HAT CREEK RECLAMATION STUDIES 1981:
AN ASSESSMENT OF TRACE ELEMENTS IN SOILS AND VEGETATION

Prepared for

British Columbia Hydro and Power Authority

September 1982

Monenco Consultants Pacific Ltd.
8th Floor
1199 West Pender Street
Vancouver, British Columbia
V6E 2R1

604H-E044

MONENCO CONSULTANTS PACIFIC LTD.

1199 WEST PENDER STREET
8TH FLOOR
VANCOUVER, B.C. V6E 2R1
TELEPHONE: (604) 687-0331
TELEX: 04-53347

20 September 1982
BCH 7972-7

B.C. Hydro & Power Authority
555 West Hastings St.
Vancouver, B.C.
V6B 4T6

RECEIVED
SEP 22 1982
THERMAL GEN.
PROJECTS DIVISION

Attention: Dr. F.G. Hathorn

Gentlemen:

We are pleased to present this final report on the assessment of trace element hazards in the reclamation of various waste materials from the proposed Hat Creek Mine. Concerns raised in your review of the draft report have been addressed. The information contained in this report represents a "state of knowledge" for most of the elements dealt with. There are, despite this, significant areas of uncertainty that result principally from the lack of standardization of sampling techniques and analytical methods in the literature.

Insofar as it is currently possible to ascertain, there are no unexpected or unusual conclusions to be drawn from this study. Zinc and boron deficiencies are evident in most of the materials listed, but these deficiencies also occur commonly throughout central British Columbia. Deficiencies of manganese and molybdenum were also noted. The only element occurring at toxic concentrations was boron in the fly ash. This is a common potentially toxic element in fly ash, but it has been observed that levels of boron decrease rapidly as ash surfaces are leached.

We have found this project to be both challenging and interesting, and we trust that you will find that it fulfills your requirements and expectations.

Report distributed as follows.
#1 To file
2 F.G.H.
3-10 To J. McDonald Documentation Coordinator.

Yours very truly,

S.W. Behie, Ph.D., P.Eng.
Manager Environmental Division
per:

A.E.A. Schumacher
Chief Agrologist

FILE:
THERMAL GENERATION PROJECTS DIVISION

ROUTE	INIT
DIV. / PROJ. MGR	
ADMINISTRATION	
HAT CREEK - D.P.M.	
POWERPLANT	
MINING	
PROJECT CONTROL	
SPECIAL PROJECTS	
MEAGER CREEK	
	6LT

ACTION F.G.H.

DOC'S

RETURN ORIGINAL TO CENTRAL FILES A.S.A.P.

PREFACE

This report fulfills client purchase order number 159816.

Major professional expertise in the preparation of this report has been provided by Peter R. Guy, Senior Biologist (literature review), Philip J. Burton, Senior Plant Ecologist (statistical analysis), and J. Cameron Bateman, Biologist (field sampling). Project Manager was Alexander E.A. Schumacher, Chief Agrologist. Interpretations, conclusions and recommendations were made by the project team, and are in part based on consultations with Canada Agriculture researchers.

ABSTRACT

Random samples of substrate material and grass and legume shoots were collected from reclamation trial plots and nearby rangeland at Hat Creek, British Columbia. The waste materials sampled included fly ash, baked clay, colluvium, gritstone and coal waste. On fly ash, baked clay and the Houth Meadows rangeland, separate plant samples were taken of roots, leaves and seed stalks. All samples were analyzed for their total contents of As, Be, B, Cd, Cr, Co, Cu, F, Pb, Mn, Hg, Mo, Ni, Se, Sn, U, V, Zn. The significance of concentration differences among waste materials and among different plant parts was statistically evaluated for each element.

The mean and range of element concentrations are compared to those documented from an extensive review of the literature. Particular attention is paid to the ranges of concentrations documented as normal for soils and plants, and to the critical levels at which deficiency and toxicity symptoms appear in plants and livestock which feed on such plant material. Reference was also made to local experience in known toxic levels and deficiencies of trace elements for plants and animals.

Although several elements had plant and soil concentrations outside the ranges previously reported as normal, only boron was found in levels toxic to plant growth, and only on fly ash. No elements were found to be at levels toxic to animals, but because of the copper to molybdenum ratios present, deficiencies or toxicities of these two elements may occur in cattle fed solely on vegetation from any of the waste materials (and from Houth Meadows rangeland as well). A number of materials also have deficiencies of B, Mn, Mo or Zn for proper plant or livestock growth. Rated in order of the least to greatest number and severity of toxicities and deficiencies are baked clay, coal waste, Houth Meadows topsoil, gritstone, Trench A topsoil and colluvium.

Alfalfa concentrated B, Cr, Mn, Mo and Ni more than did crested wheatgrass; conversely, crested wheatgrass accumulated Cu. B and Cd were concentrated by plants, to levels of up to ten times the total concentration found in the soil. Distribution within plants typically showed higher concentrations in the roots, while concentrations in the leaves and seed stalks are lower and are not significantly different from each other (except for boron, which tends to accumulate in inflorescences).

TABLE OF CONTENTS

PART 1

INTRODUCTION

PART 1 - INTRODUCTION

CONTENTS

1.1 BACKGROUND

The Hat Creek Thermal Project will involve the mining of coal from a large open pit mine to serve a mine-mouth thermal plant. Over 35 years of operation, 340 million tonnes of coal and 430 million cubic metres of waste will be removed from the pit. The waste materials will be stored at two disposal areas: Houth Meadows and Medicine Creek Valley. The waste dumps will be reclaimed to productive land uses, primarily agricultural forage production and wildlife habitat (British Columbia Hydro and Power Authority 1981).

B.C. Hydro has been conducting investigations into the revegetation potential of the waste materials since 1977. These investigations were initiated in order to develop and refine methods for land reclamation at Hat Creek. Assessments of plant growth in terms of biomass production, cover build-up, plant health and maintenance of species composition and soil nutrient status are summarized by Monenco Consultants Pacific Limited (1981) and Monenco Consultants Pacific Limited (1982). This report addresses another aspect of mine waste reclamation, that of potential trace element hazards.

Mineral deposits and mining wastes have higher concentrations of elements than those found in the biosphere. Many of these elements are required in small amounts by plants and animals, but high concentrations could, if sufficient, prove toxic. Different species respond differently to equal levels of elements, and the zone of concentration between deficiency and toxicity is often very narrow. Many studies have dealt with the responses of organisms to exceptionally high element concentrations, but in many cases the "normal" background concentration under which organisms appear to function normally is not known.

Determination of normal concentrations and critical levels for different plant and animal species is required before the hazard of any abnormal concentrations can be assessed.

Sampling of soils, mine waste and plants at Hat Creek for abnormal concentrations of trace elements has been a continuing part of the environmental studies conducted in conjunction with the Hat Creek Thermal Generation Development Project.

The 1978 study (B.C. Hydro 1979) found that, except for the fly ash plots, all trace element data were within the range of values normally found in natural soils. The levels of arsenic, boron, and copper were found to be higher in the fly ash, while the fluorine level was much lower. Comparative studies were done of total and extractable element assays, with acidic or multiple water extractions being performed to estimate the amount of trace elements that could potentially be available to plants. The fly ash and coal waste materials showed higher concentrations of some acid extractable elements (including arsenic, boron, copper and molybdenum) than the other soil materials. Gritstone also had higher levels of extractable elements than the other materials, which implies that it is easily weathered and that trace elements are readily released. Vegetation was collected from the colluvium, glacial gravel and fly ash test plots, and analyzed for trace elements. On the colluvium and glacial gravel plots, the concentrations of trace elements in vegetation were similar and it was decided that all were within the range normally found in the natural environment (B.C. Hydro 1979). Element levels in legumes were generally higher than those in grasses. Some elements such as arsenic, tin, and selenium were below their detection limits in both grasses and legumes. Topsoil appeared to have no major effect on trace element concentrations in vegetation growing on the colluvium plot. Only boron and molybdenum were more concentrated in the vegetation than in the waste material, while zinc and cadmium showed vegetation concentrations of about one half that found in the waste material. Trace element concentrations in vegetation grown on the fly ash plot were different from those on the colluvium and glacial gravel plots. The levels of arsenic, boron, copper, molybdenum and selenium were greater than in the vegetation on the other plots, and also greater than found in natural vegetation growing in the Hat Creek area. On the other hand, manganese levels in fly ash vegetation were considerably lower (B.C. Hydro 1979).

The 1979 sampling program was expanded to include analysis of selected radionuclide concentrations (B.C. Hydro 1980). In terms of the elements tested for in 1979 and 1981, most of the trace element levels in vegetation were similar to those found in the 1978 survey, although the levels of cadmium and mercury appeared to be significantly greater. The average concentration of cobalt in vegetation grown on the gritstone and bentonitic clay plots was six times the average concentration in vegetation from the colluvium, glacial gravel and fly ash plots, and concentrations were variable in plants growing on coal waste. Boron levels were found to be higher in legumes than in all other species at all of the Aleece Lake plots. The trace element concentrations in the Aleece Lake spoil materials and native soils were also generally similar to levels found in the 1978 survey. Concentrations of fluorine and uranium were consistently lower in 1979 than in 1978 in the colluvium, glacial gravel and fly ash plots, but showed no change in the native soils. In general, trace element concentrations in the colluvium and glacial gravel were similar to those in the native soils near the Aleece Lake plots and elsewhere in the region. Levels of arsenic were higher in all of the waste materials than in the native soils. In fly ash, the levels of boron, copper, molybdenum, and uranium were higher, while fluorine and manganese levels were lower than in the native soils (B.C. Hydro 1980). It was also found that roots of plants generally contained higher levels of trace elements than did the spikes and above ground portions; only boron tended to be concentrated in the shoots.

The 1981 trace element sampling program is a continuation of the 1978 and 1979 programs, with samples taken from the Aleece Lake and Trench A reclamation trial plots. Materials sampled include fly ash, coal waste, baked clay, gritstone, colluvium, topsoil, native soil (Houth Meadows) and plant tissue from the vegetation growing on these materials. Emphasis in 1981 was placed on the determination of variability, the compilation of critical element concentrations reported in the literature, and the determination of the probability that values could be beyond acceptable limits.

Eighteen of the 23 elements selected for study in 1978 were again analyzed in 1979 and 1981. These elements were arsenic (As) beryllium (Be), boron (B), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), lead (Pb), manganese (Mn), mercury (Hg), molybdenum (Mo), nickel (Ni), selenium (Se), tin (Sn), uranium (U), vanadium (V), and zinc (Zn).

1.2 OBJECTIVES

The objectives of the 1981 trace element assessment program are the following:

1. To review literature on trace element concentrations found in plants and soils to determine for each element:

    a) the range and mean concentrations of each element in natural soils and in agronomic plant species (particularly alfalfa and crested wheatgrass);
    b) the concentrations in plants at which toxicity symptoms appear;
    c) the concentrations in plants at which deficiency symptoms appear;
    d) the concentrations in soil which are toxic to plant health or plant growth;
    e) the concentrations in soil which represent deficiencies to plant needs for health and growth;
    f) concentrations in plants which are toxic to livestock or at which toxic levels may accumulate in animal tissue;
    g) concentrations in plants at which deficiencies may occur in livestock; and
    h) whether deficiencies or toxicities of each element can be overcome in livestock through the use of mineral diet supplements;

2. To determine the concentrations of 18 trace elements in different waste materials and in native soil at Hat Creek, and in the tissue of crested wheatgrass and alfalfa growing on these substrates:

    a) to test whether element concentrations are significantly different from those found in undisturbed rangeland soils and plants; and
    b) to determine whether elements are concentrated in the leaf, root or seed stalk portions of plants; and

3. Based on the findings of the literature review and the sampling program, to determine the frequency and likelihood of element concentrations being at levels such that plant growth or livestock health is adversely affected.

In addition, results are related to the findings of the 1978 and 1979 investigations wherever possible, in order to facilitate generalizations, to summarize the results to date and to base conclusions on a broader data base.

PART 2

METHODOLOGY

PART 2 - METHODOLOGY

CONTENTS

FIGURES

2.1 SAMPLING

211 TRACE ELEMENT CONCENTRATIONS

Soil and plant tissue samples were collected from the following reclaimed waste materials during the week of 29 June to 3 July 1981:

Fly ash	(Aleece Lake)
Coal waste	(Trench A)
Baked clay	(Trench A)
Sandstone (gritstone)	(Trench A)
Colluvium	(Trench A)
Topsoil	(Trench A)

Native soil samples were also obtained from a nearby pasture (Houth Meadows) to provide control data from a site not disturbed by excavation. These locations are shown in Figure 2-1.

Sampling locations at each site were determined by cardinal coordinates generated from a random numbers table. Four samples were taken of the soil or spoil material, and four samples were taken of plant shoots from each substrate type. Soil samples were composite samples of three subsamples collected from a 0-15 cm depth within 0.5 m of the randomly selected sample point. A minimum of two kilograms of substrate material was collected using a water-rinsed spade. Samples were placed in labelled heavy plastic bags and sent to Chemex Labs Ltd. in Vancouver for analysis.

Composite plant shoot samples were also collected from each substrate type, and were composed of three subsamples of the top two-thirds of plants within a 0.5 m radius of the randomly selected sample point. Sample locations were selected using a separate set of random number coordinates and did not correspond to the soil sampling locations. Two species were sampled when possible: crested wheatgrass (Agropyron cristatum) and drylander alfalfa (Medicago media). As the preferred species could not be found in the immediate vicinity, Kentucky bluegrass (Poa pratensis) was substituted for crested wheatgrass and yellow locoweed (Oxytropis sp.) was substituted for alfalfa on the native soil at Houth Meadows. Later in the summer, some alfalfa shoot samples were obtained from a farm in the area, and these samples were also analyzed for Cu and Mo; the results of these alfalfa analyses are included in Table 3-3 to provide some data on alfalfa growing in a commercial operation on undisturbed topsoil. All plants were clipped with water-rinsed shears and placed in labelled brown paper bags. Within two days, plant samples were taken to the Agriculture Canada Resear h Station at Kamloops, where they were dried in a forced-air oven at 100°C for 48 hours. All samples were then sent to Chemex Labs Ltd. in Vancouver for tissue analysis.

monenco consultants pacific ltd.

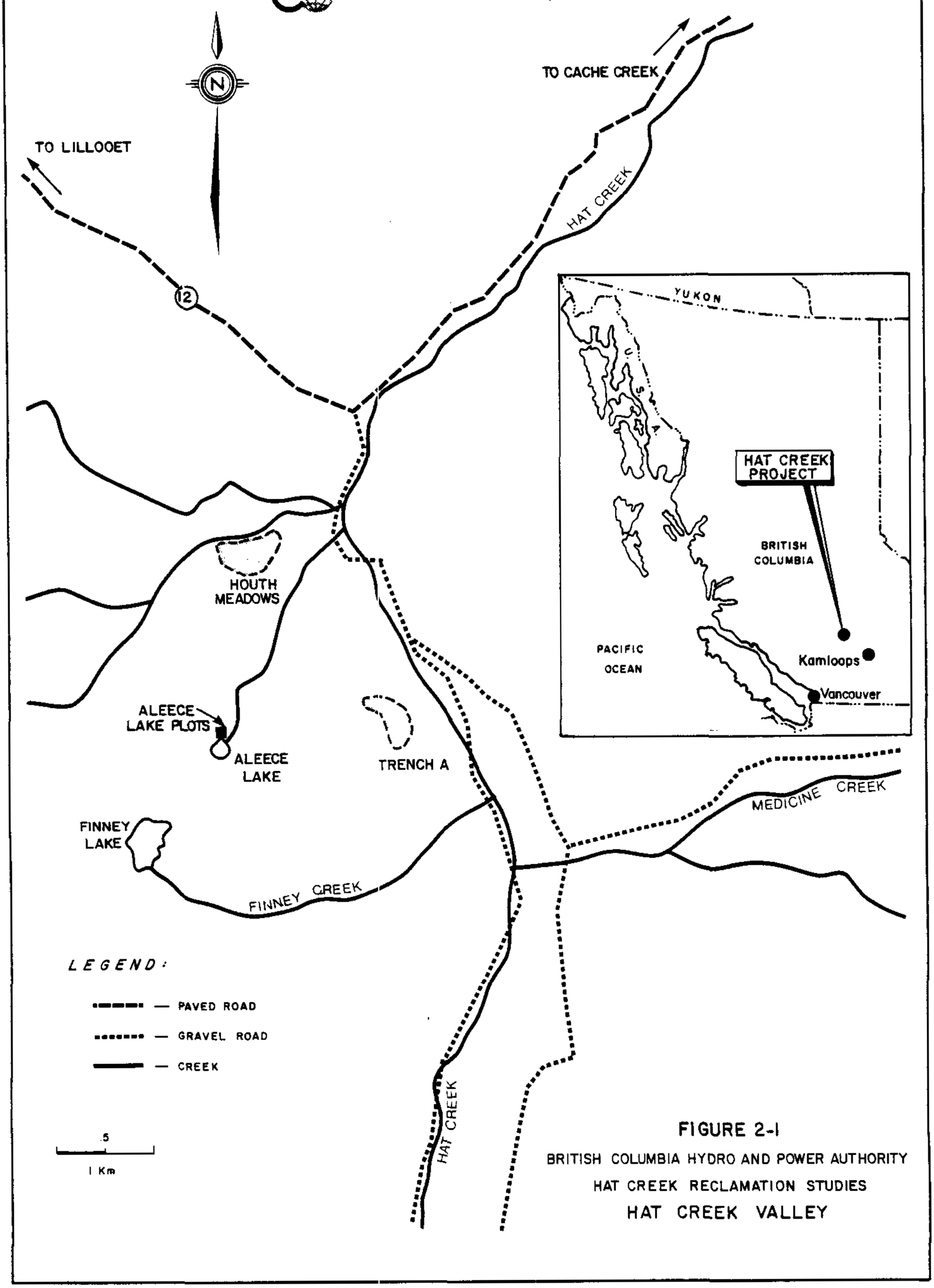

FIGURE 2-1

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK RECLAMATION STUDIES

HAT CREEK VALLEY

212 TRACE ELEMENT DISTRIBUTION

During the same week (29 June to 3 July 1981), additional samples of crested wheatgrass growing on two waste materials (fly ash and colluvium) and on native soil were sampled to determine the distribution of trace element concentrations among plant organs. Four composite samples (consisting of three subsamples each) were collected for each of the following plant parts: roots, lower leaves, and stems (seed stalks with or without flowers or seeds). Sample locations were based on a set of independently randomized coordinates for each plant part and each sample. Water-rinsed shears were used for clipping leaves and stems, and a water-rinsed spade was used to collect the root samples. Root samples were rinsed repeatedly with water until no further soil particles could be removed. Samples were kept in brown paper bags and were dried within two days of clipping in a forced-air oven at 100°C for 48 hours.

On native soil in Houth Meadows, bluegrass and locoweed samples were substituted for crested wheatgrass and alfalfa, repectively. All samples were sent to Chemex Labs Ltd. in Vancouver for analysis.

2.2 LABORATORY ANALYSIS

221 VEGETATION PROCEDURES

The plant tissue samples were dried at 45°C, weighed and milled to a minus 20 mesh size. The sample preparations and analyses were carried out by Chemex Labs Ltd., Vancouver as follows:

(i) Cd, Cu, Pb, Mn, Mo, Ni, Zn: A sample of the vegetation was wet-ashed with a combination of nitric and perchloric acids and each element was determined by direct atomic absorption using Varian AA5 or AA6 spectrophotometers. Cd, Pb, and Ni were corrected for background absorption.

(ii) As, Se: An aliquot of the above solution was reduced and both elements were analyzed as their hydrides via hot vapour flameless atomic absorption using a Varian AA6 Spectrophotometer.

(iii) Hg: Samples were digested with nitric and sulphuric acids, potassium permanganate and potassium persulphate. Mercury was reduced and analyzed via cold vapour U.V. absorption using a Jarrell Ash Spectrophotometer.

(iv) Be, Cr, Co, V: Samples were dry-ashed at 550°C, digested with nitric, perchloric and hydrofluoric acids and analyzed by direct atomic absorption.

(v) F: Samples were ashed at 550°C using sodium hydroxide as an ashing aid. The ash was fused with sodium carbonate, leached with water, buffered and analyzed for fluoride with a specific ion electrode.

(vi) Sn: Samples were ashed at 550°C, fused with ammonium iodide, leached, extracted and analyzed by atomic absorption.

(vii) B: Samples were ashed overnight at 550°C and the ash was dissolved in hydrochloric and nitric acids. Pyrex glassware (borosilicate glass) was not used. Samples were ashed in porcelain and leached in polyethylene containers. The resulting solutions were analyzed by CanTest Limited using an inductively-coupled plasma torch.

