REPORT OF THE ACID RAIN COMMITTEE

July 1977

by

Acid Rain Committee

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FOREWARD

The Acid Rain Committee was composed of 8 members:

V.G. Bartnick (Fisheries and Environment Canada, Vancouver)
R.G. Ferguson (B.C. Hydro, Vancouver), Chairman
J.G. Malick (B.C. Research, Vancouver), Editor
M.D. Nassichuk (Fisheries and Environment Canada, Vancouver)
C. Newcombe (B.C. Fish and Wildlife Branch, Victoria)
T.G. Northcote (University of British Columbia, Vancouver)
B.D. Tutty (Fisheries and Environment Canada, Vancouver)
J.A. Servizi (International Pacific Salmon Fisheries Commission, Cultus Lake).

This committee was commissioned on 19 October, 1976 at a meeting requested by the Fisheries and Marine Service under the auspices of the Regional Screening and Coordinating Committee Hat Creek Working Group, Department of Fisheries and Environment. The purpose of the meeting was to review the nature and extent of the environmental studies pertaining to the potential for aquatic acidification being conducted for B.C. Hydro and Power Authority in conjunction with the proposed Hat Creek coal thermal generation plant. Besides the two agencies mentioned above, the B.C. Fish and Wildlife Branch and the International Pacific Salmon Fisheries Commission were also represented at this meeting.

B.C. Hydro and B.C. Hydro's consultants, were requested to provide information on the nature and consequences of "acid rain" in aquatic ecosystems. Since details of this phenomenon were not available to the meeting, but were known to be in scientific literature, this committee was formed to assemble and disseminate this knowledge.

Although the committee's objectives were not defined they were assumed to be:

1. Review literature and reports on acid rain effects; particularly in regard to the characteristics of aquatic ecosystems.
2. From (1) above, suggest biological and physical-chemical parameters that should be monitored and habitats that are expected to be most sensitive to acid rain.
3. Assemble existing data on the biota and physical-chemical characteristics of watersheds downwind from Harry Lake.

The major portion of this report embodies a literature review coordinated by Dr. J. Malick. On 15 July, 1977 this committee met to finalize the report and complete monitoring recommendations. The B.C. Fish and Wildlife Branch provided physical-chemical data on water bodies in the Hat Creek study area (Appendix A), data for regional monitoring and suggestions regarding specific monitoring sites (Appendix B) and recommendation 9. Their report concerning these items is being prepared and will be issued separately. B.C. Hydro's report summarizing available meteorology data and indicating the potential for acid precipitation is incorporated in this report (Section II).

The recommendations of this committee are intended to provide an early warning of any alteration of pH in aquatic systems as well as documentation of the present environment and its capacity to neutralize any acid inputs. Because the details of plant emissions, meteorology, geology and ecology and their interactions downwind of the Harry Lake Site are not known at this time, these recommendations are necessarily general. Emissions of 0.12 X 10^6 metric tons of sulfur dioxide per year from a point source are of concern since deposition, distribution and accumulation may not be predicted with any certainty at this time.

LITERATURE REVIEW

INTRODUCTION

The detrimental effect of air pollution on trees in Cleveland was noted in 1891 (1), but it was only quite recently that acid precipitation was distinguished as being a distinct feature. Even yet there is skepticism on the adverse effects of acid from this source. This is partly related to ignorance of the chemistry and partly to ignorance of the mechanisms of airborne transport and of the acid's terrestrial and aquatic fate. Some claim no effect on biota and others claim beneficial effects on plant growth (2,3). It is the purpose of this report to review the recent documentation of the nature of "acid rain" as well as the effects on the biota, drawing heavily on information gathered by scientists in Scandinavia and northeastern North America.

Increasing acidity (decreasing pH) of rain water has been observed in Europe since 1950, and coincides with the increase in consumption of fossil fuels and the corresponding stack release of greater amounts of SO_2 and NO_4 (4,5,6,7). This was further related to increasingly acid surface waters by the late 1960's when Scandinavian scientists began pressing for cooperative research in Europe (5). Scientists in southern Norway (8) reported that chemical and biotic changes resulting from acidification occurred more rapidly in the aquatic than in the terrestrial environment. North American studies began to appear in the early 1970's (6,9,10) which indicated that acid precipitation (6) had adverse effects upon aquatic ecosystems in the Adirondack mountains (11,12,13). Atmospheric transport of pollutants from midwestern and eastern industrial centers was postulated as causing the increase in acidity of aquatic environments (13). Canadian studies of lake chemistry and biota in the Sudbury, Ontario region (9,10) have also documented the environmental effects of increased acidity, especially effects on fishes.

There have been obvious and devastating effects on the biota near large sources of SO_2 emission in the Ruhr valley in Germany, parts of the Benelux countries, industrial Britain and in Ontario near Sudbury. Effects of SO_x emission on vegetation have also been observed in British Columbia near Trail and Anyox (5,14). Long distance transport of these pollutants has also occurred, and has been concentrated by meteorological circumstances in conjunction with the mountains of southern Norway and Sweden.

Aquatic ecosystems react more rapidly to changes as a result of acidification than terrestrial ecosystems. This is particularly true of poorly buffered lakes (generally limestone deficient). In any ecosystem, the general effects of acidity tends to decrease nutrient cycling and productivity. In lakes this is manifested by an accumulation of organic material that does not decompose. Fish reproduction has been observed to fail because of the decreasing pH of rivers and lakes owing to acid rain.

While sulphur oxides are the primary cause of acid formation (sulfuric acid), nitrous oxides are also important in increasing acidity in some cases. Too little is yet known of their effects either singly or synergistically with trace metals, organics or other ions that may accompany sulfur dioxide (SO_2) and nitrogen oxides (NO_x).

POLLUTION SOURCES

Many compounds entering the atmosphere from natural and anthropogenic sources are often considered as pollutants. Among the most common air pollutants are SO_2 and NO_x. Trace materials including ammonia (NH_3), heavy metals (15,16), organic compounds, including pesticides (17,18), and alkaline particles containing carbonate, calcium, aluminum or silicon (15). Natural sources (e.g. volcanoes) may produce locally significant pollution (2,4,7,13,15,18,19,20) but are not of concern in this review.

Global anthropogenic emissions of SO_2 in 1976 totalled 130 to 200 X 10^6 metric tones (mt) (18). This may be related to the 2.5 X 10^6 mty being produced in Sudbury, Ontario and the expected 0.12 X 10^6 mty expected from the proposed Hat Creek (2000 MW) plant. Other sources of SO_2 are present near Hat Creek and include the Afton Copper Smelter (under construction), Weyerhaeuser pulp mill and the Gulf Oil refinery.

Global emissions of NO_x in 1976 were 30 to 35 X 10^6 mty (18). This pollutant comes from the combustion of fossil fuels, including increasing emissions from high temperature automobile engines (4,6,7). Additional combustion products may include chlorine, fluorine, trace metals and fly ash. Fly ash contains calcium, aluminum, silicon and other ions associated with carbonates (15).

CHEMICAL TRANSFORMATIONS

Most studies have emphasized the role of SO_2 more than NO_x in acidic precipitation and dry fallout (15). The mechanism for formation of nitric oxide has not been well described but apparently occurs during high-temperature combustion of fossil fuels (11). Other combustion products also influence the potential acidity of the emission (15). Small amounts of chlorine and fluorine may be present in fuel and may form acid radicals during combustion. Certain trace metals act as catalysts in the oxidation of SO_3 to SO_4 or NO_2 to NO_3 in solution. Other emissions such as fly ash will neutralize acids to the degree it contains elements associated with carbonate including Ca, Al, Si and others. Ammonia is weakly alkaline and is emitted when oil is burned.

The constituents of stack emissions and many of the chemical forms they assume in the atmosphere are well known but the processes producing them and their rates of production are poorly understood (20). The chemical reactions that produce either acids or neutralized salts are generally induced photochemically (15) and involve oxidation. However, powdered oxides (of Al, Cr, Fe, Pb, V or Ca) will speed the oxidation of SO_2 even without sunlight (21). Oxidation also occurs more rapidly in solutions involving metal salts. Sulfur compounds in the presence of available oxygen will react to form SO_2, SO_3, and H_2SO_4, occurring rapidly in solution, but requiring photoexcitement in the gas phase. Photolysis is faster in the presence of NO_2 which donates one atom of oxygen to the oxidation of SO_2 (20). Hydrocarbons also enhance the oxidation process (13) and ammonia (NH_3) forms ammonium sulphate or ammonium bisulphate in the presence of sulfuric acid.

Nitrogen compounds occur as ammonia, nitrous oxide, nitric oxide, nitrogen dioxide, and nitric acid vapour. The oxides of nitrogen undergo oxidation and hydrolysis to form nitric acid and nitrates. Ammonia may be scrubbed out of the atmosphere in rainfall and deposited as ammonia salts, remain in the atmosphere, or react with acid compounds. Nitrous oxide (N_2O) is produced primarily by soil bacteria and is considered inert in the troposphere. Oxidation of NO to NO_2 occurs slowly with molecular oxygen but is more rapid with ozone (20). Ozone also reacts with NO_2 to form NO_3 which in turn reacts rapidly with available NO_2 molecules to form N_2O_5 (20). The latter is rapidly converted into nitric acid vapour. Nitrogen dioxide may also be converted into nitric acid vapour.

Adverse environmental effects from acid compounds have been eliminated in a few cases where neutralizing buffering materials are released on combustion. Likens and Bormann (6) and Cadle and Allen (15) suggest that alkaline ash particles released during the combustion of fossil fuel, particularly coal, will neutralize some SO_2 and NO_x at the emission source raising the pH of the fallout but causing particulate fallout near the source. Sander and Seinfeld (20) state that alkaline constituents in fly ash can enhance oxidation of SO_2 even without sunlight and would allow more rapid conversion of SO_2 to H_2SO_4 thus decreasing the pH of local acid precipitation rather than increasing it.

In one case (22) the presence of a nearby cooling tower in some way served to decrease the acidity of precipitation. Natural alkaline dust has also been found to reduce precipitation acidity (23,24). Other types of airborne particulates may adsorb organic molecules (16).

POLLUTANT DISPERSAL

Reports of long range transport are numerous but vary in their findings concerning the distance over which transport occurs. Benaire (25) reported that 47 percent of SO_2 emitted in Paris was transported further than 37 km (23 miles), Odén (26) showed that little SO_2 fell within 10 km of a source while 50 percent fell within 100 km of a source. Nordø (27) and Ottar (28) stated that significant concentrations of pollutants from European sources were found 500-1000 miles or a few thousand kilometers from the source. The residence time of contaminants in the atmosphere depends upon precipitation and winds aloft. Fox (29) reported SO_2 atmospheric residence times of 100 to 300 hours in the summer and 35-80 hours in the winter while Odén (4) determined a residence of 72 hours for atmospheric SO_2 in a storm but only 24 hours for dry aerosols.

Ottar (28) found that most pollutants remained below a height of 1 to 2 km above sea level. He also found that at the source, rapid dilution takes place and that after a distance of 100-200 km (39-70 miles) the pollutants were evenly distributed within the 1-2 km layer. However, Nordø (27) indicated that significant stratification of pollutants may occur for several days when low level winds differ in direction from upper level winds. The problem of defining residence time and transport distance of pollutants, primarily SO_2 or other sulfur compounds, is complex. The observations reported to date can not be resolved into a comprehensive understanding.

Height of injection of the pollutants has a major effect on the distance contaminants travel and the severity of the effects of contaminants once they reach the terrestrial or aquatic ecosystems. Usually the higher the injection point the greater the distance travelled from the source. Air turbulence keeps the aerosols suspended in the atmosphere and wind velocity determines the potential transport distance (26). The potential direction in which emissions travel may be determined from wind roses for a source area but care should be taken to distinguish between upper and lower level air masses, as discussed by Nordø (27) and Fox (29), relative to the height of emission. Storm trajectories have been studied by Norwegian scientists to better determine the sources of acid precipitation falling on the southern areas of Scandinavia (4,5,26,27,28,30). They investigated individual storms or air masses passing over areas of high and low SO_2 emission and found that concentrations of contaminants in storms from high emission areas were greater than those from low emission areas (4, 27,28,30). The problems associated with storm trajectory analysis are discussed by Fox (29), who does not discount these studies but shows that spurious results can be obtained.

Physical and chemical alteration of the pollutants may take place in the atmosphere and result in a significant change in their ability to be transported. Physical changes include the adsorption of not only SO_2 and SO_4 (28), but also of trace metals and organic compounds (17) on particles, and the removal of pollutants by rainfall. Chemical changes occurring in the atmosphere may also affect the transport distance. It has been pointed out by Nordø (27) and Fox (29) that SO_2 has an order of magnitude and greater rate of deposition than SO_4 which allows longer transport of SO_4. Since SO_4 is more rapidly transformed to acid (H_2SO_4) and is more susceptible to long range transport, the environmental effects of SO_4 deposition are of immediate concern. Stack height plays an important role in the chemical conversion of SO_2 to SO_4. Higher stacks promote long-distance transport and in addition allow more time for the oxidation of SO_2 thus producing substances that may be transported further but are not necessarily dispersed more uniformly.

Most nitrogen oxide emissions are from ground level sources (29) and hence tend not to be transported over long distances. In addition, the acid HNO_3 is easily oxidized which increases its deposition rate and decreases its potential transport distance (31).

Two SO_2 sinks (or reservoirs) have been suggested: 1) chemical modification wherein acid or acid precursors are neutralized (28,30) and, 2) a high altitude pool of SO_2 (4). These sinks may result in a net loss of SO_2 in transport from the source to the point of deposition.

Transport distance is also greatly influenced by topography, flora (impaction surfaces) and season. Fox (29) stated that greater deposition of atmospheric aerosol pollutants occurs in areas such as mountainous or forested terrain, where surface wind shear stress is increased. Ottar (28) also indicated that mountainous areas in the path of pollution laden air masses receive increased deposition of pollutants through increased precipitation. Forested areas not only cause greater wind shear stress but present much greater surface area for the adsorption of aerosols (24,29).

Rainy periods effectively increase the local deposition rate of aerosols, and thereby decrease their widespread dissemination. The mechanisms are either direct involvement of the pollutant with the formation of rain ("rain out"), or collision of rain with the pollutant ("wash out") (29). A decrease in transport distance occurs during wet periods, because SO_4 is five times more susceptible to washout than SO_2 (29). Total winter pollut emission may be greater than in summer due to thermal electric generating plants' greater fuel consumption in winter while industrial input may remain relatively constant (32,33).

Long range transport of pollutants can be enhanced by a process which Odén (4) calls "looping". This process occurs when the pollutant is deposited only to be volatilized and resuspended in the atmosphere, moved to another location, and again deposited. The suspension and redeposition can occur several times.

FALLOUT MECHANISMS

DRY FALLOUT

Dry deposition is a continual process punctuated by periods of wet deposition. The rate of dry deposition of air pollutants is proportional to the size of the particle, and the amount contained in the air. The composition of dry pollutants deposited is a reflection of the components emitted into the air but chemical alterations due to oxidation or neutralization can occur. The major sulfur compound of dry fallout is SO_2; whereas, SO_4 is the major component of wet fallout (29). Generally twenty percent of the sulfates are deposited in dry deposition while the remaining 80 percent are removed as wet fallout according to Greeley et al. (34). This is a preferential process with SO_4 being removed by wet deposition leaving the SO_2 (25,29). A rain storm will remove at least 50 percent of the SO_4 present. There are no quantitative assessments of deposition of organic compounds, hydrocarbons and other materials in the literature at this time. Pollutants emitted from short stacks are removed from the atmosphere largely as local dry fallout. However, with tall stacks, the dispersal of pollutants is greater. In addition to the greater wind shear stress and dry deposition in broken topography and vegetation, forests present increased surface area for adsorption of pollutants and have been shown to increase levels of pollutants in the soils at the base of trees (29,35,36).

WET FALLOUT

The pH of rain water in equilibrium with atmospheric CO_2 is normally 5.6 or 5.7 (39,40). Precipitation is considered acid when its pH is less than this. Acid rain has been reported as low as pH 2.8 in Scandinavia (39) and pH 2.1 in the eastern United States (6). The identity of acids causing such pH reductions in rain has been quite controversial. Frolinger and Kane (37,38) stated that the acidity of rain water is due to weak acids, not strong mineral acids. Krupa et al. (39) maintained that the acidity of rain was not correlated with strong acid anions (SO_4, NO_3, Cl_2, and PO_4) but was achieved through a mixture of strong acids, non-volatile weak acids and volatile weak acids because some strong acid anions were present as neutralized salts. Other authors report that rain contains strong and weak acids and alkaline agents but they maintain that strong mineral acids (H_2SO_4, HNO_3, HCl) are the primary contributors to the low pH of rain (4,40,41). According to Galloway et al. (40,41) the weak acids (HSO_4^-, H_3PO_4, HF, $Fe(H_2O)_6^{3+}$, $Al(H_2O)_6^{3+}$, phenols, NH_4^+) occur irregularly and do not dissociate at pH <5.6 and therefore add no H^+ ions at pH <5.6.

Likens and Bormann (6) stated that generally summer rains were more acidic than winter rains in the eastern United States. However, Tabatai and Laflen (33) said that SO_4 concentration in precipitation was higher in fall and winter in Iowa, because of greater coal combustion for power production during the winter months and because less rain fell in winter.

The pH of precipitation varies with the amount of rainfall in an event and with time during larger events. Murphy (42) states that small rainfall events usually have higher concentrations of scavenged gases and particulates than big events. Precipitation which falls early in a large rainstorm contains scavenged material in higher concentrations than precipitation occurring later in the same storm (42).

