THE ADMINISTRATION OF POLLUTION CONTROL
IN BRITISH COLUMBIA
- A FOCUS ON THE MINING INDUSTRY -

by

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B.Sc., University of British Columbia, 1969

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

in the Faculty
of
FORESTRY

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

May, 1974
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Date June 26, 1973
The rapid growth in world population and industrial technology over the past few decades has resulted in increasing competition for the use of the earth's resources. This has caused what have been termed "resource-use conflicts", the resolution of which requires a "decision-making process".

In order to understand the manner in which resource-use decision-making operates in British Columbia, some legal, economic, social, administrative, and environmental factors involved were examined. As a working example of such decision-making, a detailed case history of the application for a Pollution Control Permit from the provincial Pollution Control Branch by Utah Construction and Mining Corporation is presented. The controversy surrounding the Company's plans to dispose of 9.3 million gallons of mine tailings daily into Rupert Inlet on northern Vancouver Island resulted in the holding of a public hearing by the Pollution Control Branch, the passage of new environmental legislation, and a court case. These events cast considerable light on the manner in which resource-use decision-making, that involves consideration of environmental factors, operates in British Columbia. Many weaknesses in the decision-making process are apparent, particularly the reluctance of the decision-makers to consider critical environmental factors in arriving at a conclusion regarding the use of resources.

Two experimental studies were undertaken: firstly, a brief survey of a number of mining operations in southern British Columbia to determine whether or not the administration of pollution control in the province was effectively preventing unacceptable deterioration in the quality of water draining the mined areas; and secondly, a study of the circulation of water in Rupert Inlet, and the effect of the tailings discharge on the turbidity of the water in the inlet, to test the validity of the basic assumptions behind the granting of a pollution control permit to Utah Construction and Mining Corporation. The objective of these two studies was to show that with a limited budget and in a limited time it was possible to determine the adequacy of the existing pollution control decision-making process.

The survey of the quality of water draining areas of mining activity revealed that existing mechanisms were not effectively preventing unacceptable heavy metal pollution of water, and that conventional tailings disposal is frequently
inadequate and unacceptable from an environmental standpoint. The oceanographic survey of Rupert Inlet demonstrated the falacious nature of the basic assumption underlying Utah's pollution permit. Both studies showed conclusively that the pollution control decision-making process was not operating satisfactorily in British Columbia and that with limited time and finances it was possible to generate some of the information necessary to an adequate decision-making process.
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Acknowledgements

Sincere thanks are made for the encouragement and supervision provided by Dr. J.P. Kimmins of the Faculty of Forestry at the University of British Columbia, and for the guidance and financial support provided by Dr. C.S. Holling of the Institute of Animal Resource Ecology at U.B.C.

Acknowledgement is also made of the assistance of the other members of my committee, Dr. G.L. Pickard of the Institute of Oceanography, Dr. M. Goldberg of the Faculty of Commerce and Business Administration, Dr. R.W. Wellwood of the Faculty of Forestry, and Mr. A.R. Lucas and Mr. R. Franson of the Faculty of Law.

Both Dr. H.V. Warren of the Department of Geological Sciences and Professor J.B. Evans of the Department of Mineral Engineering helped the author to understand the technology of mining and the attitudes of the mining industry.

Special thanks go to my friends Peter Heiberg, Jim Taylor, Terry Frewer, David Pritchett, Sam Marlett, David Moon, Fred Easton and Frank Allison, for accompanying me as research assistants on the field trips to Rupert Inlet and to the various mine-sites visited for water quality sampling.
CHAPTER I

INTRODUCTION

It has become abundantly clear over the past few decades that we are living in a world which has a finite quantity of natural resources for food, clothing, housing, and particularly for the supply of raw materials to maintain the growing industrial output of our society. Technological growth, fueled by an ever-increasing use of energy in the form of coal, oil, natural gas and hydro-power, has made possible the utilization of resources which were formerly unavailable for exploitation. This, in turn, has given rise to a philosophy of "technological optimism" which has led many people to believe that although a particular resource may be limited in supply, new methods will be developed and new resources will become available to support the material needs and aspirations of mankind.

It has been suggested by some, notably Buckminster Fuller and his followers, that the day will soon come when man can live apart from his natural environment, in mega-cities where a man-made ecosystem will provide all the requirements of life. Apart from the extremely sterile existence which this
prediction anticipates, it has been seriously questioned by the students of natural science whether such a future is possible on our planet. The complexity of natural ecosystems, and our present inability to fully understand the nature of our dependence on them, has led many people, particularly those engaged in ecological research, to express pessimism about the trend towards increased technological growth. Indeed, it has been suggested that even the present level of industrial output will result in irreparable damage to the natural ecosystems that are providing resources for the production of manufactured goods.

The utilization of a particular natural resource for industrial purposes frequently results in the destruction of that resource for other uses. Forest harvesting destroys the value of forests for wilderness and some types of recreation; mining often destroys the value of forests for forestry; toxic effluent from many factories destroys the aesthetic value of water, land and air. On one level, these effects can be viewed as "trade-offs", resulting in an increased material wealth at the expense of a reduction in the beauty and quality of the natural systems that are being exploited for a particular resource. So long as society is willing to make this exchange, it is reasoned, there is no cause to alter the direction of technological evolution. However, the implications of industrial exploitation may be far more serious than the simple choice between material wealth and a pleasant environment. Through the
science of ecology it has been demonstrated that natural ecosystems, and the many resources other than raw materials they provide are essential for the very survival of all the species on the planet, including our own. The destruction of agricultural land, the rapid removal of vast forests, the depletion of the ocean's fisheries, the fouling of the air and water with human and industrial wastes; all of these activities are resulting in an alteration of the global ecosystem. It is obvious, given the extent to which this ecosystem has already been modified, that it is extremely resilient and has continued to function as the life-support system for our species and others in this altered state. But there is increasing evidence that this resilience has its limits. There is a growing concern that the present trends towards increased population and technological growth will reach these limits, resulting in a partial or total collapse of the life-support function of the global ecosystem, or in progressive erosion of the quality of life.

The social manifestation of the limited supply of natural resources is extremely complex and results in what have been termed "resource-use conflicts". These conflicts are brought about by the competition between individuals and organizations for the use of resources for different purposes. In cases where such conflicts exist, and they are becoming more common and more complex as the demand for natural resources
increases, it is necessary that some form of "decision-making process" be available in order to resolve them.

Integral to the decision-making process are: some form of social organization to deal with the problem, a set of guidelines or rules for the organization to follow, and a flow of the information necessary for the realization of a desirable solution.

The major objective of this thesis is to analyze an example of the decision-making process as it operates in British Columbia, and to assess the adequacy of these processes in arriving at socially desirable decisions for resource use.

Of critical importance to the outcome of the decision-making process with regard to the environmental impact of a particular resource-use, is the collection and dissemination of information on which the decision can be based. Another major objective of the thesis will be an attempt to demonstrate that such information can be collected, disseminated, and interpreted in a limited time period and with limited financial resources. The thesis will demonstrate that constraints of time and money can not justifiably be employed to limit the collection and dissemination of such information.
The Island Copper Mine as an Example of
the Impact of Technology on the Environment

In order to study the decision-making process as it relates to the achievement of environmental quality, it was decided that many general features of the process could be determined through a detailed investigation of a specific example. The initiation of this study happened to coincide with a major resource-use conflict: that involving the development of the Island Copper Mine by Utah Construction and Mining Company (hereafter also referred to as "Utah") on Rupert Inlet at the north end of Vancouver Island. Utah is typical of the many large-scale, highly mechanized mining operations that have recently begun to operate in British Columbia. They are characterized by a heavy reliance on technology and a tremendous environmental impact, caused largely by the great volume of waste resulting from their operation. The mining industry is, in turn, a specific example of the general problem of the impact of technology on the environment. The Island Copper Mine was therefore an excellent example from which to determine the general nature of resource-use decision-making in which environmental considerations play an important role. The central
section of the thesis is a detailed case history of the events that led up to the development of this mine and particularly of the manner in which environmental factors were dealt with by the corporation, the government, and the public.