(viii) U: An aliquot of the digested solution from part (iv) was extracted with acid-deficient aluminum nitrate and other reagents into an organic solvent. The solvent was removed by evaporation and the residue fused with sodium carbonate and sodium fluoride. The uranium content of this melt was then determined fluorimetrically.

All reported values represent best estimates of total concentrations for each element, as opposed to soluble concentrations.

222 SOIL PROCEDURES

The soil samples were analyzed for the 18 elements by Chemex Labs Ltd., Vancouver. The samples were dried at 45°C and pulverized in a ring grinder to approximately minus 200 mesh.

Analytical methods used for the soil analyses were as follows:

(i) Cd, Cu, Pb, Mn, Mo, Zn: Samples were digested with a combination of nitric and perchloric acids and each metal was determined by direct atomic absorption using a Varian 275 Spectrophotometer. Cd, Pb and Ni were corrected for background absorption.

(ii) As, Se: An aliquot from the digested solution in (i) was reduced and both elements were analyzed as their hydrides via hot vapour flameless atomic absorption using a Varian AA6 Spectrophotometer.

(iii) Hg: Samples were digested with nitric and hydrochloric acids. Mercury was then reduced and analyzed via cold vapour atomic absorption using a Varian AA5 Spectrophotometer.

(iv) Be, Cr, Co, V: Samples were digested with nitric, perchloric and hydrofluoric acids and analyzed by direct atomic absorption.

(v) F: Samples were fused with sodium carbonate, leached with water, buffered and analyzed for fluoride with a specific ion electrode.

(vi) Sn: Samples were fused with ammonium iodide, leached, extracted and analyzed by atomic absorption.

(vii) B: Samples were leached in hydrochloric and nitric acids and the resulting solutions were analyzed by CanTest Limited using inductively-coupled plasma emission spectroscopy.

(viii) U: An aliquot of the digested solution from (iv) was extracted with acid-deficient aluminum nitrate and other reagents into an organic solvent. The solvent was removed by evaporation and the residue fused with sodium carbonate and sodium fluoride. The uranium content of this melt was then determined fluorimetrically.

Reported concentrations represent best estimates of the total levels of each element tested, and do not refer to soluble or plant extractable concentrations.

2.3 DATA ANALYSIS

The purpose of the random sampling procedure was to determine a statistically valid mean concentration with 95% confidence limits for each of the 18 elements in the soil and plant samples submitted for analysis. Many concentrations were reported as "less than" a particular value, representing levels below the quantitative detection limits of the methods employed. For the purposes of calculating averages, these values were converted to 70% of their stated upper possible value, a procedure commonly employed for the quantitative comparison of analytical results (Severson and Gough 1981). The mean values, each representing four composite observations or analyses, were compared with the critical values of concentration of these elements as determined from the literature search. Ratings for likelihood of normal, deficient and toxic levels of elements were developed by comparing means and confidence limits with the means and ranges reported in the literature. Based on a summation of the semi-quantitative ratings for each element, the relative hazards of the different materials are summarized.

Further statistical analyses were carried out through the use of procedures in the Statistical Analysis System (S.A.S.) package (S.A.S. Institute 1979). An analysis of variance was conducted for each element, to determine if the variability in element concentrations within each substrate material was less than the variability among different substrate types. If the different substrates accounted for most of the variability, a Duncan's Multiple Range test (Duncan 1955) was performed to evaluate which materials were significantly different from each other.

An analysis of variance due to plant part was done for each element on crested wheatgrass and alfalfa data from the fly ash, baked clay and Houth Meadows substrates. Duncan's Multiple Range tests were then done to determine if concentrations of an element in the roots, leaves or seed stalks were significantly different. Soil samples were not included as part of the accumulation pathway analysis, because soil concentrations for almost all elements were very high relative to those found in plant tissue (since they represent total concentrations, not that which is available to plants).

Paired t-tests were used to determine the significance of differences in element concentrations between crested wheatgrass and alfalfa across all substrate types.

The ratio of average shoot concentrations and average soil concentrations was calculated for each element for each species growing on each substrate. This ratio (expressed as a percentage) represents the degree of element accumulation exhibited by the two different species when growing on different waste materials. Further quantitative analyses of trace element distribution and accumulation in the plant soil system were not undertaken because of the low sample numbers and the uncontrolled nature of sample collection.

PART 3

RESULTS

PART 3 - RESULTS

CONTENTS

TABLES

3.1 LITERATURE REVIEW

Various sources were consulted in order to determine "normal" concentrations of the 18 trace elements in soils, and in alfalfa and crested wheatgrass. Most of the information was gathered from review articles of a general nature (Aubert and Pinta 1977, Bidwell 1974, Bollard and Butler 1966, Buckman and Brady 1969, Chapman 1967, Heit 1977, Jones 1967, Lisk 1972, Sauchelli 1969, Swaine 1955, Underwood 1971), although data from carefully controlled, detailed studies were also used (Brown 1976, Loneragan 1980, Romney and Childress 1963). Data specific to alfalfa and agronomic grasses are scarce, particularly with reference to the grasses. Large amounts of information on the more toxic elements such as cadmium, lead, mercury and selenium are available but were not found to be of direct value because they generally deal with atypical situations such as those close to industrial facilities and areas with anomalously high concentrations of a particular element (Mankovska 1981). Because there is no standardization of sampling techniques, it is difficult to evaluate the figures from different sources relative to one another. In addition, not only do plant species respond differently to similar concentrations of trace elements in the soils, but differences in tolerances within a species also occur, further confounding the situation (Jones 1967). Davison, Blakemore and Craggs (1979) have shown that the fluoride content of forage varies during the year, and more significantly, that on several occasions there were significant differenes in the fluoride content of their samples from day to day. Their conclusion is that if this daily change is a common occurrence, a single sample does not provide a very good measure of the fluoride content of a grass sward over long periods and although they do not allude to it in their paper, the next step is to question the value of a single measure for any element as all elements may fluctuate in a similar way. Thus, much of the data in the literature is of little value because very often no information is given as to the parts analyzed, the age of the parts, the stage of maturity of the plant, the analytical procedures used, or any other specifics. Consequently, data of this nature were not used in this analysis.

The data on the toxic or deficient levels of the elements cannot be viewed with a great deal of definity because the interactions between the elements and the influence of different elements on the different physiological functions and activities are not known in sufficient detail. Interactions such as those between manganese and iron, copper, zinc and iron, zinc and cadmium, and arsenic and selenium, have been shown to be very important, so much so that studies of the individual elements may give misleading results unless the quantitative relationships between the interacting elements are known and considered (Underwood 1971). In addition most deficiencies of, for example, copper, iron, manganese, molybdenum and zinc in plants do not result from a lack of these elements in the soil, but result from an inability of the plant to utilize the element that is present i.e. total element concentrations do not equal plant available element concentration (Hodgson 1970).

The values given in Table 3-1 must be viewed as being a rough guide to the normal concentrations found in soils, alfalfa and crested wheatgrass. In some cases, because of the wide ranges and the number of different mean values given in the literature for the same element, general plant values are given. These data naturally do not include plants that can tolerate exceptionally high or low concentrations of certain elements. Specific references are made in the table to alfalfa (*) and crested wheatgrass(**). Caution must be exercised in the interpretation of these data and in the comparison of the sample data with those given in the literature.

The soil mean concentrations must also be viewed with caution since concentrations of the elements in "normal" soils are seldom given. Most soils have "above normal" and "below normal" concentrations of one or more elements. In general, however, some standard can be adopted since most soils have consistently high or low levels of particular elements e.g. manganese and molybdenum (Chapman 1973). Other elements are present in comparatively high quantities but, as a result of complexing with the soil components, their availability to plants is extremely low. In addition, soil pH, the presence of other solutes, and the soil redox conditions may also affect their solubility or the ability of the plant to absorb them. Plant deficiencies thus frequently occur despite high total soil quantities (Antonovics _et al_. 1971). Frequently investigators give their own interpretation of "plant-available" concentrations rather than total concentrations of the elements, making comparison of the values in different soils as plant growth media impossible. Similarly, although extractable (generally taken to be plant available) concentrations of elements are given, the method of extraction is not described and because different methods of extraction give different results, comparison of published values is difficult.

It must also be remembered that the threshold values that will result in toxicity or deficiency symptoms in plants are measures of "plant available" concentrations of the different elements. These values cannot be compared directly to total concentration of the element in the soil because the availability of the different elements depends on a myriad of factors, as discussed above. Most of the figures given in Table 3-1 have been derived in laboratory experiments in which plants are grown in nutrient solutions and therefore all of the element under study is available to the plant. There is no constant factor that can be used to calculate plant available concentrations of an element from the total concentration of the element. Each case will be different.

The figures given in the columns relating to quantities of trace elements affecting livestock should also be regarded as guides only, because the relationships between trace element concentrations and livestock are, among other factors, influenced by the amount of trace

TABLE 3-1

Results of the Literature Search: Natural Ranges and Hazardous Concentrations of 18 Trace Elements

Element	Mean and range in i) plants and ii) soils (total) under natural conditions	Lower limit of concentration in plants before toxic symptoms occur	Upper limit of concentration in plants before deficiency symptoms occur	Lower limit of concentration in soil before plant growth is affected (available)	Upper limit of concentration in soil before plant growth is affected (available)	Lower limit of concentration in plants at which toxic levels accumulate in livestock	Upper limit of concentration in plants at which deficiencies occur in livestock	Notes
Arsenic	i) 1[27] * 0.2[20] 0.05[12] * ii) 6; 0.1-40[20,22,28,45] 0.3 - 38[27] 6.1[41] 5; 1 - 50[42] 7.2; 0.1 - 55[32]	>2[32]	Not proved essential for plant growth	>2[27] * >2[20]	Not proved essential for plant growth	>1[27]*	Not proved essential to mammals[39] 0.01[45]	Plants generally have an arsenic content lower than the soils in which they grow[27] Arsenic may act as a selenium antagonist in animals[45] Alfalfa has little tolerance to arsenic[32]
Beryllium	i) 0.1[20,21] ii) 6[42]; 0.1 - 40[20] 0.6[41]	>2[37]	Not proved essential for plant growth		Not proved essential for plant growth		Not proved essential to mammals[40]	
Boron	i) 20 - 100[24] * 15[5] 25 - 100[6] 53[22] 25 - 40[38] 20[12] ii) 10[22]; 5 - 159[9] 20 - 50[1] 22[41] 10; 2 - 100[42]	>100[24,44]* >200[29] >250[7a] >200[6]	<20[8,24,44] <10[29] <15[6]	>30[20]	<0.5[6]		Not proved essential to mammals[20,40] 0.15[45]	Uptake of boron by plants is very closely linked to the concentration of many other ions[6] The range between the upper and lower limits is very narrow for boron useful to plants. Contents range from values of 0.1-0.2 to 1.5 (hot water extractable) and vary in relation to plant variety. Hot water extractable boron generally represents 1-3% of total boron, but may be much more[1].
Cadmium	i) 0.64[22] 0.6[33] 0.06[20] 350 ii) 0.06[20,22,28] 0.01 - 0.7[20] 0.01 - 0.3[35] 0.18[42] 0.1 - 0.3[33]	>c.100[33]	Not proved essential for plant growth	10 - 20[20] >13[33]	Not proved essential for plant growth	>2560[45] (cattle)	Not proved essential to mammals[40]	Cadmium metabolism is very closely linked to zinc metabolism. It is also linked to copper and iron metabolism[45] Cadmium is very mobile in soil and moves readily downwards, so concentrations tend to increase with depth [50].
Chromium	i) c.0.4[11] 1[28] 0.1 - 0.5[45] 0.23[20] ii) 20 - 125[31a] 200; 5 - 1000[42] 100[22,28] 40[20]; 7 - 300[20] 100 - 300[1] 88[41]		Not proved essential for plant growth	.. 15[36] 1-5[31a]	Not proved essential for plant growth	50[45] hexavalent 65000 trivalent	0.01[45]	Trivalent chromium is postulated as being essential to mammals for glucose metabolism[20,40,45] Hexavalent chromium is very mobile in soil and trivalent chromium is thus less available to plants. Total soil chromium content is a poor measure of chromium availability to plants[31a]
Cobalt	i) 0.05 - 0.25[20] 0.2; 0.02 - 0.3[12] 0.84[22] ii) 10 - 15[1] 1.4[20] 1 - 50[9] 8[22,41] 40; 1 - 40[42]			0.1[20,46] (excesses are unlikely to occur	0.02[1]	200[45] (sheep) c.150[45] (cattle)	0.03 - 0.07[45] 0.08[16] 0.11[45] (sheep)	Required by legumes in the symbiotic fixation of nitrogen. Important in the diet of ruminants. A constituent of vitamin B_{12}[46]
Copper	i) 5 - 50[24,44] 10[37a,40] 5 - 16[12] 6[5] 9.3[22] 2.1[3] ** 14[20] 3.7[49] ** 10.8[49] * ii) 20[20,22]; 2 - 100[20] 20; 15-40[1] 5 - 150[9] 0.3 - 10[35] 70; 2 - 100[41] 10; 1.6 - 32[48] (Canada) 21[40]	50[24,29,44]* 20[30]	5[24] * 6[44] * 3[29]	25[1] 30[20]	0.5 - 3[1]	100[45] (cattle) 80[45] (sheep)	4[45] (cattle) 5[26] 2.5[19] 6[16] 6[45] (sheep)	Alfalfa is very resistive to copper levels in the soil[37a] Copper metabolism is very closely linked to that of molybdenum[45] Copper deficiencies are rarely encountered in alfalfa[29]
Fluorine	i) 6[22] 2 - 20[7] 0.1 - 10[4] 3 - 9[12] ii) 200[22] 10 - 1000[4]		Not proved essential for plant growth	7[20]	Not proved essential for plant growth	50[26] 40[45] (cattle) c.50[7]	c.0.5[45]	Fluorine uptake is only remotely related to soil fluoride content[45]

TABLE 3-1 (Cont'd)

Element	Mean and range in I) plants and II) soils (total) under natural conditions	Lower limit of concentration in plants before toxic symptoms occur	Upper limit of concentration in plants before deficiency symptoms occur	Lower limit of concentration in soil before plant growth is affected (available)	Upper limit of concentration in soil before plant plant growth is affected (available)	Lower limit of concentration in plants at which toxic levels accumulate in livestock	Upper limit of concentration in plants at which deficiencies occur in livestock	Notes
Lead	I) 0.3 - 1.5[34] 2.7[20] 4.5[22] 1[28] 2; 0.05 - 5[13] 5[12] 2[10] II) 16[30,34] 3; 2 - 10[48] (Canada) 30[20]; 2 - 200[20,34] 10[22] 16; 2 - 200[42] 0.1 - 4[35] 15 - 25[1] 18[41]		Not proved essential for plant growth	20 - 200[14] >30[20]	Not proved essential for plant growth	>3[45] (sheep) >250[34] (cattle)	Not proved essential to mammals[45]	Lead content of aerial parts of plants increases from spring to winter indicating translocation from the roots where the lead concentration is the greatest[34] With high lead concentrations the lead content decreases with depth[30]
Manganese	I) 20 - 500[25] 30 - 250[30] ** 56[22] 30-100[24] 29.2[4] ** 15[12] 32[49] ** 27[49] * II) 850; 100 - 4000[20,22] 500 - 1000[1] 389[41] 600; 200 - 3000[25] 1000; 200 - 3000[42]	>1000[25] >250[29] *	<20[24] <15[25] <10[36] * <30[30] ** <15[29] *	>c.500[25] >500[30]	<20[25]	>2000[45] (cattle)	<70[43] <30[16] <c10[45] <20[13a]	Manganese and iron metabolism is closely linked[45] Alfalfa is sensitive to high manganese levels[25]
Mercury	I) 0.01 - 0.2[30] 0.015[20,28] 0.07[31] * 0.005 - 0.035[22] II) 0.5[42] 0.3; 0.01 - 0.8[20] 0.3[28] 0.1 - 0.3[30,45] 0.055[41]		Not proved essential for plant		Not proved essential for plant	>0.18[45]	Not proved essential to mammals[39]	Mercury is associated with the absorption and transport of copper, zinc and cadmium[45] Mercury content in soil varies considerably with soil depth[14]
Molybdenum	I) 0.4 - 2[12] 0.2[5] 0.9[20] 1 - 5[44] * 0.5[11] 0.5 - 10[24] 1.13[22] 2.4[3] ** 0.6[49] ** 2.5[49] * II) 2[20,22]; 0.2 - 5[9,20] 0.2 - 10[30] 1.5; trace -20[1] 0.5 - 3.5[38] 2.3; 0.2 - 5[42]	>10[24,44] * Not known[24a] >1000[29]	<0.4[24] * <0.1[30] <0.5[29] *		<0.3[1] <0.1[23]	>15[24a] >5[23] >20[2,30] >100[26] >15 - 20[38] >5[38] 5 - 10[20] (cattle) >5[16a]	<0.1[23] <1[16]	Copper, sulphate and molybdenum requirements are closely related (at least 5 ppm Mo required in the ratio Cu:Mo of perferably 6:1)[16a] Molybdenum toxicities are very rarely noted in the field[23] and are associated with sulphur availability[29]
Nickel	I) 0.1 - 5[38] 1[47] 1.8[22] 2[12,28] 3[20] 0.5 - 3.5[45] II) 40[20,22,28]; 10 - 1000[20] 3 - 70[47] Trace - 500[1] 16[41] 100; 5 - 500[42]		Not proved essential for plant growth	>c.2[47] >50[20]	Not proved essential for plant growth	>1000[45]	<0.04[45]	Generally well distributed in the soil profile[30]
Selenium	I) 0.2[20,28] 0.05 - 0.45[40] 0.04[44a] II) 0.2[28]; 0.01 - 2[20] 0.8[32] 0.9; 0.1 - 2[42]	5[28]		>c.500[18]		>5[30] >5[1] >4[20,28]	<0.03[1] 0.04 - 2[20] <0.05[16]	Selenuim is involved in vitamin E metabolism[35]
Tin	I) 0.9[28] 0.3 - 0.4[45] 0.3[20] II) 10[20,28]; 2 - 200[20] 10[42]		Not proved essential for plant growth		Not proved essential for plant growth	5[45]	Not proved essential to mammals[39]	

TABLE 3-1 (Cont'd)

Element	Mean and range in i) plants and ii) soils (total) under natural conditions	Lower limit of concentration in plants before toxic symptoms occur	Upper limit of concentration in plants before deficiency symptoms occur	Lower limit of concentration in soil before plant growth is affected (available)	Upper limit of concentration in soil before plant growth is affected (available)	Lower limit of concentration in plants at which toxic levels accumulate in livestock	Upper limit of concentration in plants at which deficiencies occur in livestock	Notes
Uranium	i) 0.06[17] ii) c.2[41a] 4[42]		Not proved essential for plant growth		Not proved essential for plant growth		Not proved essential to mammals[39]	
Vanadium	i) 1.6[20] 1.7[34a] 0.8[28] 0.03 - 0.07[45] ii) 100[20, 22, 28]; 20 - 500[20] 100[34a] 100; trace - 300[1] 66[41] 20 - 500[42]		Not proved essential for plant	5 (in sand)[34a] 10 (in soil)[34a] > 2.5[20]	Not proved essential for plant	> c.25[45]	< 0.1[34a] (rats) < 2 mg/day[45]	One of the most abundant elements[45]
Zinc	i) 10 - 100[24] * 20 - 50[12] 35[40] 100[20] 32[22] 9 - 14[38] 15 - 60[38] 21 - 70[44] * 10[5] 13[3]** 18[49]** 38[49]* ii) 75; 35 - 300[48] (Canada) 50[20,22]; 10 - 300[20,22,30] 2 - 30[35] 50; trace - 900[1] 51[41] 80; 10 - 300[42]	100[24,44] * 400[24a] 100[29] *	< 10[44] * < 20[20,30] < 0 - 8[38] < 11[29] *	100[1] > 400[20]	< 15[12]	Generally considered non-toxic to animals[38] > c.1000[45]	20 - 40[38] < 40[19] < 20[16, 45] < 30[13a]	Zinc metabolism is related to copper, cadmium and iron metabolism[45] Zinc deficiencies are rarely encountered in alfalfa[29]

1. Aubert and Pinta 1977
2. Bidwell 1974
3. Bilncoe and Lambert 1972
4. Bollard and Butler 1966
5. Bomke 1980
6. Bradford 1973
7. Brewer 1973
8. Brown 1976
9. Buckman and Brady 1969
10. Cannon 1976
11. Cannon 1970
12. Chapman 1967
13. Chmiel and Harrison 1981
13a. Church et al. 1971
14. Dudas and Pawluk 1976 1978
16. Egan 1975
16a. Erdman et al. 1978
17. Erdman and Ebens 1979
18. Ganje 1973
19. Havre 1970
20. Heit 1977
21. Hemphill 1970
22. Hodgson 1970
23. Johnson 1973
24. Jones 1967
24a. Jones 1979
25. Labanauskas 1973
26. Lee 1975
27. Liebig 1973
28. Lisk 1972
29. Martin and Matocha 1973
30. Mortvedt, Giordiano and Liebig 1977
31. National Research Council Canada 1979a
31a. National Research Council Canada 1976
32. National Research Council Canada 1978
33. National Research Council Canada 1979c
34. National Research Council Canada 1973
34a. National Research Council Canada 1980
35. Parry et al. 1981
36. Pratt 1973a
37. Romney and Childress 1965
37a. Reuther and Labanauskas 1973
38. Sauchelli 1969
39. Schwarz 1974
40. Scott 1977
41. Severson 1979
41a. Severson and Tidball 1979
42. Swaine 1955
43. Thornton and Webb 1970
44. Trierweiler 1981
45. Underwood 1971
46. Vanselow 1967
47. Vanselow 1967a
48. Warren et al. 1970
49. Munshower and Neuman 1979
50. Taylor and Griffin 1981

* Alfalfa
** Crested Wheatgrass
c. = approximately

elements in soils ingested at the same time as the herbage (Healy 1974). In vitro studies show that soil ingestion can substantially alter the element composition of digestive fluids, and that this effect varies with soil type. Annual intakes of soil can be large, although they are probably less than 2% of the fresh herbage consumed. However, the ingested soil may supply more of various elements than the herbage. In addition, mild trace element toxicities and deficiencies in animals are difficult to diagnose because their effects are masked by those caused by a primary dietary deficit (of vitamins or other minerals) and they are seldom manifested by specific clinical signs. It is therefore difficult, if not impossible, to determine a series of "safe" dietary levels of potentially toxic trace elements, because other elements which affect their retention and absorption are also present. These considerations apply to all the trace elements in varying degrees, but are more important to some elements than others. For example, a particular intake of copper can lead to signs of copper toxicity or copper deficiency, depending on the relative intakes of molybdenum, inorganic sulphate, zinc and iron (Underwood 1971). Most trace element deficiencies or excesses result in loss of appetite and subnormal growth. The extent to which these take place and take precedence over other symptoms of the dietary abnormality varies with the trace element concerned. Trace element deficiencies in livestock are usually easier to control than toxicities, especially under natural grazing conditions (Underwood 1971).

