this case acidification of the soil and water systems may follow (along with other effects of eutrophication). The potential fertilization effect of nitrogen in acid-sensitive, nitrogen-deficient, systems in Alberta is a research need.

10.2.1.6 Deposition Modelling

Models continue to develop and improve. At present, RELAD is the best model for use in estimating acid deposition in western Canada. It is hoped that as our understanding of atmospheric chemistry, dispersion processes, and deposition mechanisms improves, the RELAD model will be upgraded.

New deposition models may become available in the future, and as stated in section 7.2, any revision of the RELAD model, or use of a new model in the evaluation of acid deposition and effects will be considered in consultation with stakeholders. Should a new model prove to be more accurate than RELAD in predicting acid deposition, the new model should be incorporated for use in the 5-year assessments.

The Target Loading Subgroup has expressed some concern about the use of a single year of meteorological data in the RELAD predictions presented in this assessment and report. While the 1990 data was judged to be representative of the meteorological data for the decade from 1981 to 1990 (Cheng and Angle, 1993), it is unknown whether these data are representative of years after 1990.

uncoupling as distance from the source(s) increases, may be a consideration in regions of Alberta where isolated sources occur (e.g. the Athabasca oil sands area). Regional application (e.g. in an ADMZ, should one be established at a future date) of the acid deposition management framework may require consideration of this aspect of deposition.

In order to resolve the concern raised by the Target Loading Subgroup, and to determine the annual variability of acid deposition amounts and patterns, it is suggested that RELAD be run each year with the emissions inventory used in the most recent 5-year assessment, and the meteorological data for the last calendar year. The results from each annual model run would be retained for use in the next 5-year assessment. The 5-year assessment would then utilize the results from each year to derive an average deposition for each grid cell for the previous 5 years. This approach would ensure annual variability is understood, and that decisions regarding monitoring, and if required emissions management, are not made on the basis of artefacts arising from the use of a particular meteorological data set. Alberta Environment is currently examining the feasibility of running RELAD on an annual basis.

While the amount, timing and location of rainfall is a major factor in determining the amount, timing and location of wet deposition, there is also evidence that rainfall patterns also affect the soil chemical processes which react to deposited sulphur (Huntington, 1996). Increased sulphur retention, coupled with decreased alkalinity, is predicted to occur under reduced rainfa conditions. This is an area that has not been well studied, and bears further examination.

10.2.2 Monitoring

10.2.2.1 Deposition Monitoring

Monitoring of chemical deposition is required to determine the amount of acid being deposited to terrestrial and aquatic systems. Wet deposition monitoring is relatively easy involving the collection of precipitation and analysis for acidic substances and base cations. Dry deposition monitoring is more difficult and less precise (section 10.2.1.2). At present, wet deposition is being monitored in selected regions of the province, but long-term databases for these regions are not available. More data may be available from which dry deposition may be estimated, since many industrial and governmental monitoring programs include ambient air monitoring for SO_2 and NO_x concentrations in ambient air (which when multiplied by the deposition velocity, provides an estimate of dry deposition). Deposition velocities for base cations have also been derived (Ruijgrok et al, 1997), however, to make full use of these, increased monitoring for ambient concentrations of base cations is needed. Enhanced chemical deposition monitoring in the province is a long-term goal.

10.2.2.2 Ecological Monitoring

Ecological monitoring involves the long-term measurement of receptor responses to environmental stress in order to ensure that long-term harmful effects are not occurring as a result to stress, such as exposure to air pollution. Should such effects be observed, the cause of the effect needs to be determined, since environmental receptors respond to a diversity o environmental stresses (and combinations of stresses), including acid deposition. At present, there only one comprehensive ecological monitoring program operating in the province for the detection of effects caused by acid deposition (by the Wood Buffalo Environmental Association) (see also section 9.3). This program includes terrestrial (soil and vegetation) and aquatic (spring pH depression) components.

Increased consolidation and interpretation of the results from these independent programs is needed in order to increase our ability to understand deposition and effects in the province as a whole. This consolidation and evaluation should be included as part of the next assessment, since limited data from these programs is available at this time.

10.2.3 Survey Sampling

Data which may indicate the sensitivity of soils systems and water bodies to acid deposition may be obtained by one-time collection of samples and subsequent analysis. Surveys give an excellent “snap-shot” indication of the sensitivity of soils and waterbodies in the various regions across the province, and the data collected from a survey can be used to assist in the estimation o the critical load for the receptor (soil unit or aquatic system).

Saffran and Trew (1996) provided an update of the database on lake sensitivity to acid deposition in Alberta. However, it is apparent from the database and the maps showing the sensitivity of Alberta lakes that there are regions in the province where there has been little or no sample collection and analysis (Figure 4).

Surveys can be conducted on a large scale (regional, provincial) or on a more restricted scale (local). Examples of large-scale surveys include the work of Holowaychuk and Fessenden (1987) for soils, and Saffran and Trew (1996) for aquatic systems. Local surveys may be conducted as part of an Environmental Impact Assessment for a proposed project. Data obtained from surveys at all scales should form part of the provincial receptor sensitivity database, and be included as part of each 5-year evaluation of acid deposition and effects.