Snowfall is another form of wet precipitation which removes atmospheric contaminants but is much less efficient than rain in scavenging sulfur compounds (43). Although not well documented, the accumulation of dry fallout on fallen snow but this factor may be important in increasing the sulfur content of initial meltwater in the spring. Odén (4) and Overein (44) report that during the initial melting period most of the contaminant ions present in the snowpack are released and that later meltwater contains fewer contaminant ions.

TERRESTRIAL ECOSYSTEM RESPONSE

VEGETATION

Sulfur compounds may have several effects on vegetation. Low dosages of SO_2 may be harmless or even beneficial in some areas since sulfur is an essential plant nutrient. However, high dosages of SO_2 and sulfur in other forms can cause severe damage to indigenous and agricultural plants (14,45). Plants are susceptible to sulfur compounds through three direct avenues; (1) fumigation with SO_2, (2) dry fallout of sulfur compounds, and (3) wet fallout of sulfur compounds, primarily sulfates. Knabe (45) states that gaseous SO_2 enters the plant mainly through the stomata and that conditions favouring open stomata [high humidity (34) and sunlight (45)] usually result in greater SO_2 uptake. The guard cells of the plant also take up sulfur and may lose their ability to close the stomata, allowing further entry of SO_2 (44). Within the leaf tissue SO_2 enters the intercellular spaces, dissolves in water and is transported toward the leaf tip or margins. While dissolved in the water SO_2 is transformed to sulfite or sulfate both of which are toxic to the cell. Actively growing plants or actively growing parts of plants (5,7,45) and larger plants are more susceptible to injury from sulfate deposition than smaller plants (45).

The general effect of fumigation on plants is to reduce their buffer capacity and change cell water status. Competition of SO_3 for HCO_3^- reduces the production of carbon dioxide-fixing enzymes, resulting in reduced photosynthesis which leads to the breakdown of chlorophyll and "leaf chlorolysis" or yellowing (44). Plasmolysis of chlorophyll-containing cells is seen in the final stages of cell injury. Other cell functions may also be affected prior to plasmolysis. Plant species show differential sensitivity to SO_2 with most sensitive species showing visible injury after fumigation with 1.3 to 2.6 mg SO_2/m^3 and the tolerant species showing injury after being exposed to < 5 mg SO_2/m^3 for a 1 hour period (45). Sensitivity of plants to fumigation has shown a positive relationship with number of stomata (46,47). Synergystic effects of SO_2 have also been indicated (45) with NO_2 or heavy metals, decreasing the resistance of plants to acidic compounds.

Acute injury in plants from exposure to SO_2 as defined by Knabe (45) results from the rapid absorption of toxic concentrations of SO_2. In deciduous plants plasmolysis of marginal or inter-veinal areas of leaves has been observed, whereas in conifers the most actively growing needles are injured first. Chronic injury caused by sublethal concentrations of SO_2 may also cause plasmolysis and death of some tissues but usually it reduces resistance to environmental stress, as manifested by slower growth or decreased production (45). Growth reduction of rye grass without visible injury has been shown in the laboratory at SO_2 concentrations of < 0.26 mg/m^3 for 63 or 77 days and for Norway spruce under field conditions at annual mean concentrations of < 0.01/mg SO_2/m^3. According to Knabe (45), lichens are affected by concentrations ranging from 0.03-0.24 mg SO_2/m^3. In the Ruhr Valley impact on growth of forests during the growing season was demonstrated at concentrations of 0.08 mg SO_2/m^3. Measurable effects on agricultural and horticultural plants during the growing season may be expected when SO_2 concentrations are in the range 0.08-0.125 mg/m^3.

The effect of dry aerosols on plant surfaces is not well described, although certain conclusions can be drawn from the studies showing that aerosol particles settle on plant surfaces and concentrate on the ground around the base of trees (29). It was also shown that the pH of dry aerosol particles are circumneutral and would likely effect little corrosive action on the plant while remaining in the dry state, but dry fallout on wet foliage has been shown to cause cellular destruction (34,46). Aerosol particles in the atmosphere, or on the plant, may indirectly reduce incident radiation causing reduced plant production (18). Wet deposition of sulfuric acid on plants is regarded as more damaging than SO_2 deposition (34). Tamm and Cowling (46) propose seven distinct direct effects on vegetation from acid precipitation; three of which could be classified as acute and the remaining four as chronic. These are listed in the following table:

<u>Acid precipitation effects on vegetation</u>

<u>Acute</u>

1. cuticle erosion or surface cells damaged
2. guard cell damage (alters transpiration rates and gas exchange)
3. plant cell poisoning

<u>Chronic</u>

4. cell metabolism and growth disturbed
5. leaf and root exudate altering microflora and fauna
6. pollen-decreased viability, fruit and seed production, fertilization
7. synergystic effects, stress factors, susceptibility to disease.

Some of the more important effects of acid rain on plants include cuticular erosion (48), decreasing populations of nitrogen fixing lichens and microflora and fauna (of the root systems) (48,49,50,51). There are also synergystic effects of cuticular erosion coupled with disease vectors which are enhanced or reduced depending on the timing of infection (48). In addition the beneficial effect of retardation of plant diseases by SO_2 fumigation has been shown (34).

Acidifying pollutants accumulate in trees where they are partly buffered. This buffering capacity is reduced with continued or increased acid precipitation (49,52). Ability to buffer wet acid precipitation varies among coniferous and deciduous forests. In the northeastern United States deciduous forests are able to neutralize 90 percent of incident acid precipitation (53). In Scandinavia throughfall was less acidic than stem-flow (51). This latter situation was true even though nitrogen compounds in the rain were absorbed on the stem by epiphytes and bark. In coniferous forests the reverse tended to be true, stemflow contained twice the concentration of acidic compounds found in throughfall, in spite of throughfall being more acidic than incident precipitation.

Acid precipitation has not been shown to effect forest growth (4,51,54, 55,56), although most authors suggest that decreased growth should occur. In contrast, forests subjected to fumigation showed increased growth ring density (57) suggesting decreased growth (58). In a British Columbia study, decreased tree growth was related by the author to the amount of copper ore processed at the nearby smelter (14).

Much of the pollutants accumulated on trees eventually appear in the soil below the tree (36). The consequent increase in soil acidity may affect forest growth but this is yet to be demonstrated. However, it has been shown that at pH <4.0 the germination of seeds and the establishment of spruce seedlings was reduced but pine seed germination was not affected (51). The fertilization effect of nitrogen in the precipitation may mask any tendency of the acidity to decrease growth. This may account for the fact that reduced growth of forest trees has not been detected. The effect of acid precipitation on productivity of agricultural plants has not been addressed although some speculation on effects exists (6,7). However, studies dealing with fumigation of agricultural crops have shown that decreased productivity is to be expected under certain conditions. During the growing season severe damage to all agricultural plants is expected where the mean concentration of SO_2 ranges between 0.125 and 0.215 mg/m^3. Sensitive plants will be substantially affected by concentrations of SO_2 between 0.08 and 0.125 mg/m^3, (45). Other studies have indicated that SO_2 in the range 0.050 to 0.100 mg/m^3 has no measurable effect on plants but does have the beneficial effect of reducing the occurrence of plant disease (34).

SOILS

Air pollutants which reach the soil may have profound long term effects on soil organisms and chemistry. Research in the area of soil macro-invertebrates has been restricted to annelids, particularly enchytraeids (51). There are indications that the number of these organisms were reduced in direct relation to increased sulfuric acid in the soil (54). Studies dealing with soil microorganisms have been contradictory. One study indicated no decrease in decomposition rates of forest litter (51) whereas, other authors indicate that the decreased activity of decomposer microorganisms was a result of soil acidification (4,45,54,55).

Reduction of decomposer organism activity would be of major concern because of the important role these organisms have in the mineralization of organic materials and nutrient cycling. Their depletion in acidified soils could have severe effects on the productivity of forest ecosystems. Nitrification and nitrogen fixation are important processes that may also be inhibited by acidification (4,54). In one study (59) acid precipitation caused a greater reduction in bacterial nitrogen fixation than in the bacterial decomposition processes. This may be the result of nitrogen, as NH_4, being leached from mycorrhizal bacteria subjected to acid precipitation indicating a net loss of nitrogen from the associated plant, which would ultimately decrease plant growth (50).

A clear understanding of the effect of soil acidification on nitrogen balance is not presently available. However, Tamm (54) presents a discussion on the theoretical long term effects of nitrogen balance, soil acidification and forest growth. The essence of his discussion is that, assuming acidification inhibits nitrification and nitrogen fixation, it is of no immediate consequence because forest trees are not obligate NO_3 users but can utilize NH_4. He further states that inhibited nitrification in the short term could be of benefit because less N would be changed into readily leachable NO_3. However, if incoming acid compounds include nitrogen then some fertilization effect is expected. Further, nitrogen can accumulate in the soil but will not contribute much to its acidity until the vegetation is removed. When this occurs nitrification of the N accumulation will lead to rapid acidification.

Soils have varying susceptibility to acidification and this can be measured by base saturation (B.S.), which is the degree to which the exchange capacity of soil is saturated with basic cations. In practical terms, base saturation is indicative of soil pH and fertility; both increase with an increase in base saturation. Nutrients in soils with high B.S. are relatively immobile, but nutrients in low B.S. soils are much more mobile. Slightly acid soils such as podzol soils, found in much of North America and Scandinavia, may be sensitive to atmospheric acid input (59,60) and may undergo significant removal of cations on a time scale of 10 to 100 years (61).

The above explanation of the susceptibility of soils to acid precipitation does not address the mechanisms of nutrient cycling, including the very complicated nitrogen and sulfur cycles (62) or the effect of acidification on the various soil horizons.

Acid rainfall on unmanaged soils may have pronounced effects but the effect on managed agricultural areas would be less because of the much greater input of nitrogen from fertilizers and the periodic incorporation of lime to neutralize the soil (62). In addition, it has been stated that sulfur is not expected to be limiting in the natural environment (54,62), but it may be limiting in managed agricultural areas that do not receive acidified precipitation because sulfur is not incorporated in fertilizers.

AQUATIC ECOSYSTEM RESPONSE

Southern Sweden and Norway, are wet, mountainous areas in the path of prevailing winds that may pass over polluting sources. Such regions become susceptible to long range transport of contaminants. In areas where soils and consequently water bodies contain calcium carbonate and other buffering agents, the effect of acid will be decreased, but in areas such as the Scandinavian countries and Canadian Shield where calcarious material is generally lacking the natural lakes are often weakly acid. Here incomplete weathering (63) and shallow soils (59) prevail and the effects of additional acid will be greater. In areas where topographical features favouring increased precipitation are combined with weak buffering systems the effects of acid inputs would be greatest (ie. southern Norway and Sweden, Canadian Shield and high altitude or northerly watersheds) (4,12,13,64).

Soils with a high buffering capacity can aid in neutralizing 40 to 90 percent of acid precipitation after it begins percolating down from the surface (65). However, such neutralizing systems can be bypassed when the ground is frozen during spring snow melt. Also in areas of surface bedrock, or where the water is channeled by roots the acid precipitation bypasses soil systems.

Severe depressions of pH have been observed in water bodies of Scandinavia and the Adirondack Mountains during the initial phases of spring runoff (4,11,42,63,66,67) and in the Adirondacks as autumn rains commence (11). Large quantities of pollutants may accumulate in the snowpack over winter. Initial melting "leaches" most of these contaminants (4,44,68). Acid addition from snow accumulation on frozen lakes may have severe effects on that lake (67). In Scandinavian countries the ground is generally frozen during initial spring snow melt and the highly contaminanted melt waters can enter streams and lakes without benefit of soil buffering (4). During later stages of snow melt the ground is thawed, the melt water flows through the soil and is neutralized prior to reaching surface waters (4). This pattern of spring runoff in streams and small lakes is characterized by a short lived rapid pH depression (4).

Several chemical changes occur as long-term pH depression of lakes progresses. Natural waters between pH 6.5 and 4.5 are very sensitive to the input of acids and pH decreases rapidly as more acidic material is added (4,65). This characteristic is illustrated by the bimodal distribution of pH in Adirondack Mountain Lakes (65). Accompanying the decreasing pH of waters is the alteration of the chemical balance. Nutrients decrease (69), total ionic content of the water decreases (63), trace metals increase (9,10,16,65,67,69,70,71,72,73,74), organic micropollutants may increase (17) and the acidic and basic ion balance in the water is altered, particularly HCO_3 or Ca and SO_4 or H^+ (4,9,10,16, 65,69,70,71,75). As a water body progressively decreases in pH, the Ca is depleted, and SO_4 replaces H_2CO_3 (72) as the major anion partly because of the reduced solubility of CO_2 in acid water (65). Natural or unaffected waters are usually chemically characterized by calcium or magnesium bicarbonate but acid polluted waters are characterized by hydrogen, calcium, or magnesium sulfate (65).

Two chemical indices have been suggested to determine the status of a natural body of water with respect to acidification. Odén (4) suggests that a sensitive index for monitoring continued acidification of natural waters is the ratio of HCO_3 to SO_4. The rate of decrease of the index was related to increasing acid fallout. This index is zero at about pH 5.5 at which point the water body is no longer considered to be in a "healthy" state. The second index is given by Kramer (76) and is called the Calcite Saturation Index (CSI). This index enables the determination of whether a natural water body is susceptible to acid precipitation. If the CSI is ≤ 3 the water body is stable relative to acid precipitation and if the CSI is between 4-6 the water body is unstable relative to acid precipitation.

The formula is:

$$CSI = p(Ca^{+2}) + p(Alk) - p(H^{+}) + pK$$

$$\text{where } p(Ca^{+2}) = (\text{mol } Ca^{+2}/1) \log_{10},$$

$$p(Alk) = (eq/1)\log_{10}, \text{ and } p(H^{+}) = (eq/1)\log_{10}, \; pK = +2.$$

The response of aquatic biological communities to acidification results from changes in pH and the ionic balance of chemicals in the water. Many streams and lakes in southern Norway and Sweden as well as Finland (66) and the northeastern United States and southeastern Canada are becoming increasingly acidic. The aquatic biota in these areas are further stressed by the sudden short term shifts in pH attributed to initial spring snow melt. The pH shift in streams will usually affect the entire water column whereas in lakes the immediate effect of the pulse of acidic water will be confined to the surface layers because of winter thermal stratification. This stratification will allow time for gradual dilution of acids by mixing with the remaining lake water (67,77).

The study of acidification effects on fauna has been confined almost entirely to fish, however, some information is available concerning organic decomposition, primary production, benthic invertebrates and zooplankton, notably the review by Hendrey et al. (78) and Grahn et al. (75). Organic detrital material is recognized as a major food source for many aquatic organisms. Mineraliztion of moribund organic matter is also important in the nutrient cycling within aquatic ecosystems so that any interruption of decomposition could drastically affect the entire ecosystem. Acidification of streams and lakes reduces the decomposition rate by reducing the number of bacterial decomposers and allowing less efficient fungi to flourish (7,75,78). This not only reduces the food supply of many of the macroinvertebrates and the mineralization rate, but the accumulation of organic matter on lake bottoms prevents nutrient exchange (75,78). It should be noted that, as a consequence of the above, primary productivity is reduced, thereby affecting total productivity of an ecosystem.

Sphagnum moss growth increases in acidic waters covering the sediment further, reducing ion exchange and offering a poor substrate for benthic organisms (75,77,79). Attached algae biomass in lakes or streams have been shown to either increase or decrease because of acidification; increases were linked with reduced grazing by invertebrates (76). Phytoplankton have shown mixed responses to low pH. In one study phytoplankton biomass decreased by 2/3 to 8/9 as pH decreased from 6.5 to 4.5 (69). In another case, biomass did not decrease even though species composition was changed (80). Acid tolerant algal species were (80) presumably able to maintain their biomass because of their tolerance, reduced competition and possibly reduced predation. Green algae are the algae most affected by acidification (78).

Diversity of zooplankton communities is reduced in acidified lakes. Surveys in Sweden and Ontario indicated that the numbers of zooplankton species decreased with pH (69). DeCosta (81) found that Daphnia disappear at pH 5.8 or 6.0 (82), while Bosmina seem better adapted to acid conditions.

Benthic macroinvertebrates in acidified water showed decreased diversity and biomass (67,68). In Norway one of the important fish food organisms, an amphipod (Gammarus lacustris), no longer occurs in lakes where the pH has dropped to 6.0. Snails were not found at pH less than 5.2 and were rare between pH 5.2 and 5.8 in a survey of 832 Scandinavian lakes (78). Reports indicated that the tolerance of aquatic insects varied during their life cycles but they were particularly sensitive to pH values <5.5 during emergence (78). Sudden shifts in pH occurring during spring snow melt may have severe effect on the survival of spring emerging insects (78).

Acidification of lakes and streams has caused acute and chronic or sublethal toxic effects to fish populations leading to their extinction in some cases. Acute toxicity to a fish population refers to that level of a toxicant which will cause death to any life stage - egg, fry, juvenile or adult. Chronic or sublethal toxicity refers to the level of toxicant which causes stress. Stress reduces the reproductive viability of the population and increases the possibility of mortality through disease, predation and other vectors of mortality. Resistance to stress may vary with life stage.

Death of fish as a direct result of acidification has been recorded only in streams (63) but Hagen and Langeland (67) suggest that mortalities have occurred in shallow or dystrophic lakes. Synergystic effects caused by reduced pH and increased heavy metals and carbon dioxide have been hypothesized as producing fish kills but remains unproven (11). In a Scandanavian stream a fish kill induced by lowered pH was the result of reduced active transport of Na and Cl through the epithelium of the fish (63). Fish can withstand decreasing pH longer in the presence of high ion concentrations in the water (11).