The "normal" values and designated deficiency and toxicity levels for trace element concentrations given in the summary table (Table 3-2) were obtained by averaging the individual values given by various authors in Table 3-1. When a range of values was given, the mean of the upper and lower limits was taken as the mean value, on the assumption that the values are normally distributed between the two extremes. This method was used in the absence of any convenient method of obtaining a single value from a set of figures giving means and ranges, and takes into account some of the variability in the literature. Single "less than" or "more than" values were regarded as being unsuitable for identifying the normal range and were rejected. Single values, in the absence of any other data, were taken as being definitive. It is not possible to put confidence limits on the mean values obtained in this way because of their method of derivation. All values reported in the tables represent total concentrations except where soil element concentrations resulting in toxicity or deficiency symptoms in plants are reported, in this case they are noted as "available", because of the very large differences that frequently occur between the total amount found in the soil and the amount actually available to the plants.

The ranges to be expected of "normal" concentrations, as summarized in Table 3-2, have likewise been derived from the values given in Table 3-1. They must not be considered absolute figures since the

TABLE 3-2

Summary of "Normal" Mean and Ranges In Trace Element Concentrations (Total) In Plants and Soils and of Trace Element Levels Causing Toxicity or Deficiency Symptoms In Plants and Mammals, ppm

Parameter	As	Be	B	Cd	Cr	Co	Cu	F	Pb	Mn	Hg	Mo	Ni	Se	Sn	U	V	Zn
Mean value (plants)	0.4	0.1	45	0.4	0.3	0.3	11	7	2.3	110	0.03	1.8	2.3	0.2	0.4	0.06	1	40
Range (plants)	< 1	0.1	20-100	0.1-0.6	0.1-0.5	0.02-0.5	5-30	2-15	0.1-5	30-250	0.01-0.05	0.4-5	0.1-5	0.05-0.45	0.2-0.5	0.06	0.05-2	10-100
Mean value (soils)	6	3.3	15	0.1	100	16	30	200	15	700	0.3	2	50	0.6	10	3	125	50
Range (soils)	0.25-45	0.1-40	10-100	0.04-0.4	30-400	4-75	4-70	10-1000	4-70	200-3000	0.07-0.5	0.2-8	5-500	0.05-2	2-200	ND	15-450	15-350
Plant toxicity level (plant content)	> 2	> 2	120	100	3	ND	40	ND	ND	250	ND	500	ND	5	ND	ND	ND	400
Plant deficiency level (plant content)	NE	NE	20	NE	NE	ND	4	NE	NE	15	NE	0.3	NE	ND	NE	NE	NE	10
Plant toxicity level (soil content) (available)	> 2	ND	> 30	14	9	0.1	27	7	125	500	ND	ND	25	500	ND	ND	6	250
Plant deficiency level (soil content) (available)	NE	NE	0.5	NE	NE	0.02	1.7	NE	NE	20	NE	0.2	NE	ND	NE	NE	NE	15
Livestock toxicity level	13	ND	ND	2000	50^{6+} 65000^{3+}	200	100	50	250	2000	0.18	10	1000	5	5	ND	25	1000
Livestock deficiency level	0.01	NE	NE	NE	0.01	0.08	5	0.5	NE	30	NE	0.5	0.04	0.04	NE	NE	0.1	30

ND - No data given in the literature.
NE - Not yet proved essential to plants or livestock.

ranges will vary from soil to soil, with the species, the part and stage of maturity of the plant being analyzed, and the analytical method. Although this method may be inexact, the data are offered as a guide against which the values obtained from the samples at Hat Creek can be compared.

The levels found by analysis of the vegetation growing on the different substrates at Hat Creek have been evaluated on the basis of the mean levels and normal ranges found from the literature review. The results of this comparison are given in Part 4.

3.2 1981 HAT CREEK SAMPLING RESULTS

Tables 3-3, 3-4 and 3-5 show the concentratrations of the eighteen elements analysed for in alfalfa, crested wheatgrass and waste material, respectively, for 1978, 1979 and 1981. All 1981 values are expressed with a 95% confidence interval, where upon repeated sampling, the mean concentration of that element would probably fall within the expressed interval 95% of the time. Values expressed with an approximately sign (≃) have been averaged using one or two figures which were below the detection level, so should only be taken as a best estimate.

It is of interest to note that concentrations of elements in waste materials fluctuate from year to year. Chromium concentrations for example have decreased in all substrates since 1978. This may be due to sampling error or actual leaching of this element through the soil profile. Vanadium concentrations are also noted as decreasing on fly ash, coal waste and colluvium.

Levels of arsenic, boron, cobalt, copper, lead, molybdenum, nickel and vanadium are higher in all waste materials than in the native soil at Houth Meadows, whereas manganese concentrations are lower in fly ash and coal waste than in the native soil sampled at Houth Meadows.

Table 3-6 is the result of the analyses of variance and Duncan's Multiple Range tests used to determine significant differences in trace element concentrations among the substrate materials. The concentration of each element is compared among all substrates and the natural soil. Consistent similarities among any two substrates do not exist for all 18 elements. Tin, selenium and cadmium concentrations are not significantly different among any of the seven materials tested.

TABLE 3-3

Alfalfa Shoot Trace Element Concentrations, ppm

Element	Fly Ash				Coal Waste			Baked Clay	Gritstone			Colluvium				Topsoil		Houth Meadows
	1978*	1979*	1981	Average	1979	1981	Average	1981	1979	1981	Average	1978	1979	1981	Average	1981	1981 (Farm Field)	1981 (*Oxytropis* sp.)
Arsenic	3	1.5	x	2.3	0.5	< 1	0.6	<1	0.5	< 1	0.51	1	0.5	<1	0.6	<1	-	< 1
Beryllium	-	-	x	-	0.02	< 0.04	0.03	0.04	0.04	0.04±0.04	0.04	-	0.05	0.04	< 0.04	0.03±0.01	-	< 0.04
Boron	-	-	x	-	98	48.0±2.0	73	56.0±48.0	93	42.0±9.0	68	-	56	56±12.8	56	50.0±5.2	-	32±8
Cadmium	< 0.2	0.1	x	≃0.12	0.8	0.22±0.16	0.5	0.04±0.03	0.8	0.23±0.05	0.5	0.1	0.7	0.24±0.08	0.3	0.13±0.08	-	0.18±0.10
Chromium	-	-	x	-	1.2	0.7±0.3	0.9	0.9±0.3	2.2	0.9±0.6	1.6	-	0.8	1.5±0.6	1.2	1.1±0.3	-	1.4±0.8
Cobalt	-	-	x	-	0.72	1.5±1.0	1	0.2±0.2	0.39	0.4±0.4	0.4	-	0.04	0.3±0.2	0.17	0.1±0.1	-	0.2±0.2
Copper	16	21	x	19	17	8.2±2.0	13	7.6±1.9	16	8.1±3.1	12	5	13	9.6±2.1	9.2	9.6±2.0	11±3.4	9.6±4.0
Fluorine	-	-	x	-	1.4	3±2	2	4±3	2.5	7±5	4.9	-	1.4	6±4	3.6	1±0	-	5±2
Lead	< 2	2	x	≃ 1.7	2	1.4±0.4	2	0.5±0.2	4	1.7±1.2	2.9	1	2	1.2±0.4	1.3	0.7±0.4	-	0.5±0.5
Manganese	25	65	x	45	153	148±48	150	57±8	80	107±18	94	110	48	64±21	74	39±11	-	63±36
Mercury	-	-	x	-	0.080	0.033±0.008	0.0565	0.012±0.009	0.105	0.024±0.021	0.063	0.03	0.105	0.012±0.010	0.049	0.049±0.026	-	0.093±0.065
Molybdenum	22	14	x	18	1	1.4±0.7	1	4.2±0.9	5	3.2±1.4	4.1	4	4	9.5±3.3	5.8	3.3±1.7	9.0±9.8	3.6±1.7
Nickle	3	2	x	2.5	2	4.2±2.1	2	1.0±0.4	2	2.3±2.6	2.2	1	2	1.3±0.3	1.4	1.2±1.1	-	1.8±1.3
Selenium	0.2	0.2	x	0.2	< 0.2	< 1	< 1	< 1	0.3	< 1	0.5	0.2	0.2	1	0.3	1	-	1
Tin	-	-	x	-	< 1	≃ 0.8±0.2	< 1	< 1	< 1	< 1	<1	-	< 1	≃ 0.7±0.2	0.7	≃ 0.9±0.3	-	≃ 0.9±0.3
Uranium	-	-	x	-	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	≃ 0.08±0.02	≃0.08	-	0.1	< 0.1	0.1	< 0.1	-	< 0.1
Vanadium	-	-	x	-	1.2	1±0	1	1±0	2.2	1±0	2	-	1.2	1.0±0	1.1	1.0±0	-	1.3±0.8
Zinc	30	50	x	40	54	36.2±15.1	45	16±2	107	17±3.4	62	36	1.8	19.0±5.4	24	17.2±8.3	-	18.4±8.3

* 1978 and 1979 values from B.C. Hydro (1979, 1980)

x Insufficient material for analysis

** for purposes of averaging "less than" values (<) are taken as being 70% of the stated upper limit

TABLE 3-4

Crested Wheatgrass Shoot Trace Element Concentrations, ppm

	Fly Ash				Coal Waste			Baked Clay	Gritstone			Colluvium				Topsoil	Houth Meadows
Element	1978*	1979*	1981	Average	1979	1981	Average	1981	1979	1981	Average	1978	1979	1981	Average	1981	1981
Arsenic	1	2.0	< 1	1.2	0.5	< 1	0.6	< 1	0.5	< 1	0.6	1	0.5	< 1	0.63	< 1	1.0±1
Beryllium	0.02	0.04	< 0.04	0.03	0.01	< 0.04	0.02	< 0.04	0.02	< 0.04	0.03	0.1	0.02	< 0.04	0.049	0.02±0.00	< 0.04
Boron	488	372	211.5±59.9	357.2	21	18.7±5.1	19.8	66.3±92.4	25	16.4±12.7	20.7	-	19	7.2±5	13.1	13.3±17.3	11.1±9.6
Cadmium	< 0.1	1.0	0.25±0.05	0.64	0.5	0.25±0.10	0.4	0.14±0.05	0.6	0.27±0.11	0.44	0.1	0.6	0.22±0.06	0.45	0.36±0.14	0.30±0.14
Chromium	-	2.5	0.7±0.6	1.6	0.9	0.4±0.0	0.65	0.4±0.0	2.5	0.5±0.3	1.5	2.5	0.8	0.9±1.2	1.4	0.4±0.0	0.5±0.3
Cobalt	0.24	0.28	0.1±0.1	0.2	0.11	0.4±0.4	0.3	0.2±0.2	0.40	0.3±0.2	0.35	0.04	0.05	0.2±0.2	0.09	0.1±0.1	0.15±0.16
Copper	8.5	23	12.2±3.6	14.6	10	12.5±2.7	11	14.2±2.5	15	11.3±5.0	13.15	4.5	9	11.9±2.3	8.5	10.0±3.6	11.8±4.2
Fluorine	< 10	1.2	4±1	4	2.4	1±1	2	2±0	3.8	4±2	3.9	< 10	1.9	1±0	2.6	4.8±1.5	5.0±2.2
Lead	< 1	3	1.4±0.5	2	2	0.8±0.7	1.4	1.1±0.4	1	2.0±1.5	1.5	1	1	1.7±0.8	1.23	1.6±0.5	0.5±0.6
Manganese	19	28	15±12	21	95	51±14	73	28±4	70	58±8	64	52	63	26±11	47	25±4	48±30
Mercury	0.02	.115	.029±.04	0.05	.075	.033±.008	0.054	.036±.024	.095	.016±.008	0.06	0.01	.065	.033±.017	21.7	.029±.024	.022±.027
Molybdenum	9	11	4.6±1.3	8.2	1	0.3±0.3	0.5	2.2±0.2	4	0.3±0.2	2.15	< 1	1	0.2±0.1	0.63	0.6±0.7	0.7±0.8
Nickel	< 1	1	.4±0.5	0.7	1	0.7±1.1	0.85	0.3±0.4	2	0.3±0.4	1.15	< 1	< 1	0.1±0.0	0.5	0.1±0.0	1.1±0.7
Selenium	0.35	0.4	1	0.5	< 0.2	< 1	0.42	< 1	0.8	1	0.75	< 0.2	< 0.2	< 1	0.3	< 1	< 1
Tin	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0.9±.3	< 1	0.8	0.75	< 1	< 1	< 1	< 1	0.08±0.02	< 1
Uranium	-	< 0.1	0.8	0.45	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.08	< 0.1	-	< 0.1	< 0.1	< 0.1	0.08	< 1
Vanadium	3.0	6.2	1±1	3.4	1.4	1±0	1.2	2±1	2.4	1±0	1.7	0.5	1.0	1±0	0.8	1±0	1±0
Zinc	17	19	18.8±9.3	18.3	40	25.7±14.4	32.8	10.9±4.5	87	24.5±9.8	55.75	36	15	14.7±4.5	21.9	9.6±9.0	11.7±5.4

* 1978 and 1979 values from B.C. Hydro (1979, 1980)

** for purposes of averaging, "less than" values (<) are taken as being 70% of the stated upper limit

TABLE 3-5

Waste Material Trace Element Concentrations, ppm

	Fly Ash				Coal Waste			Baked Clay			Gritstone				Colluvium				Topsoil	(Houth Meadows) Native Soil		
Element	1978*	1979*	1981	Average	1978	1981	Average	1978	1981	Average	1978	1979	1981	Average	1978	1979	1981	Average	1981	1979	1981	Average
Arsenic	16	23	16±3	18	5	23±25	14	9	15±3	12	6	8	12±3	9	10	20	11±6	14	12±3	2	4±1.8	3
Beryllium	2.0	2.6	2.0±0	2.2	1.5	1±0	1.3	2.5	2.3±0.8	2.4	2.0	1.5	2±0	2	2.0	1.5	1.0±0.0	1.5	1.0±0.0	1.7	1.0±0	1.35
Boron	178	147	162±109	162	17	9±5	13	13	8±4	11	8.8	6.8	9±5	8	11	9.9	5±3	9	4.8±1.5	4.1	3.2±3.4	3.7
Cadmium	< 0.2	0.1	0.1±0	0.1	< 0.2	0.1±0	0.1	< 0.2	0.1±0.1	0.1	< 0.2	0.1	0.1±0	0.1	< 0.2	0.1	0.1±0.0	0.1	0.1±0.0	0.1	0.1±0.0	0.1
Chromium	128	124	103±24	118	105	49±12	77	135	102±19	118	133	98	81±16	104	125	86	76±3	95	16±1	135	87±50	111
Cobalt	10	11	10±2	10	11	13±6	12	14	17±4	16	18	19	17±5	18	15	15	17±3	16	81±8	12	9±4	11
Copper	530	460	398±61	463	55	55±7	55	61	54±14	58	46	44	48±14	46	39	42	53±16	45	50±5	30	26±5	28
Fluorine	20	108	109±29	79	133	245±66	189	123	138±67	130	200	273	250±34	241	203	305	259±139	256	265±46	218	180±7.9	199
Lead	2	4	4±3	3	6	7±4	7	3	5±6	4	6	6	6±3	6	4	3	16±24	8	6±1	2	3±3	3
Manganese	288	260	263±49	270	140	206±242	173	453	476±431	464	330	223	495±38	349	533	535	469±71	512	603±62	695	459±263	577
Mercury	0.050	0.055	0.051±0.014	0.052	0.105	0.119±0.078	0.112	0.049	.0238±.0076	0.0364	0.096	0.075	0.030±0.022	0.067	0.090	0.100	0.075±0.023	0.088	0.070±.017	0.050	0.045±0.020	0.048
Molybdenum	5.5	11	6±2	8	4	2±1	3	3	2±1	3	2	2	3±1	2	2	2	2±1	2	2±1	1	1±1	1
Nickel	53	59	47±9	53	45	48±30	47	60	57±9	59	51	45	57±15	51	45	43	56±15	48	51±7	30	17±8	24
Selenium	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Tin	-	< 1	1±0	0.9	-	1±0	1	-	1±0	1	-	< 1	1±0	1	-	< 1	1±0	1	1±0	< 1	1±0	1
Uranium	0.5	1.5	1.7±0.6	1.2	< 0.5	1.4±0.4	0.9	< 0.5	1.8±.5	1.1	0.5	1.5	2.3±.0.5	1.4	0.5	1.3	1.4±.4	1.1	1.3±0.3	0.5	1.1±.0.4	0.8
Vanadium	270	258	225±17	251	150	118±10	134	245	250±17	248	145	120	204±51	156	135	118	107±24	120	121±31	103	78±15	90.5
Zinc	50	46	40±19	45	57	64±42	61	51	42±26	47	82	75	68±26	75	75	66	87±13	76	90±8	82	58±32	70

* 1978 and 1979 values from B.C. Hydro (1979, 1980)

** for purposes of averaging, "less than" values (<) are taken as being 70% of the stated upper limit

*** 1978 Values from Extract @ 55 - 60°C
1979 Values from Extract @ 45°C
1981 Values from Extract @ 45°C

TABLE 3-6

Average Trace Element Concentrations in Waste Materials (ppm)

Element	F Value	PR>F *	Grouping **	Fly Ash	Baked Clay	Colluvium	Gritstone	Mouth Meadows	Topsoil	Coal Waste
Arsenic	3.30	0.019	A B C	16.00 [AB]	14.50 [AB]	10.75 [BC]	12.25 [BC]	4.00 [C]	12.00 [BC]	23.25 [A]
Beryllium	13.64	0.0001	A B C	2.57 [AB]	2.80 [A]	1.73 [C]	2.25 [B]	1.63 [C]	1.75 [C]	1.45 [C]
Boron	20.43	0.0001	A B	161.75 [A]	8.00 [B]	4.00 [B]	9.00 [B]	3.18 [B]	4.75 [B]	9.25 [B]
Cadmium	-	-	A	0.10 [A]	0.10 [A]	0.10 [A]	0.10 [A]	0.10 [A]	0.10 [A]	0.10 [A]
Chromium	10.29	0.0001	A B C	103.25 [A]	102.00 [A]	75.75 [B]	80.50 [B]	86.75 [AB]	81.00 [B]	49.00 [C]
Cobalt	9.51	0.0001	A B C D	9.75 [CD]	16.50 [AB]	17.00 [A]	16.50 [AB]	8.50 [D]	15.75 [AB]	13.00 [BC]
Copper	280.98	0.0001	A B C	398.00 [A]	54.00 [B]	52.50 [B]	47.50 [BC]	26.25 [C]	50.25 [BC]	54.75 [B]
Fluorine	7.53	0.0002	A B C	108.75 [C]	137.50 [C]	258.75 [A]	250.00 [AB]	180.00 [BC]	265.00 [A]	245.00 [AB]
Lead	2.21	0.0827	A B	3.50 [B]	5.00 [B]	16.00 [A]	5.50 [B]	2.75 [B]	5.50 [B]	6.50 [B]
Manganese	4.20	0.0063	A B C	263.00 [BC]	476.00 [AB]	468.75 [AB]	495.00 [A]	459.25 [AB]	602.50 [A]	206.25
Mercury (ppb)	9.24	0.0001	A B C	51.25 [BC]	23.75 [C]	75.00 [B]	30.00 [C]	44.50 [BC]	70.00 [B]	118.75 [A]
Molybdenum	16.28	0.0001	A B	5.50 [A]	1.75 [B]	1.88 [B]	2.50 [B]	1.50 [B]	2.25 [B]	2.00 [B]
Nickel	8.40	0.0001	A B	46.75 [A]	56.75 [A]	55.50 [A]	56.75 [A]	17.25 [B]	55.50 [A]	48.25 [A]
Selenium	0.76	0.6108	A	0.73 [A]	0.70 [A]	0.80 [A]	0.70 [A]	0.80 [A]	0.70 [A]	0.70 [A]
Tin	-	-	A	1.00 [A]	1.00 [A]	1.00 [A]	1.00 [A]	1.00 [A]	1.00 [A]	1.00 [A]
Uranium	6.90	0.0004	A B C D	1.68 [BC]	1.75 [B]	1.38 [BCD]	2.25 [A]	1.13 [D]	1.25 [CD]	1.38 [BCD]
Vanadium	57.89	0.0001	A B C D	225.00 [AB]	250.00 [A]	107.00 [C]	204.00 [B]	76.00 [CD]	121.00 [C]	107.00 [C]

TABLE 3-6 (Cont'd)

Element	F Value	PR>F *	Grouping **	Fly Ash	Baked Clay	Colluvium	Sandstone	Mouth Meadows	Topsoil	Coal Waste
Zinc	5.71	0.0012		40.25	41.50	86.25	67.50	58.25	89.75	64.25
			A			A	A		A	A
			B				B	B		B
			C	C	C			C		C

* If (PR>F) <0.05, then variability among waste materials is significantly greater than variability within waste materials.