The Problem of Attitudes Towards Environmental Considerations

There are many social factors related to the achievement of environmental quality. The larger social issues, such as those involving community development, employment, and environmental education, are outside the scope of this thesis and are therefore not considered in detail. These factors should be kept in mind however, as they are often influential in, and influenced by, any changes in the legal, economic and administrative approach to environmental quality. Environmental education in particular could have a great effect on the social awareness and activities related to the achievement of environmental objectives.

A particular problem in solving resource-use conflicts involving environmental considerations is the attitudes of people engaged in the decision-making process. Attitudes are a reflection of values, whether moral, social, political or environmental. It is important to be aware that resource-use decisions are based ultimately on values and are influenced to a large degree by the attitudes of the decision-makers. Attitudes towards environmental quality appear to be as varied as the people who are involved in assessing the relative value of alternate resource uses. They are often characterized as "corporate" attitudes, "bureaucratic"
attitudes, "elitist" attitudes, etc. These attitudes are often seen as a polarization of values that exist between the "rip-off capitalists" on the one hand and the "raving eco-freaks" on the other. The government is usually found in the position of having to side with one or the other of these positions or of acting as a buffer between them.

A few direct quotes from people involved in resource-use decision-making (this includes "opinion-makers" as well as individuals who are in an official capacity) will serve to illustrate the tremendous range of attitudes involved. Ralph Nader, in his foreword to the Sierra Club book "Eco-tactics" provides what could be considered a typical attitude towards environmental destruction:

To deal with a system of oppression and suppression, which characterizes the environmental violence of this country, the first priority is to deprive the polluters of their unfounded legitimacy. Too often they assume a conservative, patriotic posture when in reality they are radical destroyers of a nation's resources and the fundamental rights of people. Their power to block or manipulate existing laws permits them, as perpetrators, to keep the burden of proof on the victims. In a country whose people have always valued the 'open book', corporate and government polluters crave secrecy
and deny citizens access to the records of that which is harming their health and safety.¹

A British Columbia organization, the Environmental Systems Community Association, is one of the most politically radical in the province. In a brief to the International Joint Commission on the subject of the proposed High Ross Dam on the Skagit River they stated:

But we have learned that we must defend our communities from this spirit (unrestrained free enterprise) and tie down economic man like Gulliver with endless rules and regulations, prohibitions, penalties, boards, commissions, watchdogs, standards, and investigations. If he is not so restrained and constantly watched over, he will lay waste entire regions in his well trained pursuit of the main chance. Whoever considers the analogy exaggerated might reflect on the reckless lunge of the oil men in search of the profit from Alaskan oil, an industrial development pursued with all the social responsibility of a crowd of Norse Vikings descending on a medieval village.²

On the other hand, there are also extreme statements on record that describe the attitude of the corporations
and their proponents towards environmental values. Egil Lorntzsen, the discoverer of the Lornex Copper Mine and a major figure in the mining industry in British Columbia, was quoted in the Vancouver Province of December 20, 1972 as stating:

The mining industry has nothing to apologize for, and least of all to the long-hairs, ... When we compare the acreage that's destroyed by the bulldozer with the vast area of British Columbia, the Yukon, and the Northwest Territories, these people's talk sounds damn silly ... An open pit mine is a beautiful thing to look at. I say to the Sierra Club, if they want to do something about a scene that hurts their eyeballs, then they ought to restore an ugly thing like a washed out creek.3

Speaking at the Pacific Logging Congress in Portland, Oregon, William H. Hunt (president of Georgia-Pacific Corp.) had the following to say about environmentalists:

The new battle today is against the wildfire of emotionalism, fanned by misstatement, ignorance, half-truths, and sometimes no truth at all. The public can not be blamed for the damage done. But I do blame those misguided individuals who, for various reasons of their own, feed such material under the guise of gospel to an often
unsuspecting media ... These prophets of doom, loose with the facts and surely with the full knowledge of the dangers they create in our democracy, often sound like woodsy witchdoctors of a revived ancient nature cult that insults the intelligence of those they would sway.4

Although it is perhaps not typical of the attitude of industry in general, an article by Murray Watts, a man with a long experience in the mining industry in Canada, indicated the kind of emotional response often encountered by environmentalists. In the Western Miner he stated that:

It may be interesting to list some of the attackers of the mining industry ... These include a real mish-mash of welfare, anti-establishment, loudmouths and hippies, muckrakers (politicians), so-called intellectuals, share-the-wealthers, anti-pollutionists and ecologists, and plain rabble rousers. These groups have some things in common: leftist leanings, a contempt for hard work, and extreme pessimism and disrespect for the ability of the aggressive individual who aspires to succeed economically through hard work and the daring to take a chance.5

It is apparent from these statements that there is a wide range of attitudes towards the problem of achieving
environmental quality. On the one hand there is a reformist or even revolutionary attitude, while on the other there is an extremely reactionary and defensive attitude. No doubt the majority of people fall somewhere between these extremes. It is likely, however, that the problem of polarization will remain and that those who are involved in working towards environmental quality objectives will have to operate in an emotionally charged atmosphere. Confrontations, at least on the verbal level, will undoubtedly continue to be central to environmental issues. It will be a tremendous challenge to overcome this difficulty and to create a decision-making process that will incorporate environmental values in an objective and meaningful manner.

**Economics and Environmental Quality**

Although there are many interests competing for the use of natural resources, it is common that factors related to the economics of a particular use are the most persuasive in determining the outcome of the decision-making process. This is particularly true in resource-use conflicts that involve competition between environmental and economic considerations. Indeed, the present controversy surrounding virtually all issues of resource development is a consequence of the conflicting conclusions reached by these two approaches. It will be the objective of this section to analyze the economic approach
to resource-use decisions and to evaluate its usefulness in determining the most desirable allocation of natural resources.

Virtually all economic factors related to a particular resource development can be included in what is known as a "cost-benefit analysis". This is simply a process of computing the total monetary cost of a development and comparing it to the total monetary benefit to be derived from the development. If the benefits sufficiently exceed the costs, the development is said to be economically desirable. The fact that a particular use of a resource is economically desirable, however, does not necessarily indicate that it is environmentally or socially desirable. This weakness in the economic approach can be clearly illustrated by a discussion of the particular techniques employed in cost-benefit analysis.

Cost-Benefit Analysis

A central feature of all cost-benefit analyses is the interest rate or "discount rate". This factor is based on the same principle used in all financial matters and is used to calculate the present monetary value of the costs and benefits of a development. In terms of the individual or corporate investor, this provides an estimate of the amount of capital that must be available to meet present and future costs and an estimate of the present value of future benefits to be derived from the development. This is explained as follows in "A Guide to Benefit-Cost Analysis" published by the Department of
Northern Affairs and Natural Resources:

Benefits and costs do not all accrue immediately, but over time. Sometimes they are spread evenly over the life of the project, but usually the costs are concentrated at the outset, while the benefits occur as a delayed stream. Whatever the time pattern, it is necessary that values arising at different dates be adjusted to be comparable at a given time period. Unless this adjustment is made, benefit-cost analysis cannot ensure that capital and savings are at least as well used in this project as in other desirable delayed benefit projects. Consequently, future payments must be discounted to the "present value", which, if invested at interest today, would amount to the future payment which is expected to occur at that time. A payment of $110 expected next year is equivalent to $100 today at 10 per cent per year, because anyone expecting to receive that $110 at the end of next year can instead borrow $100 today, pay 10 per cent interest for one year, and repay in full the capital and interest of $110. Similarly, anyone expecting to make a payment of $110 next year could make the payment this year by placing $100 in the bank and letting it accumulate 10 per cent for the year. Thus a future benefit or cost, expected in the remote future, is only worth today what would have to be paid into a bank today in order to amount to the expected value in the future.⁶
It is clear from this explanation that resource development decisions that are based entirely on economic considerations are concerned only with the present value of the costs and benefits involved. An hypothetical example will serve to illustrate a major weakness of employing an interest rate when computing the costs and benefits of a development.