Fish kills may also occur as a result of suffocation at pH <3 due to the coagulation of mucus on gill surfaces (11) however, such levels are rarely observed. Variable tolerance of different life stages to lowered pH has been suggested by several authors (10,11,67,69,83,84). Laboratory studies using flagfish (Jordanella floridae) found no effect on survival of eggs to hatching in response to pH 4.5 to 6.0 but fry survival was reduced (83). Brook trout (Salvelinus fontinalis) egg hatchability was similar from pH 4.5 to 8.0 but differential mortality of swim-up fry suggested that fry from eggs incubated at lower pH levels were less likely to undergo acid-induced mortality (85). Studies referred to by Hagen and Langeland (67) showed that critical pH for hatching of Atlantic salmon eggs was 5.0 to 5.5; 4.5 to 5.0 for char; 4.5 for trout (probably brown trout)(67); and was 4.6 to 4.5 for roach and perch (91). It has been suggested that the yolk-sac stage of development may be the most sensitive to pH change (67) and this stage is subjected to the most severe pH stress associated with spring snow melt (11,67). Schofield (11) suggests that larval and juvenile fish are more susceptible to lower pH than older fish since small fish have a greater body volume and larger gill surface area per unit weight resulting in more rapid detrimental ion fluxes.

Chronic toxicity is a process whereby fish populations may proceed to extinction before the cause is identified and corrected. In acid stressed lakes and streams chronic toxicity is the most likely process at work causing the extinction of fish populations (10,11,70). The adaptation rate of fish to decreasing pH is unable to match the more rapid rate of pH decrease in the environment (11,84). Lack of recruitment through reproductive failure is suspected as the major cause of fish population extinction (10,11,70). Population extinction may also be caused by reduction in food organisms as suggested by the linear relationship between the number of zooplankton and fish species shown by Harvey (71). However, Beamish et al. (69) could not attribute fish extinction to reduction in food organisms.

Early fish population studies in Ontario described the loss of fish relative to acidification of lakes and indicated some failure of females to reach spawning condition (9). As a result of these findings lakes were termed "critically acidic" at pH <4.5 (9). Later studies attempted to identify the mechanisms causing extinction of fish populations in Ontario lakes. One such study showed abnormal ovarian development occurring in fish resident in acid lakes where pH was <4.5 (10). Because of these findings the term "critically acidic" was redefined as any lake where: 1) with respect to fish populations, concentration of acid was sufficient to inhibit reproduction of resident species which were most acid sensitive, and 2) with respect to a species, when the concentration of acid is sufficient to inhibit reproduction (10). Mature female suckers resident in acid lakes had depressed serum calcium levels, and spinal deformities developed in previously normal fish (69). The deformities were attributed to the physiological stealing of bone calcium to buffer acid in serum, and the low serum calcium during maturation in females was associated with abnormal development of the ovaries (69). Recent studies with flagfish indicated that spermatogenesis was lowest between pH 6.0 and 4.5 (86). Female flagfish reproductive capabilities were reduced at pH 6.0 but, in contrast to males, underwent further reduction when pH decreased below 6.0. Brook trout will spawn and eggs will show no decrease in hatchability to pH 4.5 but survival of fry is reduced below pH 6.0 unless the eggs were exposed to acidic water during incubation (85). In another study of reproduction using flagfish reproductive processes had the following order of decreasing sensitivity to lowered pH: egg production > fry survival > fry growth > egg fertility (83). Beamish (70) compiled a list of "critically acidic" levels for fish of the Sudbury region (Table 1). He (10) also reported that the more resistant species increased in numbers prior to their "critically acidic" level, probably as a result of decreased competition, or predation from less tolerant species.

A few lake reclamation studies have been conducted in Ontario involving anthropogenically acidified lakes (87,88,89,90). The results of these studies are tenuous at this point. The authors indicate that more time is needed to evaluate duration and degree of effect on the biota. A 1958 study showed that a lake which received a single treatment of limestone had returned to a very acidic state by 1973, indicating the short-term effects for a single treatment of neutralizing agent (88). These authors referred to another acidic lake that was receiving smelter tailings mixed with crushed limestone and indicated that pH was increasing and general water quality was improving. Adamski and Michalski (87) also indicated the lack of success in the 1958 study, but referred to an associated experiment which showed the greater buffering capacity of calcium hydroxide ($Ca(OH)_2$) as opposed to calcium carbonate ($CaCO_3$).

The Ontario Ministry of the Environment currently has a program to evaluate neutraliztion of acidic lakes. Studies began in 1973 with the neutralization of Lohi and Middle Lakes. Middle Lake was treated with $Ca(OH)_2$ and $CaCO_3$ but Lohi Lake was treated with $Ca(OH)_2$ only. Within one year Lohi Lake once again became acidic while Middle Lake remained near neutral (87,88). It was concluded that $CaCO_3$ restored some of the long-term buffer capacity in Middle Lake making it more resistant to acidification. Treated lakes showed an immediate decrease in dissolved heavy metals and a reduction of phytoplankton, zooplankton and zoobenthos populations (87,88). Phytoplankton subsequently increased in numbers

TABLE 1. Approximate pH at which fish in the La Cloche Mountain Lakes, Ontario, stopped reproduction (70).

pH	Species	Family
6.0+ to 5.5	Smallmouth bass *Micropterus dolomieu*	Centrarchidae
	Walleye *Stizostedion vitreum*	Percidae
	Burbot *Lota lota*	Gadidae
5.5 to 5.2	Lake trout *Salvelinus namaycush*	Salmonidae
	Troutperch *Percopsis omiscomaycus*	Percopsidae
5.2 to 4.7	Brown bullhead *Ictalurus nebulosus*	Ictaluridae
	White sucker *Catostomus commersoni*	Catostomidae
	Rock bass *Ambloplites rupestria*	Centrarchidae
4.7 to 4.5	Lake herring *Coregonus artedii*	Salmonidae
	Yellow perch *Perca flavescens*	Percidae
	Lake chub *Couesius plumbeus*	Cyprinidae

and the species composition shifted to one closely resembling the natural lakes (87,88). During neutralization the initial reduction of biological productivity was associated with rapid pH change. The decrease in population size of zoobenthos and zooplankton species may have occurred because neutralization occurred at the end of their reproductive cycles. Some associated laboratory experiments using water columns determined that fertilization may speed the recovery of acidified lakes (88).

Other experiments conducted in the Sudbury region of Ontario included the neutralization and fertilization of Hannah Lake, upstream of Middle Lake. Preliminary results were similar to previous studies with the exception that a more rapid improvement in the phytoplankton community was indicated (89). Preliminary results of a third Ontario study, of a less acidic lake, were somewhat different; the initial decrease of the biota from "pH shock" was not observed (90) and phytoplankton species dominance did not change. The chemical characteristics of this lake, including the initially low concentration of heavy metal levels, remained unchanged after neutralization. The authors observed that a deep, thermally stratified lake may be difficult to treat effectively using surface application of chemicals because of a vertical pH gradient.

HEAVY METALS

Little definitive work has been performed on heavy metals relative to combustion of fossil fuels, subsequent release to the atmosphere, or fallout and cycling through the terrestrial and aquatic ecosystems. Most authors refer to an abundance of heavy metals in emissions or simply suggest that heavy metals may be a problem without elaborating further. Trace metals are found in emissions from the combustion of most fossil fuels, and this is particularly so at Sudbury (10,16,70, 71,78). Other authors merely mention that metals are an important constituent of anthropogenic air pollution, and contribute to high loadings in the aquatic or terrestrial environment (7,65,67,71).

Metal content of soil around a power plant has been correlated with wind and metal content of the coal being combusted (91). This and one other study found that loadings of metals decrease with distance from the source (91,92) except mercury which could spread further because it occurred as smaller particles and was revolatilized and spread by looping (91).

Up to 90 percent of the trace metals from an emission source are concentrated in the top 15 cm of soil (91,92). Tamm (54) indicated that heavy metals in the soil are released as soil acidity increased. The effect of trace metals on soil organisms is not discussed in any of the reviewed papers.

The effect of heavy metals on forest vegetation is briefly described by Buchaeuer (92). This author states that metals entering plants through the stomata are rendered biologically inert and that only metals entering the plant through the roots will be damaging. Further, metal contamination in some trees may cause chlorolysis, tissue damage similar to that caused by SO_2 (91).

Measurements of heavy metals have been concentrated in fresh water areas but the source of the metals is still not clear. Kemp and Thomas (74) found heavy metals decrease with depth in the sediments of the Great Lakes and imply anthropogenic input. Peyton et al. (72) found increased concentrations of heavy metals in a small lake and related these increases generally to anthropogenic emission sources. Two Scandinavian studies indicated large inputs of heavy metals occurred during spring thaw (68,77); one of the studies indicated that metals were in high enough concentrations to damage the biota but evidence of such damage was not presented (67). High levels of heavy metals were found in all acidified lakes studied in Ontario (10,69,70,73,87,88,89,90). It appeared from these studies that the source of high nickel content was the smelter in Sudbury, and manganese and zinc may have been mobilized from sediments in lakes with decreasing pH (70,73).

The detrimental effect of heavy metals on aquatic biota is generally recognized, but Beamish (70) found no relationship between concentrations of metals in lakes and concentrations observed to affect fish in laboratory tests. He suggested that a synergistic effect of pH and heavy metals may cause the disappearance of sensitive fish species. Kramer (76) also suggested that a synergistic effect of trace metals and pH may cause decreased biological survival at higher pH's and lower metal concentrations than occurs when administered singly.

MATERIAL CORROSION

The corrosive properties of anthropogenic air pollutants have been documented by several authors (24,34,93). Sulfuric and nitric acids have been shown to cause damage to paint, metals, leather and textiles (34,93). The most senstive of these materials are steel, limestone and marble (34) although nickel, zinc and copper are also quite susceptible to this type of corrosion (93).

Kucera (93) found that materials placed in urban and industrial areas corroded more rapidly than similar materials placed in rural areas and that this was positively correlated with the SO_2 content of the atmosphere. He indicated that in areas where dry deposition predominated "washing" of stack gases to remove sulfur compounds prior to emission would be expected to reduce corrosion. Rate of corrosion will be regulated by wet deposition in areas where equal deposition of dry and wet sulfur compounds occur. In areas where wet deposition predominates it will determine the corrosion rate, but the corrosion rate will be highly dependent on pH of the rain and this in turn is controlled by basic carbonates, sulfates or oxides, especially zinc or copper oxides.

HEALTH HAZARDS

The effect of sulfur compounds on human health is not well understood because of the great number of biological and meteorological variables which must be considered (34). Greeley et al. (34) refer to four studies where respiratory distress was related to suspended sulfates but not to sulfur dioxide, however a positive relation with suspended particles was also shown. These studies agree with research on animals by Coffin and Knelson (94) who indicated that oxidation products of SO_2 were more irritating to test animals. Their findings showed that histamine production was related to the specific cation associated with the sulfate particle.

Lunde (17) in his discussion of organic micropollutants states that polycyclic hydrocarbons, some of which are recognized carcinogens, were found with other atmospheric pollutants arising from industrialized Europe but does not discuss their origin.

SUMMARY

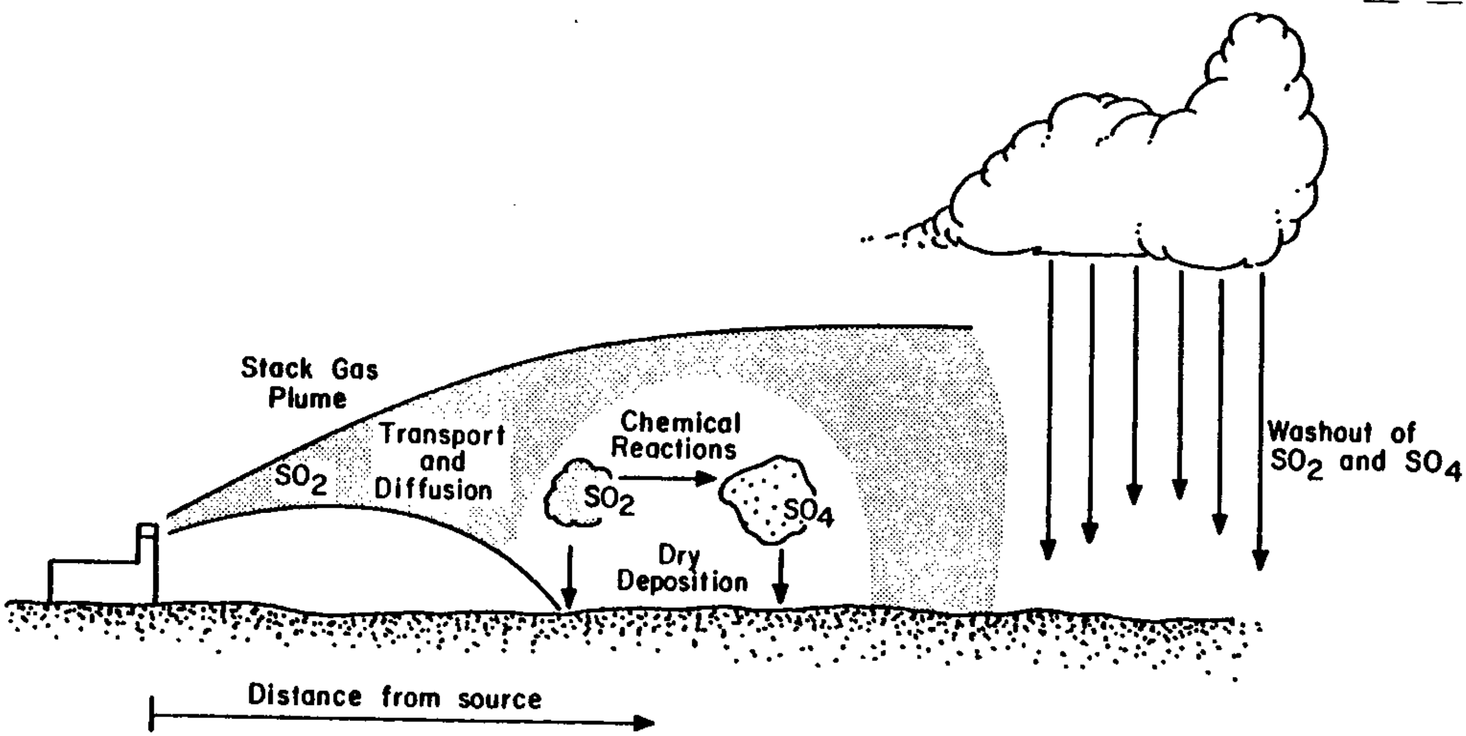
The environmental response to the input of sulfur compounds is the result of several variables including the chemical form of sulfur, the manner in which it is removed from the atomosphere and the characteristics of the target vegetation and soils. The chemical form of sulfur compounds is primarily dependent on residence time in the atmosphere, or the presence of precipitation. The environmental effect near a source probably reflects greater fumigation of vegetation in combination with the SO_2 deposition. At greater distances the effects of fumigation decrease, whereas SO_2 deposition and its effects increase. Environmental damage from oxidation products of SO_2 increase with greater distance from the source. Figure 1 presents an idealistic view of the processes involved in fallout of sulfur compounds. Precipitation events or areas causing wind shears may occur at any location in the path of the polluted air mass and will cause local increases in deposition. Increased stack height may cause a total decrease in SO_2 deposition in favour of SO_4 deposition because of increased time for photooxidation to occur.

Vegetation is affected differently by fumigation, dry and wet deposition. Fumigation has much more immediate and noticeable effects, whereas the effects of dry and wet deposition are less detectable. Dry and wet deposition do not enter the plant directly and are not afforded the opportunity for direct interaction between the pollutant and the plant cells. Dry fallout on plant surfaces is not as damaging as wet deposition which coats the plant in an acid solution. The cuticle of leaves may be eroded by wet deposition allowing leaching of buffering compounds from within the plant and increasing the possibility of disease.

FIGURE 1

PROCESSES INVOLVED IN THE RELATIONSHIP OF SULFUR OXIDE EMISSIONS TO AIR QUALITY

(Greeley et. al.(34))



Plants may also be affected by pollutants which have reached the soil and are subsequently taken up by the root system. The effects of this mechanism have not been determined because of the confounding of this effect with many other natural factors and the combination of detrimental and beneficial effects of the pollutants themselves.

The effect of sulfur compounds on soils depends on the availability of buffering materials. Where $CaCO_3$ formations are prominent acidity is neutralized and the effect of sulfur compounds on soil chemistry and organisms is minimal but in areas where the buffering capacity of the soil is low neutralization does not occur and the effect on soil chemistry and soil organisms will be greater.

Aquatic environments achieve their buffering capacity from chemicals leached from their watersheds. In well buffered watersheds the effects of acid precipitation will be minimal but in poorly buffered areas the continued input of acid-forming compounds will eventually diminish the ability of the environment to buffer acidic inputs thus resulting in a decrease in pH. As pH is depressed the process of decomposition and mineralization of organic material and nutrient cycling are slowed. Species diversity and eventually biomass of plankton and benthic organisms are reduced and fish are lost from the system generally by reproductive failure although acute toxic levels of pollutants may occur at initial spring snow melt. The summary effect of acid precipitation on the aquatic ecosystem is lower productivity, and the reduction of food chains allowing greater temporal fluctuations to occur thereby causing instability of the ecosystem.

Atmospheric loading of sulfur compounds in European countries is great being 60×10^6 metric tons (21), and near the major source areas the environmental damage is also apparently great (45). In southern Scandinavia acid precipitation is having devastating ecological effects. The source for the acidic compound is apparently from industrialized Europe. The compounds are apparently transported long distances by storms and are deposited in Scandinavia by orographic precipitation. Since this area is poorly buffered the acidic precipitation has been able to cause severe damage especially to aquatic ecosystems. Studies in northeastern North America have also shown the detrimental effects of acid precipitation. Here again, the documented effect has been most severe in aquatic ecosystems.