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12 GLOSSAR

The terms in this glossary are defined in the context of acidifying emissions and acid deposition.

Acid Deposition Management Zone (ADMZ)	A zone established in the event that a Target Load is exceeded in one or more grid cells. The boundaries of the ADMZ will be specified by Alberta Environment and the Energy and Utilities Board, and stakeholders within these boundaries will be responsible for reducing emissions from within the ADMZ in order to reduce acid deposition to below the Target Load in the exceedance grid cell(s).
Acidification	The process by which a receptor (soil, water) becomes more acidic, through deposition of acidic compounds, or through the loss o substances which are able to act as buffers.
Acid Neutralizing Capacity (ANC)	A measure of an aquatic system's ability to neutralize acid input. This measurement includes inorganic, organic, and metal buffering processes, and is a more integrated measure of buffering capacity than measurement of calcium carbonate concentration alone.
Anion	A negatively charged ion such as sulphate (SO_4^{2-}) and nitrate (NO_3^-)
Base Cation (BC)	A substance that is able to substitute for a hydrogen ion (acid), thus reducing the acidity of the soil or water body. Calcium, magnesium, potassium and sodium are the predominant base cations. Greater concentrations of base cations in soil or water increase the buffering capacity of the soil or water, making the receptor less sensitive to chemical change due to acid deposition.
Bog	A peat-covered area or peat-filled wetland, generally with a high water table. The surface is unaffected by nutrient-rich groundwater from surrounding areas, making the bog generally nutrient-deficien and naturally acidic.
Cation	A positively charge ion such as calcium (Ca^{2+})and sodium (Na^+)
Cation Exchange Capacity (CEC)	An indicator of the fertility and buffering capacity of a soil. Reflects the ability of the soil to absorb positively charged ions (e.g. Ca2+, Na+, NH4-), many of which are important plant nutrients. A higher CEC generally indicates a greater ability to neutralize acid input.
Critical Chemical Value	A numerical value used in a receptor model (e.g. ForSust) to represent a cut-off point above which (or below which) negative environmental effects occur. Critical chemical values are based on experimental measurement and monitoring results, and may be specific to the receptor type. A series of critical chemical values ma be used to estimate the magnitude of the potential effect, or the risk of the effect occurring. This is an area of active research.

Critical Load	The highest load of acid deposition that will not cause chemica changes leading to long-term harmful effects on the most sensitive ecological systems.
Deposition Velocit	The speed at which substances (either as gases or attached to particles) are deposited to surfaces (leaves, waterbodies, soils). Relevant to the estimation of dry deposition: when the ambien concentration of a substance is multiplied by the deposition velocity for that substance, an estimate of the dry deposition of the substance is obtained.
Dry Deposition	A constant (in units of length per unit time), relating atmospheric vertical flux and concentration of a depositing chemical species. An integrated measure of molecular transport through the air layers near the Earth's surface and surface absorption. Does not include deposition of substances dissolved in rain or snow (see "we deposition").
Emissions Inventor	A database containing the emissions of the substances of interes from the area of interest. Emissions inventories may also contain information regarding the source of the emissions (urban, industrial, etc.), the height at which the emissions enter the atmosphere (e.g. a ground-level, or from the top of a tall stack), or other information.
Environmental Objective	A level below which deposition (or concentrations in the case of an ambient air quality objective) is to be maintained. Should depositi occur above the Environmental Objective (in this case the Targe Load), management actions are taken to reduce deposition.
Equivalent (eq) [includes kiloequivalent (keq) and milliequivalent (meq)]	A term that expresses the amount of a substance in terms o equivalency to another. For acidification, amounts are expressed in terms of their equivalency to hydrogen ions (H^+), which is an expression of their potential to cause acidification. For alkalinity, amounts may be expressed in terms of their equivalency to calciu carbonate, an expression of their ability to neutralize acidity. "Kilo" is the System International unit for 1000, "milli" the SI unit for one-thousandth.
Eutrophic (eutrophication)	A system rich in nutrients. Eutrophication is the process of making a system richer in nutrients, often beyond the ability of the system to assimilate and utilize the added nutrient load.
Exceedance	A term used to describe the deposition (or concentration) above a defined value. In the case of acid deposition management, exceedances of monitoring, target and critical loads are discussed, with actions specified when deposition exceeds each of these values.