** Means with the same letter are not significantly different
Alpha level = .05

3.3 TRACE ELEMENT DISTRIBUTION

Table 3-7 shows the results of the trace element distribution in plants sampled on two waste materials (fly ash and baked clay) and from a natural situation at Houth Meadows. For each set of plant organs (roots, leaves, and inflorescences), a mean concentration and 95% confidence interval for the mean has been calculated for each of the 18 elements. Table 3-8 shows the results of the Duncans Multiple Range test indicating significant differences of mean trace element concentrations among the three plant organs. The lines under these means join plant parts that are not significantly different from each other at the 95% confidence level. The distribution of arsenic concentration, for example, is significantly higher in roots than either leaves or stems in crested wheatgrass grown on fly ash and baked clay, while there are no significant differences in concentrations between the three plant tissue types growing at Houth Meadows.

TABLE 3-7

Trace Element Distribution in Plants Grown on the Three Substrates
Mean and 95% Confidence Interval, ppm

Element/Plant Tissue	Fly Ash (Agropyron cristatum)			Baked Clay (Agropyron cristatum)			Mouth Meadow (Poa pratensis)		
	Roots	Leaves	Inflorescence	Roots	Leaves	Inflorescence	Roots	Leaves	Inflorescence
Arsenic	1.2±3.4	1±0	1±0	3±1	1±1	1±1	1±0	1±0	1±0
Beryllium	0.75±0.26	0.04±0.01	0.04±0.00	0.84±0.26	0.04±0.04	0.03±0.04	0.52±0.26	0.04±0.04	0.04±0.08
Boron	125±23	98±82	216.8±68.3	33.8±14.0	39±60	61.0±81.5	6.9±1.0	5.0±1.1	10.4±5.8
Cadmium	0.36±0.04	0.10±0.08	0.18±0.10	0.47±0.10	0.25±0.25	0.18±0.23	0.52±0.13	0.14±0.03	0.20±0.11
Chromium	22.3±7.4	0.5±0.3	0.4±0.0	19.0±10.5	0.4±0.0	0.4±0.0	20.0±5.0	0.6±0.4	1.6±2.5
Cobalt	6.8±4.4	0.2±0.2	0.1±0.0	10.0±0.8	0.1±0.0	0.2±0.2	4.0±2.6	0.2±0.2	0.2±0.2
Copper	377.5±78.5	10.9±4.8	18.1±3.8	51.6±20.5	8.5±0.9	21.8±4.3	19.6±1.9	11.8±1.3	16.5±3.8
Fluorine	3±2	2±1	4±2	9±4	2±1	2±0	8±0	5±0	6±2
Lead	6.4±1.0	0.4±0.2	1.3±0.2	4.1±3.8	1.3±0.8	1.1±0.2	2.4±1.0	0.7±0.3	0.6±0.4
Manganese	155±83	19±15	17±6	193±60	45±27	30±4	384±121	38±20	65±73
Mercury (ppb)	36±26	35±16	12.5±8.0	30±26	85±81	26±31	27±40	9.4±6	11±5
Molybdenum	18.7±6.3	3.8±2.2	3.8±1.5	1.8±0.7	0.7±0.9	1.2±1.2	2.1±0.8	1.4±1.4	1.1±0.8
Nickel	24.0±7.1	0.5±0.5	0.7±0.5	29.9±9.2	0.1±0.0	0.2±0.2	14.4±1.3	0.7±0.3	1.0±0.4
Selenium	1±1	1±1	1±1	1±1	1±1	1±1	1±0	1±0	1±0
Tin	1±1	1±1	1±1	1±1	1±1	1±1	1±0	1±0	1±0
Uranium	0.4±0.5	0.1±0.0	0.0±0.1	0.6±0.2	0.1±0.1	0.1±0.1	0.1±0.1	0.1±0.0	0.1±0.0
Vanadium	69±27	1±1	1±0	78±26	1±0	1±1	33±19	1±0	1±0
Zinc	42.4±21.8	19.1±9.6	22.7±7.7	31.2±7.6	7.3±3	20.1±6.9	44.1±23.4	15.7±3.1	17.7±2.8

TABLE 3-8

Trace Element Distribution in Plants Grown on Three Substrates;
Mean Concentrations in ppm, Unless Otherwise Noted

	Fly Ash (Crested Wheatgrass)					Baked Clay (Crested Wheatgrass)					Houth Meadows (Kentucky Bluegrass)				
Element	*Grouping	Substrate	Roots	Leaves	Inflorescence	Grouping	Substrate	Roots	Leaves	Inflorescence	Grouping	Substrate	Roots	Leaves	Inflorescence
Arsenic	A, B	16	12	1	1	A, B	15	3	1	1	A	72	1	1	1
Beryllium	A, B	2	0.75	0.04	0.03	A, B	2.3	0.84	0.03	0.03	A, B	2	0.52	0.04	0.03
Boron	A, B	162	125	98	218	A	8	34	39	61	A, B	9	7	5	10
Cadmium	A, B, C	0.1	0.36	0.10	0.18	A, B	0.1	0.47	0.25	0.18	A, B	0.1	0.52	0.14	0.20
Chromium	A, B	103	22.3	0.5	0.4	A, B	102	19.0	0.4	0.4	A, B	81	20.0	0.6	1.6
Cobalt	A, B	10	6.8	0.2	0.1	A, B	17	10.0	0.1	0.2	A, B	17	4.0	0.2	0.2
Copper	A, B	398	377.5	10.9	18.1	A, B, C	54	51.6	8.5	21.8	A, B, C	48	19.6	11.8	16.5
Fluorine	A	109	3	2	4	A, B	138	9	2	2	A, B	250	8	5	6
Lead	A, B, C	3.5	6.4	0.4	1.3	A, B	5	4.1	1.3	1.0	A, B	6	2.4	0.7	0.6
Manganese	A, B	263	155	19	17	A, B	476	193	45	30	A, B	495	384	38	65
Mercury (ppb)	A, B	51	36	35	12.5	A*, B	23.8	30	85	26	A*, B	30	27	9	11
Molybdenum	A, B	6	18.7	3.8	3.8	A*, B	2	1.8	0.7	1.2	A	3	2.1	1.4	1.1
Nickel	A, B	47	24.0	0.5	0.7	A, B	57	29.9	0.1	0.2	A, B	57	14.4	0.7	1.0
Selenium	A	1	1	1	1	A	1	1	1	1	A	1	1	1	1
Tin	A	1	1	1	1	A	1	1	1	1	A	1	1	1	1
Uranium	A*, B	1.7	0.4	0.1	0.1	A, B	1.8	0.6	0.1	0.1	A, B	2.3	0.1	0.1	0.1
Vanadium	A, B	225	69	1	1	A, B	250	78	1	1	A, B	204	33	1	1
Zinc	A, B	40	42.4	19.1	22.7	A, B	42	31.2	7.3	20.1	A, B	68	44.1	15.7	17.7

* Means with the same letter are not significantly different
Alpha = .05 df = 3

A* The difference between means should not be considered significant because the probability associated with the F statistic is less than 95%.

PART 4

DISCUSSION

PART 4 - DISCUSSION

CONTENTS

TABLES

4.1 TRACE ELEMENT HAZARD ASSESSMENTS

It is to be noted that trace element concentration found at Houth Meadows were not all within the normal or safe ranges reported in the literature (especially for boron and zinc). Because of this, the following discussion is based largely on comparisons with the literature rather than the significance of differences between waste materials and Houth Meadows.

Based on the results of the literature review, the trace element levels obtained by analysis of the alfalfa, crested wheatgrass, bluegrass and locoweed growing on the different substrates has indicated the following general conclusions: vegetation has below normal levels of Be and above normal levels of Cr; and only five elements (arsenic, selenium, tin, uranium and vanadium) occur in levels that are within the normal range for all species on all substrates. Other elements that are either in excess or below normal levels depend on the species involved and the substrate. The results are summarized in Tables 4-1 and 4-2. More detailed assessments are given in Appendix B (Tables B-1, B-2 and B-3).

The low levels of beryllium do not indicate a deficiency, since there is no information to show that beryllium is an essential element for either plants or animals. The high levels of chromium are difficult to assess, since the values represent total concentrations (not available) and the Cr^{3+} and Cr^{6+} ions have different mobilities. Studies have indicated that most of the Cr^{6+} in the soil solution remains mobile and therefore available to the plants. On the other hand, nearly all the Cr^{3+} is immobilized in soils with a moderate to high cation exchange capacity since it is readily absorbed or complexed (National Research Council of Canada 1976). Total chromium content of the soil is therefore a poor measure of plant available chromium. In general, poorly drained soils with decaying organic matter have more total chromium than well drained soils; about half the plant available chromium is contained in the clay fraction, even though clay may only contain 10-20% of the total chromium; and Cr^{3+} is most available in sandy soils with little decaying organic material.

There are data to show that 1-5 ppm of available Cr^{3+} or Cr^{6+} is the toxic threshold for a number of plant species, indicating that there is little difference in the action of either form of chromium on the plant. Once absorbed by the plants, both forms can interfere with the uptake of essential nutrients through their inhibiting effects on the functioning of the roots. There are, however, no recorded examples of deleterious plant responses which can be attributed directly to chromium toxicity (National Research Council of Canada 1976). The high levels of chromium therefore need not be a cause for concern, but should receive further study to ascertain the available concentrations involved.

TABLE 4-1

Trace Elements Occurring in the Vegetation in Levels
Outside the Normal Range for Plants

Substrate	Species	Be	B	Cd	Cr	Co	Cu	F	Pb	Mn	Hg	Mo	Ni	Zn
							Elements							
Fly Ash	CWG	--	+++		++	-				---		+	-	-
Coal Waste	CWG	--	--			+		--				--	-	-
	A	--		-	++	++		-					+	
Baked Clay	CWG	--	-	--				-		-		-		-
	A	--	-	---	+++	-	-	-			-	+		-
Gritstone	CWG	--	--		+			-			-	--	-	
	A	--			++	-	-	-					-	-
Colluvium	CWG	--	---		++	-		---		--		---	-	-
	A	--			+++			-			-	+++		-
Topsoil	CWG	--	--			-				---		-	-	--
	A	--		-	+++	-		---		-	+	+	-	-
Houth Meadows	BG	--	--		+				-	-		-		-
	O	--	-	-	+++	-	-		-	-	++	+		-

CWG Crested Wheatgrass
A Alfalfa
BG Bluegrass
O Locoweed.
--- definitely abnormal - mean and Confidence Limit (C.L.) below normal range
-- abnormal - mean below normal range but C.L. extends into this range
- slightly abnormal - mean inside range, C.L. extends below normal range
+++ definitely abnormal - mean and C.L. above normal range
++ slightly abnormal - mean above normal range but C.L. extends into this range
+ slightly abnormal - mean inside range, but C.L. extends above normal range

TABLE 4-2

Trace Elements Occurring in Substrate Materials in Levels Outside the Normal Range for Soils

Substrate	Elements										
	As	B	Cr	Co	Cu	Pb	Mn	Hg	Mo	Sn	U
Fly Ash		++			++	-		---	+	--	-
Coal Waste	+	--				-	-			--	-
Baked Clay		--				-	-	---		--	-
Gritstone		--				--		---		--	-
Colluvium		---				-		-		--	-
Topsoil		---	---	+++				-		--	-
Houth Meadows		---				--		---		--	-

--- definitely abnormal - mean and Confidence Limit (C.L.) below normal range
-- adnormal - mean below normal range but C.L. extends into this range
\- slightly abnormal - mean inside range, C.L. extends below normal range
+++ definitely abnormal - mean and C.L. above normal range
++ slightly abnormal - mean above normal range but C.L. extends into this range
\+ slightly abnormal - mean inside range, but C.L. extends above normal range

Often there is no clear case of a particular element having below or above normal levels. The same elements may be in excess in some substrates but deficient in others: such is the case with cobalt and molybdenum. The trend, however, is for most elements to be below normal levels, but this is not confined to a particular species except for boron in crested wheatgrass, where it is deficient in all cases except for fly ash. On baked clay the individual boron levels in the shoots are very variable, with a range of 21-127 ppm (Appendix A). The tendency is for the boron to be present in concentrations below normal.

The trace elements which occur at concentrations deficient or toxic to plants or animals are listed in Table 4-3. Boron may be widely deficient in grasses, but toxic in those growing on fly ash. Zinc will be in levels deficient to livestock which feed on vegetation growing on all substrates, and manganese and molybdenum are present in insufficient amounts on several of the waste materials. This is not unusual for central British Columbia rangelands (Van Ryswick 1982).

Some of the deficiencies and toxicities noted may be an artifact of the method used to derive the normal range found in soils, and a more thorough literature search may produce more data. This is particularly true for the levels of beryllium, tin and uranium in plants, as the figures for each element given in Tables 3-1 and 3-2 are based on a single reference. It seems unlikely, however, that this would result in any major changes in conclusions drawn. Had earlier workers shown or suspected that these elements were an integral component in the physiology of plants, it is probable that more data would be available in the literature. It is probably safe to infer, therefore, that the levels of arsenic, beryllium, selenium, tin, uranium and vanadium are within normal ranges for all species in all substrates and are neither toxic nor deficient.

Crested wheatgrass and bluegrass will possibly show deficiency symptoms for the following elements:

1) boron on all substrates except fly ash (where there may be toxic levels) and baked clay;
2) manganese on fly ash; and
3) molybdenum on coal waste, gritstone and colluvium.

Alfalfa is unlikely to show any toxicity or deficiency symptoms on any of the substrates. Although the mean values are sometimes greater than, or less than, the normal value, they do not approach the critical toxic or deficiency levels.

TABLE 4-3

Trace Elements Occurring in the Vegetation in Levels
That are Either Toxic to or Deficient for Plants or Livestock

Substrate			Element			
			B	Mn	Mo	Zn
Fly Ash	Plant	CWG	+++	-		
	Livestock	CWG		--		--
Coal Waste	Plant	CWG	--		--	
		A				
	Livestock	CWG			--	-
		A				
Baked Clay	Plant	CWG				
		A				
	Livestock	CWG				--
		A				--
Gritstone	Plant	CWG	--		-	
		A				
	Livestock	CWG			--	-
		A				--
Colluvium	Plant	CWG	--		--	
		A				
	Livestock	CWG		--	--	--
		A				--
Topsoil	Plant	CWG	--			--
		A				
	Livestock	CWG		--	-	--
		A				--
Houth Meadow	Plant	BG	--			
		O				
	Livestock	BG				--
		O				--

--- Very deficient, mean and Confidence Limit (C.L.) below deficient level
-- Deficient, mean below deficient level but C.L. extends above
- Slightly deficient, mean above deficient level but C.L. extends below
+++ Very toxic, mean and C.L. above toxic level
++ Toxic, mean above toxic level but C.L. extends below
+ Slightly toxic, mean below toxic level but C.L. extends above.
CWG Crested Wheatgrass
A Alfalfa
BG Bluegrass
O Locoweed

As shown in Table 4-3, livestock grazed on pastures of alfalfa or crested wheatgrass may show zinc deficiency symptoms (except in alfalfa pastures on coal waste). Manganese deficiency symptoms may be encountered in cattle grazed on crested wheatgrass on fly ash, colluvium and topsoil, and molybdenum deficiency symptoms may be found in cattle grazed on crested wheatgrass on coal waste, gritstone, colluvium and topsoil.

Toxicity symptoms may be encountered in livestock grazing on any species on any substrate but are unlikely to manifest themselves, because element levels are, in general, well below the toxic levels. As indicated below, however, the physiology of trace elements in diets is not well understood (Table 4-3). In the case of molybdenum, the copper/molybdenum ratio is very important (Erdman _et al._ 1978). Five ppm is the approximate upper limit tolerated by cattle, although values of 2 ppm have been considered important in molybdenum-induced hypocuprosis. It is possible that it is not the levels of molybdenum _per se_ that cause the development of hypocuprosis symptoms, but rather the copper/molybdenum ratio. Hypocuprosis symptoms result from abnormally low levels of copper and moderately high levels of molybdenum; molybdenosis symptoms result from abnormally high molybdenum levels and normal copper levels. A recommended copper:molybdenum ratio for cattle is 6:1 (Erdman _et al._ 1978), although Buckley (1982) recommends 4:1. Assuming that the copper levels are normal, a ratio of 2:1 will probably result in the development of molybdenosis symptoms. The copper: molybdenum ratio varies for each species in each substrate and different symptoms will develop depending on the ratio (Table 4-4).

The syndromes produced by dietary molybdenum in ruminants are consequently very complex, not only in their biochemical pathogenesis but in the variety of effects produced, both che ical and clinical. A syndrome may have two interrelated components: copper deficiency _per se_ arising from the interference with copper absorption as a result of the interaction of molybdenum and sulphur in the alimentary canal; and molybdenosis arising from high molybdenum intakes and normal copper intakes. Molybdenum and copper affect copper metebolism by interacting in the rumen to form molybdates. These compounds decrease the availability of dietary copper and, if absorbed, they impede the metabolism of tissue copper and inhibit copper enzymes. Thus, because of the complexity of these reactions it is difficult to draw any firm conclusions as to the likely effects on grazing cattle absorbing molybdenum and copper from plants in the field - too little of the different interaction is known at present (Underwood 1971, Buckley 1982). It must be emphasized, therefore, that Table 4-4 outlines possible symptoms, not necessarily probable symptoms.

Other interactions between the different elements are less easy to define in terms of ratios. Many interact with each other and can, in some cases, partially substitute for each other in certain physiological reactions. Some of the more important interactions between plant nutrients (micronutrients and macronutrients) are;

TABLE 4-4

Copper: Molybdenum Ratios in Plant Shoots and Their Potential Impact on Livestock

Substrate	Plant Species	Cu Level	Mo Level	Cu:Mo Ratio	Possible Symptoms in Livestock
		ppm	ppm		
Fly Ash	Wheatgrass	12.2	4.6	2.7	Molybdenosis*
	Alfalfa				
Coal Waste	Wheatgrass	12.5	0.3	41.7	Copper toxicity**
	Alfalfa	8.2	1.4	5.9	-
Baked Clay	Wheatgrass	14.2	2.2	6.5	-
	Alfalfa	7.6	4.2	1.8	Hypocuprosis***
Sandstone	Wheatgrass	11.3	0.3	37.7	Copper toxicity
	Alfalfa	8.1	3.2	2.5	Hypocuprosis
Colluvium	Wheatgrass	11.9	0.2	59.5	Copper toxicity
	Alfalfa	9.6	9.5	1.0	Molybdenosis
Topsoil	Wheatgrass	10.0	0.6	16.7	Copper toxicity
	Alfalfa	9.6	3.3	2.9	Molybdenosis
Houth Meadows	Bluegrass	0.2	0.7	0.3	Hypocuprosis
	Locoweed	9.6	3.6	2.7	Molybdenosis

Normal Cu level in vegetation: 11 ppm
Normal Mo level in vegetation: 1.7 ppm

* Molybdenosis symptoms result from abnormally high levels of molybdenum and normal levels of copper.