Among all the literature reviewed only the studies in the Sudbury, Ontario area show a relation to one large point source with severe effects on aquatic ecosystems which have been shown up to 65 km distance from the source. Severe effects of air pollution on the vegetation near the source have also been shown. However, it must be noted that Sudbury is the largest point source in the world, accounting for approximately 3 percent (25×10^6 mt of SO_2) of the global emission rate. Slight acidification of lakes has been documented elsewhere in Canada where acid emissions are less. One such area was found near Flin Flon, Manitoba (70).

Emission of SO_2 in this area was between 0.2 and 0.4 X 10^6 mt, which is the range Beamish considers to be "potential sources of acid precipitation to nearby lakes" (70). Beamish also states that no published studies exist for long-range transport of acid precipitation in Canada. Acid precipitation has not been detected in British Columbia except down-wind of Vancouver (43,95) where about .05 X 10^6 metric tons of SO_2 are emitted (70).

GLOSSARY

Aerosol	- colloidal particles suspended in a gas (43).
Dry deposition	- adsorption of pollutant gases and impaction of particles on exposed surfaces (93).
Gas	- a substance with perfect molecular mobility and the property of indefinite expansion (43).
Particle	- an agglomeration of heterogeneous materials forming a mass, larger than a colloidal particle.
pH	- logarithm of the reciprocal of hydrogen ion concentration in gram atoms per liter.
Rainout	- when the pollutant is involved in the precipitation formation process (29) mainly aerosols and larger particles.
Scavenging	- this term may be applied to any process by which contaminants are removed from the atmosphere, e.g. rainout, washout, or deposition on natural surfaces.
Stemflow	- precipitation and inclusions which impinge on a tree and are channelled along the stem and thence to the ground.
Throughfall	- precipitation and inclusions which impinge on a leaf surface and then drip off to the ground.
Washout	- when the pollutant is removed by simple collision with falling precipitation (29) and evidently includes gas, aerosols and larger particles.
Wet deposition	- removal of pollutant gases or aerosols by precipitation (93) (rain or snow).

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A PRELIMINARY METEOROLOGICAL INVESTIGATION OF POTENTIAL ACIDIFICATION OF PRECIPITATION RELATED TO THE PROPOSED HAT CREEK THERMAL POWER FACILITY

INTRODUCTION

This report documents the efforts of British Columbia Hydro and Power Authority to evaluate the potential for increased acidification of precipitation due to atmospheric emissions from a proposed thermal generating station near Cache Creek. Of particular concern is the frequency and duration of weather conditions that might involve transport of the stack plume toward the mountain chains to the east during periods of precipitation there. Heavy winter snowfalls characterize these mountainous regions, and much of British Columbia's major river flow originates from the melting of these snowpacks. Economically and ecologically important biological species populate the rivers and their tributaries. Such considerations require investigation of potential impacts such as acid precipitation at a time when flexibility in the selection of plant design criteria still exists.

As a specific example of an area where such effects may be important, we have chosen here to focus attention upon the Wells Gray Provincial Park, located about 150 km to the northeast of the proposed plant site. The park includes peaks with elevations greater than 8,000 feet MSL and several mountain lakes that drain into the North Thompson River. Total seasonal snowfalls of 10 meters or more are common in the region. In addition, as will be discussed in Section 2, the prevailing winter winds aloft will tend to transport airborne material from the Cache Creek area toward the northeast. Thus, estimates of expected impacts within the Wells Gray Park may be considered as 'worst case' results.

The findings reported here are not definitive. The number of interrelated physical mechanisms that may affect transport, dispersion, transformation, and removal of airborne contaminants in a given locale is truly enormous. Our calculations necessarily reflect many simplifying assumptions. Further limitations inherent in the analysis result from the remoteness of the study area and the corresponding scarcity of data for verification purposes. We have attempted to identify the most important aspects of the problem, and to ensure that, where doubt exists, all assumptions are conservative in nature, i.e. potential impacts due to the proposed thermal generating station will not be underestimated.

A more complete understanding of precipitation pH effects related to operation of the generating station will result from a full-scale modeling study currently being sponsored by B.C. Hydro. In that analysis, sophisticated numerical techniques will be used to simulate transport, chemical transformations, and deposition mechanisms that govern the behaviour of gaseous and particulate emissions from the proposed plant. The results of the major modeling effort will be used to refine the simple worst-case calculations presented here.

REVIEW AND ANALYSIS OF METEOROLOGICAL DATA BASE

PREVAILING WINDS AND PERSISTENCE

The Wells Gray Provincial Park is about 150 km northeast of the Cache Creek area. Thus, directionally persistent air flow from the southwest must accompany any incident of potential concern. Furthermore, such winds must occur near the equilibrium height of the plume emitted from the proposed thermal plant. The elevation of the preferred site is about 4500 feet MSL. Although the design of the stack for this facility has not yet been finalized, it is anticipated that emissions will be released at least 800 feet above local grade. Plume rise resulting from the initial relative buoyancy and excess vertical momentum of the stack gases will increase the effective release height by up to another 2,000 to 3,000 feet. Thus, the winds of concern for long-range transport phenomona are those on the order of 7300 feet above sea level.

This elevation is somewhat above the mean height of the 800 mb pressure surface, but it is our judgement that available 800 mb wind data are suitable to depict the transport of plume material from the proposed generating station. They are certainly preferable to surface measurements, where terrain channeling is often the dominant factor determining wind direction. Such data, unless taken from well-exposed sites at the highest local elevations, can be quite misleading for purposes of understanding winds aloft in regions of complex terrain.

The winter season is probably most important in the context of this investigation, since buildup of acidity in the mountain snowpacks is considered by fisheries biologists as the greatest potential mechanism for effects on salmon through the lowering of pH in the rivers and streams of British Columbia. In the Wells Gray Park area, the snow season generally commences in early or mid-October, and lasts through the month of April. The monthly average frequencies of southwest winds at the 800 mb level for Vernon, B.C. from October 1971 through August 1976 are summarized in Table 1. Corresponding frequencies developed from the combined records at two B.C. Hydro stations located on high terrain in the vicinity of the proposed thermal station site are also listed for comparison.

TABLE 1. Frequencies of Southwest Winds at 800 mb for Vernon

Month	Vernon @ 800 mb (6410' MSL)	Cornwall Hills (6648' MSL) and Pavillion Mountain (6848' MSL)
January	30%	14%
February	32% *	33% *
March	28% *	18%
April	24% *	31%
May	28% *	24%
June	28% *	22%
July	32% *	29%
August	32% *	17%
September	25% *	48% *
October	29% *	26% *
November	26%	missing
December	27%	24%

*Denotes month with prevailing SW winds.

Clearly the southwesterly direction is quite important, not only during the snow season, but throughout the year. This is significant in terms of the present investigation, since a substantial amount of the annual precipitation on the western slopes of mountains in the southern interior comes in the form of short, heavy showers and thunderstorms. Total precipitation on the western side of the Selkirk Range (southeast from Wells Gray Park) is the highest measured anywhere in the Interior of British Columbia.

Evidently, then, transport of tall stack emissions from the Cache Creek region toward Wells Gray Park could occur frequently. However, since the distance separating the two areas is about 150 km considerable directional persistence is required for such material to actually reach the Park area. In general, persistent winds reflect organized synoptic circulations with moderate to strong velocity; conversely, light and variable winds are typical of periods during which such well-defined flow patterns are absent.

Wind persistence statistics may be developed only from data collected by means of continuous measuring equipment. Rawinsonde measurements, such as those at Vernon, are taken only twice daily. The weather stations operated by B.C. Hydro at Cornwall Hills and Pavillion Mountain provide the most representative information available for characterizing persistence of winds aloft in the vicinity of the proposed thermal plant. Table 2 lists the number of periods between 19 November 1974 and 30 September 1976 corresponding to observed constant southwest winds for durations of from 2 to 30 hours or more at each station.

TABLE 2. Wind persistence at Cornwall Hills and Pavillion Mountain

Duration of Steady SW Winds (hrs)	Number of Occurrences	
	Cornwall Hills	Pavillion Mountain
2	41	37
3	25	27
4	17	22
5	18	9
6	13	8
7	9	9
8	6	7
9	4	13
10	6	3
11	5	10
12	2	5
13	1	3
14	1	5
15	3	4
16	2	1
17	0	3
18	0	5
19	1	0
20	0	3
21	0	1
22	1	0
23	1	0
24	0	1
25	1	0
26	-	;
27	0	0
28	1	0
29	0	1
30	0	1
>30	2	7

Maximum monthly mean wind speeds recorded at the two stations are near 5 and 6 km/hr. respectively. At these speeds, steady southwesterly flow of 25 to 30 hours would be required to transport contaminants to the Wells Gray Park area. As evidenced in Table 2, such persistence is measured infrequently. As discussed earlier, however, it is probable that the periods corresponding to very persistent flow are also characterized by higher wind speeds. For average velocities of 15 to 30 km/hr., the transport time to the Park is only 5 to 10 hours. On some occasions, wind trajectories from Hat Creek may reach Wells Gray Park by more circuitous routes. Such incidents would not necessarily correspond to persistent southwesterly flow near the proposed site.

In any case, dilution of plume material from a single source over a travel distance of 150 km or more, would under any expected circumstance reduce concentrations to extremely low level.[1] As noted in the Introduction, detailed modeling studies currently in progress will assist in providing realistic estimates of potential ambient levels of several contaminants on a regional scale. This information will be used to re-assess possible impacts regarding precipitation acidification.

PRECIPITATION DATA

Documentation of precipitation amounts in the vicinity of Wells Gray Park is limited to information provided by the Snow Survey Bulletins published six times per year by the Hydrology Division, Water Hydrology Branch, Water Resources Service of the British Columbia Department of the Environment. A preliminary estimate of total seasonal snowfall for each year at most high elevation snow course sites can be computed from the snow depth-water equivalent information reported in these Bulletins for samples taken in early to mid May. Other sources contain more detailed information, such as annual and monthly average precipitation and maximum 24-hour rain and snowfall at many locations throughout British Columbia. Unfortunately, the nearest such stations with respect to Wells Gray Park are in Williams Lake and Valemount. Since both are located in river valleys such precipitation data is not representative of the mountainous region under study here. Thus only the snow course information is considered valid for consideration. Seven snow courses in the North Thompson drainage area are in or near the Wells Gray Park. Table 3[2] indicates approximate seasonal snowfall (average and maximum) for each site. The tabulated values are the depths (in meters) estimated from snow pack core measurements taken near the first of May.

No information regarding the chemical properties of precipitation in the Wells Gray Park area is presently available. Snow water samples from the Cornwall Hills near the proposed site of the thermal generating station have been collected and analyzed during February to May of 1977. The

[1] The results of local-scale dispersion modeling already completed indicate that, at a distance of 25 km, hourly maximum SO_2 concentrations attributable to the proposed thermal plant will be less than 25 mg/m^3.

[2] Compiled from Snow Survey Bulletin - Water Investigations Branch, Water Resources Service, Province of British Columbia, Dept. of Environment, 1 May, 1976.

TABLE 3. Wells Gray Park region snowfall.

Station Name	Elevation (meters)	No. Years Recorded	Seasonal Snowfall (meters)	
			Average	Maximum
Mount Cook No. 2	1580	2	14.2	15.3
Azure River	1620	6	14.9	12.5
Kostal Lake	1770	2	11.8	10.4
Mount Saint Anne	1770	1	N/A	15.4
Trophy Mountain No. 1	1900	6	7.3	9.7
Trophy Mountain No. 2	1860	2	6.1	7.9
Mount Albreda	1920	9	9.1	11.5

results indicate a 'natural' pH of 5.3-5.5 with a sulfate concentration of 5 mg/liter of water. This pH range is near that often reported in the literature for precipitation in equilibrium with carbonic acid resulting from atmospheric absorption of carbon dioxide (CO_2). It is expected that the major potential contributor to increased acidity due to operation of the power plant would result from increased concentration of sulfur dioxide (SO_2). Since no measurements or model estimates of SO_2 levels in the Wells Gray Park area are currently available, the example calculations discussed in the next section reflect consideration of a range of ambient concentrations.

TYPICAL pH CALCULATIONS

Three sets of computations were performed to estimate changes in precipitation pH after absorption of SO_2. Different assumptions regarding the relative importance of some of the many possible chemical processes that may affect pH distinguish the three cases which are presented in absence of detailed measurements. All results, however, have in common the following underlying assumptions.

(a) An 'initial' atmospheric SO_2 concentration distributed evenly throughout an hypothetical box measuring 100 km X 100 km X 1 km. Values of 3 and 30 $\mu g/m^3$ are considered.

(b) Precipitation occurs at a rate of 2 mm/hr. rain (results also apply roughly to snowfall rate of 20 mm/hr.) lasting for one hour. Sulfate concentration in precipitation is 5 mg/liter.

(c) Sixty percent of the atmospheric SO_2 is scavenged by precipitation washout during one hour.

(d) All SO_2 removed by washout is dissolved in the precipitation and becomes sulfate.

(e) The precipitation is originally in equilibrium with atmospheric CO_2 presents at 300 ppm. Original pH is 5.5.

(f) All estimates are based on the applications of principles advocated by Stumm and Morgan (1970), Fair and Geyer (1954), and Junge (1963).

Case 1

Assumption: Precipitation interacts chemically only with SO_2 and CO_2, not with particles or other atmospheric gases.

Results: For initial SO_2 concentration of 30 $\mu g/m^3$, the initial pH of 5.5 would be reduced to about 3.7; the corresponding value for 3 $\mu g/m^3$ SO_2 is not less than 4.5.

Case 2

Assumption: Ammonia (NH_3) is present in the atmosphere (2 $\mu g/m^3$) and 70% of this compound is scavenged simultaneously with 60¢ of the original SO_2.

Results: For 30 μg SO_2/m^3, pH would remain above 4.5; for 3 $\mu g/m^3$, the initial pH would not be expected to decrease.

Case 3

Assumption: The total carbonate content of the precipitation is increased by a factor of 10 bryond that provided by equilibrium with atmospheric CO_2 because of dissolution of particulate salts in the atmosphere.

Results: The results reported above would not be significantly altered; at 30 $\mu g/m^3$ SO_2, e.g. pH would not be below 3.9.

Case 4

Assumption: Natural precipitation contains sundry buffering materials such as ammonium and organic salts as well as measurable sulfate and carbonic acid constituents.

Results: It is entirely possible that this case represents the most realistic depiction of actual rainfall chemistry. Such buffering materials could continue to buffer the rain/snow at 5.5 despite small increments of SO_2 in the atmosphere. Whether or not there would in fact be any reduction in precipitation pH due to SO_2 emissions diluted to air concentrations below 30 $\mu g/m^3$ can be established only by very careful measurement.

CONCLUSIONS

The primary conclusions of this investigation may be summarized as follows:

(a) Prevailing winds aloft in the vicinity of the proposed generating station would transport tall stack emissions toward the Wells Gray Park area much of the time. However, the natural variability of winds, the irregular nature of the underlying terrain, and the large travel distance involved would tend to minimize the likelihood that contributions to air quality levels in the Park area would be noticeably affected by operation of the Hat Creek facility.

(b) Large seasonal snowfalls and intermittent summer thunderstorms contribute to high total precipitation levels on the western slopes of mountain ranges to the east and northeast of the proposed site. Precipitation rates in the region between the site and the western slopes (including those in the Wells Gray Park) are considerably smaller.

(c) Worst case calculations indicate that, for unrealistically conservative concentrations of atmospheric SO_2, and greatly simplified chemical interaction assumptions, the pH of precipitation could be intermittently reduced by as much as 1.2 units. However, for more realistic chemical assumptions, i.e., allowing for the probable presence of organic salts and ammonium as buffering agents, it is almost certain that the actual degree of acidifcation resulting from operation of the proposed thermal plant would be much less.

(d) Modeling studies currently in progress will provide information regarding long-range transport of stack emissions from the Hat Creek station and resulting air concentrations of several contaminants. The results of these calculations will be used to re-assess the potential for precipitation acidifcation on a regional basis.

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Environmental Research & Technology, Inc.
Environmental Services Section, B.C. Hydro
Structures Department, B.C. Hydro

RECOMMENDATIONS

1. If a monitoring or surveillance program is to be effective it must also be operational as an early warning system. Because increases in the acidity of precipitation would be measurable before the corresponding changes in surface waters, the establishment of existing precipitation quality and the routine monitoring of it is perhaps the most basic need of a monitoring program.

2. Siting of precipitation sampling stations for dry, wet and bulk fallout as well as snow sampling stations should be determined by supporting meteorological studies on emission dispersion patterns. The stations should be located such as to be able to assess both short and long distance transport.

3. The surface water chemistry parameters with a potential for change that should be monitored are very numerous. These include the most indicative parameters for identifying reduced buffering capacity and acidification potential such as pH, acidity, alkalinity (titration curve), calcium, sulphate, conductivity, chloride, total carbonates, nitrate, total dissolved solids, bicarbonate and saturation index. Other relevant parameters are Mg, Na, SIO_2, PO_4, Br and NH_4. If combustion test data are not available it is recommended that the following list of parameters should be monitored as required in surface waters and precipitation samples: cyanide, arsenic, mercury, cadmium, lead, chromium, copper, zinc, iron, manganese, lithium, molybdenum, selenium, nickel, boron and fluorine.

4. Siting of surface water sampling stations is most crucial if the monitoring program is to identify potential water body acidification problems. Biological and chemical symptoms of acidification will first be observed in small lakes with high retention periods. Thus high altitude lakes with a naturally low buffering capacity represent the best indicators for acidification potential. Therefore emphasis must beplaced on the smaller tributaries and lakes. However, owing to their importance to fishery resources, large, moderate and small lakes at lower altitudes should be included in the monitoring program.