Let us imagine that the provincial government is considering a hydro-power development on a major salmon spawning river in the province. It is anticipated that the benefits from the project in terms of power sales over the next thirty years, the projected life-expectancy of the dam, will amount to $400 million. The costs will include $250 million for construction and maintenance of the dam and a loss of $125 million in revenue from the salmon run which will be completely destroyed by the development. All these values are present values as calculated by using an interest rate of 10 per cent per annum. At this rate of interest, all costs and benefits that will occur after about thirty years have little or no effect on the present cost-benefit values. Because all the benefits, and costs related to construction and maintenance, will occur during the thirty year life-expectancy of the project, these factors are the greatest contributors to the resulting ratio between benefits and costs (in this case the "benefit-cost ratio" is 400/375 or 1.07). The loss of revenue from the salmon fisheries will not necessarily cease after thirty years, however. It is possible that the
dam will become useless for the production of electric energy after thirty years due to silt buildup in the reservoir. This would not result in a restoration of the fisheries as the dam would still remain an obstacle to the migration of salmon. Therefore, even if the fisheries were completely wiped out for 10,000 years as a result of the dam, only about thirty years of this cost would be effectively accounted for in the cost-benefit analysis. This is obviously not a realistic estimate of the actual loss involved.

The Problem of External Costs

Another serious weakness of the cost-benefit analysis, particularly for developments with a major environmental impact, is the problem of "externalities" or external costs and benefits. For the purpose of this discussion, it will be sufficient to focus on the external costs as these are the most significant in relation to environmental quality. As the term implies, an external cost is a cost of a development that is not directly related to the purpose of the development. The omission of such costs in a cost-benefit analysis invariably results in an incomplete appraisal of the development involved. External costs can be classified under two general categories: "tangible" and "intangible".

Tangible External Costs

Tangible external costs are those costs that are not related to the purpose of the development but which can be
expressed in monetary values. Instances of this type of externality can be found in many developments that involve environmental disturbance. For example, imagine an open-pit copper mining operation that is planned for an area that is presently used as forest-land for the production of saw-logs. The development of the copper mine will involve the removal of the forest soil and therefore will result in the elimination of the area's wood production. It is possible that natural soil forming processes will require many hundreds of years to restore the land to its original fertility. This loss of wood production is a direct result of the mining development and is therefore a real cost of the operation.

The value of the land for forest production could undoubtedly be calculated in monetary terms. This could be expressed as the dollar value of the sustained yield production of wood on an acre per year basis. It is therefore a "tangible" cost of the mining operation and could be included in a cost-benefit analysis of the development. Yet, in practice, this type of cost is often not considered in the decision-making process leading to the development of a mine.

The problem of tangible external costs is not the result of any inherent weakness in the cost-benefit analysis
itself. Rather it is a consequence of the structure and functions of the corporate and government organizations involved in resource development investments. The developer is simply not obliged, by any legal or traditional regulations, to pay for many of the costs, particularly environmental costs, that are a direct result of the resource development. From the point of view of the individual or organization that is investing in a particular development, it is only necessary to consider the costs that will actually be paid for by the investor. Therefore, only these costs need be included in the cost-benefit analysis in order to determine the profitability of the development. With a corporate investor, for example, there results a discrepancy between the "corporate" cost-benefit ratio and the "social" cost-benefit ratio. While the corporation is usually able to realize the total benefits of its operation (the only real benefit from the copper mine being the value of the ore produced) it is only required to meet those costs which are essential to the exploitation of the resource. These include such costs as labour, land rental, physical plant, electric and fuel energy, explosives, etc. The costs that are a direct result of the development, but which are not essential to its operation, are seldom met by the developer. They are therefore passed on as "social costs" that must be borne by some other individuals or organizations. It is therefore quite possible that a resource development which appears
to be profitable from the standpoint of a corporate investor would actually result in a net economic loss if all the tangible costs associated with it were considered.

**Intangible External Costs**

The other category of external costs, those termed intangible, are of a fundamentally different nature from tangible external costs. They are the result of a weakness in the cost-benefit analysis and of the underlying economic system on which it is based. An intangible cost is a cost that cannot be expressed as a monetary value and therefore cannot be included in a cost-benefit analysis. Most of the detrimental environmental effects of resource developments fall into this category of costs.

Again, using the example of the copper mine that required removal of the forest soil, it is possible to recognize many intangible external costs associated with its development. When an entire forest community is removed from an area it is not only wood production that is eliminated. Many non-commercial species of trees, shrubs and herbaceous plants grew from the same soil and among them they provided a large variety of habitats for birds, wildlife, insects, soil bacteria, etc. It is impossible to assign any meaningful monetary value to such resources. True, it may be possible to approach this problem by considering the recreational potential of the area
in terms such as dollars spent per day per person per acre of forest land. This is a very incomplete and superficial estimate of the total value of the forest community, however. The ecological or environmental value of the forest (or any other community of organisms) as part of the biological life-support system (biosphere) cannot be expressed in monetary terms.

It can be seen from the previous discussion that decision-making that is based entirely upon economic considerations could lead to the development of a resource even though it is neither socially nor environmentally desirable to do so. The reasons for this can be summarized as follows:

1. The use of a discount rate often tends to minimize the future costs of the degradation or elimination of a particular resource.

2. Individuals and organizations that invest in a resource development are reluctant and usually not obliged to pay for costs of the development other than those that will increase the benefits to the investor. This gives rise to tangible external costs.

3. Many of the social and environmental costs of resource developments cannot be expressed adequately in monetary terms. This gives rise to intangible external costs.
Economic Values vs. Environmental Values

The use of economics as the primary tool for resource-use decision-making is attractive because the decision can be reduced to a simple numerical expression. Numbers have about them an aura of objectivity, even when they are used to express human values rather than some absolute quantity. It is one thing to say that a particular project will result in the production of 200 pounds of copper per day and quite another to say that the same project will result in the production of 200 dollars worth of copper per day. The first statement is an expression of quantity; the second is a statement of value.

At its foundation, economics involves the study of quantities. It is based upon the flow of goods (materials) and services (energy) as they pass through the human population. This is the science of economics and it is comparable to the science of ecology in that it is an endeavor to quantify the material and energy relationships among the individuals in a group. Our knowledge of the flows of materials and energy among the human population is quite complete. It is, therefore, possible to place relative values on them and thereby arrive at decisions that will result in the most efficient (and presumably, therefore, the most desirable) use of the available materials and energy.

The real weakness of economics lies in the fact that
it only considers those material and energy exchanges that take place among members of one species, i.e. Homo sapiens. Only these exchanges are given value by this system and only these exchanges are given consideration in decision-making that is based on monetary values. In fact there are many exchanges of materials and energy that take place outside the human species which are of great value to man's well-being and survival. It is this concept that has been strengthened through the science of ecology. It has been demonstrated irrefutably that the survival of our species and of all others depends upon the preservation of the eco-systems that provide us with food through the use of the sun's radiant energy, carbon dioxide, oxygen and nitrogen from the atmosphere, and mineral nutrients that centuries of weathering have released from the earth's crust. The flow of materials and energy that begins with the phytoplankton in the sea and the green plants on the land continues through all living things. It is an extremely complex system of exchanges, however, and has not yet been quantified to a degree approaching that of economics in relation to the human system.