Fen	A class (containing several types) of peat-covered or peat-filled wetland which generally contain a moderate or abundant supply of nutrients. The water table is generally at or above the surface of the peat.
ForSust	The Forest Sustainability receptor model. A model that predicts the response of forest trees to changes in soil chemistry that result fro acid deposition.
Key Chemical Criteria	See Critical Chemical Value.
Leaching	A process whereby minerals, contaminants or nutrients are moved downward through rock or soil by water. May be enhanced by the presence of acid in the water.
Marsh	A class of wetlands (mineral or organic) which is periodically inundated by standing or slowly moving water. Marsh water i nutrient-rich.
Mesotrophic	A system moderately rich in nutrients.
Mineral Soil	A soil system derived from mineral origins. Gravel, sand, silt, and clay are the primary components of a mineral soil. Organic material forms a smaller (less than 30%) proportion of the soil.
Monitoring Load	A level of acidic atmospheric deposition assigned to a grid cell tha leads to the initiation of studies of receptor sensitivity and monitoring of acid deposition to confirm or adjust the critical load applied to the grid cell, and to assess the accuracy of deposition model predictions.
NO_x	A class of compounds composed of nitrogen and oxygen (e.g. NO, NO_2, N_2O), generally referred to as oxides of nitrogen.
Oligotrophic	A system deficient in nutrients.
Organic Soil	A soil derived primarily from vegetation debris (litter, dead and decaying plant material). Generally associated with wetlands, where a thick layer of organic material provides the substrate for plant growth, and generally governs the chemical and physical properties of the soil. Organic soils contain 30% or higher organic matter content.
Passive Monitor	A monitoring device that absorbs (or adsorbs) the substance o interest, such that the average concentration of the substance in air can be estimated for the period during which the passive monitor was deployed in the field. Passive monitors can not provide information on the maximum level of the substance, nor the duration of maximum concentration. Use of passive monitors is an active area of research.

pH — A measure of the activity of hydrogen ions in a solution, which determines the acidity or alkalinity of that solution. A difference o one unit in pH (e.g. 6.0 and 7.0) represents a 10-fold difference in activity.

Receptor — Any biological or physical component of the ecosystem that receives acid deposition. Receptors include soils, vegetation, and aquatic systems.

RELAD — The REgional Lagrangian Acid Deposition model. A mathematical model that estimates the amount of acid deposition based upon inputs containing meteorological data, emissions inventory data, and estimates of atmospheric chemical reactions.

Saturati — The concentration at which a substance can no longer (a) dissolve into the solution, or (b) be assimilated by a system. An example o (a) is base saturation, where 100% base saturation indicates that the maximum amount of base cations is present in the soil. An example of (b) is nitrogen-saturation, where additional inputs of nitrogen (from the air) can not be assimilated by vegetation, leading to increased nitrogen content in the soil, and in the streams and rivers leaving the watershed.

Target Load — The maximum level of acidic atmospheric deposition that affords long-term protection from adverse ecological consequences, and that is practically and politically achievable. An Environmenta Objective.

Throughfall — Precipitation that has fallen through the tree canopy and has come in contact with leaves. In passing through the tree canopy, rainfall (or snow) may pick up some of the material deposited onto the leaf surface since the preceding rainfall. Measurement of the concentration of substances in throughfall is sometimes used to obtain an estimate of dry deposition.

Watershed — An area within which water flows to a clearly identified waterbod (stream, river, or lake). The chemical, physical, and biologica components within a watershed typically govern the chemical, physical, and biological characteristics of the receiving waterbody.

Wet Deposition — Deposition of substances dissolved, or suspended, within precipitation (snow, rain).

Wetland — An area within which the soil remains permanently wet (excep perhaps the top few centimetres) due to the presence of the water table at or near the surface. Wetlands may be organic in nature (e.g. fens and bogs), or mineral in nature (e.g. marshes). Wetlands are typically small and shallow, with a depth of 2 m or less.

APPENDIX I

TARGET LOADING SUBGROUP

CLEAN AIR STRATEGIC ALLIANCE

CONSENSUS AGREEMENT

The following signature form has been reproduced from the report presented to the CASA Board of Directors by the Target Loading Subgroup.

FRAMEWORK FOR THE APPLICATION OF CRITICAL AND TARGET LOADS FOR THE EVALUATION AND MANAGEMENT OF ACID DEPOSITION

Target Loading Subgroup
April 1999

By signing below, the members of the Target Loading Subgroup indicate their consensus agreement that the *Framework for the Application of Critical and Target Loads for the Evaluation and Management of Acid Deposition* be recommended to the Acidifying Emissions Management Implementation Team, and subsequently, to the CASA Board of Directors for acceptance. Such acceptance will become a recommendation that the *Framework* be forwarded from CASA to Alberta Environmental Protection for implementation.

Dr. Kenneth R. Foster, Chairman
Alberta Environmental Protection

Mr. Kim Eastlick
Alberta Energy and Utilities Board

Dr. Karen McDonald, Secretary
Environment Canada

Dr. Martha Kostuch
Prairie Acid Rain Coalition

Dr. Ron Pauls
Syncrude Canada Ltd.

Mr. Les Johnston
EPCOR

Mr. David McCoy
Husky Oil Ltd.

Mr. Dave Ballagh, Saskatchewan Environment and Resource Management, also participated in the work of the Target Loading Subgroup. As this document and the processes set out within it are for application in Alberta, Saskatchewan Environment and Resource Management has elected to neither indicate acceptance nor rejection of the *Framework for the Application of Critical and Target Loads for the Evaluation and Management of Acid Deposition.* The members of the Target Loading Subgroup appreciate the participation by Saskatchewan Environment and Resource Management, and specifically, for the contribution made by Mr. Ballagh.