   Similarly with tributary monitoring, the smallest tributaries in those watersheds feeding the major basins and located upstream of the major lakes in a river basin represent the best sampling sites. Samples of actual runoff can be taken in the smaller watersheds and be used to identify trends in acidification and/or leaching of materials from soils.

5. Sampling times are equally important considerations in the design of a monitoring program to collect pre-development surface water quality data and/or surveillance data. At least two sampling periods are recommended for monitoring surface waters. The first sampling period should be in early spring when snow melt begins to occur and should continue through the snow melt period. Accumulations of fallout on snow surfaces will be introduced to water bodies at this time and marked changes in pH and other parameters may be observed. This period also coincides with the critical reproductive and juvenile stages of fishes. The literature has clearly documented the serious effects of even small changes in pH on aquatic biota.

   The second period for surface water sampling should be the late summer in those mountainous areas where glacier melt provides a significant runoff. Monitoring should continue throughout this period which usually extends from late July until early September.

6. Sampling frequencies and replication are important if a monitoring porgram is to detect long term trends. To establish a significant or real trend over time, it is necessary to determine the variability of particular measurements made.

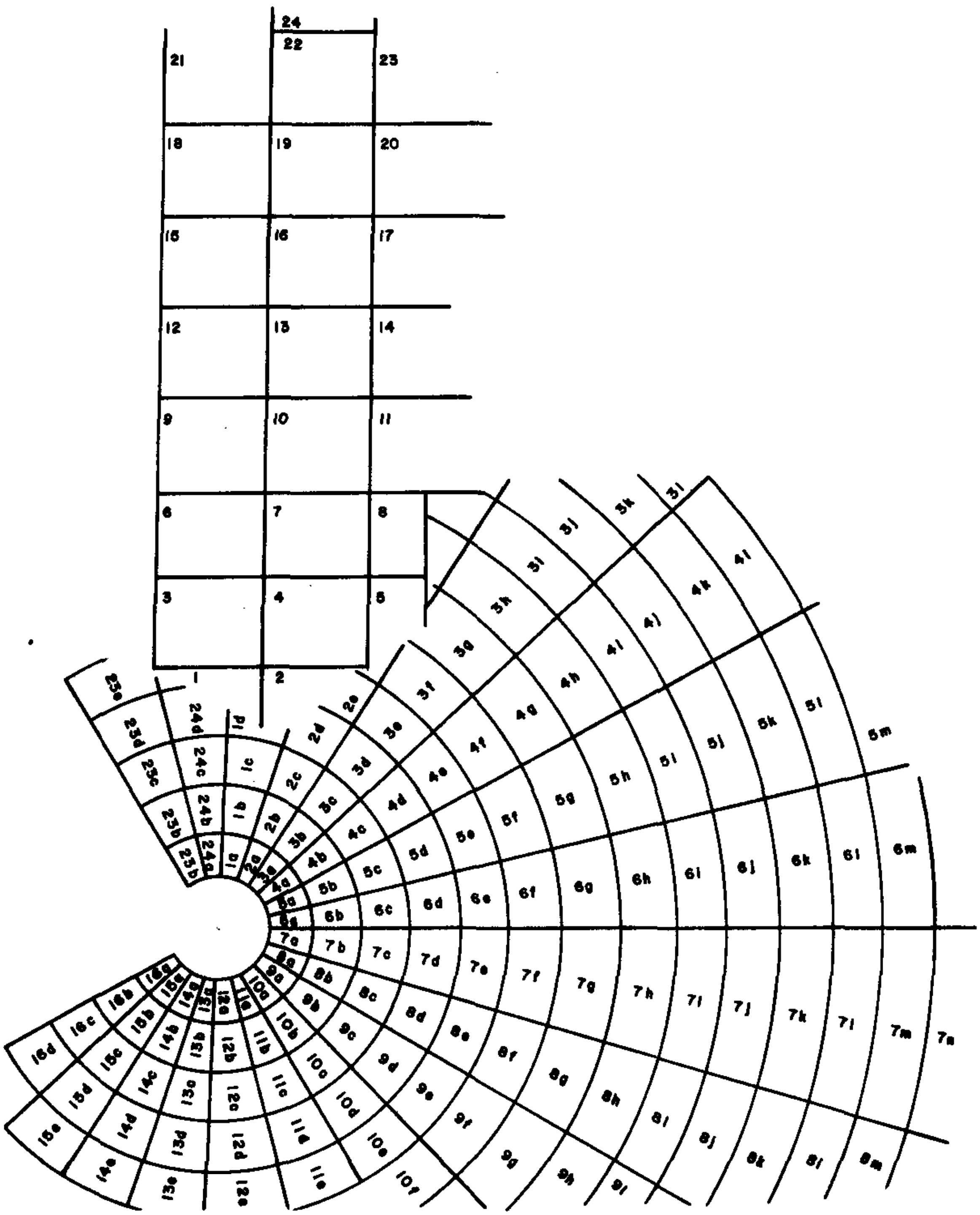
7. It is recommended that biological studies accompany the chemical monitoring of selected high altitude low buffering capacity lakes. The biological program should include phytoplankton, zooplankton and fish population studies.

8. Under arid climatic conditions, changes will be mainly due to dry fallout and will first be observable in the terrestrial environment (i.e. vegetation, soils, etc.). Therefore, a monitoring program for the terrestrial ecosystem must be developed.

9. The British Columbia Fish and Wildlife Branch recommends 10 sampling sites in the East Cariboo region and 35 sites in the Thompson-Okanagan area. These are described and justified in Appendix B.

APPENDIX A

PHYSICAL-CHEMICAL CHARACTERISTICS OF WATER BODIES IN THE HAT CREEK STUDY AREA



HAT CREEK STUDY AREA: OVERLAY SHOWS GRID AND SECTIONS USED IN APPENDIX B

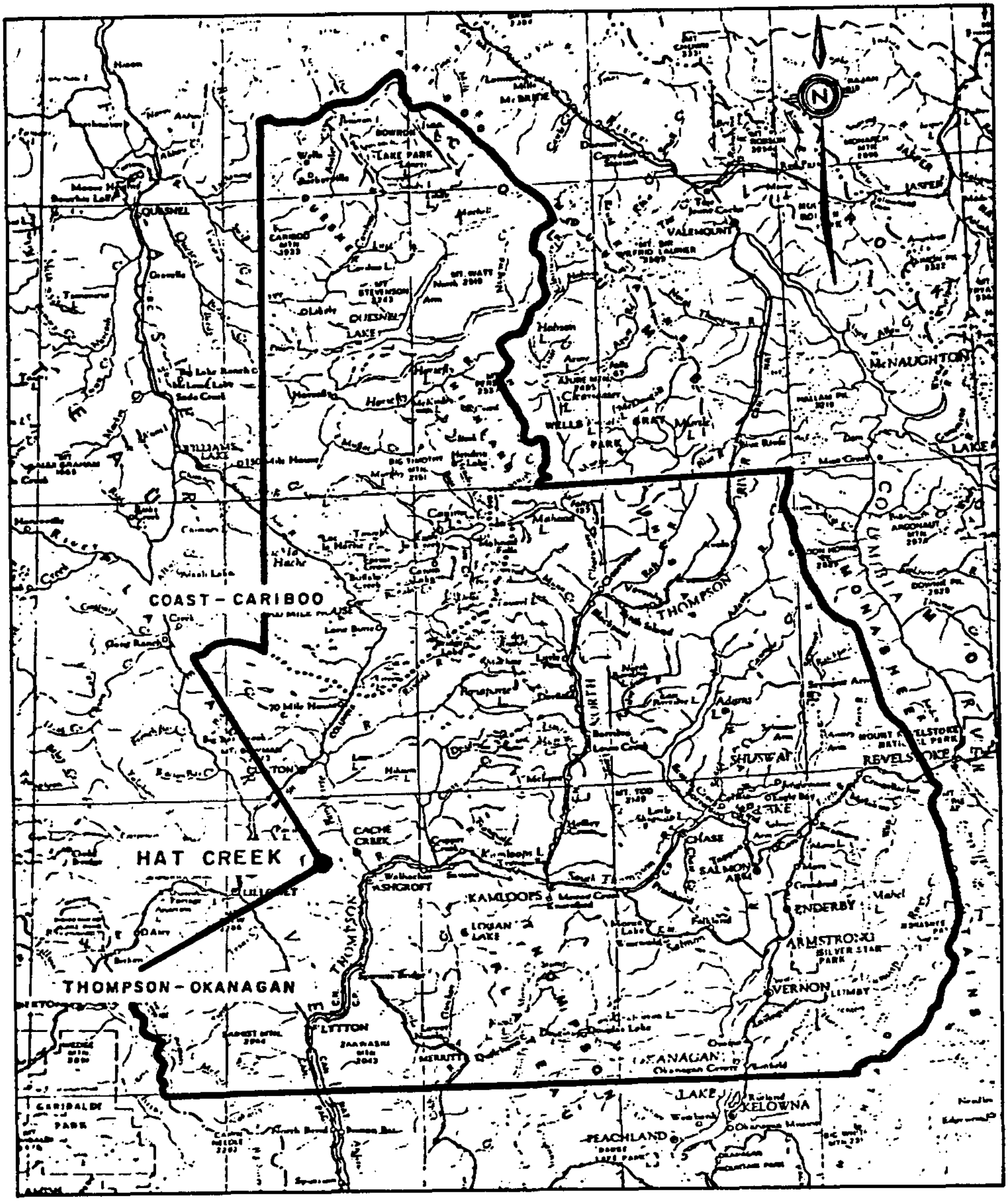


TABLE 1. Lakes and streams, for which data are available, having pH ≤7.0 relative units, or alkalinity ≤50.0 mg/l, or filterable residue ≤70.0 mg/l, or specific conductivity ≤119.0 μmho/cm (provided by B.C. Fish and Wildlife Branch).

Name of Lake or Stream	pH	Total Alkalinity (mg/l)	Filterable Residue (mg/l)	Specific Conductivity (μmho/cm)
COAST CARIBOO				
Tiny Tim Lake	7.2		70	
Kellington Lake	7.8		62	
Boss Creek	7.1 ± 0.5	28.0 ± 9.3	68.3 ± 16.8	116.6 ± 111.4
Hendrix Lake	6.8		35	
McKinley Creek	7.5 ± 0.3	42.4	70.0	94.5 ± 0.5
Hendrix Creek	7.2 ± 0.2	22.8 ± 2.5	60.0 ± 4.0	70.5 ± 39.0
Moffat Lakes	6.6		47	
Crooked Lake	6.9		34	
Horsefly River				
at Horsefly	7.2 ± 0.8	43.3 ± 14.0	66.8 ± 18.8	100.4 ± 29.5
Morehead Lake	7.5		65	
Rollie Lake	6.5		19	
Quesnel River	7.4 ± 0.6	47.0 ± 3.1	62.8 ± 4.9	118.6 ± 31.1
Cariboo River				
near Likely	7.4 ± 0.7	52.2 ± 7.3	67.4 ± 8.9	113.9 ± 34.4
Willow River				
at CNR bridge	7.6 ± 0.2	44.9 ± 12.1	75.3 ± 10.4	102.0 ± 38.1
at highway bridge	7.2 ± 0.4	33.5 ± 1.3	58.0 ± 2.0	94.7 ± 5.6
near lake	7.2 ± 0.4	38.7 ± 1.1	74.0 ± 8.0	117.0 ± 9.0
Bowron River				
below Bowron Lake	7.3 ± 0.5	35.9 ± 9.6	49.2 ± 11.2	125.9 ± 130.0
THOMPSON-OKANAGAN				
Tranquille River	7.6 ± 0.2	40.4 ± 4.2	60.0 ± 10.0	80.0 ± 8.9

Name of Lake or Stream	pH	Total Alkalinity (mg/1)	Filterable Residue (mg/1)	Specific Conductivity (μmho/cm)
Kamloops Lake				
opposite Copper Creek	7.6 ± 0.1	38.5 ± 4.6	71.3 ± 2.5	100.7 ± 11.1
opposite Cherry Bluff	7.5 ± 0.1	39.0 ± 2.5	66.7 ± 3.4	99.3 ± 10.6
Thompson River				
at Wallachin	7.4 ± 0.6	33.8 ± 3.5	56.2 ± 8.6	94.6 ± 17.2
Barriere River				
at mouth	7.6 ± 0.3	48.0 ± 8.2	71.0 ± 8.3	132.4 ± 111.5
Stuart Lake	7.1	44	71	94 @ 41°F
Nicola River		48 to 125	80 to 90	108 to 227
Dunn Lake			63	
Clearwater River				
at Clearwater	7.5 ± 0.4	35.3 ± 3.1	52.3 ± 5.0	106.5 ± 106.1
Adams Lake			57	
Adams River				
at Adams Lake outlet	7.6 ± 0.1	22.5 ± 0.7	39.3 ± 3.0	55.0 ± 3.8
Little Shuswap Lake				
surface			68	
at pier				74.0
at centre	7.5	31.0	50.0	73.5 ± 0.5
north east end	7.6 ± 0.0	31.0 ± 0.0	49.0 ± 1.0	74.0
south east end	7.6	30.4	50.0	
at inlet	7.6	29.2	50.0	70.0
South Thompson River				
at Chase	7.5 ± 0.7	37.0 ± 8.0	55.5 ± 12.7	94.7 ± 21.5
Seymour River				
at mouth	7.0 ± 0.3	12.1 ± 3.4	24.8 ± 4.6	48.3 ± 41.8
Scotch Creek				
at mouth	7.9 ± 0.4	37.1 ± 1.7	61.0 ± 19.0	80.0 ± 25.2

Name of Lake or Stream	pH	Total Alkalinity (mg/l)	Filterable Residue (mg/l)	Specific Conductivity (μmho/cm)
Shuswap Lake				
surface	7.5	40	64	92 @ 50°F
at Blind Bay	7.6 ± 0.3		51.0 ± 1.0	83.0 ± 7.6
at Blind Bay, NW	8.0 ± 0.4		52.0 ± 2.0	87.7 ± 9.0
at Blind Bay, SE	7.7 ± 0.2		57.0 ± 3.0	97.3 ± 9.1
at Blind Bay	7.6 ± 0.2	36.0 ± 1.2	53.5 ± 3.0	102.5 ± 11.7
at Eel Ruckell Pt.	7.5 ± 0.3	34.2 ± 2.2	52.4 ± 3.3	96.6 ± 12.2
at SE Sandy Ptd.	7.7 ± 0.4	48.2 ± 4.2	83.3 ± 17.5	143.5 ± 29.8
opposite Salmon Arm	7.9 ± 0.4	53.6 ± 6.1	81.9 ± 7.5	139.1 ± 26.0
opposite Marble Point	7.6 ± 0.3	39.6 ± 2.7	58.5 ± 3.8	109.5 ± 15.2
west of Sorrento	7.6 ± 0.3	34.4 ± 2.4	51.2 ± 5.2	96.7 ± 11.7
North Thompson River				
at Birch Island	7.4 ± 0.3	35.4 ± 48.1	59.3 ± 53.6	101.7 ± 114.3
Mara Lake				
east of Shuswap River	7.8 ± 0.3		62.5 ± 7.5	118.2 ± 28.9
opposite Fossett	7.6 ± 0.3	42.7 ± 5.1	64.5 ± 9.4	118.0 ± 16.7
Eagle River				
upstream of Three Valley Lake	7.4 ± 0.2	19.0 ± 6.6	42.0	50.6 ± 18.7
Blue River				
at mouth	7.2 ± 0.7	14.9 ± 5.0	29.3 ± 7.9	43.3 ± 12.9

TABLE 2. Physical-chemical characteristics of water bodies located downwind of the proposed Hat Creek thermal plant (provided by B.C. Fish and Wildlife Branch).