How then, can the value of material and energy flows that take place outside the human population be expressed in such a way that they can be taken into consideration in resource-use decision-making? It must be accepted, at least at present, that it cannot be reduced to a numerical expression
but must be stated in a less quantitative manner. What is required is a process that weighs the environmental effects of resource development as at least an equal, and preferably as the dominant factor in decision-making. This would produce a resource-use policy in which environmental considerations would be paramount in determining the desirability of a particular development. Monetary considerations would be employed for investment decisions within the constraints set by this environmental approach. This would likely result in a much different resource-use pattern than is presently occurring when the environmental effects of a development are dictated primarily by monetary considerations.

Conclusion

Resource-use conflicts necessarily involve consideration of information from many different academic and professional disciplines, as well as an understanding of the social environment in which they are occurring. The thesis approaches the problem from a number of directions in order that this fact can be more fully appreciated. There has been a conscious attempt to avoid unnecessary use in the text of specialized terminology which often results in difficulty in communication between different disciplines. It is often impossible to avoid such terminology, however, and in such cases an attempt has been made to define the terms in such a way that they can be
comprehended by anyone interested in the subject matter of the thesis.

The second chapter of the thesis provides a brief history of the legislation related to the achievement of environmental quality in British Columbia.

Chapter three is a review of the effects of heavy metals on aquatic organisms and contains a review of the literature related to the impact of heavy metal mining on water quality in selected locations in Canada. In order to determine the possible extent of heavy metal pollution caused by mining operations in British Columbia (there being very little published data on the subject), and to ascertain whether or not existing pollution control in this province was effectively preventing unacceptable heavy metal water pollution, a field trip was undertaken in order to make a limited survey of the heavy metal content of mine drainage water from a number of mines in the south of the province. The results of this field trip, which indicate that there is frequently a considerable increase in heavy metal levels in water as a result of mining, are also presented in Chapter three. This chapter demonstrates the relative ease with which it is possible to determine whether or not heavy metal pollution control in British Columbia is effective.

Chapter four is the main body of the thesis and is a
case history of the application for a Pollution Control Permit by Utah Construction and Mining Company, and the resulting legislation and court action following the granting of the permit.

Chapter five reports on experimental work conducted as part of the thesis. This chapter contains the results obtained from oceanographic research at Rupert Inlet in order to determine the general pattern of water movement in the inlet. This information was used to predict the effects of the waste discharge from the Utah copper mine on the turbidity of the inlet.

The Conclusion of the thesis is a summary of the major weaknesses in the decision-making process as determined by the case history and also contains a section dealing with the feasibility of obtaining information necessary to the decision-making process with limited financial resources and limited participation by expert professionals in the many fields of study involved in the research project.
Footnotes for Chapter 1


3 Vancouver Province, December 20, 1972, p. 18.


CHAPTER 2

A REVIEW OF THE LEGISLATION RELATED TO POLLUTION CONTROL IN BRITISH COLUMBIA

Introduction

The respective roles of the public, industry and government in pollution control are to a great extent determined by specific provisions contained in various provincial and federal statutes. The legislation provides the terms of reference and outlines the duties and powers of the government agencies responsible for its application and enforcement. It sets out the positions of both industry and the public in the decision-making process and to some degree their relative influence in this process. An understanding of the law is therefore necessary to an understanding of the framework within which economic, social, political and environmental interests compete for the use of resources. A review of the historical evolution of the legislation is interesting since it reflects to a certain degree the evolution of society's aspirations for environmental quality.

Much of the material in the following chapter is
Early Legislation

The early legislation in British Columbia that was directed at what we now term pollution control concerned itself primarily with sewage and its implications for the public health. The Colony's Health Ordinance of 1869 empowered the Governor in Council (Cabinet) to delineate Health Districts and to direct local Boards of Health in matters relating to such things as "drains, sewers, privies, pigsties, slaughterhouses .... and for the summary abatement of any nuisance or injury to public health likely to arise therefrom". A set of regulations was established under the Health Act by the Board of Health in 1896. These included the first provision in British Columbian law to deal with stream pollution. Section 45 of the regulations provided that:

No solid waste matter of any kind shall be deposited in any stream ... unless the best means have been adopted to purify the same.

However, the means of purification constituting the "best means" in any particular case was not defined by either the Act or the Regulations.

The Sewerage Act was passed in 1910 setting up Sewerage Districts with the power to require proper plumbing, sewer connections and waste disposal. In 1913 the Burrard
Peninsula Joint Sewerage Act gave power to the City of Vancouver and surrounding districts to expropriate land necessary for sewerage works. This has been retained to the present day and is now in the form of the Greater Vancouver Sewerage and Drainage District Act. It is this Act which provides the authority necessary for such developments as the Iona Island and the Annacis Island sewage treatment plants.

In 1903 the Water Courses Obstruction Act was passed as a means of controlling the use of water for waste disposal. Section 2 of the Act provided that:

... in case a person throws or in case an owner or occupier of a mill suffers or permits to be thrown into any lake, river, stream or watercourse, slabs, bark, sawdust, waste stuff or other refuse of any sawmill, or ... driftwood, waste wood or leached ashes ... he shall incur a penalty not exceeding ten dollars and not less than one dollar for each day during which the contravention of this Act continues, over and above all damages arising therefrom.

This section is incorporated into the present Water Act in a form which is changed to provide that no offence occurs unless the Water Recorder or Engineer has first ordered the polluter to desist.
This early legislation was drawn up at a time when there was virtually no heavy industry other than sawmilling in British Columbia. Population centres were small and required only routine public health measures which were aimed primarily at the containment of water-borne communicable diseases. Prior prevention of pollution was made difficult because only existing pollution could be the subject of a penalty under the various Acts.¹⁴

Despite the fact that there was continual growth of British Columbia's industrial capacity, particularly in the pulp and paper industry, there was no further legislation forthcoming from the provincial government that dealt with pollution control for nearly forty years after consolidation of the Health Act in 1917.¹⁵ During this time there was also considerable increase in the population of the province, particularly in Vancouver and the surrounding districts on the lower Fraser River delta. The problems created by the need to deal effectively with a growing sewage load led to public controversy in the mid 1950's. The City of Vancouver wished to expropriate land in Richmond to build the Iona Island sewage treatment plant. The Richmond municipal officials objected to the plan as it would require the dumping of primary treated sewage into the north arm of the Fraser River, the main waterway for the district and an area with considerable recreation, wildlife, agriculture and fisheries values.
The First Pollution Control Act, 1956

Although industrial pollution was at the time a more serious problem than that presented by municipal sewage, it was the latter which resulted in the first attempt at legislation dealing with water pollution from the standpoint of environmental quality rather than that of the public health. The fact that the sewage problem was closer to home than industrial pollution for a large number of people, the latter being confined largely to the outlying areas of the province, probably contributed to a greater awareness of this issue by the general public and their representatives in government office.