** Copper toxicity symptoms result from abnormally high levels of copper and abnormally low levels of molybdenum.

*** Hyposcuprosis symptoms result from abnormally low levels of copper and moderately high levels of nolybdenum.

- zinc with phosphorus, copper, nitrogen, magnesium and iron;
- iron with phosphorus, manganese, molybdenum and copper;
- copper with phosphorus and molybdenum;
- molybdenum with phosphorus and sulphur; and
- boron with calcium.

No doubt similar interactions between elements exist in livestock and wildlife. These are less well documented because of the complexity of the interactions as in the copper/molybdenum/sulphur interaction.

In cases where deficiency symptoms result, these can be corrected by adding the deficient element as a feed supplement. Element supplements to salt blocks are usually not used, because of chemical reactions with salt ions. In cases of the element being in deficient quantities in the plant, it is added as a fertilizer (Buckley 1982). Such additions of boron are commonly applied to forage crops in the British Columbia interior every three to five years (Van Ryswick 1982).

4.2 COMPARISON OF TRACE ELEMENT ACCUMULATIONS IN CRESTED WHEATGRASS AND ALFALFA

To determine whether creasted wheatgrass and alfalfa accumulate significantly different quantitites of trace elements when grown on the same material, a paired Student's t-test was performed using the 1981 concentrations. Values were compared from crested wheatgrass and alfalfa samples grown on coal waste, baked clay, gritstone, colluvium and topsoil. Fly ash was not included in the comparison as data for alfalfa grown on this material were not available. The results of this comparison are shown in Table 4-5. The mean value for each element is given for both crested wheatgrass and alfalfa, along with the respective Student's t value and the level of significance associated with this value. From this comparison it is evident that alfalfa accumulates approximately twice the levels of boron, chromium and manganese, and six times the levels of molybdenum and nickel; crested wheatgrass accumulates significantly more copper than does alfalfa when grown on these materials. All other trace elements analysed do not vary significantly between these two plant species.

4.3 TRACE ELEMENT DISTRIBUTION

The concentration of trace elements in plants is dependent on four basic interdependent factors;

TABLE 4-5

Comparison of Trace Element Accumulation in Crested Wheatgrass and Alfalfa Shoots

Element	Crested Wheatgrass	Alfalfa	Calculated t	Significance
Arsenic	0.70	0.82	1.63	N.S.
Beryllium	0.03	0.03	1.49	N.S.
Boron	24.38	50.4	2.62	+
Cadmium	0.24	0.17	1.76	N.S.
Chromium	0.52	1.02	7.07	**
Cobalt	0.25	0.48	1.33	N.S.
Copper	11.98	8.62	3.25	*
Fluorine	2.56	4.2	1.11	N.S.
Lead	1.44	1.10	1.33	N.S.
Manganese	37.6	83.0	3.21	*
Mercury	0.03	0.02	1.33	N.S.
Molybdenum	0.72	4.32	2.47	+
Nickel	0.30	2.0	3.42	*
Selenium	0.7	0.7	1.63	N.S.
Tin	0.76	0.78	0.34	N.S.
Uranium	0.07	0.08	2.05	N.S.
Vanadium	1.2	1.0	0.99	N.S.
Zinc	17.1	21.1	1.3	N.S.

** Very significant ($t>4.604$, 99% confidence at df=4) difference between species
* Significant ($t>2.776$, 95% confidence at df=4)
+ Marginally significant ($t>2.122$, 90% confidence at df=4)
N.S. Not Significant ($t<2.132$, 90% confidence at df=4)

- the genus, species or strain of plant;
- the soil type in which the plant has grown;
- the conditions during growth; and
- the stage of maturity of the plant.

Not all elements occur in equal concentrations in all parts of the plant. Copper, for example, usually occurs in all plant tissues but concentrates in the leaves and seeds. Zinc and vanadium also occur in all plant tissues but usually vary in concentration in the following order from most to least: roots, stem, leaves, and fruits. Molybdenum, lead and chromium generally occur in greater quantities in the roots than in stems, leaves or seeds (Sauchelli 1969, Pratt 1973a, Brewer 1973b, National Research Council of Canada 1973 1976.) Jones (1959) and Cannon (1976) reported concentrations of lead in roots with limited translocation to the shoots. Arsenic has also been reported to be more concentrated in plant roots than in above-ground portions (Liebig 1973). As a result, analysis of the above-ground parts of plants for arsenic usually provides little information on plant toxicity, since root rot as a result of arsenic toxicity will take place before the symptoms are manifested above-ground. Cobalt concentrates in the root nodules of legumes, but most other plants have greater concentrations of cobalt in the above-ground parts (Vanselow 1973). The generally high concentration of fluorine in the above ground parts of plants compared to the roots has been interpreted to indicate the atmosphere is the principal source of fluorine for plants (Brewer 1973a), although some fluorine is taken up from the soil.

The distribution of beryllium, chromium, cobalt, manganese, nickel, selenium, tin, uranium and vanadium does not differ from the plants grown on the two waste materials tested (fly ash and baked clay) and those grown at Houth Meadows. However, vanadium concentrations in roots on the two waste materials tend to be higher than those at Houth Meadows. The distribution of arsenic, boron, cadmium, copper, fluorine, lead, mercury, molybdenum and zinc in the plant varies between substrates (Table 3-7). Boron concentrations are higher in the infloresence than either the roots or leaves on all substrates. This is possibly because boron is readily translocated through the xylem but on arriving in the apices, it becomes one of the least mobile of the elements (Mortvedt et al. 1972). The high concentration of this element in the seedhead of crested wheatgrass plants grown on fly ash may be due to the relatively high concentrations of boron found in this substrate (Monenco Consultants Pacific Limited 1981). Although 218 ppm of boron concentrated in the infloresence is higher than the upper limit in plants before toxicity symptoms occur, no such symptoms were noted in the plants in the field. There are no data available to determine whether this level of boron is toxic to livestock.

Cadmium uptake and accumulation by crested wheatgrass differs between fly ash and baked clay. The roots, leaves and inflorescences of plants growing on fly ash all have different levels of cadmium. The level of cadmium in plants growing on baked clay is statistically the same in leaves and inflorescences and is different from the level in the roots.

Grass plants grown on fly ash and baked clay accumulate much higher levels of copper in roots than the comparable tissue at Houth Meadows: 377.5 and 51.6 ppm fly ash and baked clay, respectively, compared to 19.6 ppm at Houth Meadows, respectively. This may be a result of the higher copper levels in these two substrates (Table 3-5), or because crested wheatgrass may concentrate copper more than does bluegrass. Copper levels in the above ground portions of these plants do not vary significantly between substrates.

The fluorine level in the crested wheatgrass grown on fly ash is in equal concentrations throughout the plant, but for the plants growing on baked clay and in the native soil of Houth Meadows it occurs in a higher concentration in the roots than in the leaves and inflorescences. Just how much these observations mean is debatable because the atmosphere is considered the principal source of fluoride for plants. In addition, Davison et al. (1979) have shown that the fluorine content of forage varies during the year, and that there are significant changes in fluoride content from day to day. They further question the use of an single sample for the analysis of plant fluoride content.

The lead concentration of the plants growing on the baked clay and the Houth Meadows is highest in the roots and is found in equal concentrations in the leaves and inflorescences. In the tissue taken from plants on the fly ash there are different levels of lead in the different parts of the plant. In all cases however, there is a tendency for lead to accumulate in the roots, a trend which reflects the typical situation.

Mercury levels in leaves from crested wheatgrass plants grown on baked clay are much higher than in any other portion of the plant but are still below the upper limit of concentration in plants of 180 ppb at which toxic levels accummulate in livestock (Underwood 1971). The accumulation of mercury in the crested wheatgrass and bluegrass is not the same on the three substrates. This may be a result of species differences but the mercury accumulation in crested wheatgrass alone is also different on fly ash and baked clay.

Molybdenum concentrations tend to be very high in crested wheatgrass roots grown on fly ash. Levels in above ground tissues are also higher than those found in plants grown on baked clay and at Houth Meadows, however, they are below the upper limit of concentration in plants at which toxic levels accumulate in livestock (Underwood 1971).

Manganese levels in roots from plants sampled at Houth Meadows are above the upper limit for plant toxicity defined by Martin and Matocha (1973) but within the limit defined by Labanauskas (1973).

Zinc in all three cases is found in greater concentration in the roots than in the inflorescences or leaves. In the plants grown on the baked clay the zinc accumulation is higher in the inflorescences than in the leaves; in the plants grown on the fly ash and in the natural soil of the Houth Meadows the leaf and inflorescence concentrations are equal. With increasing maturity the levels of zinc may increase in the leaves and the more typical situation be adopted in the plants growing on the baked clay. At the time of sampling however, there was a tendency for the inflorescences to have higher zinc concentrations than the leaves, although this difference is not significant except on baked clay.

Table 4-6 shows the ratio of the average shoot concentrations and average soil concentrations of each element, as calculated for each substrate. Although these accumulation percentages vary widely, they are generally of the same magnitude for each element for all species across all substrates. Interpretation of these values must be based on the realization that the soil values represent total concentrations, of which only a small portion is available to plants. Elements which are shown as being concentrated (ratios greater than 100%), therefore, are most assuredly being accumulated. Elements which are indicated as being excluded from plants (ratio less than 100%), however, cannot confidently be assumed to be excluded from plant shoots.

Boron and cadmium are noticeably accumulated by all plants growing on all substrates: the only exception is Alfalfa on baked clay (where cadmium was not concentrated). An apparent "active" exclusion of elements (as indicated by shoot to soil concentrations arbitrarily set at less than 10%) may be occurring for arsenic, beryllium, chromium, cobalt, fluorine, nickel and vanadium. The remaining elements showed no marked deviation between soil and plant shoot value.

The physiological explanations for the accumulation or exclusion of certain elements are beyond the scope of this report. The ratios reported in Table 4-6 are largely useful for roughly predicting expected elemental concentrations in plants on the basis of soil analyses.

TABLE 4-6

Trace Element Concentrations in Plant Shoots Relative to Substrate Concentration (%)

	Fly Ash	Coal Waste			Baked Clay			Sandstone			Colluvium			Topsoil			Houth Meadows		
Element	Crested Wheatgrass	Crested Wheatgrass	Alfalfa	Mean	Crested Wheatgrass	Alfalfa	Mean	Crested Wheatgrass	Alfalfa	Mean	Crested Wheatgrass	Alfalfa	Mean	Crested Wheatgrass	Alfalfa	Mean	Bluegrass	Locoweed	Mean
Arsenic	4.4	5	5	5	4.7	4.7	4.7	5.8	5.8	5.8	6.4	9.1	7.8	5.8	8.3	6.9	*25	25	25
Beryllium	1.3	3	4	3.5	1.2	1.2	1.2	1.3	2	1.7	2.7	4.0	3.4	*2.0	3.0	*2.5	*2.0	4.0	30
Boron	130.6	208	533	370.5	947	700	770	182	470	326	135	1120	632	277	1042	798	416	1000	708
Cadmium	250	250	220	235	140	40	90	270	230	250	220	240	230	360	130	245	360	180	270
Chromium	0.68	0.8	1.4	0.8	0.4	0.9	0.7	0.6	1.1	0.9	1.2	2.0	1.6	2.5	6.9	4.7	0.5	1.6	1.1
Cobalt	1	3	12	7.5	1.2	1.2*	1.2	1.8	2.4	13	1.2	1.8	1.5	0.1	0.1	0.1	1.1	2.2	1.7
Copper	3.1	23	15	19	26	14	20	23	17	20	22	18	20	20	19	20	38	37	37.5
Fluorine	3.7	0.4	1.2	0.6	1.4	2.9	2.2	1.6	2.8	2.2	0.4	2.3	1.4	1.8	0.4	1.1	2.7	2.8	2.9
Lead	35	11	20	15.5	22	10	16	33	28	30	11	7.5	9.3	27	12	19.5	53	17	35
Manganese	5.7	25	72	48.5	5.9	12	9.0	12	22	17	5.5	14	9.8	4.1	6.5	5.3	5.4	14	9.7
Mercury	56.8	28	28	28	150	50	100	53	80	67	44	16	30	41	70	55.5	64	207	135.5
Molybdenum	77	15	70	42.5	110	210	160	10	107	59	10	475	243	30	165	97.5	60	360	210
Nickel	0.85	1	9	5	0.5	1.8	1.2	0.5	4.0	2.3	0.2	2.3	1.3	0.2	2.4	1.3	0.6	11	5.8
Selenium	*100	*100	*100	*100	*100	*100	*100	*100	*100	*100	*100	*100	*100	*100	*100	*100	*100	143	143
Tin	*70	*70	*80	75	*90	*70	*80	*80	*70	*75	70	70	70	*8	110	59	*8.0	90	49
Uranium	47	*50	*50	50	*39	3.9	21	30	3.5	17	50	7.1	29	6.2	7.7	7.0	*7.3	9.1	8.2
Vanadium	0.44	0.8	0.8	0.8	0.8	0.4	0.6	0.5	0.5	0.5	0.9	0.9	0.9	0.8	0.8	0.8	1.3	1.7	1.5
Zinc	47	40	57	48.5	26	38	32	36	25	31	17	22	20	11	19	15	17	32	24.5

* Values calculated with figures below detection limit in plant tissue, therefore a possibly high estimate.

PART 5

CONCLUSIONS

PART 5 - CONCLUSIONS AND RECOMMENDATIONS

CONTENTS

TABLES

5.1 CONCLUSIONS

All waste materials being evaluated for reclamation at Hat Creek have been compared with natural soil of Houth Meadows for trace element concentrations. Significant differences between the substrates were as follows:

1. Fly ash had significantly higher concentrations of the following elements: arsenic, beryllium, boron, copper, molybdenum, nickel, uranium and vanadium;

2. Baked clay had significantly higher concentrations of arsenic, beryllium, copper and nickel;

3. Colluvium had significantly higher concentrations of cobalt, copper, lead, nickel and zinc;

4. Gritstone had significantly higher concentrations of beryllium, cobalt, nickel, uranium and vanadium;

5. Trench A topsoil had significantly higher concentrations of cobalt, fluorine, nickel and zinc; and

6. Coal waste differed significantly from Houth Meadows topsoil in terms of its concentrations of arsenic and mercury (higher than Houth Meadows) and chromium and manganese (lower than Houth Meadows).

It was found that the concentrations of cadmium, selenium and tin do not vary significantly between substrates.

A similarity in elemental concentrations with undisturbed rangeland does not indicate that the levels of trace elements in a particular waste material are not potentially dangerous, since the native topsoil tends to have boron, manganese, molybdenum or zinc deficiencies as well. The results of comparisons to reported deficient and toxic levels for plant and livestock growth are summarized for these critical elements in Tables 4-3 and 5-1, and are more relevant than comparisons between the substrates and native topsoil. Boron from fly ash is the only element found in concentrations toxic to vegetation, although no toxicity symptoms were noticed in vegetation sampled in 1981. Although chromium is accumulated in plants to above normal levels, the questions of ionic composition and availability make it difficult to assess whether these levels would be toxic to wildlife and livestock. Chromium levels have been rated as not being dangerous, but further work needs to be done on this element.

TABLE 5-1

Rating of Substrate Deficiencies and Toxicities

		Element								Ratings		
		B		Mn		Mo		Zn		Number of Deficiency	Number of Toxicity	Total
Substrate	Species	Plant	Animal	Plant	Animal	Plant	Animal	Plant	Animal	(-)	(+)	Score
Fly ash	Wheatgrass	+++		-	--				--	5	3	8
Coal waste	Wheatgrass	--				--			-	5	0	5
	Alfalfa											
Baked clay	Wheatgrass								--			
	Alfalfa								--	4	0	4
Gritstone	Wheatgrass	--				-	--		-	8	0	8
	Alfalfa								--			
Colluvium	Wheatgrass	--			--	--	--		--	12	0	12
	Alfalfa								--			
Topsoil	Wheatgrass	--			--		-	--	--	11	0	11
	Alfalfa								--			
Houth Meadows	Bluegrass	--							--	6	0	6
	Locoweed								--			

--- Very deficient, mean and Confidence Limits (C.L.) below deficient level
-- Deficient, mean below deficient level but C.L. extends above
- Slightly deficient, mean above deficient level but C.L. extends below
+ Slightly toxic, mean below toxic level but C.L. extends above
++ Toxic, mean above toxic level but C.L. extends below
+++ Very toxic, mean and C.L. above toxic level

Note: No data on molybdenum in animals is given for wheatgrass on fly ash, alfalfa on topsoil and locoweed in Houth Meadows because the Cu: Mo ratio may be more important than the actual value.

A crude scale for rating the different materials was developed (Table 5-1) based on a simple summation of the number and extent of element deficiencies or toxicities exhibited by each substrate. In terms of overall trace element hazards therefore, the materials are grouped in the following order (from worst to best):

Colluvium
Trench A Topsoil
Fly Ash
Gritstone
Houth Meadows Topsoil
Coal Waste
Baked Clay

Additional criteria such as the ability to support plant growth (Monenco Consultants Pacific Limited 1982) must of course be used in assessing the overall suitability of materials for reclamation purposes. In general, none of the materials pose any trace element problems which could not be overcome through treatment and proper management. None of the potential deficiency problems are serious from a practical point of view, especially since they tend to occur naturally on undisturbed materials throughout the region.

Although no toxic levels of copper or molybdenum were found to accumulate in plant shoots, levels which would be toxic to cattle were found in crested wheatgrass roots growing on fly ash. Furthermore, because of complex copper and molybdenum interrelationships, the levels in vegetation are such that toxicity or deficiency symptoms may appear in cattle grazing solely on that material. Molybdenosis may arise from eating solely vegetation growing on fly ash, colluvium, Trench A topsoil or Houth Meadows topsoil. Copper toxicity may come from plants grown on coal waste, gritstone, colluvium or Trench A topsoil. Hypocuprosis may result from vegetation grown on baked clay or gritstone.

In terms of element distribution and accumulation, it was found that alfalfa concentrated boron, chromium, manganese, molybdenum and nickel more than crested wheatgrass; conversely, crested wheatgrass accumulated copper. Boron and cadmium were concentrated in plant shoots, at up to ten times the total concentration found in the soil. Distribution within the plant typically showed higher concentrations in the roots, while concentrations in the leaves and inflorescences are lower and not significantly different from each other (except for boron, which tends to accumulate in inflorescences).

All evaluations of plant uptake and accumulation in relationship to soil concentrations are greatly limited by the fact that total concentrations have been assayed for, and these values do not necessarily reflect the amount available to plants.

5.2 RECOMMENDATIONS

Since there are no severe trace element hazards, no special management techniques need be applied to ameliorate their potential danger. To offset the boron toxicity of fly ash, it can be buried beneath other materials or treated with sulphur and manure. Possible manganese, molybdenum, zinc and copper deficiencies and possible copper toxicity can be avoided by never feeding cattle solely on forage from the Hat Creek or interior B.C. area. A more realistic alternative is to provide mineral supplements to their diet, but appropriate blends and doses would have to be carefully studied first. Copper to molybdemum ratios, their effects on cattle, the effects of sulphur on copper availability and methods of controlling these ratios deserve particular attention for further investigation.

Further field sampling programs, literature reviews and laboratory studies should emphasize the following elements: boron, cadmium, chromium, copper, manganese, molybdenum, selenium and zinc. All future soil samples should be analyzed by methods which more closely estimate available concentrations of elements, and all should measure the pH of the soil samples since this very often can be used as a guide in determining the availability of elements. More sensitive analytical techniques are needed to properly evaluate selenium, as methods used in this analysis can not detect the low concentrations at which deficiencies occur. Buckley (1982) has suggested that hydride generation is the most efficient method of selenium detection. Further investigation of the literature would be worthwhile in order to better determine what levels of chromium, fluorine, lead, mercury, nickel, tin, uranium and vanadium are toxic to plants, what levels of cobalt and selenium are deficient to plants, and what levels of beryllium, boron and uranium are toxic to animals.

As far as levels of trace elements are concerned, the baked clay material would most likely provide the best substrate for plants. Colluvium is likely to be the worst substrate , and in between these two extremes lie the other substrate, grouped from worst to best: Trench A topsoil, fly ash, gritstone, Houth Meadows topsoil and coal waste. This rating should be combined with productivity ratings (Monenco Consultants Pacific Limited 1982) to select the most suitable materials with which to surface the waste dumps. Such an assessment would have to weigh potential trace element problems against productivity, and any resulting recommendations would have to be based on cost-benefit assumptions and risk analyses that are beyond the scope of this document.