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92P/5;1;56)										
Flat Lake										3700
(92P/6;1;56)										
Bullock Lake										3700
Bishop Lake										3700
Davis Lake										3700
Eighty-three Lake	1									3600
Taylor Lake	2					313				3200
Boyd Lake										3500
Eighty-three mile Creek	3									3600
(92P/6;2;60)										
Green Lake	2	9.0				800				3507
Gwenie Lake										4000
Watch Lake	3					242				3500
Little Horse Lake	1									3500
Little Green Lake										3500

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92P/6;2;60)										
Lake of the Woods										3500
Jim Lake										3500
Nolan Lake										3500
Tin Cup Lake										3500
McMahon Lake										3500
Hutchison Lake										3500
Watch Creek	3									3520
(92P/7;2;60)										
Number 1 Lake										
Number 2 Lake										
Graham Lake										3500
Rayfield Creek										
(92P/11;3;68)										
Kelsey Lake										3500
Edmund Lake	1	8.5				280				4000
Exeter Lake	3					362				3100
Big Lake	1									3500
Savon Lake										3500

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH		Total Alkalinity (mg/l as $CaCO_3$)		Filterable Residue (105°C)mg/l		Specific Conductivity umho/cm		Approximate Elevation (ft)
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	
(92P/11;3;68)										
Mirage Lake										3300
McKinlay Lake										3300
Lilly Pad Lake										3000
108 Mile Lake	3	>8.4				610				3300
105 Mile Lake	1									3000
103 Mile Lake	1	9.0				655				3000
101 Mile Lake	1									3000
Stephenson Lake	1									3000
Davy Lake	1									3000
Watson Lake										3000
Tatton Lake										3000
Carment Lake										3000
(92P/12;3;68)										
Gustafsen Lake	3									3500
Neilson Lake	2									3500
Holden Lake	1									3500
Little Holden Lake	1									3500
Enterprise Lake										3300

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92P/10;4;76)										
Chris Lake	3	> 8.5				160				3200
Dorritt Lake										3500
Drewry Lake	3	> 8.5				385		400 @ 62°F		3500
Balfour Lake										3500
Dragonfly Lake										3500
Parks Lake										3500
Hathaway Lake	3	> 8.5				480		600 @ 70°F		3780
Deka Lake	3	> 8.5				320		390 @ 68°F		3653
Longbow Lake	3	7.5				250				3500
Sulphurous Lake	3	> 8.5				393		500 @ 72°F		3600
Sutherland Lake										3750
Higgins Lake	2					150				3750
Marais Lake	3	7.7				180				3500
Dombey Lake										4000
Duckling Lake										4000
Carton Lake										4000
Fawn Lake	3					310				3500
Sheridan	3					272				3600

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92P/10;4;76)										
Lonely Lake										3500
Roe Lake	2									3600
French Lake										4000
Manning Lake										4000
Bridge Creek	3									3500
(92P/11;4;76)										
Lilyleaf Lake	1									3500
Buffalo Lake	1					390		450 @ 62°F		3260
Edwards Lake	2	8.5				402		490 @ 65°F		3270
Chicken Lake										3500
Alans Lake										3500
Fiset Lake										3500
Earle Lake										3500
Horse Lake	3	> 8.5				200				3252
Irish Lake	1									3500
Guessagain Lake										3500
Parting Lakes										3500
Hartwig Lake										4000

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92P/11;4;76)										
Simon Lake										3000
Straight Lake	1									3000
Roundup Lake	1									3000
(92P/10;5;84)										
Rat Lake	3	7.2				88				3700
Lorin Lake	3	> 8.5				120				3700
Bowers Lake	3	8.0				307		390 @ 72°F		3700
Bannerman Lake										3700
Needa Lake	3	> 8.5				331		400 @ 72°F		3720
Cougar Lake	3									3700
Lynx Lake	3									3700
Jim Creek	3									
Otter Lake	3	> 8.5				114				3800
(92P/13;6;84)										
Maze Lake										3500
130 Mile Lake	3									3500
Long Johnny Lake										3000

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92P/13;6;84)										
Phililloo Lake	1	> 8.5				710				3100
Helena Lake	1	> 8.5				482				3150
Hale Lake										3100
Muench Lake										3100
Dixon Lake										3000
Lac La Hache	3	8.1				365				2650
north end		8.6[4]	±0.1	268.3[4]	±2.7	304.7[3]	±1.9	444.9[7]	±22.9	
at San Juan		8.7[6]	±0.1	256.7[3]	±1.7	286.7[3]	±2.5	458.8[5]	±4.5	
at NW		8.5[13]	±0.2	254.0[8]	±4.9	297.8[9]	±7.2	458.9[13]	±23.4	
at Lac La Hache		8.4[9]	±0.4	262.8[6]	±5.1	292.8[5]	±6.9	450.6[10]	±34.6	
off Emerald		8.2[4]	±0.4	259.0[2]	±4.0	289.0[2]	±3.0	463.8[4]	±13.9	
Thirsty Lake										3400
Walmith Lake										3400
Forbes Creek	3	8.2[24]	±0.3	278.3[11]	±41.9	321.1[11]	±41.5	488.5[25]	±75.8	
San Jose River	3	8.3[40]	±0.5	274.1[17]	±19.0	307.4[17]	±20.3	485.4[44]	±55.3	
(92P/14;6;84)										
Goose Lake										3000

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/1 as $CaCO_3$) $\bar{X}$	Total Alkalinity (mg/1 as $CaCO_3$) SD	Filterable Residue (105°C)mg/1 $\bar{X}$	Filterable Residue (105°C)mg/1 SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92P/14;6;84)										
Bear Paw Lake										3400
Hautso Lake										3400
Ogden Lake										3400
McDougall Lake										3500
Rail Lake	3	>8.5				471		540 @ 62°F		3520
Spout Lake	3	9.0				250				3535
Peach Lake	3									3500
Lower Peach Lake	3									3500
Fly Lake	3									4000
Sandhill Lake										4000
Timothy Lake	3					184		225 @ 69°F		3046
Greeny Lake	3					343				3165
Sherman Lake										3150
Whitehorse Lake	3	8.5				240				3000
Pete Kitchen Lake										2700
Larson Lake										3000
Club Lake										3000
Chub Lake	3	8.1				200				2800

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92P/14;6;84)										
Tubbs Lake										3500
Sucker Lake	2	7.5				475				3500
Soda Lake	3	> 8.4				1550				3000
Soda Creek										
111 Mile Creek	3	7.9^{25}	±0.5	210.3^{10}	±37.2	269.6^{10}	±67.5	436.7^{25}	154.3	
Rail Creek	1									
Big Lake	1	> 8.4				650				3500
(92P/14;7;92)										
Lang Lake	3									2687
Bedingfield Lake	1									3000
Ruth Lake	3	9.0				335				2600
Wilcox Lake	3	> 8.0				244				2900
Dempsey Lake	3	8.0				165				3000
Lake of the Trees	3	8.5				255				2800
Spring Lake	3	> 8.0				228				2800
Upper Lake	1									2800
Lower Lake	3	8.1				425				3000
Lucile Lakes										

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH		Total Alkalinity (mg/l as $CaCO_3$)		Filterable Residue (105°C)mg/l		Specific Conductivity umho/cm		Approximate Elevation (ft)
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	
(92P/14;7;92)										
Nettie Lakes										
Bradley Creek	3									
(92P/15;7;92)										
Susan Lake										3000
Judy Lake										3000
Roger Lake	2	> 8.5				287		320 @ 62°F		2710
Succor Lake	2	7.2				170				3500
Christmas Lake	2	7.6				200				3000
Hawkins Lake	3	9.0				190				3000
Greenlee Lake	3	8.0				265				3500
Howard Lake	3	8.3				190				3000
McNeil Lake	3	> 8.5				218		270 @ 71°F		3695
Eagle Creek	3									
(92P/15;8;96)										
Hotfish Lake										3500
Beartrack Lake										3500
Weller Lake	3	8.3				96				3200

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/1 as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/1 $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92P/15;8;96)										
Tiny Tim Lake	1	7.2				70				3200
Kellington Lake	1	7.8				62				3300
Christopher Lake										3000
Roserim Lake	3	> 8.5				770		950 @ 69°F		2740
Streak Lake										3000
Boss Creek (above Hendrix Creek)	3	7.1^{115}	±0.5	28.0^{46}	±9.3	68.3^{45}	±16.8	116.6^{105}	±111.4	
Deception Creek	3									
Canim River (above Canim Falls)	3	8.0^{6}	±0.7	79.7^{5}	±5.1	106.5^{4}	±4.6	175.4^{9}	±61.5	
Canim Lake	3	8.5				215				2534
near Round Is.		7.7^{4}	±0.2	75.7^{2}	±0.6	101.0^{2}	±1.0	156.8^{4}	±5.8	
opposite Bridge Cr.		8.0^{2}	±0.4	77.4^{6}	±3.2	103.0^{6}	±1.9	154.9^{10}	±5.3	
opposite Eagle Cr.		7.9^{2}	±0.4	72.9^{5}	±0.8	99.6^{5}	±1.5	149.4^{8}	±4.5	
opposite Hendrix Cr.		7.7^{10}	±0.5	75.6^{6}	±4.2	100.0^{6}	±4.0	152.8^{11}	±6.2	
at outlet		7.9^{2}	±0.2	81.0^{2}	±2.6	105.0^{2}	±1.0	159.8^{4}	±1.8	
at deepest point		8.1^{2}	±0.0	80.7^{2}	±3.3	103.0^{2}	±3.0	156.5^{4}	±6.1	

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(93A/3;9;104)										
McIntosh Lakes (north)	2	8.3				120				3000
(south)	2	8.7				115				3000
Cossack Lake										3500
Walters Lake										3500
Moffat Creek	3									
(93A/4;9;104)										
Kilgore Lake										
Squawk Lake	3	7.4				235				3500
Two Mile Lake	3	8.4				200				2900
Tillicum Lake										
Miner Lake		7.5				75				3400
Coldspring Creek	1									
(92A/2;10;108)										
Buster Lake										
Tisdall Lake	3									3145
Elbow Lake	3	7.5				120				3000
Boscar Lake	3	8.0				100				3300

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(93H/3;22;180)										
Unna Lake	3	> 9.0								3000
Babcock Lake	3	> 9.0								3000
Huckey Lake										
(93H/2;23;184)										
Headwaters of the Upper Cariboo	3									3300
(93H/3;24;188)										
Kibbee Lake	3	> 9.0								3000
(93H/6;24;188)										
Kruger Lake										3000
Indian Point Lake	3	9.0								3000
Thompson Lake										3000
Bowron River	3									
below Bowron Lake		7.3^{35}	±0.5	35.9^{15}	±9.6	49.2^{15}	±11.2	125.9^{40}	±130.0	
at Mainline Road		7.9^{16}	±0.2	73.0^{14}	±14.7	92.5^{8}	±13.6	144.4^{20}	±31.3	

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(93A/5;12;120)										
Gavin Lake	3	7.7				140				3500
McCauley Lake	3	8.5				282		350 @ 76°F		2600
Robert Lake	3	8.1				270				2600
Ballon Lake										2500
Beveridge Lake	3	8.1				170				2900
Jessica Lake										3500
Batten Lake										3500
Meiss Lake										3500
Beaux Yeux Lakes	2									3500
Sausser Lake										3300
Moorhouse Lake										3300
Edney Lake										3300
Antoine Lake	3	> 8.5				257		260 @ 62°F		2650
Veith Lake										
Beaver Creek	3	8.0^{2}	±0.2	167.0^{4}	±8.6	206.5^{4}	±11.6	320.1^{11}	±19.2	
(93A/6;12;120)										
Shiko Lake	3									3000

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(93A/6;12;120)										
Eric Lake	1	8.8				240				2535
Ratdam Lake	3	8.5				260				2705
Abbott Lake	3	8.1				210				2750
Malcolm Lake										3000
Starlike Lake	2	8.0				200				3000
Corner Lake										3000
Triplet Lake										3000
Sucker Lake										3000
Lemon Lake		8.5				310				2800
Armstrong Lake										3000
Wawn Lake	1									2580
Gruhs Lake	3									2750
Little Horsefly Lake	3	8.3				116				2750
Alah Lake	3									3000
Jim Lowry Lake	2									3000
Lea Lake	2									3000
Hooker Lake	2									3000
Kwun Lake	2									3000

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(93A/6;12;120)										
Ussa Lake	2									3000
Niquidet Lake	2	7.8				84				3000
Nikwit Lake	2									3000
Horsefly River (at Horsefly)	3	7.2[38]	±0.8	43.3[18]	±14.0	66.8[18]	±18.8	100.4[43]	±29.5	
Little Horsefly River	3									
(93A/6;13;124)										
Keno Lake	3	7.9				110				2500
Whiffle Lake	3	8.0				195				2760
Dillabough Lake										3000
Jacques Lake	3	7.6				77				2911
Hen Ingram Lake	3	8.1				80				2800
Patenaude Lake	3	8.3				76				3300
(93A/7;13;124)										
Suey Lake										3000
McKinley Lake	3	7.5				75				3250
Doreen Lake	3	9.2				177				3800

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(93A/7;13;124)										
Horsefly Lake	3	8.5				130		140@ 63°F		2571
McKusky Creek	3									
(93A/7;14;136)										
McKay River	3									
(93A/11;15;140)										
Spanish Lake	3	7.8				78				3014
Spanish Creek	3									
Boswell Lake										3500
Benney Lake	3									3500
Freshette Lake										3500
Annette Lake										3500
(93A/12;15;140)										
Poquette Lake	2	8.0				210				2700
Jacobie Lake	3	8.2				185				3680
Little Lake	2	$>$ 8.5				201		220 @ 70°F		2430
Morehead Lake	3	7.5				65				3000

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/1 as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/1 $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(93A/12;15;140)										
Trio Lake		7.2				58				3510
Bootjack Lake	3	7.6				94		120 @ 76°F		2790
Polley Lake	3	8.5				122				3012
Prior Lake										
Rollie Lake	2	6.5				19				4000
Wolverine Lake	3	7.5				88				3400
Quesnel River	3	7.9		54		68.5		117 @ 54°F		
		7.4[41]	±0.6	47.0[17]	±3.1	62.8[18]	±4.9	118.6[46]	±31.1	
Cariboo River (near Likely)	3	7.4[38]	±0.7	52.2[14]	±7.3	67.4[14]	±8.9	133.9[41]	±34.4	
Morehead Creek	3									
(93A/10;16;144)										
Wasko Lake										2500
(93A/11;16;144)										
Quesnel Lake	3	7.5		52		77		117 @ 40°F		2390
Tasse Lake										2500
Klinne Lake	3	8.0				175				2500

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(93A/9;17;152)										
Stranger Lake										3000
Summit Lake										3000
(93A/10;17;152)										
Buckingham Lake										3000
(93A/14;18;160)										
Cariboo Lake	3	7.6				108		130 @ 72°F		2650
(93A/14;19;164)										
Kimball Lake	3									3500
Upper Cariboo River	3									
Ghost Lake	3									3500
Maeford Lake	3									4000
Matthew River	3									
(93A/15;20;168)										
Mitchell Lake	3									3500
Hilda Lake										3500

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(93A/16;20;168)										
Christian Lake										3500
(93H/3;21;176)										
Spectacle Lakes	3	> 8.0								3000
Swan Lake	3	> 8.0								3000
Bowron Lake	3	> 8.0				88				2940
Atan Lake										3500
Chisel Lake										3500
Selina Lake										3500
Antler River	3									
(93H/4;21;176)										
Jack of Clubs Lake	3	7.3				180				3500
Eight Mile Lake		7.5				160				4000
Nine Mile Lake										4000
West Pass Lake										
Lottie Lake										
Willow River	3									

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(93H/4;21;176)										
Willow River Continued										
at CNR Bridge		7.6^{15}	±0.2	44.9^{14}	±12.1	75.3^{2}	±10.4	102.0^{19}	±38.1	
2 miles below wells		7.3^{8}	±0.4	59.7^{4}	±11.9	84.5^{4}	±12.6	139.4^{5}	±23.3	
above Mosquito Creek		7.3^{6}	±0.5	59.1^{3}	±13.9	82.0^{3}	±14.7	140.0^{4}	±25.4	
below Mosquito Creek		7.4^{33}	±0.5	78.7^{16}	±26.2	108.9^{16}	±26.9	276.6^{33}	±254.7	
at bridge on highway		7.2^{4}	±0.4	33.5^{2}	±1.3	58.0^{2}	±2.0	94.7^{3}	±5.6	
near lake		7.2^{4}	±0.4	38.7^{2}	±1.1	74.0^{2}	±8.0	117.0^{2}	±9.0	
Mosquito Creek (at Willow River)		7.5^{2}	±0.5	93.0		110.0		219.5^{2}	±30.5	
Big Valley Creek										
Williams Creek		7.1^{12}	±0.4	104.8^{5}	±42.4	124.4^{5}	±38.9	219.0^{14}	±82.0	
(93H/2;22;180)										
Isaac Lake	3	9.0								3110
Lanezi Lake	3	> 8.0								2980
McLeary Lake	3	> 8.5								3000
(93H/3;22;180)										
Sandy Lake	3	>7.5								2980

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(93H/3;22;180)										
Unna Lake	3	> 9.0								3000
Babcock Lake	3	> 9.0								3000
Huckey Lake										
(93H/2;23;184)										
Headwaters of the Upper Cariboo	3									3300
(93H/3;24;188)										
Kibbee Lake	3	> 9.0								3000
(93H/6;24;188)										
Kruger Lake										3000
Indian Point Lake	3	9.0								3000
Thompson Lake										3000
Bowron River	3									
below Bowron Lake		7.3^{35}	±0.5	35.9^{15}	±9.6	49.2^{15}	±11.2	125.9^{40}	±130.0	
at Mainline Road		7.9^{16}	±0.2	73.0^{14}	±14.7	92.5^{8}	±13.6	144.4^{20}	±31.3	

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92I/14;2a;15)										
Bonaparte River (above Hat Creek)		8.3		169.0		216.0		355.0		
Hat Creek (at mouth)		8.5^{25}	±0.3	242.2^{15}	±33.3	336.7^{15}	±42.7	521.0^{25}	±85.4	
(92I/11;8a;15)										
Barnes Lake	3									2300
(92P/4;24a;15)										
Alkali Lake	0									2962
(92P/3;1b;25)										
Wohlleben Lake	0									3400
Knife Lake										3700
Bonaparte River (above Clinton Cr.)		8.1^{29}	±0.3	115.8^{15}	±36.7	147.6^{15}	±38.6	231.1^{35}	±70.1	
(92P/3;2b;25)										
Loon Lake	4									2820
at inlet		8.9^{2}	±0.0	295.0^{2}	±0.0	320.0^{2}	±0.0	505.0^{2}	±5.5	
off White Moose		8.5^{3}	±0.3	292.7^{3}	±1.7	328.7^{3}	±2.5	517.7^{6}	±7.9	

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92P/3;2b;25)										
Loon Lake Continued										
off gov't campground		8.5^{3}	±0.3	292.7^{3}	±1.7	326.7^{3}	±4.1	517.2^{5}	±8.6	
at rock bluff		8.7^{3}	±0.3	293.3^{3}	±0.5	323.3^{3}	±6.2	514.8^{6}	±9.3	
at outlet		8.9^{2}	±0.0	294.0^{2}	±0.0	320.0^{2}	±4.0	507.0^{4}	±2.1	
Dougherty Lake										3150
(92P/3;3b;25)										
Hihium Lake										4480
(92I/4;5b;25)										
Cultus (Baldwin) Lake	3	7.5		59		86		165 @ 53°F		2750
(92I/4;9b;25)										
Bose Lake	3									4200
(92I/6;9b;25)										
Quiltanton (Divide) Lake	3									4100
(92I/6;10b;25)										
Calling Lake	3									5100