The dispute over the Iona Island sewage treatment plant was resolved at the provincial level with the passage of the Pollution Control Act of 1956. The Act was to be administered by the Department of Municipal Affairs and its jurisdiction was limited to municipalities in the lower Fraser River valley. A Pollution Control Board was empowered to set standards for effluent discharges into all surface and ground waters. The Act defined pollution as:

... anything done or any result or condition existing, created, or likely to be created, affecting land or water which, in the opinion of the Board, is detrimental to the health, sanitation or the public interest.
No person was permitted to discharge any waste into any waters under the jurisdiction of the Board without first obtaining a permit to do so. It was at the discretion of the Board that permits were granted, and conditions were set as to the treatment required for the effluent where deemed necessary. Any person who felt that his rights would be affected by the effluent discharge was entitled to object to the permit application within thirty days from the date it was announced in the British Columbia Gazette. Upon receipt of the objection in written form, the Board decided "in its sole discretion whether or not the objection would be the subject of a hearing" and notified the objector of its decision. The wording of this provision makes it clear that an objector was not automatically entitled to a public hearing, but had to hope for a favourable decision by the Board. The Board was also given the power to conduct tests and surveys to determine the condition of various waters in the province.

The Act was intended only to deal with sewage originating from a municipality and did not include any provision for industrial waste, even when the industry was based in a municipality. The definition for "works" provided in the Act included:

- drains, ditches, intercepting sewers, sewage treatment and disposal plants and works, pumping
stations, and other works necessary thereto, and outlets for carrying off, treating and disposing of drainage and sewage, and any other and all works, structures, lands, and conveyances included and necessary to the completion of a sewage or drainage system.22

The legislation was therefore single-purpose in nature and did not in any way provide the broad terms of reference necessary for a comprehensive approach to pollution control.

In 1963 the Board's jurisdiction under the Act was expanded to include all municipalities which drained into the Fraser River, the Gulf Islands, and the south-east coast of Vancouver Island. In 1965 the administration of the Act was transferred from the Department of Municipal Affairs to the Department of Lands, Forests and Water Resources. The definition of "works" was amended by inserting "including industrial waste" and the jurisdiction of the Board was expanded further by regulation to include some lands outside municipal boundaries.

The Pollution Control Act, 1967

Major steps in the evolution of pollution control legislation in British Columbia have, for the most part, been slightly preceded by specific controversial public issues.
Just as the Iona Island treatment plant controversy sparked the original Pollution-Control Act, so the debate surrounding the proposal by Western Mines Ltd. to discharge mine effluent into Buttle Lake resulted in the next significant change in pollution control law. Buttle Lake is situated in Strathcona Provincial Park on Vancouver Island and drains eventually into the Campbell River which provides the supply of drinking water for the municipality of Campbell River. As a result of opposition by the Greater Campbell River Water District to the proposed waste disposal, Strathcona Park was included in 1966 in the area of jurisdiction under the 1956 Pollution Control Act. The fact that Western Mines was therefore obliged to obtain a permit to discharge its waste did not satisfy the Water District, and so the issue eventually required a settlement through the courts. The resulting litigation will be discussed more fully later, but at this point it is sufficient to note that the dispute eventually brought about the repeal of the 1956 Act and the passage of the Pollution Control Act, 1967. The new legislation was largely a revision and expansion of the 1956 Act, but it contained provisions which amounted to a considerable change in the structure of pollution control administration. The definition of "pollution" was changed to read:

The introduction into a body of water, or storing upon, in, or under land or discharging or emitting into the air such substances or
or contaminants of such a character as to substantially alter or impair the usefulness of the land, water or air.\textsuperscript{24}

The wording used suggests that the definition was intended to apply very broadly to resource use. However, the definition is perhaps rather weak because of an inadequate definition of the term "substantially".

The new legislation provided for the continued existence of a Pollution Control Board "which shall consist of a Chairman and such other members as the Lieutenant-Governor in Council may from time to time determine."\textsuperscript{25} The Board may be directed by the Lieutenant-Governor in Council to inquire into and to determine the cause of any matter related to the polluted condition of water, land or air. The Board may also be required to:

(a) take such remedial action as the Board considers necessary in the public interest; or

(b) to report to the Lieutenant-Governor in Council, who may thereafter direct the Board to take whatever remedial action it considers necessary in the public interest.\textsuperscript{26}

The Board may determine its own procedure and may elect an Acting Chairman in the absence of the Chairman.\textsuperscript{27}

The functions of the Board are limited by the Act to
the following powers and duties:

(a) to determine what qualities and properties of water, land and air shall constitute a polluted condition;

(b) to prescribe standards regarding the quality and character of the effluent or contaminant which may be discharged into any waters, land or air;

(c) to appoint such advisory and technical committees from time to time as may be deemed necessary to inform the Board with regard to whatever matters may be referred by the Board. 

**Director of Pollution Control Appointed**

The most significant feature of the 1967 Act is the appointment of a Director of Pollution Control who is responsible for the day-to-day administration of the Act. His powers include all matters related to the granting, amendment and enforcement of permits. The Director has the power to suspend or cancel any permit upon failure by the permittee to comply with the conditions of the permit or an order of the Director. The more general powers of the Director for carrying out the intent of the Act include the following:

(a) to determine what qualities and properties of water, land or air shall constitute a
(b) to prescribe standards regarding the quality and character of the effluent, other waste materials, or contaminants which may be discharged or emitted into water, land or air;

(c) to conduct tests and surveys to determine the extent of pollution of water, land or air;

(d) to notify all persons who discharge effluent or waste, or emit contaminant into water, land or air when the effluent, waste or contaminant fails to meet the prescribed standards.31

It can be seen that there is considerable overlap in the functions of the Board and the Director in terms of prescribing standards and determining a polluted condition. It is probable that the Board would only use its powers when directed to do so by the Lieutenant-Governor in Council and then only in co-operation with the Director.32 The recent history of the Board would indicate that its function is in practice restricted to an advisory role where matters of policy are concerned.33

As well as appointing a Director, the Act provides for the naming of an Assistant Director, and such engineers, officers, clerks and other employees necessary, in accordance with the Civil Service Act.34,35 The Director and his staff
operate as the Pollution Control Branch within the Water Resources Service of the Department of Lands, Forests and Water Resources. The position of the Branch in the administrative structure emphasizes the government's philosophy towards pollution control. The recommendations of the Branch are only one of many inputs into decisions involving resource development and waste disposal and are not necessarily of distinct and possibly overriding significance.

A number of other changes were made in the 1967 Act. By defining "waters" as "all streams, lakes, ponds, inland waters, salt waters, watercourses and all other surface and ground waters within the jurisdiction of the province" the legislation clearly applies to the entire province. It is also provided that no action may be brought against the Board or any engineer for any act done in good faith in the performance of any authority or duty imposed under the Act. The Lieutenant-Governor in Council is given the power to make regulations for carrying out the purpose of the Act and to divide the province into pollution control districts for administrative purposes.

The Act states that any person who intends to begin discharging sewage or other waste material after January 1, 1970 must first obtain a permit from the Director. Any person who was discharging waste prior to January 1, 1970 and had not obtained a permit, must notify the Director before March, 1972 and file with him the following information:
(i) the type of sewage, effluent or other waste discharged;
(ii) the daily average and maximum rate of discharge; and
(iii) the location of the works and area of the discharge.\textsuperscript{39}

The person is then required to make formal application for a permit within sixty days following a written order from the Director to do so.\textsuperscript{40}

\textbf{Application for Pollution Control Permits}

Permits under the Pollution Control Act may be applied for on a standard form which is supplied by the Director. The application is then forwarded to him for processing through the Branch. The information required by the Director includes:

1. Name and address of the applicant.
2. Type of works involved, e.g. copper concentrator, sewage treatment plant, etc.
3. Location of works.
4. Point of discharge of effluent.
5. Quantity of effluent to be discharged including maximum rate, maximum 12 and 24 hour rates and operating season of discharge.
6. Characteristics of the effluent and specifically, where applicable, suspended solids, total solids, biochemical oxygen demand, pH
range, temperature, coliform bacteria, and toxic chemicals.