Any additional studies into the physiology of trace element uptake, accumulation or exclusion should be done on the basis of controlled experiments. Once quantitative estimates of flow rates and physiological responses are desired, a sampling survey approach is not as useful as an experimental approach conducted in a controlled laboratory setting.

REFERENCES

REFERENCES

Adriano, D.C. and P.L. Brisbin (eds.). 1978. Environmental Chemistry and Cycling Processes. Proceedings of a Symposium held at Augusta, Georgia, April 28 - May 1, 1976. Department of the Environment, Symposium Series 45. National Technical Information Service, Springfield, Virginia.

Andersson, A. 1967. Mercury in the soil. Grundforbattring 20:95-105.

Antonovics, S., A.D. Bradshaw and R.G. Turner. 1971. Heavy metal tolerance in plants. Adv. Ecol. Res. 7:1-85.

Aubert, H. and M. Pinta. 1977. Trace Elements in Soils. Elsevier Scientific Publishing Company, Amsterdam. 395 pp.

Beckett, P.H.T. and R.D. Davis. 1977. Upper critical levels of toxic elements in plants. New Phytol. 79:95-106.

Bidwell, R.G.S. 1974. Plant Physiology. MacMillan Publishing Co., Inc., New York. 643 pp.

Blincoe, C. and T.L. Lambert. 1972. Micronutrient trace element composition of crested wheatgrass. J. Range Manage 25:128-130.

Bollard, E.G. and G.W. Butler. 1966. Mineral nutrition of plants. Ann. Rev. Plant Physiol. 17:77-112.

Bomke, A.A. 1980. Fertilizers and soil amendments in mine reclamation. In: British Columbia Ministry of Energy, Mines and Petroleum Resources and the Mining Associates of British Columbia (eds). Proceedings of the Forth Annual British Columbia Mine Reclamation Symposium. Vernon, British Columbia.

Bradford, G.R. 1973. Boron. In: H.D. Chapman (ed.). Diagnostic Criteria for Plants and Soils. H.D. Chapman, Riverside, California. pp. 33-61.

Brewer, R.F. 1973a. Fluorine. In: H.D. Chapman (ed.). Diagnostic Criteria for Plants and Soils. H.D. Chapman, Riverside, California. pp. 180-196.

Brewer, R.F. 1973b. Lead. In: H.D. Chapman (ed.). Diagnostic Criteria for Plants and Soils. H.D. Chapman, Riverside, California. pp. 213-217.

British Columbia Hydro. 1979. Hat Creek Project, 1978 Environmental Field Programs. British Columbia Hydro and Power Authority, Vancouver, B.C.

British Columbia Hydro. 1980. Hat Creek Project, 1979 Environmental Field Programs. British Columbia Hydro and Power Authority, Vancouver, B.C.

British Columbia Hydro and Power Authority. 1981. Hat Creek Project; Environmental Impact Statement. British Columbia Hydro and Power Authority, Vancouver, B.C.

Brown, J.C. Genetic potentials for solving problems of soil mineral stress: Iron deficiency and boron toxicity in alkaline soils. In: M.J. Wright (ed.). Plant Adaptation to Mineral Stress in Problem Soils. A special publication of Cornell University Agricultural Experiment Station, Cornell University, Ithaca, New York. pp. 83-94.

Buckley, W. 1982. Personal Communication, January 18, 1982. Research Scientist, Agriculture Canada. Agassiz, B.C.

Buckman, H.O. and N.C. Brady. 1969. The Nature and Properties of Soils 7th edition. The Macmillan Company. 653 pp.

Cannon, H.L. 1970. Trace element excesses and deficiencies in some geochemical provinces of the United States. In: D.D. Hemphill (ed.). Trace Substances in Environmental Health - III. Proceedings of University of Missouri's 3rd Annual Conference on Trace Substances in Environmental Health. University of Missouri, Columbia, Missouri. pp. 21-44.

Cannon, H.L. 1976. Lead in vegetation. In: Lovering, T.G. (ed.). Lead in the Environment. Geological Professional Paper 957. U.S. Department of the Interior, Washington.

Chapman, H.D. 1967. Plant analysis values suggestive of nutrient status of selected crops. In: G.W. Hardy (ed.). Soil Testing and Plant Analysis. Part II. Plant Analysis. Number 2 in the Soil Science Society of American (SSSA) Special Publication Series. Soil Science Society of America, Madison, Wisconsin. pp. 77-92.

Chapman, H.D. (ed.). 1973. Diagnostic Criteria for Plants and Soil. H.D. Chapman, Riverside, California. 793 pp.

Chmiel, K.M. and R.M. Harrison. 1981. Lead content of small mammals at a roadside site in relation to the pathways of exposure. Sci. Total Environ. 17:145-154.

Church, D.C., G.E. Smith, J.P. Fontenot and A.T. Rallston. 1971. Digestive Physiology and Nutrition of Ruminants - Vol. 2 - Nutrition. Oregon State University.

Davis, R.D. and P.H.T. Beckett. 1978. Upper critical levels of toxic elements in plants. II. Critical levels of copper in young barley, wheat, rape, lettuce and ryegrass, and of nickel and zinc in young barley and ryegrass. New Phytol. 80:23-32.

Davison, A.W. J. Blakemore, and C. Craggs. 1979. The fluoride content of forage as an environmental quality standard for the protection of livestock. Environ. Pollnt. 20:279-296.

Dudas, M.J. and J. Pawluk. 1976. The nature of mercury in Chernozemic and Luvisolic soils in Alberta. Can. J. Soil Sci. 56:413-423.

Duncan, D.B. 1955. Multiple range and multiple F tests. Biometrics 11:1-42.

Eaton, F.M. 1944. Deficiency, toxicity, and accumulation of boron in plants. J. Agric. Res. 69:237-277.

Egan, A.R. 1975. The diagnosis of trace element deficiencies in the grazing ruminant. In: D.J.D. Nicholas and A.R. Egan (eds.). Trace Elements in Soil-Plant-Animal Systems. Academic Press Inc., New York. pp. 371-384.

Erdman, J.A. 1978. Potential toxicologic problems associated with strip mining. Proceedings of the Fourth Biennial Veterinary Toxicology Workshop. Utah State University.

Erdman, J.A. and R.J. Ebens. 1979. Element content of crested wheatgrass grown on reclaimed coal spoils and on soils nearby. J. Range Manage. 32(2):159-161.

Erdman, J.A. and L.P. Gough. 1979. Mineral composition of wheat from coal-mine spoils and farms in the Northern Great Plains, U.S.A. In: M.K. Wali (ed.). Ecology and Coal Resource Development, Volume Two. International Congress for Energy and the Ecosystem, University of North Dakota, Grand Forks. Pergamon Press, New York. pp. 878-886.

Erdman, J.A., R.J. Ebens and A.A. Case. 1978. Molybdenosis: a potential problem in ruminants grazing on coal mine spoils. J. Range Manage. 31:34-46.

Ganje, T.J. 1973. Selenium. In: H.D. Chapman (ed.) Diagnostic Criteria for Plants and Soils. H.D. Chapman, Riverside, California. pp. 394-404.

Goodall, D.S. and F.G. Gregory. 1947. Chemical Composition of Plants as an Index of their Nutritional Status. Imp. Bur. Hort. Plantation Crops Tech. Comm. 17. 167 pp.

Gough, L.P., R.C. Severson and J.M. McNeal. 1979. Extractable and total-soil element concentrations favorable for native plant growth in the Northern Great Plains. In: M.K. Wali (ed.). Ecology and Coal Resource Development, Volume Two. International Congress for Energy and the Ecosystem, University of North Dakota, Grand Forks. Pergamon Press, New York. pp. 859-869.

Grant, A.B. 1981. Observations on analysis of selenium in plant and animal tissues and in soil samples. N. Zealand Journal of Science 24:65-79.

Hardy, G.W. (ed.). 1967. Soil Testing and Plant Analysis. Part II. Plant Analysis. Numer 2 in the Soil Science of America (SSSA) Special Publication Series. Soil Science Society of America, Madison, Wisconsin.

Harve, G.N. 1970. The mineral composition of lichen related to studies of trace element metabolism in reindeer. In: C.F. Mills (ed.). Trace Element Metabolism in Animals. Proceedings of WAAP/IBP International Symposium, Aberdeen, Scotland, July 1969. E. & S. Livingstone, Edinburgh. pp. 380-382.

Healy, W.B. 1974. Ingested soil as a source of elements to grazing animals. In: W.G. Hoekstra, J.W. Suttie H.E. Ganther and W. Mertz. (eds.). Trace Element Metabolism in Animals-2. University Park Press, Baltimore, Maryland. pp. 448-450.

Heit, M. 1977. A Review of Current Information on Some Ecological and Health Related Aspects of the Release of Trace Metals into the Environment Associated with the Combustion of Coal. Health and Safety Laboratory, Energy Research and Development Administration Information Centre, Oak Ridge, Tennessee. 51 pp.

Hemphill, D.D. (ed.). 1980. Trace Substances in Environmental Health - III. Proceedings of Unviersity of Missouri's 3rd Annual Conference on Trace Substances in Environmental Health. University of Missouri, Columbia, Missouri. 391 pp.

Hodgson, J.F. 1970. Chemistry of trace elements in soils with reference to trace element concentration in plants. In: D.D. Hemphill (ed.). Trace Substances in Environmental Health - III. Proceedings of University of Missouri's 3rd Annual Conference on Trace Substances in Environmental Health. Unversity of Missouri, Columbia, Missouri. pp. 45-58.

Hoekstra, W.G., J.W. Suttie, H.E. Ganther and W. Mertz. (eds.). Trace Element Metabolism in Animals - 2. University Park Press, Baltimore, Maryland. 775 pp.

Howell, F.G., J.B. Gentry and M.H. Smith (eds.). 1975. Mineral Cycling in Southeastern Ecosystems. Proceedings of Symposium held at Augusta, Georgia, May 1 - 3, 1974. Energy Research and Development Administration Symposium Series 36. National Technical Information Service, Springfield. Virgina.

Jarvis, S.C. and L.H.P. Jones. 1980. The contents and sorption of cadmium in some agricultural soils of England and Wales. J. Soil Sci. 31:469 - 479.

Johnson, C.M. 1973. *Molybdenum.* In: *H.D. Chapman (ed.). Diagnostic* Criteria for Plants and Soil. H.D. Chapman, Riverside, California. pp. 286-301.

Jones, J.B. 1967. Interpretation of plant analysis for several agronomic crops. In: G.W. Hardy (ed.). Soil Testing and Plant Analysis. Part II. Plant Analysis. Number 2 in the Soil Science Socity of America (SSSA) Special Publication Series. Soil Science Society of America, Madison, Wisconsin. pp. 49-58.

Jones, J.B. 1977. Plant tissue analysis for micronutrients. In: J.J. Mortvedt, P.M. Giordano and W.L. Lindsay (eds.). Micronutrients in Agriculture. Proceedings of a Symposium at Muscle Shoals, Alabama. Soil Science Society of America, Madison, Wisonsin. pp. 319-346.

Jones, L.H.P., C.R. Clement and M.J. Hopper. 1973. Lead uptake from solution by perennial ryegrass and its transport from roots to shoots. Plant and Soil 38:403-414.

Keisling, T.C. and B. Mullinix. 1979. Statistical considerations for evaluating micronutrient tests. Soil Sci. Soc. Am. J. 43:1181-1184.

Kubota, J. and W.H. Allaway. 1977. Geographic distribution of trace element problems. In: J.J. Mortvedt, P.M. Giordano and W.L. Lindsay (eds.). Micronutrients in Agriculture. Proceedings of a Symposium at Muscle Shoals, Alabama. Soil Science Society of America, Madison, Wisconsin. pp. 524-554.

Lee, H.J. 1975. Trace elements in animal production. In: D.J.D. Nicholas and A.R. Egan (eds.). Trace Elements in Soil-Plant-Animal Systems. Academic Press, New York. pp. 39-54.

Liebig, G.F. 1973. Arsenic. In: H.D. Chapman (ed.). Diagnositc Criteria for Plants and Soils. H.D. Chapman, Riverside, California. pp. 13-23.

Lisk, D.J. 1972. Trace metals in soils, plants and animals. Adv. in Argron. 24:267-325.

Loneragan, J.F. 1980. Plant efficiencies in the use of B, Co, Cu, Mn, and Zn. In: M.J. Wright (ed.). Plant Adaptation to Mineral Stress in Problem Soils. A special publication of Cornell University Agricultural Experiment Station, Cornell Unviersity, Ithaca, New York. pp. 193-203.

Mankovska, B. 1981. Contamination of beech and oak by Mg, S, F, Pb, Cd and Zn near magnesite works. Biologia (Bratislava) 36(7):489-496.

Martin, W.E. and J.E. Matocha. 1973. Plant Analysis as in aid in the fertilization of forage crops. In: L.M. Walsh and J.D. Beaton (eds.). Soil Testing and Plant Analysis. Soil Science Society of America, Inc., Madison, Wisconsin. pp. 393-426.

McFee, W.W., W.R. Byrnes and J.G. Stockton. 1981. Characteristics of coal mine overburden important to plant growth. J. Environ. Qual. 10(3):300-308.

Mills, C.F. (ed.). 1970. Trace Element Metabolism in Animals. Proceedings of WAAP/IBP International Symposium, Aberdeen, Scotland. July 1969. E. & S. Livingstone, Edinburgh. 550 pp.

Monenco Consultants Pacific Limited. 1981. Hat Creek Project Revegetation Potential of Waste Materials. Prepared for Acres Consulting Services, Vancouver.

Monenco Consultants Pacific Limited. 1982. Hat Creek Reclamation Studies 1981: Forage Productivity of Waste Materials and Rangeland. Prepared for B.C. Hydro, Vancouver.

Monenco Limited. 1982. Wabamun Ash Lagoon Reclamation Studies, 1981. Prepared for TransAlta Utilities, Calgary, Alberta (In preparation).

Mortvedt, P.M., Giordano and W.L. Lindsay (eds.). 1977. Micronutrients in Agriculture. Proceedings of a Symposium at Muscle Shoals, Alabama. Soil Science Society of America, Madison, Wisconsin. 666 pp.

Munshower, F.F. and D.R. Neumann. 1979. Trace element concentrations in plants from revegetated strip mined lands and native range in southeastern Montana. In: M.K. Wali (ed.). Ecology and Coal Resource Development. Volume Two. International Congress for Energy and the Ecosystem, University of North Dakota, Grand Forks. Pergamon Press, New York. pp. 887-891.

National Research Council Canada. 1973. Lead in the Canadian Environment. National Research Council Canada, Ottawa, Canada. 116 pp.

National Research Council Canada. 1976. Effects of Chormium in the Canadian Environment. National Research Council Canada, Ottawa, Canada. 168 pp.

National Research Council Canada. 1977a. Sulphur and its Inorganic Derivatives in the Canadian Environment. National Research Council Canada, Ottawa, Canada. 426 pp.

National Research Council Canada. 1977b. The Effects of Alkali Halides in the Canadian Environment. National Research Council Canada, Ottawa, Canada. 171 pp.

National Research Council Canada. 1977c. Environmental Fluoride 1977. National Research Council Canada, Ottawa, Canada. 151 pp.

National Research Council Canada. 1978. Effects of Arsenic in the Canadian Environment. National Research Council Canada, Ottawa, Canada. 363 pp.

National Research Council Canada. 1979a. Effects of Lead in the Environment - 1978. Quantitative Aspects. National Research Council Canada, Ottawa, Canada. 779 pp.

National Research Council Canada. 1979b. Effects of Mercury in the Canadian Environment. National Research Council Canada, Ottawa, Canada. 290 pp.

National Research Council Canada. 1979c. Effects of Cadmium in the Canadian Environment. National Research Council Canada, Ottawa, Canada. 148 pp.

National Research Council Canada. 1980. Effects of Vanadium in the Canadian environment. National Research Council of Canada, Ottawa, Canada. 94 pp.

Nicholas, D.J.D. and A.R. Egan (eds.). 1975. Trace Elements in Soil-Plant-Animal Systems. Academic Press Inc., New York. 417 pp.

Parry G.D.R., M.S. Johnson and R.M. Bell. 1981. Trace metal surveys of soil as a component of strategic and local planning policy development. Environ. Poll. (Ser. B) 2:97-107.

Pratt, P.F. 1973a. Chromium. In: H.D. Chapman (ed.). Diagnostic Criteria for Plants and Soil. H.D. Chapman, Riverside, California. pp. 136-141.

Pratt, P.F. 1973b. Vanadium. In: H.D. Chapman (ed.). Diagnostic Criteria for Plants and Soil. H.D. Chapman, Riverside, California. pp. 480-483.

Reith, R.W.S. 1970. Soil factors influencing the trace element content of herbage. In: C.F. Mills (ed.). Trace Elements Metabolism in Animals. Proceedings of WAAP/IBP International Symposium, Aberdeen, Scotland. July 1969. E. & S. Livingstone, Edinburgh. pp. 410-412.

Reuther, W. and C.K. Labanaukas. 1973. Copper. In: H.D. Chapman (ed.). Diagnostic Criteria for Plants and Soil. H.D. Chapman, Riverside, California. pp. 157-179.

Romney, E.M. and J.D. Childress. 1965. Effects of beryllium in plants and soil. Soil Science 100(3):210-217.

S.A.S. Institute. 1979. Statistical Analysis System Users Guide. SAS Institute, Inc., Raleigh, North Carolina.

Sauchelli, V. 1969. Trace Elements in Agriculture. Van Nostrand Reinhold Company. New York. 248 pp.

Schwarz, K. 1974. New essential trace elements (S, V, F, Si): progress report and outlook. In: W.G. Hoekstra, J.W. Suttie, H.E. Ganther and W. Mertz (eds.). Trace Element Metabolism in Animals - 2. University Park Press. Baltimore, Maryland. pp. 355-380.

Scott, M.L. 1977. Trace elements in animal nutrition. In: J.J. Mortvedt, P.M. Giordano and W.L. Lindsay (eds.). Micronutrients in Agriculture. Proceedings of a symposium at Muscle Shoals, Alabama. Soil Science Society of America, Madison, Wisconsin. pp. 555-591.

Severson, R.C. 1979. Regional Soil Chemistry in the Bighorn and Wind River Basins, Wyoming and Montana. Geological Survey Professional Paper 1134-B, U.S. Department of the Interior, Washington, D.C. 9 pp.

Severson, R.C. and L.P. Gough. 1981. Geochemical variability of natural soils and reclaimed mine-spoil soils in the San Juan Basin, New Mexico. Geological Survey Professional Paper 1134-C, U.S. Department of the Interior, Washington, D.C. 39 pp.

Severson, R.C. and R.R. Tidball. 1979. Spatial variation in total element concentration in soil within the northern Great Plains coal region. Geological survey Professional Paper 1134-A. U.S. Department of the Interior Washington, D.C. 17 pp.

Shacklette, H.T., J.C. Hamilton, J.G. Boerngen and J.M. Bowles. 1971. Elemental compositon of surficial materials in the conterminous United States. U.S. Geological Survey Professional Paper 574 - D. 171 pp.

Swaine, D.J. 1955. The Trace-Element Content of Soils. Commonwealth Agricultural Bureau, England. p. 157.

Taylor, R.W., and G.F. Griffin. 1981. The distribution of topically applied heavy metals in the soil. Plant and Soil 62: 147-152.

Thornton, I. and Webb, J.J. 1970. Geochemical reconnaissance and the detection of trace element disorders in animals. In: C.F. Mills (ed.). Trace Element Metabolism in Animals. Proceedings of WAAP/IBP International Symposium, Abedeen, Scotland, July 1969. E. & S. Livingstone, Edinburgh. pp. 397-409.

Trierweiler, J.F. 1981. Personal communication. August 1981. Associate Professor, Ohio Agricultural Research and Development Center, Wooster, Ohio.

Underwood, E.J. 1971. Trace Elements in Human and Animal Nutrition. 3rd ed. Academic Press, New York. 543 pp.

Vanselow, A.P. 1973. Cobalt. In: H.D. Chapman (ed.). Diagnostic Criteria for Plants and Soil. H.D. Chapman, Riverside, California. pp. 142-156.

Van Ryswick, A. 1982. Personal Communication, January 18, 1982. Research Scientist, Agriculture Canada. Kamloops, B.C.

Wali, M.K. (ed.). 1979. Ecology and Coal Resource Development, Volume Two. International Congress for Energy and the Ecosystem, University of North Dakota, Grand Forks. Pergamon Press, New York. 548 pp.

Walsh, L.M. and J.D. Beaton. (eds.). 1973. Soil Testing and Plant Analysis. Soil Science Society of America, Inc. Madison, Wisconsin. 491 pp.

Warren, H.V., R.E. Delavault and C.H. Cross. 1970. Base metal pollution in soils. In: J.D. Hemphill (ed.). Trace Substances in Environmental Health - III. Proceedings of University of Missouri's 3rd Annual Conference on Trace Substances in Environmental Health. University of Missouri, Columbia, Missouri. PP. 9 - 20.