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92P/4;23b;25)										
Leighwood Lake	2									3400
(92P/4;24b;25)										
Three-mile Lake	0									3049
Clinton Creek (above Clinton)		8.3[2]	±0.2	272.5[4]	±18.3	340.5[4]	±35.7	539.4[2]	±84.5	
(92P/6;1c;35)										
Sodium Lake	1									3600
Marsden Lake	1									3600
(92P/3;2c;35)										
East Camp Lake	1									3700
Mokian Lake	1									3700
(92P/6;2c;35)										
Hutchinson Lake	1									3650
(92P/3;3c;35)										
Upper Loon Lake	0									3170

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92P/4;3c;35)										
Vidette Lake	3					301				2500
(92P/2;4c;35)										
Jules Lake	3									3800
Mowich Lake	3									2500
Chartrand Lake	1									4200
Marshy Lake	1									3800
Skookum Lake	3									2700
Deadman Lake	3									2700
Outpost Lake	0									2700
Allie Lake	0									3500
Rock Lake	0									3450
Converse Lakes										3700
(92P/2;4c;35)										
Fatox Lake	4									3700
Snohoosh Lake	3									2600

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92I/15;5c;35)										
Red Lake	4					362				3100
Saul Lake	4									4800
Deadman River (above Criss Cr.)		8.2^{34}	±0.3	151.1^{17}	±44.7	194.5^{17}	±48.8	312.9^{35}	±96.7	
Tranquille River (at Bridge #3)		7.6^{5}	±0.2	40.4^{2}	±4.2	60.0^{2}	±10.0	80.8^{6}	±8.9	
(92I/10;7c;35)										
Six-mile Lake (at centre)	4	8.7^{2}	±0.0	323.0^{2}	±0.0	420.0^{2}	±2.0	600.7^{6}	±31.7	1900
Six-mile Creek (above lake)		8.4^{2}	±0.0	261.0		326.0		466.0^{3}	±46.7	
Duffy Lake (at centre)	4	8.8^{2}	±0.0	427.0		760.0		967.0		3800
Duffy Creek (near mouth)		8.2	±0.0	230.0		404.0		602.5^{2}	±22.5	
(92I/15;7c;35)										
Kamloops Lake	2					78				1100
opposite Copper Creek		7.6^{3}	±0.1	38.5^{3}	±4.6	71.3^{3}	±2.5	100.7^{3}	±11.1	
opposite Cherry Bluff		7.5^{3}	±0.1	39.0^{3}	±2.5	66.7^{3}	±3.4	99.3^{3}	±10.6	

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92I/15;7c;35)										
Kamloops Lake Continued										
south of Tranquille Sch.		7.6		36.0		64.0		94.0		
site 0920174		7.5^{48}	±0.2	34.0^{48}	±5.0	46.5^{6}	±8.7	90.0^{48}	±16.3	
site 0920175		7.5^{53}	±0.2	36.0^{52}	±4.4	44.5^{2}	±2.5	95.7^{53}	±14.2	
site 0920176		7.5^{24}	±0.2	36.0^{20}	±4.1	55.0		94.8^{24}	±13.3	
site 0920177		7.5^{23}	±0.4	35.3^{20}	±4.2			93.0^{23}	±14.0	
site 0920178		7.5^{33}	±0.4	33.4^{13}	±4.7	55.0		92.9^{33}	±13.3	
at Frederick		7.6^{20}	±0.1	35.3^{20}	±4.2	38.0		94.1^{20}	±13.9	
(92I/15;8c;35)										
Tunkwa Lake	4					200				3751
(92I/7;9c;35)										
Bill Lake	3									4700
(92I/7;9c;35)										
Logan Lake	1									3600
east end		8.5^{2}	±0.1	414.0^{2}	±1.0			822.5^{2}	±7.5	
west end		8.5^{3}	±0.2	415.0^{3}	±0.8			577.2^{3}	±350.5	
Guichon Creek		8.0^{6}	±0.1			243.8^{6}	±24.3	289.0^{16}	±50.8	

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92I/7;10c;35)										
Roscoe Lake	3									5200
(92J/18;16c;35)										
Duffey Lake										3700
(92P/5;23c;35)										
Big Bar Lake	4									3630
(92P/4;24c;35)										
Magnesia Lake	0									3700
Trurans Lake	0									3650
(92P5/24c;35)										
Beaverdam Lake	4									3648
Goodenough Lake	2									3555
Last Chance Lake	0									3550
River Lake	0									3550
Little White Lake	0									3640

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92P/6;1d;45)										
Loch Lomond	1									3540
(92P/6;2d;45)										
Pressy Lake	2									3350
(92P/2;3d;45)										
Young Lake	3									3070
Enright Lake	1									3700
Boyer Lake	1									3700
Bog Lake	0									4010
(92P/2;3d;45)										
Last Course Lake	1									4000
Scott Lake	2									3900
(92P/7;3d;45)										
Spectacle Lake	2									3500
Sharpe Lake	2					256				3350

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92P/2;4d;45)										
Lily Lake	2									3200
Duck Lake										3800
Hiahkwah Lake	2									4700
Stadia Lake	2									4400
Elbow Lake	2									4700
Hammer Lake	4									4130
Uren Lake										3810
Tuleric Lake	2									4200
Ternan Lake	0									4100
Semlin Lake	0									3700
(92P/2;5d;45)										
Beaverhut Lake	1									4900
Tranquille Lake	3									4598
Tsintsunko Lake	3									5200
(92I/16;5d;45)										
Wentworth Lake	1									5800

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92I/10;7d;45)										
Ned Roberts Lake	2	8.1^{4}	±0.2	227.5^{2}	±20.5	292.0^{2}	±16.0	449.8^{5}	±33.9	2250
Thompson River (at Wallachin)		7.4^{21}	±0.6	33.8^{34}	±3.5	56.2^{34}	±8.6	94.6^{82}	±17.2	
(92I/10;8d;45)										
Face Lake	3									4750
Paska Lake	3									4800
(92I/8;8d;45)										
Lac Le Jeune	4									4177
surface						176				
deepest point		7.7^{3}	±0.2	135.3^{3}	±2.6	181.3^{3}	±4.7	266.8^{6}	±7.0	
north end		8.1^{2}	±0.1	130.0^{2}	±3.0	175.0^{2}	±5.0	257.7^{3}	±6.3	
south end		7.7^{5}	±0.7	130.7^{3}	±2.6	172.7^{3}	±2.5	266.6^{7}	±14.9	
west end		7.7^{5}	±0.4	130.5^{4}	±3.0	175.3^{3}	±3.4	271.9^{7}	±16.4	
(92I/7;9d;45)										
Mamit Lake	2									3100
Frogmoore Lake	3									4700
Surrey Lake	3									4550

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92I/7;9d;45)										
Sussex Lake	3									4600
(92I/4;13d;45)										
Kwoiek Lake	2									2800
(92P/5;23d;45)										
Clink Lake										
Little Big Bar Lake	3									3450
Long Lake	0									3500
Meadow Lake	0					136				5000
Mule Lake	0									3550
Pigeon Lake	0									3500
Ridge Lake	0									3700
(92P/5;23d;45)										
Riley Lake	3									3350
White Lake	0									3400
(92P/5;24d;45)										
Alberta Lake										3600

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92P/5;24d;45)										
Cunningham Lake										3700
McKinley Lake										3700
Toby Lake										3700
Valenzuela Lake										3700
(92P/7;3c;55)										
Eagan Lake	2									3440
Machete Lake	2									3700
Peel Lake										4150
Muskrat Lake										3700
Raspberry Lake										3900
(92P/7;3e;55)										
Hansen Lake										3800
Henley Lake	2									3850
Rutherford Lake										3750
Crystal Lake	2					150				3700
Crescent Lake	3									3800
Eugene Lake	3					207				3800
Burn Lake	3									3800

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92P/7;3e;55)										
Knight Lake	3									3900
Montana Lake	3									3700
(92P/1;4e;55)										
Mollimarn Lake	4									4650
Lloyd Lake	4									4700
Adler Lake	4									4750
Coutoure Lake	4									4950
(92P/1;4e;55)										
Willowgrouse Lake	4									4600
Bogmar Lake	4									4100
Mayson Lake	4									4150
Allan Lake	4					160				3895
Beauregard Lake	4									4200
Totunkwa Lake	4									4200
Dunsapie Lake	4									4300
Siam Lake	4									4700
Estelle Lake	4									4850
Dagger Lake	4									4800

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/1 as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/1 $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92P/1;4e;55)										
Hoover Lake	4									4800
Barriere River (at mouth)		7.6^{22}	±0.3	48.0^{14}	±8.2	71.0^{12}	±8.3	132.4^{24}	±111.5	
(92P/2;4e;55)										
Bare Lake	4									4650
(92P/8;4e;55)										
Bonaparte Lake	3									3900
Akehurst Lake	3									4500
Hoopatatkwa Lake	4									4550
Norma Lake	4									4750
(92P/1;5e;55)										
Bob Lake	3									5700
Black Lake	3									4300
Cannine Lake	3									4700
Meighan Lake	3									5600
Parky Lake	3									4400
Rea Lake	3									5500

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92P/1;5e;55)										
Stuart Lake	3	7.1		44		71		94 @ 41°F		3600
Windy Lake	3									4900
Shelley Lake	3									5000
(92P/2;5e;55)										
Whitewood Lake	2									4200
(92I/9;7e;55)										
Shumway Lake	2					392				2240
Jocko Lake	4	8.2^{2}	±0.0	236.0^{2}	±0.0	453.0^{2}	±1.0	652.8^{4}	±7.3	2950
Petersen Creek (below Jocko Lake)		7.9^{5}	±0.2	317.0^{2}	±19.0	590.0^{2}	±8.0	864.8^{5}	±45.6	
(92I/8;8e;55)										
Stump Lake	4					1200				2460
Trapp Lake	3									2260
(92I/9;8e;55)										
McConnell Lake	4	8.2^{2}	±0.0	141.0^{2}	±0.0	191.0^{2}	±1.0	296.3^{4}	±10.2	4250

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92I/2;9e;55)										
Mab Lake	3									4500
(92I/2;9e;55)										
Nicola Lake	3									2060
surface		8.2								
deepest point		7.7^{5}	±0.5	88.1^{3}	±2.5	142.7^{3}	±6.8	213.7^{6}	±8.0	
outlet		8.1^{3}	±0.1	88.1^{2}	±0.7	143.0^{2}	±3.0	222.3^{4}	±10.6	
opposite Nicola River		7.8^{5}	±0.4	87.9^{3}	±4.0	140.7^{3}	±5.7	223.7^{7}	±25.9	
at east end		7.9^{5}	±0.4	87.2^{3}	±2.9	140.7^{3}	±5.7	212.3^{7}	±6.6	
Nicola River	3			48 to 125		80 to 190		108 to 275		2056
(92I/4;13e;55)										
Hannah Lake										1050
(92J/1;15e;55)										
Stein Lake	3									3400
(92P/5;23e;55)										
Canoe Lake										3384

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue ($105^{o}C$)mg/l $\bar{X}$	Filterable Residue ($105^{o}C$)mg/l SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(920/8;23e;55)										
Onion Lake										3700
(92P/10;2f;65)										
Lesser Fish Lake										3700
(92P/7;3f;65)										
Tortoise Lake	2									3800
Tobe Lake	2									3750
Twin Lake	2									3705
Lac Des Roches	3					153				3720
Phinetta Lake	3					129				3650
Webb Lake	3									3800
Whitely Lake	3									3900
(92P/8;3f;65)										
Nomans Lake	2									3950
Emar Lake	2									4100
Long Island Lake	3									4200
Birch Lake	3					144				3650

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92P/10;3f;65)										
Willow Lake	3									4220
Wavey Lake	3									3950
Faulkner Lake	3									3950
Muddy Lake	3									3750
Wilson Lake	3									3700
Otter Lake	3									3700
Bridge Lake	3									3718
(92P/1;4f;65)										
Boulanger Lake										4190
(92P/8;4f;65)										
Frog Lake										4500
Gorman Lake	3					180 - 250				3700
Janning Lake	3									4100
Mulholland Lake	3									3700
Posby Lake										2300
Patrick Lake										4500
Sanborn Lake										1450

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH		Total Alkalinity (mg/l as $CaCO_3$)		Filterable Residue (105°C)mg/l		Specific Conductivity umho/cm		Approximate Elevation (ft)
		X̄	SD	X̄	SD	X̄	SD	X̄	SD	
(92P/8;4f;65)										
Smith Lake	3									3700
Thuya Lakes	3									4300
Caverhill Lake	3									4520
Powder Lake	3									4200
Lupin Lake	3									4000
(92P/1;5f;65)										
Camp Nine Lake										2400
Rexford Lake										2800
Badger Lake	4									4200
Coyote Lake										2850
Knouff Lake	4					152				3768
Little Badger Lake	4									4600
Martin Meadows Lake	1									3400
Spooney Lake	4									3500
Struthers Lake	1									2400
Genier Lake	4					250				2000
(92I/16;6f;65)										
Community Lake	3									4500

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity SD	Filterable Residue ($105^{\circ}C$)mg/l $\bar{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92I/16;6f;65)										
Heffley Lake	4					206				3095
Heffley Creek	4	8.4^{5}	±0.1	214.3^{3}	±25.0	346.0^{2}	±84.0	519.0^{6}	±155.7	2200
(92I/16;6f;65)										
Hyas Lake	4					196				4060
Sullivan Lake	4									3800
(92I/9;7f;65)										
Campbell Lake	1									3500
Buse Lake	1									2200
Scuitto Lake	1									3500
Paul Lake	3									2542
surface		8.1				212				
west end		8.2^{8}	±0.3	155.5^{4}	±3.3	216.0^{4}	±1.4	330.9^{10}	±28.4	
south end		8.2^{10}	±0.3	156.4^{5}	±3.2	216.8^{5}	±4.8	344.2^{13}	±17.5	
north end		8.3^{8}	±0.3	156.0^{4}	±2.9	214.5^{4}	±3.0	336.4^{10}	±12.6	
east end		8.3^{8}	±0.2	156.3^{4}	±2.7	215.0^{4}	±3.0	336.8^{10}	±13.1	
Pinantan Lake	4	8.1				238				2800

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue ($105^{o}C$)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92I/8;8f;65)										
Dardanelles Lake	3									4100
Plateau Lake	4									4000
Roche Lake										3721
(92I/8;9f;65)										
Peter Hope Lake	4					192				3650
(92I/2;10f;65)										
Courtney Lake	4					341				3450
(92P/8;3g;75)										
Latremouille Lake	3					100				4000
Lynne Lake	3									4100
(92P/9;3g;75)										
Lemieux Lake	3									4000
Lemieux Creek (near mouth)	3	8.0[2]	±0.2	109.5[2]	±8.5	139.0[2]	±15.0	234.1[2]	±32.8	2450

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92P/9;3g;75)										
Taweel Lakes	4									3900 – 4900
Lost Lake	3									4300
Moosehead Lake	3									4150
Deer Lake										4400
Tintlhonton (Tuloon) Lake	3									4100
Hardcastle Lake	3									4200
Rock Island Lakes	3									4100
Crater Lake	3									4200
Silver Lake	4									4400
Laurel Lake	3					75				4500
(92P/8;4g;75)										
Dum Lake										3800
Dum Lake #1,#2,#3										3800
Dunn Lake	3					63				1480
(92P/8;4g;75)										
Hallamore Lake	3					175				3000

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue ($105^{o}C$)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92P/8;4g;75)										
McTaggart Lakes	3									1430
Demers Lake										2300
near centre		7.7^{6}	±0.2			210.0^{2}	±0.0	341.6^{8}	±25.2	
at outlet		7.7^{4}	±0.5					305.8^{4}	±45.7	
east of pier		7.9^{6}	±0.3	133.5^{2}	±9.5	187.7^{2}	±7.0	312.0^{6}	±36.1	
west of pier		8.1^{3}	±0.1	124.0		172.0		282.3^{3}	±32.6	
south of pier		7.9^{6}	±0.1	150.0^{2}	±0.0	207.0^{2}	±3.0	323.5^{8}	±20.1	
(82M/4;5g;75)										
Forest Lake	3									1950
Long Lake										3450
Sams Lake										3400
Saunders Lake										3650
Dixon Lake	3									3500
Needmore Lake										3700
(92P/8;5g;75)										
Leonie Lake										3400

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(82L/13;6g;75)										
Aylmer Lake	4									2650
McGillavary Lake	4									5300
Niskonlith Lake	4									1684
(82L/12;7g;75)										
Monte Lake	4					160				2245
Monte Creek	3	8.5^{16}	±0.4	267.4^{10}	±84.8	350.0^{10}	±106.3	475.8^{18}	±187.4	2650
(92I/1;8g;75)										
Chapperon Lake	1									3100
Index Lake	1									3100
(92I/8;8g;75)										
Rush Lake	1									3100
Salmon Lake	4					168				3070
(92I/1;9g;75)										
Douglas Lake	3									2625
Nicola River (below Douglas Lake)		8.0^{24}	±0.3	70.1^{17}	±17.6	147.4^{17}	±39.4	210.0^{35}	±76.0	

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(92I/1;10g;75)										
Minnie Lake	3									3500
(92P/9;3h;85)										
Moose Lake	2									4200
Lolo Lake	3									3650
Dutch Lake	3									1000
Star Lake	3									3450
Surprise Lake	2									4550
Grizzly Lake	2									4450
Reflector Lake	2									4450
Clearwater River (at Clearwater)		7.5[20]	±0.4	35.3[11]	±3.1	52.3[12]	±5.0	106.5[23]	±106.1	
(92P/9;4h;85)										
McCarthy Lake	2									2400
(82M/5;4h;85)										
North Barriere Lake	3					80.5				2080