7. Type of treatment to be applied to the waste.41

A copy of the application must then be posted on the ground at the site of the proposed discharge and another copy published in the British Columbia Gazette and in such local newspapers as the Director may suggest.42

Objections to the Granting of Permits

As was the case with the 1956 Act, the Pollution Control Act, 1967 contains provisions which allow objections from interested parties so long as they are received within thirty days of the filing of an application. The original wording in the Act stated that:

(1) Any person whose rights would be affected by the granting of a permit may, within such time as prescribed in the regulations, file an objection thereto.

(2) The Director shall decide, in his sole discretion, whether or not the objection will be the subject of a hearing.43

A 1968 amendment to the Act changed this section in such a way as to limit the class of persons who may object directly to the Director. Subsection 1 - 3 of Section 13 was revised to read:
(1) An objection to the granting of a permit may be filed in such manner and within such time as may be prescribed in the regulations.

(2) Where the application is for a permit to discharge sewage or waste materials on, in, or under any land or into any water, an objection under subsection (1) may be filed by any person who has an interest in the land or who is an applicant for or the holder of a permit or licence issued under this Act or the Water Act and who claims that the land or any interest under such permit or licence would be affected by the granting of a permit.

(3) Where the application is for a permit to discharge or emit contaminant into air, an objection may be filed

(a) by any person who is resident within five miles of the proposed or existing point of discharge or emission of the contaminant into the air; or

(b) any immediately adjoining municipality that may be affected by the granting of the permit.

A person who is not qualified to file an objection under this
provision may file an objection with the Pollution Control Board. The Board must determine whether the public interest requires that the Director shall also take such an objection into consideration. The decision of the Board is final. The manner in which the Board is to determine the meaning of "public interest" is not enlarged upon in the Act.

In the case of a decision or directive from any member of the Branch it is possible to appeal the order to higher authority. Any order from an engineer of the Branch may be appealed to the Director and any order from the Director may be appealed to the Board, so long as this is done within fifteen days of the date of the order. Any order from the Board may be appealed either to the Lieutenant-Governor in Council, who may designate any number of Provincial Cabinet members to hear the appeal, or to the Supreme Court of British Columbia, whichever the appellant chooses. In this case the appeal must be made within thirty days of the order. The appeal tribunal may require the appellant to deposit a sum of money to cover the expected costs of the hearing. The decision of the Executive Council or of the Supreme Court is final. An appeal cannot act as a stay of execution. Thus, it is not until after a decision on the appeal has been handed down that any change in procedure is required.

The 1968 amendment to the Act included a section
dealing with penalties for failure to obtain a pollution control permit. Anyone found guilty of discharging wastes on or into any land or water is liable to a fine of up to $1000.00 or to a prison term of up to three months, or to both. For a continuing offence there is a provision for a fine of up to $500.00 per day the offence continues.\textsuperscript{53}

A 1970 amendment to the Act broadened the penalty section to include other violations besides the failure to obtain a permit. An offence is now committed by any person who:

(a) contravenes any provision of the Act or the regulations;

(b) wilfully destroys, injures or interferes with the works of any permit holder without lawful authority;

(c) destroys, injures or tampers with any works or any gauge, weir, measuring device, structure, appliance, cable, boat, instrument or tool belonging to or placed in position by any applicant, permit holder, or official of the Government of Canada or of the Province;

(d) fails or neglects to pay a fee or charge, or fails to give security, as required under this Act or regulations.\textsuperscript{54}

The Director also has the power to suspend or cancel any permit for any length of time if the holder fails to comply with the
Act, fails to pay money in respect to the permit, disobeys any order of the Director, or fails to comply with any provision of the permit.55

Although it is no doubt the most significant legislation in British Columbia on the grounds of its comprehensive approach to pollution control, the Pollution Control Act is not the only statute with provisions that relate to pollution. As the most important of these is the Federal Fisheries Act, it will be discussed first followed by a number of other provincial Acts.

The Federal Fisheries Act

By virtue of its authority in matters related to sea coast and inland fisheries,56 the federal government is empowered to pass legislation which protects these resources from pollution. This function is provided by the Fisheries Act which until recently stated that:

No person shall cause or knowingly permit to pass into, or put, or knowingly permit to be put, lime, chemical substances or drugs, poisonous matter, dead or decaying fish, or remnants thereof, mill rubbish or sawdust or any other deleterious substance or thing, whether the same is of a like character to the substances named in this section or not,
in any water frequented by fish, or that flows
into such water, nor on ice over either such
waters.\textsuperscript{57}

A fine of up to $1000.00 for a first offence was provided as a
deterrent against violations of the Act. Despite the obvious
intent of the above provision, it was difficult to conduct
successful prosecutions under the Act. The courts tended to
interpret the wording to mean that actual death or injury to
fish must be shown and that this must be linked beyond reason-
able doubt to the presence of a deleterious substance which had
been put in the water.\textsuperscript{58} This amounted to a very difficult
problem for the Fisheries officials, particularly if the
polluter had been operating for a long time and had killed or
driven away the majority of the fish in its vicinity.

In an attempt to clarify the intent of the Act, an
amendment was passed in 1970 which provided that:
\begin{quote}
no person shall deposit or permit the deposit
of a deleterious substance of any type in
water frequented by fish or in any place under
any conditions where such deleterious substance
or any other deleterious substance that results
from the deposit of such deleterious substance
may enter such water.\textsuperscript{59}
\end{quote}

The Act goes on to define "deleterious substance" as:
any substance that, if added to water, would degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered deleterious to fish or to the use by man of fish that frequent that water. 60

Further, the Governor in Council (Cabinet) may make regulations prescribing substances and classes of substances which are to be regarded as deleterious to fish. 61 The Minister (of the Department of the Environment) is empowered to require modifications in any development or to prohibit the development if in his opinion it will result in the deposition of any deleterious substance. 62 Penalties of up to $5000.00 for the first offence are provided 63 and up to $5000.00 per day if the offence is continuous in nature. 64

Other Provincial Legislation

A number of other provincial statutes besides the Pollution Control Act contain provisions relating to environmental quality. Although these are in many ways peripheral to the overall scheme of pollution control, they are often relevant in specific cases and a review of their contents will provide a more rounded appraisal of the provincial situation.

The Health Act

The Regulations for the Health Act provide that:
No person shall suffer the accumulation on or escape from his premises, or deposit, or permit the deposit, upon any land belonging to him or under his control, of anything so as to endanger the public health, or shall deposit, or suffer or permit to be deposited, in, upon, on or into any street, square, lane, byway, wharf, dock, ship, lake, pond, bank, harbour, river, stream, or water, any manure or other refuse, or vegetable or animal matter, or filth of any kind, or any dead animal. and that:

No solid refuse or waste matter of any kind shall be deposited in any stream so as to obstruct its flow, or put into any stream or lake so as to pollute its waters, and no solid or liquid sewage matter from either public or private sewers shall be discharged into any stream or lake, but if it can be proved that the best means have been adopted to purify the sewage etc., before it enters the stream or lake, no offence is committed, that is unless the local Board has notified the offending parties that the means adopted are insufficient: nor shall any poisonous, noxious
or polluting liquid proceeding from any other
source be passed into any lake or stream
unless the best means have first been adopted
to purify the same.68

As in the original regulations established in 1896, there is
little guidance as to the definition of "best means" in the
Act. One would assume that this implies tertiary treatment of
sewage and the complete elimination of any water pollution
from this source. But this is obviously not the interpretation
given to the wording by the Health Service officials. Many
communities in British Columbia continue to dump raw sewage
into the water and only primary treatment will be required by
1975.69

Any person violating the terms of the Act is liable
to a fine of up to $100.00 or six months imprisonment, or both.70

The Water Act

Section 41 of the Water Act71 provides that any
person is guilty of an offence who:

Puts into any stream any sawdust, timber,
tailings, gravel, refuse, carcass, or other
thing or substances, after having been ordered
by the Engineer or Water Recorder not to do so.72

Violators of the Act are liable to a fine of up to $250.00 and,
in default of payment, imprisonment of up to twelve months.73
The Land Act

The Land Act\textsuperscript{74} provides that:

No person shall throw, deposit, dump, or in any way cause to be placed upon crown land any glass, metal, soil, garbage, or any other substance without the authority of the minister.\textsuperscript{75}

Any person found guilty of doing so is liable to a fine of up to $300.00 or to imprisonment of up to sixty days, or both.\textsuperscript{76}

The Mines Regulation Act

As a result of the controversy surrounding the plans of Kaiser Resources Ltd. to trip mine for coal in the East Kootenay, the government amended the Mines Regulation Act\textsuperscript{77} in 1969 and passed the Coal Mines Regulation Act\textsuperscript{78} to provide some control over the reclamation of land disturbed by the industry. The legislation provides that:

\textit{It is the duty of every owner, agent or manager of a surface mine to institute and carry out a program for the protection and reclamation of the surface of the land and watercourses affected thereby, and, on the discontinuance or abandonment of a surface mine, to undertake and complete the program to leave the land and watercourses in condition satisfactory to the minister; and such a}
program shall be submitted to and approved by the minister.\textsuperscript{79}

Notice of the filing of the reclamation program must be published in the Gazette and in such local newspapers as the minister prescribes.\textsuperscript{80} The minister is required to hear advice from other government departments and to hear "representations from any other persons in any way affected by the report and the program" and after sixty days must either approve or reject the report or approve it in a revised form.\textsuperscript{81} The minister must require that the person receiving approval for a reclamation program deposit up to but not exceeding $500.00 for each acre of land disturbed.\textsuperscript{82} This money may be applied toward the cost of reclamation in the event the owner or manager fails to do a job that is satisfactory to the minister.\textsuperscript{83} The minister has the power to cancel the permit and to "order the owner, agent or manager and all other persons to cease and desist from carrying on the mining operation".\textsuperscript{84}

\textbf{Conclusion}

A review of the legislation that is relevant to the achievement of pollution control suggests that there are ample provisions covering most aspects of the problem. Although improvements are certainly possible, and some will be suggested later, it appears that all acts of despoilment and degradation have been outlawed almost to the point of redundancy by the
various statutes dealing with them. Given sufficient finances and enforcement, it seems probable that all pollution could be halted within the context of the existing law alone. In fact, if the law were interpreted liberally in favour of environmental quality, it is unlikely that very many of the province's pulp mills, mines, refineries, sewage plants, etc. could continue to operate in their present condition. Certainly very few of them are employing the "best means" of treatment or are operating in such a way as not to "impair the usefulness of the land or waters".

The legislation is in itself of little use unless it is enforced and unless the courts interpret it in a manner which favours the intent of maintaining environmental quality. In his article on the enforcement of anti-pollution legislation, Good reports that to the best of his knowledge there have been no prosecutions under Section 41 (k) of the Water Act in recent years. The same is true for the Pollution Control Act and the Land Act and only three prosecutions have been carried out under the Health Act in recent times. These facts are suggestive that there has been no attempt to provide consistent and determined enforcement of the provincial legislation.
Footnotes for Chapter 2


4 B.C. Ordinances 1868-69.


8 S.B.C. 1910, c. 43.

9 S.B.C. 1913, c. 7.


11 S.B.C. 1903, c. 28.

12 R.S.B.C. 1960, c. 405.

13 Lucas, 1969, p. 64.

14 Id.

15 Order in Council No. 829, July 20, 1917. These regulations remain virtually intact under the present Health Act.

16 S.B.C. 1956, c. 36.
17 see Lucas, 1969, pp. 65-66 for the source of the material related to the Pollution Control Act, 1956.

18 R.S.B.C. 1960, c. 289, s. 2.

19 Id., as amended S.B.C. 1965, c. 37, s. 17(1).

20 Id., s. 17(2).


22 R.S.B.C. 1960, c. 289, s. 2.

23 S.B.C. 1967, c. 34.

24 Id., s. 2.

25 Id., s. 3(1).

26 Id., s. 3(3).

27 Id., s. 3(4).

28 Id., s. 4.

29 Id., s. 5 and s. 6.

30 S.B.C. 1968, c. 38, s. 4.

31 S.B.C. 1967, c. 34, s. 10.


33 Lecture at U.B.C. Department of Forestry by F.S. McKinnon, at the time Chairman of the Pollution Control Board, March 23, 1971.

34 S.B.C. 1967, c. 34, s. 9.

35 R.S.B.C. 1960, c. 289, s. 4(am.).

36 S.B.C. 1967, c. 34, s. 2.

37 Id., s. 20.
38 Id., s. 19.

39 Id., s. 5(1a).

40 Id., s. 5(1b).

41 copy of application form used by Utah Construction and Mining Co. in applying for a permit from the Pollution Control Branch, dated October 2, 1969.

42 Id.

43 S.B.C. 1967, c. 34, ss. 13(1) and 13(2).

44 S.B.C. 1968, c. 38, s. 5.

45 Id., this provision is now incorporated as section 13(6): see R.C.S. 1970 c. 36, s. 13.

46 Id., s. 12(1).

47 Id., s. 12(2).

48 Id., s. 12(1).

49 Id., s. 12(2).

50 Id., s. 12(4).

51 Id., s. 12(6).

52 Id., s. 12(7).

53 S.B.C. 1968, c. 38, s. 9.

54 S.B.C. 1970, c. 36, s. 20A.

55 S.B.C. 1968, c. 38, s. 4.

56 B.N.A. Act, 1867, c. 3, s. 91.

57 R.S.C. 1952, c. 119, s. 33(2).

59 S.C. 1970, c. 63, s. 3(2).
60 Id., s. 3(11a).
61 Id., s. 3(12).
62 Id., s. 33A(2).
63 Id., s. 3(5).
64 Id., s. 3(6).
65 B.C. Reg. 142/59.
67 B.C. Reg. 142/59, s. 9.
68 Id., s. 66.
69 Fraser River Report, 1970. A study conducted by the Society for Pollution and Environmental Control. p. 4.
70 R.S.B.C. 1960, c. 170, s. 113.
71 R.S.B.C. 1960, c. 405.
72 Id., s. 41.
73 Id.
74 S.B.C. 1970, c. 17.
75 Id., s. 59(1).
76 Id., s. 60.
77 R.S.B.C. 1960, c. 242, as amended, 1967, c. 25, 1969, c. 18, s. 11.
78 S.B.C. 1969, c. 3.
79 Id., s. 8.
80 S.B.C. 1969, c. 18, s. 11(1).

81 Id., s. 11(4).

82 Id., s. 11(5).

83 Id., s. 11(14).

84 Id., s. 11(14).

85 Good, 1971.
CHAPTER 3

THE HEAVY METAL CONTENT OF MINE DRAINAGE WATER AND MINE EFFLUENT IN RELATION TO ITS TOXIC EFFECTS ON AQUATIC ORGANISMS

Introduction

From the analysis of existing pollution legislation in the previous chapter, it was suggested that there has been a failure to enforce what might otherwise be an adequate set of statutes. In order to determine empirically if this conclusion is warranted, a three-part study was undertaken. Firstly, the types of heavy metal mines and mining technologies were reviewed. Secondly, a review was conducted of several aspects of heavy metal pollution, ranging from the formation of acid mine drainage, to the recommended heavy metal pollution standards. Thirdly, with these reviews as background, a survey of a number of mines in southern British Columbia was undertaken to determine levels of heavy metals in associated water bodies.
Heavy Metal Mines

and Mining Technology

The presently widespread practice of surface mining for metals results in considerable environmental disturbance of both land and water resources. In British Columbia this technique is employed primarily for the mining of copper, but the metals zinc, iron, lead, molybdenum, nickel, silver, cadmium and gold are also extracted (see Fig. 1).