Wright, M.J. (ed.). Plant Adaptation to Mineral Stress in Problem Soils. A special publication of Cornell University Agricultural Experiment Station, Cornell University, Ithaca, New York. 420 pp.

APPENDIX A

1981 LABORATORY ANALYSIS RESULTS

TABLE A

Lab Analysis Results - Trace Element Concentrations in Vegetation Grown on Waste Materials

OBS	Substrate	Species	Plant part	Rep	*Cu	Mo	Pb	Zn	Cd	Ni	Co	Cr	As	U	Se	Sn	Hg (ppb)	F	Mn	V	Be	B
1	Houth	Bluegrass	Leaves	1	12.0	2.0	0.6	17.0	0.12	0.6	0.3	0.4	< 1.0	<0.1	<1.0	< 1.0	< 10	5	48	1	< 0.04	5.8
2	H	B	L	2	12.9	2.2	1.0	17.2	0.16	0.5	0.1	0.4	< 1.0	<0.1	<1.0	< 1.0	<10	5	39	1	< 0.04	4.3
3	H	B	L	3	11.3	0.6	0.6	15.6	0.14	0.8	0.1	0.8	< 1.0	<0.1	<1.0	< 1.0	<10	5	45	1	0.08	4.5
4	H	B	L	4	11.0	0.6	0.6	13.0	0.14	1.0	0.1	0.8	< 1.0	< 0.1	<1.0	< 1.0	15	5	20	1	< 0.04	5.3
5	H	B	Tops	1	15.8	1.8	0.8	19.5	0.12	0.7	0.2	4.0	< 1.0	< 0.1	<1.0	< 1.0	10	5	59	1	< 0.04	8.3
6	H	B	T	2	15.3	0.8	0.7	17.3	0.16	0.8	0.3	0.8	< 1.0	< 0.1	<1.0	< 1.0	15	8	132	1	0.04	15.8
7	H	B	T	3	20.0	1.0	0.2	17.9	0.24	1.0	0.1	0.8	< 1.0	< 0.1	<1.0	< 1.0	10	6	32	1	< 0.04	8.3
8	H	B	T	4	14.8	0.6	0.6	15.9	0.26	1.3	0.1	0.8	< 1.0	< 0.1	<1.0	< 1.0	< 10	5	38	1	< 0.04	9.3
9	H	B	Roots	1	20.0	2.4	2.9	55.0	0.50	15.0	5.0	22.0	< 1.0	0.20	<1.0	< 1.0	45	8	440	42	0.64	6.5
10	H	B	R	2	18.7	2.0	2.2	39.3	0.58	14.3	4.0	18.0	< 1.0	0.10	<1.0	< 1.0	15	8	350	30	0.44	7.0
11	H	B	R	3	20.0	1.8	2.2	38.1	0.48	14.0	2.9	20.0	< 1.0	0.10	<1.0	< 1.0	20	8	362	28	0.48	7.3
12	H	B	Shoots	1	9.1	1.4	0.1	14.9	0.26	1.4	0.2	0.8	< 1.0	< 0.1	< 1.0	< 1.0	< 10	7	65	1	< 0.04	5.3
13	H	B	S	2	15.4	0.4	0.4	13.2	0.20	0.7	0.1	0.4	2.0	< 0.1	< 1.0	< 1.0	15	4	63	1	< 0.04	13.0
14	H	B	S	3	10.8	0.4	0.7	12.0	0.34	0.8	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	20	4	30	1	< 0.04	7.5
15	H	B	S	4	11.9	0.6	0.9	7.0	0.40	1.5	0.2	0.4	< 1.0	< 0.1	< 1.0	< 1.0	45	5	33	1	< 0.04	18.8
16	H	Oxytropis	S	1	6.0	2.0	0.7	13.8	0.22	1.5	0.2	0.8	< 1.0	< 0.1	< 1.0	1.0	40	5	90	1	< 0.04	30.0
17	H	O	S	2	9.8	3.8	0.3	14.0	0.12	2.4	0.2	1.6	< 1.0	< 0.1	< 1.0	1.0	100	7	72	1	< 0.04	40.0
18	H	O	S	3	11.7	4.4	0.2	23.7	0.16	2.6	0.4	2.0	< 1.0	< 0.1	< 1.0	< 1.0	90	4	48	2	< 0.04	34.0
19	H	O	S	4	10.9	4.0	0.8	21.9	0.24	0.8	0.1	1.2	< 1.0	< 0.1	< 1.0	< 1.0	140	5	40	1	< 0.04	22.0
20	Ash	Crested	Tops	1	15.0	4.2	1.1	19.7	0.14	0.3	0.1	0.4	< 1.0	< 0.1	2.0	< 1.0	10	4	18	1	< 0.04	265.0
21	A	C	T	2	20.2	2.6	1.3	29.4	0.26	0.6	0.1	0.4	< 1.0	< 0.1	< 1.0	1.0	10	5	18	1	< 0.04	188.0
22	A	C	T	3	17.4	3.4	1.5	18.7	0.20	0.7	0.1	0.4	< 1.0	< 0.1	< 1.0	1.0	27	3	19	1	< 0.04	174.0
23	A	C	T	4	19.7	4.8	1.3	23.0	0.12	1.1	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	< 10	2	11	1	< 0.04	240.0
24	A	C	Roots	1	336.0	13.4	5.8	32.2	0.38	20.0	4.2	18.0	10.0	< 0.1	2.0	1.0	37	5	95	54	0.60	141.0
25	A	C	R	2	346.0	23.0	6.0	29.0	0.38	20.7	5.3	19.0	11.0	< 0.1	< 1.0	< 1.0	42	4	130	56	0.64	132.0

* Values expressed in parts per million (ppm) unless otherwise noted.

TABLE A (Cont'd)

OBS	Substrate	Species	Plant part	Rep#	Cu	Mo	Pb	Zn	Cd	Ni	Co	Cr	As	U	Se	Sn	Hg (ppb)	F	Mn	V	Be	B
26	Ash	Crested	Roots	3	383.0	19.0	6.7	55.0	0.36	25.8	7.3	24.0	12.0	0.60	2.0	< 1.0	25.0	2	210	74	0.80	120.0
27	A	C	R	4	445.0	19.2	7.2	53.5	0.32	29.5	10.5	28.0	15.0	0.70	1.0	< 1.0	40	2	186	90	0.96	107.0
28	A	C	Leaves	1	15.3	2.6	0.4	21.9	0.16	0.7	0.2	0.8	< 1.0	0.10	< 1.0	< 1.0	30	3	26	2	0.04	42.5
29	A	C	L	2	10.0	2.4	0.3	25.9	0.12	0.3	0.2	0.4	< 1.0	< 0.1	< 1.0	< 1.0	20	2	27	1	0.04	69.5
30	A	C	L	3	10.0	5.0	0.6	16.5	0.08	0.1	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	30	2	14	1	< 0.04	118.0
31	A	C	L	4	8.4	4.8	0.5	12.2	0.04	0.7	0.2	0.4	< 1.0	< 0.1	< 1.0	< 1.0	30	2	8	1	< 0.04	163.0
32	Baked Clay	Alfalfa	Shoots	1	7.3	4.8	0.5	16.0	0.04	1.3	0.1	0.8	< 1.0	< 0.1	< 1.0	< 1.0	< 10	5	52	1	< 0.04	101.0
33	B	A	S	2	6.8	4.4	0.3	14.4	0.04	0.8	0.2	1.2	< 1.0	< 0.1	< 1.0	< 1.0	20	5	54	1	< 0.04	44.0
34	B	A	S	3	9.3	3.8	0.6	16.0	0.02	0.8	0.1	0.8	< 1.0	< 0.1	< 1.0	< 1.0	10	2	60	1	< 0.04	47.0
35	B	A	S	4	6.8	3.6	0.6	17.2	0.06	1.2	0.3	0.8	< 1.0	< 0.1	< 1.0	< 1.0	10	2	63	1	< 0.04	35.0
36	B	Crested	S	1	13.5	2.0	1.3	8.5	0.18	0.6	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	40	2	30	2	< 0.04	150.0
37	B	C	S	2	15.9	2.2	1.3	8.4	0.16	0.4	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	55	2	29	1	< 0.04	41.0
38	B	C	S	3	15.1	2.2	0.9	14.0	0.12	0.1	0.1	0.4	< 1.0	< 0.1	< 1.0	1.0	30	2	29	1	< 0.04	56.5
39	B	C	S	4	12.4	2.2	0.9	12.5	0.12	0.1	0.3	0.4	< 1.0	< 0.1	< 1.0	1.0	20	2	25	2	< 0.04	17.5
40	B	C	Roots	1	51.0	2.4	4.8	26.0	0.50	35.0	10.4	20.0	3.0	0.50	< 1.0	1.0	35	9	150	80	0.96	22.0
41	B	C	R	2	69.0	1.4	6.0	28.3	0.38	29.5	9.5	27.0	3.0	< 0.1	< 1.0	1.0	35	5	176	100	1.00	40.0
42	B	C	R	3	38.0	1.8	4.8	35.8	0.50	21.9	9.7	18.0	4.0	0.60	< 1.0	< 1.0	10	10	212	64	0.72	41.0
43	B	C	R	4	48.5	1.6	0.6	34.5	0.50	33.0	10.5	11.0	3.0	0.50	< 1.0	< 1.0	40	10	235	68	0.68	32.0
44	B	C	Tops	1	24.6	0.1	1.2	26.0	0.22	0.4	0.3	0.4	< 1.0	< 0.1	< 1.0	< 1.0	10	2	29	2	< 0.04	39.5
45	B	C	T	2	20.0	1.6	1.0	18.0	0.36	0.1	0.2	0.4	< 1.0	< 0.1	< 1.0	< 1.0	10	2	28	1	< 0.04	143.0
46	B	C	T	3	25.5	1.6	1.0	20.5	0.02	0.3	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	50	2	31	1	< 0.04	31.5
47	B	C	T	4	21.0	1.6	1.0	16.0	0.10	0.1	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	35	2	33	1	< 0.04	30.0
48	B	C	Leaves	1	8.1	0.1	1.5	9.8	0.10	0.1	0.1	0.4	< 1.0	< 0.1	1.0	2.0	155	2	45	1	< 0.04	17.5
49	B	C	L	2	8.2	1.4	1.6	6.5	0.12	0.1	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	55	1	45	1	< 0.04	12.9
50	B	C	L	3	8.5	0.8	0.5	7.3	0.40	0.1	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	90	2	65	1	< 0.04	98.0

TABLE A (Cont'd)

OBS	Substrate	Species	Plant part	Rep#	Cu	Mb	Pb	Zn	Cd	Ni	Co	Cr	As	U	Se	Sn	Hg (ppb)	F	Mn	V	Be	B
51	B	C	L	4	9.3	0.4	1.5	5.4	0.36	0.1	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	40	2	23	1	< 0.04	29.0
52	Waste	Crested	Shoots	1	13.5	0.1	0.7	13.3	0.32	0.1	0.2	0.4	< 1.0	< 0.1	< 1.0	< 1.0	40	1	55	1	< 0.04	19.3
53	W	C	S	2	13.5	0.6	0.3	31.0	0.24	1.6	0.6	0.4	< 1.0	< 0.1	< 1.0	< 1.0	30	1	48	1	< 0.04	16.0
54	W	C	S	3	13.0	0.4	0.8	33.7	0.28	0.8	0.6	0.4	< 1.0	< 0.1	< 1.0	< 1.0	30	2	40	1	< 0.04	23.0
55	W	C	S	4	10.0	0.2	1.3	24.8	0.18	0.1	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	30	1	60	1	< 0.04	16.5
56	W	Alfalfa	S	1	8.8	1.2	1.2	31.8	0.26	3.0	1.0	0.8	< 1.0	< 0.1	< 1.0	< 1.0	30	2	145	1	< 0.04	48.0
57	W	A	S	2	6.7	1.0	1.4	26.0	0.08	3.5	0.9	0.4	< 1.0	< 0.1	< 1.0	< 1.0	30	2	155	1	< 0.04	47.0
58	W	A	S	3	9.5	1.2	1.7	48.0	0.30	6.0	2.0	0.8	< 1.0	< 0.1	< 1.0	< 1.0	30	4	125	1	< 0.04	49.0
59	W	A	S	4	7.6	2.0	1.2	39.0	0.26	4.2	2.0	0.8	< 1.0	< 0.1	< 1.0	1.0	40	2	167	1	< 0.04	49.0
60	Colluvium	Crested	S	1	10.0	0.2	2.4	16.7	0.16	0.1	0.3	2.0	< 1.0	< 0.1	< 1.0	< 1.0	20	1	34	1	< 0.04	10.8
61	C	C	S	2	13.5	0.1	1.6	17.4	0.22	0.1	0.1	0.8	< 1.0	< 0.1	< 1.0	< 1.0	30	1	27	1	< 0.04	8.5
62	C	C	S	3	11.6	0.2	1.3	13.2	0.26	0.1	0.2	0.4	< 1.0	< 0.1	< 1.0	< 1.0	35	1	24	1	< 0.04	4.3
63	C	C	S	4	12.3	0.2	1.6	11.5	0.24	0.1	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	45	1	17	1	< 0.04	5.0
64	Topsoil	Alfalfa	S	1	11.2	2.0	0.9	24.5	0.20	2.2	0.2	1.2	< 1.0	< 0.1	< 1.0	1.0	45	1	32	1	0.04	46.0
65	T	A	S	2	9.0	3.6	0.4	17.0	0.14	0.8	0.1	0.8	< 1.0	< 0.1	< 1.0	< 1.0	50	1	35	1	< 0.04	54.0
66	T	A	S	3	8.3	4.6	0.8	14.8	0.10	1.1	0.1	1.2	< 1.0	< 0.1	< 1.0	< 1.0	70	1	45	1	< 0.04	50.0
67	T	A	S	4	10.0	3.0	0.7	12.5	0.08	0.8	0.1	1.2	< 1.0	< 0.1	< 1.0	< 1.0	30	1	45	1	< 0.04	50.0
68	Gritstone	A	S	1	7.2	3.8	1.8	18.8	0.24	1.0	0.2	0.8	< 1.0	< 0.1	< 1.0	< 1.0	30	5	120	1	< 0.04	49.0
69	G	A	S	2	6.0	2.0	2.6	17.6	0.28	4.4	0.8	1.2	< 1.0	< 0.1	< 1.0	< 1.0	35	12	105	1	0.08	41.0
70	G	A	S	3	8.5	3.0	1.2	18.0	0.22	1.0	0.3	1.2	< 1.0	< 0.1	< 1.0	< 1.0	10	5	92	1	< 0.04	41.0
71	G	A	S	4	10.6	3.8	1.0	14.0	0.20	2.6	0.3	0.4	< 1.0	0.10	< 1.0	< 1.0	10	7	109	1	< 0.04	35.0
72	Topsoil	Crested	S	2	8.7	0.4	1.3	6.5	0.48	0.1	0.1	0.4	< 1.0	0.10	< 1.0	1.0	15	6	21	1	< 0.04	9.0
73	T	C	S	3	9.2	0.4	1.4	6.0	0.36	0.1	0.2	0.4	< 1.0	< 0.1	< 1.0	< 1.0	25	5	26	1	< 0.04	11.0
74	T	C	S	4	8.6	0.2	2.0	7.9	0.36	0.1	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	25	4	26	1	< 0.04	29.0
75	Gritstone	C	S	1	8.2	0.4	0.8	15.5	0.18	0.1	0.3	0.4	< 1.0	0.10	< 1.0	< 1.0	15	6	57	1	< 0.04	21.0

TABLE A (Cont'd)

OBS	Substrate	Species	Plant part	Rep#	Cu	Mb	Pb	Zn	Cd	Ni	Co	Cr	As	U	Se	Sn	Hg (ppb)	F	Mn	V	Be	B
76	Gritstone	Crested	Shoots	2	9.4	0.2	3.0	27.0	0.34	0.1	0.2	0.4	< 1.0	< 0.1	< 1.0	< 1.0	20	5	64	1	< 0.04	6.0
77	G	C	S	3	15.2	0.4	2.0	29.5	0.28	0.2	0.2	0.4	< 1.0	< 0.1	< 1.0	< 1.0	10	3	58	1	< 0.04	14.5
78	G	C	S	4	12.2	0.2	2.2	26.0	0.28	0.6	0.4	0.8	< 1.0	< 0.1	< 1.0	1.0	20	3	52	1	< 0.04	24.0
79	Colluvium	Alfalfa	S	1	11.5	8.8	1.3	17.5	0.22	1.0	0.4	1.6	< 1.0	< 0.1	< 1.0	1.0	< 10	5	55	1	< 0.04	60.0
80	C	A	S	2	9.2	8.2	1.5	23.5	0.22	1.5	0.3	1.2	< 1.0	< 0.1	< 1.0	< 1.0	< 10	4	58	1	< 0.04	65.0
81	C	A	S	3	9.1	8.4	1.1	19.2	0.20	1.2	0.4	1.2	< 1.0	< 0.1	< 1.0	< 1.0	15	5	83	1	< 0.04	49.0
82	C	A	S	4	8.5	12.6	1.0	15.6	0.32	1.6	0.1	2.0	< 1.0	< 0.1	< 1.0	< 1.0	20	9	58	1	< 0.04	49.0
83	Ash	Crested	S	1	13.8	5.6	1.6	12.0	0.30	0.3	0.1	1.2	< 1.0	< 0.1	< 1.0	< 1.0	20	4	10	1	< 0.04	239.0
84	A	C	S	2	14.5	4.6	0.9	16.5	0.24	0.8	0.2	0.8	< 1.0	0.10	< 1.0	< 1.0	25	4	12	2	< 0.04	216.0
85	A	C	S	3	10.1	3.6	1.4	25.5	0.24	0.3	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	40	4	13	1	< 0.04	157.0
86	A	C	S	4	10.5	4.6	1.5	21.2	0.22	0.1	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	30	5	26	1	< 0.04	234.0
87	Topsoil	C	S	1	13.3	1.2	1.6	18.0	0.26	0.1	0.1	0.4	< 1.0	< 0.1	< 1.0	< 1.0	50	4	27	1	< 0.04	4.0
88	Colluvium	Root	Medium	1	60.0	2.0	11.0	80.0	0.10	62.0	19.0	76.0	10.0	1.50	< 1.0	1.0	70	320	440	115	1.80	4.0
89	C	R	M	2	57.0	2.5	38.0	98.0	0.10	63.0	17.0	77.0	15.0	1.50	1.1	1.0	60	305	445	117	1.70	5.0
90	C	R	M	3	55.0	1.0	8.5	85.0	0.10	55.0	17.0	74.0	12.0	1.00	< 1.0	1.0	95	130	535	110	1.80	4.0
91	C	R	M	4	38.0	2.0	6.5	82.0	0.10	42.0	14.0	75.0	6.0	1.50	< 1.0	1.0	75	280	455	85	1.60	3.0
92	Topsoil	R	M	1	47.0	2.0	5.0	93.0	0.10	44.0	15.0	76.0	10.0	1.00	< 1.0	1.0	85	240	620	110	1.80	4.0
93	T	R	M	2	50.0	2.0	6.0	95.0	0.10	52.0	16.0	78.0	12.0	1.00	< 1.0	1.0	60	290	630	115	1.80	5.0
94	T	R	M	3	50.0	2.0	5.0	86.0	0.10	52.0	16.0	82.0	15.0	1.50	< 1.0	1.0	65	240	615	110	1.60	6.0
95	T	R	M	4	54.0	3.0	6.0	85.0	0.10	54.0	16.0	88.0	11.0	1.50	< 1.0	1.0	70	290	545	150	1.80	4.0
96	Waste	R	M	1	50.0	2.0	5.0	98.0	0.10	76.0	18.0	48.0	35.0	1.00	< 1.0	1.0	190	210	430	115	1.60	7.0
97	W	R	M	2	54.0	2.0	10.0	47.0	0.10	38.0	10.0	46.0	10.0	1.50	< 1.0	1.0	80	270	175	125	1.40	11.0
98	W	R	M	3	60.0	3.0	5.0	40.0	0.10	36.0	12.0	42.0	9.0	1.50	< 1.0	1.0	95	210	105	110	1.40	13.0
99	W	R	M	4	55.0	1.0	6.0	72.0	0.10	43.0	12.0	60.0	39.0	1.50	< 1.0	1.0	110	290	115	120	1.40	6.0

TABLE A (Cont'd)