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/1 as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/1 $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(82M/4;5h;85)										
Gilfried Lake										5450
Johnson Lake	4					211				3500
Nikivikwaia Lake	2									6000
East Barriere Lake	2					70				2100
South Barriere Lake	2									3100
Upper South Barriere Lake	2									3300
(82M/6;5h;85)										
Adams Lake	3					57				1300
(82L/13;6h;85)										
Adams River (at Adams Lake outlet)	4	7.6^{12}	±0.1	22.5^{6}	±0.7	39.3^{6}	±3.0	55.0^{12}	±3.8	
(82L/13;6h;85)										
Chum Lake	2									1800
Phillips Lake	2									1850
Little Shuswap Lake	3									1135
surface						68				
at pier								74.0		

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(82L/13;6h;85)										
Little Shuswap Lake Continued										
at centre		7.5		31.0		50.0		73.5^{2}	±0.5	
northeast end		7.6^{2}	±0.0	31.0^{2}	±0.0	49.0^{2}	±1.0	74.0		
southeast end		7.6		30.4		50.0				
at inlet		7.6		29.2		50.0		70.0		
South Thompson River (at Chase)		7.5^{42}	±0.7	37.0^{12}	±8.0	55.5^{11}	±12.7	94.7^{45}	±21.5	
(82L/5;7h;85)										
Pinaus Lake	4									3200
Salmon River		8.0		111.0		174.0		235.5^{2}	±4.5	
(82L/11;7h;85)										
Bolean Lake	3									4700
(82L/12;7h;85)										
Pillar Lake	3									2889
(82L/12;9h;85)										
Mellin Lake	1									4600
Pennask Lake	4	7.6				27				4600

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(92P/5;2i;95)										
Tommy Archer Lake	2									3300
(92P/16;2i;95)										
Mahood Lake	3									2060
at rock bluffs		7.5^{6}	±0.2	52.1^{3}	±0.3	74.0^{3}	±0.0	109.7^{6}	±2.6	
at Lunker Bay		7.4^{4}	±0.2	51.2^{2}	±0.9	73.0^{2}	±3.0	107.3^{4}	±4.3	
off Deception River		7.6^{4}	±0.1	51.6^{2}	±1.2	73.0^{2}	±1.0	107.8^{4}	±4.8	
off provincial park		7.8^{4}	±0.1	54.8^{2}	±2.1	75.0^{2}	±1.0	113.8^{4}	±4.1	
(92P/16;2i;95)										
Pendleton Lake	3									3450
(92P/16;3i;95)										
Moira Lake	3									4050
Efdee Lake	3									4050
(82M/5;4i;95)										
Saskum Lake										2700

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	SD	Filterable Residue (105°C)mg/l $\overline{X}$	SD	Specific Conductivity umho/cm $\overline{X}$	SD	Approximate Elevation (ft)
(82M/12;4i;95)										
McCorvie Lake	3									4250
(82M/3;5i;95)										
Pisima Lake										3300
Seymour River (at mouth)		7.0^{14}	±0.3	12.1^{2}	±3.4	24.8^{8}	±4.6	48.3^{12}	±41.8	
(82L/14;6i;95)										
Scotch Creek (at mouth)		7.9^{6}	±0.4	37.1^{5}	±11.7	61.0^{2}	±19.0	80.0^{7}	±25.2	
(82L/14;6i;95)										
Shuswap Lake	3									1200
surface		7.5		40		64		92 @ 50°F		
at Blind Bay		7.6^{4}	±0.3			51.0^{2}	±1.0	83.0^{4}	±7.6	
at Blind Bay, NW		8.0^{4}	±0.4			52.0^{2}	±2.0	87.7^{3}	±9.0	
at Blind Bay, SE		7.7^{4}	±0.2			57.0^{2}	±3.0	97.3^{3}	±9.1	
at Blind Bay		7.6^{13}	±0.2	36.0^{4}	±1.2	53.5^{8}	±3.0	102.5^{24}	±11.7	
at Eel Ruckell Pt.		7.5^{31}	±0.3	34.2^{10}	±2.2	52.4^{16}	±3.3	96.6^{78}	±12.2	
at SE Sandy Pt.		7.7^{21}	±0.4	48.2^{6}	±4.2	83.3^{12}	±17.5	143.5^{78}	±29.8	

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(82L/14;6i;95)										
Shuswap Lake Continued										
opposite Salmon Arm		7.9^{25}	±0.4	53.6^{11}	±6.1	81.9^{13}	±7.5	139.1^{33}	±26.0	
opposite Marble Point		7.6^{31}	±0.3	39.6^{10}	±2.7	58.5^{16}	±3.8	109.5^{80}	±15.2	
west of Sorrento		7.6^{36}	±0.3	34.4^{14}	±2.4	51.2^{20}	±5.2	96.7^{74}	±11.7	
(82L/11;6i;95)										
White Lake	4					228				1541
(82L/11;7i;95)										
Blair Lake	3									4950
Spa Lake	3									5000
(82M/13;3j;105)										
Moul Lake										5100
Fight Lake	3									6050
(92P/16;3j;105)										
Foot Lake	3									2350
Placid Lake	3									2400
Jonah Lake	3									2100

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(82M/13;4j;105)										
Silence Lake	2									2500
(82M/12;4j;105)										
Running Bear Lake										4250
Big Graffunder Lake	2									4096
(82M/12;4j;105)										
Small Graffunder Lake	2					170				4100
N. Thompson River (at Birch Island)		7.4[36]	±0.3	35.4[20]	±48.1	59.3[20]	±53.6	101.7[40]	±114.3	
(82M/6;5j;105)										
Gannett Lake										3300
Little Momich Lake										1600
Momich Lake										1500
Stukemapten Lake										1900
Telfer Lake										3200
First Momich Lake										1550
Tsikwustum Lake										4900

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(82L/11;7j;105)										
Cardom Lake						410				1750
(82M/13;3k;115)										
Stevens Lake										5000
(82M/11;4k;115)										
Dudgeon Lake	2									3000
Harbour Lake	2					34				2700
Upper Harbour Lake	2									2900
(82M/2;5k;115)										
Hunakwa Lake	2									1200
(82M/6;5k;115)										
Humamilt Lake	2									1850
(82L/11;6k;115)										
Mara Lake	3									1150
east of Shuswap R.		7.8^{8}	±0.3			62.5^{4}	±7.5	118.2^{40}	±28.9	
opposite Fossett		7.6^{36}	±0.3	42.7^{15}	±5.1	64.5^{22}	±9.4	118.0^{94}	±16.7	

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\bar{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\bar{X}$	Total Alkalinity (mg/l as $CaCO_3$) SD	Filterable Residue (105°C)mg/l $\bar{X}$	Filterable Residue (105°C)mg/l SD	Specific Conductivity umho/cm $\bar{X}$	Specific Conductivity umho/cm SD	Approximate Elevation (ft)
(82M/11;41;125)										
McGibbney Lake										5700
Sunset Lake										5500
(82M/14;41;125)										
Tumtum Lake	2									2150
(82M/11;51;125)										
Bischoff Lake										5900
(82L/15;6m;135)										
Griffin Lake	3									1450
(82L/16;6m;135)										
Three Valley Lake	3									1600
Eagle River (upstream of Three Valley Lake)		7.4^{6}	±0.2	19.0^{3}	±6.6	42.0		50.6^{5}	±18.7	
(82L/10;6m;135)										
Hidden Lake										2100
Twin Lake										4700

Name and Location* of Lake or Stream	Present** & Potential*** Fish Values	pH $\overline{X}$	pH SD	Total Alkalinity (mg/l as $CaCO_3$) $\overline{X}$	Total Alkalinity SD	Filterable Residue ($105^{\circ}C$)mg/l $\overline{X}$	Filterable Residue SD	Specific Conductivity umho/cm $\overline{X}$	Specific Conductivity SD	Approximate Elevation (ft)
(83D/3; ;)										
Blue River (at mouth)		7.2[12]	±0.7	14.9[11]	±5.0	29.3[11]	±7.9	43.3[20]	±12.9	

APPENDIX B

PROPOSED LOCATIONS OF SAMPLING STATIONS FOR SNOWPACK, SNOW-FED STREAMS AND LAKES IN THE HAT CREEK STUDY AREA

Location Lat. Long.	Sampling Sites (Coast Cariboo)
51° 58', 121° 41'	Hendrix Creek (where the road to Hotfish Lake crosses)
52° 17', 121° 10'	Patenaude Lake Creek (above the Crooked Lake road crossing)
52° 26', 121° 8'	Jacques Lake Creek (above Keno Lake road crossing)
52° 34', 121° 42'	Trio Lake Creek (at the confluence with Morehead Creek)
52° 39', 121° 32'	Wolverine Creek (above the Keithley Creek road crossing)
53° 13', 121° 52'	Yuzkli Creek (where the Willow River forest development road crosses)
53° 11', 121° 22'	Loskey Creek (where the Matthew River forest development road crosses)
52° 47', 121° 5'	Little River (where the Maeford Lake road crosses)
52° 1', 121° 9'	Eagle Creek (above the Coffee Lake road crossing)
53° 6', 121° 25'	Antler Creek (below the confluence with Pleasant Valley Creek)
	Sampling Sites (Thompson-Okanagan)
50° 56', 122° 16'	Yalakom River (at bridge crossing)
50° 38', 122° 3'	Cayoosh (at bridge crossing)
50° 39', 121° 48'	Kwotlenemo
50° 51', 121° 40'	Pavilion Cr. (just below Lake and Pavilion Cr. junction)
50° 34', 121° 21'	Venables Lake
50° 16', 121° 23'	Nicomen River
50° 26', 121° 33'	Pasulko Lake (in Bontanie Creek)
50° 42', 121° 15'	Barnes Lake
50° 37', 120° 51'	Tunkwa Lake

Location		Sampling Sites (Thompson-Okanagan) cont'd.
Lat.	Long.	
50° 18',	120° 27'	Moose Creek (above ranch)
50° 0',	120° 8'	Pennask Lake
50° 27',	120° 12'	Roche Creek
50° 34',	119° 36'	Blair Creek (at the Chase Creek road crossing)
50° 52',	119° 18'	Outlet to White Lake (near Salmon Arm)
51° 0',	118° 52'	Perry River (at highway)
50° 56',	119° 23'	Scotch Creek
51° 14',	119° 56'	Barriere River (at junction of 3 River)
51° 20',	119° 50'	North Barriere Lake
50° 52',	119° 47'	McGillivray Lake
51° 8',	120° 47'	Deadman River (above Vidette Lake)
50° 53',	120° 42'	Red Lake
51° 8',	121° 8'	Brigade Creek
51° 5',	121" 15'	Loon Lake
51° 23',	120° 39'	Bonaparte River (above Eagan Lake)
51° 27',	120° 30'	Phinetta Lake
51° 22',	120° 25'	Caverhill Lake
51° 25',	120° 9'	Dunn Lake
51° 38',	119° 58'	Raft River
50° 43',	120° 23'	Coldscaur Lake
51° 58',	120° 8'	Murtle River (at Dawson Falls)
51° 55',	120° 3'	Hemp Creek
51° 29',	119° 17'	Adams River (at first bridge above Adams Lake)
51° 53',	119° 7'	Tum Tum Lakes
51° 19',	118° 52'	Ratchford or Seymour Lake

H A T C R E E K M O N I T O R I N G

(RATIONALE FOR CHOICE OF SAMPLE SITES THOMPSON-OKANAGAN REGION)

Yalakom River

This is a major drainage lying west of, but facing, the Hat Creek Project. River is extremely subject to freshet conditions in spring and very low in summer. Has experienced some mining activity in past. Should monitor east component of the wind. Accessible during all seasons.

Cayoosh Creek

This is an extremely large watershed in a heavy snow belt. Faces northeast and should monitor northeast component of wind over Hat Creek. Creek is accessible during all seasons.

Kwotlenemo Lake (Fountain Lake)

This lake lies just over the ridge west of Hat Creek and should serve to monitor any local westward flow impingement. Has relatively no development other than some logging and cattle ranching. This should monitor the local impingement effect of the east component.

Pavilion Creek

This creek has no development on it except Pavilion Lake with its summer cabins and outboard use. The station should sample local impingement effect of south and southeast winds. Pavilion Lake will get local impingement from the east and Pavilion Creek will get any local impingement coming in from the south and east.

Venables Lake

Venables Lake should serve to monitor impingement from the north wind. It is a relatively undeveloped valley except for logging and some old homsteading activities.

Nicomen River

This is a fairly major river coming out of a north-facing watershed. There has been no development in the watershed save, extensive logging which has led to very quick fresheting conditions. It is an extremely heavy snow area and should serve to monitor the long distance north wind effect.

Pasulko Lake

This is a very small lake with a very small tributary system. It is a south-facing watershed and would monitor the impingement effect of the north winds but in a much smaller watershed than Venables Lake. The site lies in an Indian Reserve and access is restricted during the winter.

Barnes Lake

This is a major recreational lake, accessible in winter. The lake is out in a bench with very little fresheting watershed. It would probably have a very long turn-over rate. It is accessible at all times.

Tunkwa Lake

This is a higher elevation plateau lake and is probably one of the ten most important Fish and Wildlife lakes in the province. It is regulated by a dam, both inlet and outlet, and is only 12 feet deep as an average. Tunkwa Lake would be typical of the lakes on the plateau south of the Thompson River and east of the Nicola River.

Moose Creek

This creek would sample a south-facing slope and thus would not lie in a direct line-of-site precipitation area. It would, however, typify the dryer range areas in a southeast direction from the Hat Creek site.

Penask Lake

This is a very high elevation lake and is the prime fisheries concern in the Kamloops region and probably in the Province of British Columbia. Approximately 50% of our eggs for our hatcheries are collected from this lake each year. The lake should typify the higher elevation lakes south and east of the Douglas Lake-Salmon River country. It has a major drainage flowing into it which is highly spring fresheting.

Roche Creek

Roche Creek would sample the plateau country east of the Merritt-Kamloops Highway. The sample site will sample both the lake and a major tributary stream which drains many other lakes but bypasses Roche Lake itself. The lakes sampled by this site are extremely important Kamloops fisheries lakes.

Blair Creek

Sampling of this drainage would sample a major logged-over basin, a major fisheries lake and a moderate snow fall area lying almost east of the Hat Creek site.

Outlet to White Lake

This lake is extremely important recreationally over near Salmon Arm and of limited drainage basin area.

Perry River

This is a major tributary of the Eagle River and comes out of a watershed which is heavily logged and which has no other activities taking place. The river comes out of a major snow fall area and would be our eastern-most proposal for checking of acid rain.

Scotch Creek

Scotch Creek is a very major tributary draining an entire plateau basin between Adams River and Seymour River. There has been no activity in this basin except logging and the creek itself is a very important salmon spawning stream.

Barriere River

Sampling of Barriere River at the proposed site would be a gross sample station for a very large area lying directly east of Hat Creek in a heavy snow belt.

North Barriere Lake

This will be a sub-sample of the previous sample station but would monitor higher elevation snow falls.

McGillivray Lake

This would be a typical lake on the plateau between the Thompson River and Adams River. It is of limited drainage, depth, and yet is of maximum importance to the fishery resource.

Deadman River

Sampling at the first proposed location would sample the plateau between Deadman River and Thompson River in the easterly direction from the Hat Creek site. The higher elevation sampling site would be highly freshet prone and influenced by almost no logging for the near future, (the only influence being some cattle use at the present time).

Red Lake

This is a lake on the plateau being sampled by the Deadman River. The lake is of limited drainage basin, very shallow, highly eutrophic and accessible all year round.

Brigade Creek

Brigade Creek sample site would sample the plateau between Deadman Creek and Cariboo Highway. It is a highly freshet prone creek and the basin is subject only to major logging influences.

Loon Lake

This sample site is well-documented chemically, a very important fishery lake, and would monitor the major wind pattern emanating from Hat Creek site.

Bonaparte River

The sample site proposed would monitor the plateau area lying directly in the path of the prevailing wind from Hat Creek. The area is heavily affected by logging, high-subject fresheting, accessible all year long.

Phinetta Lake

This lake is typical of the lakes lying on the plateau east of Bridge Lakes chain. It has small tributaries, highly subject to fresheting, excellent fishery, resort, access 10 months of the year.

Caverhill Lake

Similar to Phinetta.

Dunn Lake

This lake is highly oligotrophic, very big in size and would sample the entire Dunn Creek drainage. Access all year round. Relatively slow turn-over rate.

Raft River

This sample site would sample a very major drainage basin in a direct north-east direction of the prevailing wind from Hat Creek. The area is of extremely high snow fall, high freshet, and a high wildlife value zone. The only major impact in the valley to date has been logging.

Coldscaur Lake

This lake joins a very large number of other lakes, all of which lie in a very heavily logged plateau under the prevailing wind from Hat Creek. All lakes have high to moderate fishing values and low tds.

Murtle River

This site would sample a very large basin of all terrain which has had no activity occurring, (Wells Gray Park).

Hemp Creek

This site would sample a relatively similar area to Murtle River on a smaller scale and is accessible all year round.

Adams River
Obvious.

Tum Tum Lake

This sample site would sample the Adams River area on a much more limited basis and would sample the higher elevation, high fresheting part of the system.

Ratchford Creek or Seymour River

These sites would sample the major easterly drainage we would suggest to monitor. Both sites have been relatively untouched, save for logging or hydro rights-of-way.

S.J. MACDONALD
REGIONAL HABITAT PROTECTION BIOLOGIST
9/5/77