OBS	Substrate	Species	Plant part	Rep#	Cu	Mb	Pb	Zn	Cd	Ni	Co	Cr	As	U	Se	Sn	Hg (ppb)	F	Mn	V	Be	B
100	Ash	Root	Medium	1	360.0	5.0	6.0	57.0	0.10	40.0	10.0	84.0	15.0	2.00	< 1.0	1.0	55	130	300	210	2.60	76.0
101	A	R	M	2	400.0	5.0	2.0	30.0	0.19	46.0	10.0	102.0	14.0	2.00	< 1.0	1.0	60	110	235	235	2.60	197.0
102	A	R	M	3	450.0	7.0	3.0	35.0	0.10	48.0	10.0	120.0	16.0	1.50	< 1.0	1.0	50	110	240	225	2.80	233.0
103	A	R	M	4	382.0	5.0	3.0	39.0	0.10	53.0	9.0	107.0	19.0	1.20	0.8	1.0	40	85	277	230	2.30	141.0
104	Baked Clay	R	M	1	44.0	1.0	1.0	23.0	0.10	54.0	15.0	114.0	14.0	2.00	< 1.0	1.0	25	120	815	235	3.60	8.0
105	B	R	M	2	50	2.0	4	42	0.1	50	16	110	15	1.5	< 1.0	1.0	30	110	432	255	2.8	6.0
106	B	R	M	3	57	2.0	5	63	0.1	62	20	92	12	2.0	< 1.0	1.0	20	200	502	260	2.8	12.0
107	B	R	M	4	65	2.0	10	38	0.1	61	15	92	17	1.5	< 1.0	1.0	20	120	155	250	2.0	6.0
108	Houth	R	M	1	29	2.0	5	88	0.1	25	11	92	5	1.5	< 1.0	1.0	60	110	630	100	1.6	6.0
109	H	R	M	2	22	2.0	3	46	0.1	14	5	111	5	1.0	1.1	1.0	33	180	262	57	1.5	3.0
110	H	R	M	3	27	1.0	2	53	0.1	15	9	76	3	1.0	< 1.0	1.0	50	220	555	70	1.6	3.0
111	H	R	M	4	27	1.0	1	46	0.1	15	9	68	3	1.0	< 1.0	1.0	35	210	390	75	1.8	0.7
112	Gritstone	R	M	1	40	2.0	4	58	0.1	49	14	94	11	2.0	< 1.0	1.0	50	220	475	160	2.0	5.0
113	G	R	M	2	55	3.0	8	88	0.1	66	20	82	11	2.5	< 1.0	1.0	20	250	490	225	2.4	9.0
114	G	R	M	3	40	3.0	4	52	0.1	48	14	72	12	2.0	< 1.0	1.0	25	260	530	200	2.4	12.0
115	G	R	M	4	55	2.0	6	72	0.1	64	18	74	15	2.5	< 1.0	1.0	25	270	485	230	2.2	10.0
116	Farmers Field	Alfalfa	Shoots	1	11	6.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
117	F	A	S	2	13	5.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
118	F	A	S	3	12	5.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
119	F	A	S	4	8	18.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Dirt = Soil Sample
Houth = Hout Meadows (native soil)
Crested = Crested Wheatgrass
Ash = Fly Ash
Waste = Coal Waste
Gritstone = Sandstone

APPENDIX B

COMPARISON OF MEANS AND CONFIDENCE LIMITS WITH PUBLISHED VALUES FOR ALFALFA, CRESTED WHEATGRASS AND SOILS

TABLE B-1

Comparison of mean level and confidence limits of the eighteen elements on the five substrates for alfalfa shoots

Sample	As	Be	B	Cd	Cr	Co	Cu	F	Pb	Mn	Hg	Mo	Ni	Se	Sn	U	V	Zn
al Waste 1978									- No data -									
1979	0.5	0.02	98	0.8	1.2	0.72	17	1.4	2.	153	80	1	2	0.2	1	0.1	1.2	54
1981	1	0.04	48.3±1.5	0.22±0.16	0.7±0.3	1.5±1.0	8.2±2.0	2.5±1.6	1.4±0.4	14.8±28.3	0.033±0.008	1.4±0.7	4.2±2.1	1	1	0.1	1.0±0.0	36.2±15.1
Normal value	0	X-	0	0-	X+	X+	0	0-	0	0	0	0	0+	0	0	0	0	0
Plant toxicity	0	0	0	0	ND	ND	0	ND	ND	0	ND	0	ND	0	ND	ND	ND	0
Plant deficiency	NE	NE	0	NE	NE	ND	0	NE	NE	0	NE	0	NE	ND	NE	NE	NE	0
Livestock toxicity	0	ND	ND	0	*	0	0	0	0	0	0	0	0	0	0	ND	0	0
Livestock deficiency	0	NE	NE	NE	0	0	0	0	NE	0	NE	0	0	0	NE	NE	0	0
Baked Clay 1978									- No data -									
1979									- No data -									
1981	1	0.04	56.8±47.6	0.04±0.03	0.9±0.3	0.2±0.2	7.6±1.9	3.5±2.8	0.5±0.2	57.3±8.2	0.011±0.010	4.2±0.9	1.0±0.4	1	1	0.1	1.0±0.0	15.9±1.8
Normal value	0	X-	0+	X--	X++	0-	0-	0-	0	0	0-	0+	0	0	0	0	0	0-
Plant toxicity	0	0	0	0	ND	ND	0	ND	ND	0	ND	0	ND	0	ND	ND	ND	0
Plant deficiency	NE	NE	0	NE	NE	ND	0	NE	NE	0	NE	0	NE	ND	NE	NE	NE	0
Livestock toxicity	0	ND	ND	0	*	0	0	0	0	0	0	0	0	0	0	ND	0	0
Livestock deficiency	0	NE	NE	NE	0	0	0	0	NE	0	NE	0	0	0	NE	NE	0	X-
Sandstone 1978									- No data -									
(Gritstone) 1979	0.5	0.04	93	0.8	2.2	0.39	16	2.5	4	80	105	5	2	0.3	1	0.1	2.2	107
1981	1	0.04	41.5±9.1	0.23±0.05	0.9±0.6	0.4±0.4	8.1±3.1	7.3±5.3	1.7±1.2	106.5±18.4	0.021±0.021	3.2±1.4	2.3±2.6	1	1	0.1	1.0±0.0	17.1±3.4
Normal value	0	X-	0	0	X+	0-	0-	0-	0	0	0	0	0-	0	0	0	0	0-
Plant toxicity	0	0	0	0	ND	ND	0	ND	ND	0	ND	0	ND	0	ND	ND	ND	0
Plant deficiency	NE	NE	0	NE	NE	ND	0	NE	NE	0	NE	0	NE	ND	NE	NE	NE	0
Livestock toxicity	0	ND	ND	0	*	0	0	0	0	0	0	0	0	0	0	ND	0	0
Livestock deficiency	0	NE	NE	NE	0	0	0	0	NE	0	NE	0	0	0	NE	NE	0	X-
lluvium 1978	1	-	-	0.1	-	-	5	-	1	110	0.03	4	1	0.2	-	-	-	36
1979	0.5	0.05	56	0.7	0.8	0.04	13	1.4	2	48	105	4	2	0.2	1	0.1	1.2	18
1981	1	0.04	55.8±12.8	0.24±0.08	1.5±0.6	0.3±0.2	9.6±2.1	5.0±3.5	1.2±0.4	63.5±20.9	0.011±0.012	9.5±3.3	1.3±0.4	1	1	0.1	1±0	19.0±5.4
Normal value	0	X-	0	0	X++	0	0	0-	0	0	0-	X++	0	0	0	0	0	0-
Plant toxicity	0	0	0	0	ND	ND	0	ND	ND	0	ND	0	ND	0	ND	ND	ND	0
Plant deficiency	NE	NE	0	NE	NE	ND	0	NE	NE	0	NE	0	NE	ND	NE	NE	NE	0
Livestock toxicity	0	ND	ND	0	*	0	0	0	0	0	0	0	0	0	0	ND	0	0
Livestock deficiency	0	NE	NE	NE	0	0	0	0	NE	0	NE	0	0	0	NE	NE	0	X-
Topsoil 1978									- No data -									
1979									- No data -									
1981	1	0.04	50.0±5.2	0.13±0.08	1.1±0.3	0.1±0.1	9.6±2.0	1.0±0	0.7±0.4	39.3±10.7	0.049±0.026	3.3±1.7	1.2±1.1	1	1	0.1	1±0	17.2±8.3
Normal value	0	X-	0	0-	X++	0-	0	X--	0	0-	0+	0+	0-	0	0	0	0	0-
Plant toxicity	0	0	0	0	ND	ND	0	ND	ND	0	ND	0	ND	0	ND	ND	ND	0
Plant deficiency	NE	NE	0	NE	NE	ND	0	NE	NE	0	NE	0	NE	ND	NE	NE	NE	0
Livestock toxicity	0	ND	ND	0	*	0	0	0	0	0	0	0	0	0	0	ND	0	0
Livestock deficiency	0	NE	NE	NE	0	0	0	0	NE	0	NE	0	0	0	NE	NE	0	X-
+ Mouth Meadows 1978									- No data -									
1979									- No data -									
1981	1	0.03±0	31.5±12.0	0.18±0.10	1.4±0.8	0.2±0.2	9.60±4.0	5.3±2.0	0.5±0.5	62.5±36.3	0.093±0.065	3.6±1.7	1.8±1.3	1	1	0.1	1.3±0.8	18.4±8.3
Normal value	0	X-	0-	0-	X++	0-	0-	0	0+	0-	X+	0+	0	0	0	0	0	0-
Plant toxicity	0	0	0	0	ND	ND	0	ND	ND	0	ND	0	ND	0	ND	ND	ND	0
Plant deficiency	NE	NE	0	NE	NE	ND	0	NE	NE	0	NE	0	NE	ND	NE	NE	NE	0
Livestock toxicity	0	ND	ND	0	*	0	0	0	0	0	0	0	0	0	0	ND	0	0
Livestock deficiency	0	NE	NE	NE	0	0	0	0	NE	0	NE	0	0	0	NE	NE	0	X-

\+ *Oxytropis* sp.

0 mean and C.L.'s inside normal normal range unlikely to be a problem

0-/+ slightly abnormal, mean inside normal range, C.L.'s (when applicable) extend below/above normal range

-/+ abnormal, mean outside normal range, C.L.'s (when applicable) extend below/above normal range

--/++ definitely abnormal, mean and C.L.'s (when applicable) outside normal range

* Cr^{3+} and Cr^{6+} have very different toxicity levels (50 pm for Cr^{6+} and 65000 ppm for Cr^{3+}). The analysis was for total Cr and not for Cr of different valencies. An evaluation cannot be made here.

ND - No data given in the literature

NE - Not yet proved essential to plants or livestock

TABLE B-2

Mean level and confidence limits of the eighteen elements in Crested Wheatgrass shoots on the six substrates. The results of the comparison of these values against published deficiency levels and toxicity levels in plant growth and animal nutrition are given.

Sample		As	Be	B	Cd	Cr	Co	Cu	F	Pb	Mn	Hg	Mo	Ni	Se	Sn	U	V	Zn
ly Ash	1978	1	0.02	488	0.1		0.24	8.5		1	19	0.02	9	1	0.35	1		3.0	17
	1979	2.0	0.04	372	1.0	2.5	0.28	23	12	3	28	0.115	11	1	0.4	1	0.1	6.2	19
	1981	1	0.04	211.5±0.05	0.25±0.05	0.7±0.6	0.1±0.1	12.2±3.6	4.3±0.8	1.4±0.5	15.3±11.6	0.029±0.014	4.6±1.3	0.4±0.5	1	1	0.1	1.3±0.8	18.8±9.3
Normal values		0	X-	X++	0	X+	0-	0	0	0	X--	0	0+	0-	0	0	0	0	0-
Plant toxicity		0	0	X++	0	ND	ND	0	ND	ND	0	ND	0	ND	0	ND	ND	ND	0
Plant deficiency		NE	NE	0	NE	NE	ND	0	NE	NE	0-	NE	0	NE	ND	NE	NE	NE	0
Livestock toxicity		0	ND	ND	0	*	0	0	0	0	0	0	0	0	0	0	ND	0	0
Livestock deficiency		0	NE	NE	NE	0	0	0	0	NE	X-	NE	0	0	0	NE	NE	0	X-
oal Waste	1978									- No data -									
	1979	0.5	0.01	21	0.5	0.9	0.11	10	2.4	2.0	95	0.075	1	1	0.2	1	0.1	1.4	40
	1981	1	0.04	18.7±5.1	0.25±0.10	0.4±0.0	0.4±0.4	12.5±2.7	1.3±0.8	0.8±0.7	50.8±13.8	0.033±0.008	0.3±0.4	0.7±1.1	1	1	0.1	1±0	25.7±14.4
Normal value		0	X-	X-	0	0	0+	0	X-	0	0	0	X-	0-	0	0	0	0	0-
Plant toxicity		0	0	0	0	ND	ND	0	ND	ND	0	ND	0	ND	0	ND	ND	ND	0
Plant deficiency		NE	NE	X-	NE	NE	ND	0	NE	NE	0	NE	X-	NE	ND	NE	NE	NE	0
Livestock toxicity		0	ND	ND	0	*	0	0	0	0	0	0	0	0	0	0	ND	0	0
Livestock deficiency		0	NE	NE	NE	0	0	0	0	NE	0	NE	X-	0	0	NE	NE	0	0-
Baked Clay	1978									- No data -									
	1979									- No data -									
	1981	1	0.04	66.1±92.5	0.14±0.005	0.4±0	0.2±0.2	14.2±2.5	2.0±0	1.1±0.4	28.3±3.5	0.036±0.024	2.2±0.2	0.3±0.4	1	1	0.01	1.5±0.9	10.9±4.5
Normal value		0	X-	0-	X-	0	0	0	0-	0	0-	0	0	0-	0	0	0	0	0-
Plant toxicity		0	0	0	0	ND	ND	0	ND	ND	0	ND	0	ND	0	ND	ND	ND	0
Plant deficiency		NE	NE	0	NE	NE	ND	0	NE	NE	0	NE	0	NE	ND	NE	NE	NE	0
Livestock toxicity		0	ND	ND	0	*	0	0	0	0	0	0	0	0	0	0	ND	0	0
Livestock deficiency		0	NE	NE	NE	0	0	0	0	NE	0	NE	0	0	0	NE	NE	0	X-
andstone	1978									- No data -									
(Gritstone)	1979	0.5	0.02	25	0.6	2.5	0.4	15	3.8	1	70	0.095	4	2	0.8	1	0.1	2.4	87
	1981	1	0.04	16.4±12.7	0.27±0.11	0.5±0.3	0.3±0.2	11.3±5.0	4.3±2.4	2.0±1.5	57.8±7.8	0.016±0.008	0.3±0.2	0.3±0.4	1	1	0.1	1.0±0.0	24.5±9.8
Normal value		0	X-	X-	0	0+	0	0	0-	0	0	0-	X-	0-	0	0	0	0	0
Plant toxicity		0	0	0	0	ND	ND	0	ND	ND	0	ND	0	ND	0	ND	ND	ND	0
Plant deficiency		NE	NE	X-	NE	NE	ND	0	NE	NE	0	NE	0-	NE	ND	NE	NE	NE	0
Livestock toxicity		0	ND	ND	0	*	0	0	0	0	0	0	0	0	0	0	ND	0	0
Livestock deficiency		0	NE	NE	NE	0	0	0	0	NE	0	NE	X-	0	0	NE	NE	0	0-
olluvium	1978	1	0.01		0.1		0.04	4.5	10	1	52	0.01	1	1	0.2	1		0.5	36
	1979	0.5	0.02	19	0.6	0.8	0.05	9	1.9	1	63	0.065	1	1	0.2	1	0.1	1.0	15
	1981	1	0.04	7.2±4.9	0.22±0.06	0.9±1.2	0.2±0.2	11.9±2.3	1.0±0.0	1.7±0.8	25.5±11.2	0.033±0.017	0.2±0.1	0.1±0	1	1	0.1	1±0	14.7±4.5
Normal value		0	X-	X--	0	X+	0-	0	X--	0	X-	0	X--	0-	0	0	0	0	0-
Plant toxicity		0	0	0	0	ND	ND	0	ND	ND	0	ND	0	ND	0	ND	ND	ND	0
Plant deficiency		NE	NE	X-	NE	NE	ND	0	NE	NE	0	NE	X-	NE	ND	NE	NE	NE	0
Livestock toxicity		0	ND	ND	0	*	0	0	0	0	0	0	0	0	0	0	ND	0	0
Livestock deficiency		0	NE	NE	NE	0	0	0	0	NE	X-	NE	X-	0	0	NE	NE	0	X-
Topsoil	1978									- No data -									
	1979									- No data -									
	1981	1	0.04	13.3±17.3	0.36±0.14	0.4±0	0.1±0.1	10.0±3.6	4.3±1.5	1.6±0.5	25.0±4.3	0.029±0.024	0.6±0.7	0.1±0	4	4	0.1	1±0	9.6±9.0
Normal value		0	X-	X-	0	0	0-	0	0	0	X--	0	0-	0-	0	0	0	0	X-
Plant toxicity		0	0	0	0	ND	ND	0	ND	ND	0	ND	0	ND	0	ND	ND	ND	0
Plant deficiency		NE	NE	X-	NE	NE	ND	0	NE	NE	0	NE	0	NE	ND	NE	NE	NE	X-
Livestock toxicity		0	ND	ND	0	*	0	0	0	0	0	0	0	0	0	0	ND	0	0
Livestock deficiency		0	NE	NE	NE	0	0	0	0	NE	X-	NE	0-	0	0	NE	NE	0	X-
Howth Meadows	1978									- No data -									
	1979									- No data -									
	1981	1	0.03±0	11.2±9.6	0.30±0.14	0.5±0.3	0.2±0.1	11.8±4.2	5.3±2.2	0.5±0.6	47.8±30.0	0.021±0.027	0.7±0.8	1.1±0.7	1	1	0.1	1±0	11.8±5.4
Normal value		0	X-	X-	0	0+	0	0	0	0-	0-	0	0-	0	0	0	0	0	0-
Plant toxicity		0	0	0	0	ND	ND	0	ND	ND	0	ND	0	ND	0	ND	ND	ND	0
Plant deficiency		NE	NE	X-	NE	NE	ND	0	NE	NE	0	NE	0	NE	ND	NE	NE	NE	0
Livestock toxicity		0	ND	ND	0	*	0	0	0	0	0	0	0	0	0	0	ND	0	0
Livestock deficiency		0	NE	NE	NE	0	0	0	0	NE	0	NE	0	0	0	NE	NE	0	X-

Bluegrass

0 Mean and C.L.'s inside normal range - unlikely to be problem

0-/+ slightly abnormal; mean inside normal range, C.L.'s (when applicable) extend below/above normal range

-/+ abnormal; mean outside normal range; C.L.'s (when applicable extend below/above normal range.

--/++ Definitely abnormal; mean and C.L.'s (when applicable) outside normal range.

Cr^{3+} and Cr^{6+} have very different toxicity levels (50 ppm for Cr^{+6} and 65000 ppm for Cr^{+3}). The analysis was for total Cr and not for Cr of different valences. An evaluation can not be made here.

NE - Not yet proved essential to plants or livestock

ND - No data given in the literature

TABLE B-3

Comparison of means and confidence limits of the eighteen elements
in the seven substrates with published values

	Element																	
Substrate	As	Be	B	Cd	Cr	Co	Cu	F	Pb	Mn	Hg	Mo	Ni	Se	Sn	U	V	Zn
Mean Value	6	3.3	15	0.1	100	16	30	200	15	700	0.3	2	50	0.6	10	3	125	50
Range	0.25-45	0.1-40	10-100	0.04-0.4	30-400	4-35	4-70	10-1000	4-100	200-3000	0.07-0.5	0.2-8	5-500	0.05-2	2-200	-	15-450	15-350
Fly Ash	0	0	X+	0	0	0	X++	0	0-	0	X—	0+	0	0	X-	-*	0	0
Coal Waste	0+	0	X-	0	0	0	0	0	0-	0	0	0	0	0	X-	-	0	0
Baked Clay	0	0	X-	0	0	0	0	0	0-	0-	X—	0	0	0	X-	-	0	0
Sandstone	0	0	X-	0	0	0	0	0	X-	0	X—	0	0	0	X-	-	0	0
Colluvium	0	0	X—	0	0	0	0	0	0-	0	0-	0	0	0	X-	-	0	0
Topsoil	0	0	X—	0	X—	X++	0	0	0	0	0-	0	0	0	X-	-	0	0
Houth Meadows	0	0	X—	0	0	0	0	0	X-	0	X—	0	0	0	X-	-	0	0

* Too few data are given in the literature for a valid comparison to be made for uranium.

0 Mean and C.L.'s inside normal range - unlikely to be a problem

0-/+ Slightly abnormal, mean inside normal range, C.L.'s (when applicable) extend below/above normal range

X-/+ Abnormal, mean outside normal range, C.L.'s (when applicable) extend below/above normal range

X—/+ Definitely abnormal, mean and C.L.'s (when applicable) outside normal rante