Most of the ore-bodies presently being exploited consist of large formations of low-grade copper sulfides (0.5 - 5.0% recoverable metal) that are close enough to the land surface to permit extraction by the open-pit method. Among the exceptions to this are such operations as the Anaconda Mine at Britannia, which is a shaft mine with high copper and zinc values, the Sullivan Mine operated by Cominco at Kimberly, where silver, lead and zinc are mined, and open-pit mines such as those at Atlin and Alice Arm where the predominant metal mined is molybdenum.
Figure 1. Map of British Columbia showing the principle mining operations and the major metals being extracted at these mines.
(from B.C. Economic Review, 1971)
Perhaps the most serious environmental problem associated with these operations is the introduction of heavy metals into waters in the vicinity of the mining activity. Other factors such as siltation, accelerated erosion, loss of land from timber or crop production, and the contamination of water bodies by toxic chemicals used in the milling of the ore are also important and are sometimes of overriding significance. As will be demonstrated, however, these problems are strongly interrelated with that of heavy metal pollution and can be dealt with in the framework of techniques which must be used to correct it.

An understanding of the manner in which open-pit mining alters the environment and results in the introduction of heavy metals into aquatic systems can be more readily achieved through a knowledge of the techniques employed. There are three major phases in open-pit mining: firstly, the removal of the raw ore from the ore-body; secondly, the milling or concentrating of the ore in preparation for shipment to a smelter; and thirdly, smelting to recover the metal. The environmental problems associated with smelting or refining will not be discussed here as this is outside the scope of the study and as the greater part of the ore mined in British Columbia is shipped overseas for processing.

The Removal of the Ore From the Ore-body
The economic potential of a particular ore-body is determined by the analysis of drill-core samples which are taken during preliminary investigation at the candidate mine-site. Disturbance to the land can be caused by this operation as a result of clearings and minor excavations necessary to set up the equipment. After the decision is made to exploit the ore-body, the first large-scale disturbance involves the removal of vegetation from the entire mine-site as well as from an area nearby which will be used for construction of the concentrating facilities. (In the case of the Utah mine at Rupert Inlet the site was highly productive forest land of approximately thirty year old second growth mixed hemlock and amabilis fir. The trees were harvested and shipped to the Port Alice pulp mill for processing.) The soil and overburden are then removed from the pit area and the foundation for the mill facilities is prepared by excavating to bedrock. During this operation large areas of land are exposed to the forces of erosion and unless a great deal of care is taken, a considerable amount of the soil and overburden may be washed away from the site, causing serious siltation and turbidity of rivers, lakes or inlets into which the site drains.

Removal of ore from the mine-site is carried out in a systematic manner in order to ensure stability of the pit walls and continuous access by ore trucks to the active areas. The rock is broken by drilling and blasting and is then loaded into
ore trucks and hauled to the concentrator. From an environmental viewpoint the most significant factor in this process is the exposure of the mineral surface to the atmosphere and particularly to oxygen. Throughout the life of the mine new surfaces are continually being exposed to weathering. The minerals in the ore are predominantly metal sulfides such as pyrite (FeS), chalcopyrite (CuFeS₂), galena (PbS), and sphalerite (ZnS).

These minerals are quite rapidly oxidized upon exposure to the atmosphere and react to form the corresponding metal sulfates. Whereas the sulfides are virtually insoluble in water, the sulfates are usually highly soluble. These oxidation products are therefore easily leached away from the ore surface by runoff water. As the pit excavation usually forms a depression in the land surface, the drainage eventually finds its way to the bottom of the open pit. From here the usual procedure is to pump the drainage water out of the pit either into the concentrator and from there into the tailings discharge, or directly into the tailings discharge.

The Mineral Concentration Process

The raw ore is carried by truck and in some instances by conveyor to the mill where it is initially crushed by mechanical means into particles with a maximum diameter of about eight to ten inches. In most of the large-scale mining operations that are presently operating and in virtually all that are
planned the ore is then finely ground by autogenous grinding mills into particles which have a diameter of about 250 microns. The maximum diameter is often less than this, however, depending on the size of the mineral particles in the ore. (In the case of the Utah ore, for example, the maximum size of the ground ore is required to be less than 70 microns.) The objective of the grinding operation is the physical separation of the valuable mineral particles from the host rock in which they are embedded.

The central operation in the concentrating process is termed "froth flotation". This is a physio-chemical method of treatment which produces a hydrophobic film on the surface of the mineral particles through the use of chemicals that are termed "collectors". The ground ore is mixed with water to which a number of chemicals are added and is fed into flotation chambers in which the ore-water-chemical mixture is continually agitated in order to keep the particles in suspension. One group of chemicals added to the ore (known as frothers) lowers the surface tension of the water and produces a froth on the surface of the mixture. The minerals, which have adhered to the collector, are held in this froth whereas the material not so affected remains in the water below. Continual circulation of the material is achieved by means of a jet of air bubbles rising from the bottom of the flotation chamber. Upon completion of the separation, the froth, which contains the mineral
particles, is skimmed off the water.

Many ores contain a number of valuable metal sulfides and these must be separated from each other as well as from the waste material of gangue. The first step in the separation process is usually a "bulk flotation" of all the metal sulfides, often with the exception of iron sulfide which is generally depressed and disposed of with the gangue (tailings). The metal sulfides are then separated from each other by "differential flotation" through the further use of frothers and collectors and by the use of "modifying agents" which impart differential flotation characteristics to the various minerals. (At the Utah mine, for example, it is necessary to separate chalcopyrite (CuFeS) from Molybdenite (MoS₂) by simultaneously floating the molybdenite and depressing the chalcopyrite.)

The most common group of chemicals used as collectors are the xanthates. Other compounds that may be used for this purpose include thiocarbamates, dithiophosphates, thiocarbanilide, and xanthogen formates. These are all sulfur containing hydrocarbon esters. Very little is known about the toxicity of these substances to aquatic organisms and Duncan (1970) found no reference to their effects in the literature of English-speaking countries. The chemicals used as frothers are usually alcohols such as hexyl, heptyl and octyl alcohol. Pine oil (terpineol) and cresylic acid (xylenol) are also used for this
purpose in some processes.

The most diverse group of chemicals used in the concentration of metal sulfides are the modifying agents. These can be grouped into three classes on the basis of the function they perform in ore separation. The pH of the flotation mixture may be regulated with alkaline substances such as lime (CaO), soda ash (Na$_2$CO$_3$), and caustic soda (NaOH) and with acids such as sulfuric acid and hydrochloric acid. Another group of substances is employed as "resurfacing agents". They include such cations as copper, lead, zinc and silver, anions such as silicate, phosphate and cyanate, and organic colloids such as dextrin, starch and glue. These substances are often used to improve the selectivity of the flotation process when minerals with similar properties are being separated. Yet another group of chemicals, termed "precipitants" are used to precipitate naturally occurring ions that interfere with the flotation process. The substances in this category include soda ash, cyanide and various sulfites.

Upon completion of the mineral separation, the concentrate is stored for shipment and the waste (tailings) is disposed of in most cases in a tailings pond, or, as with Utah and other mines located near the sea or lakes, by means of a pipe which carries the tailings into a body of water. Both the ore concentrate and the tailings have been ground to a fine
powder and therefore have a very large surface area exposed to the atmosphere and to any water that drains through them. As the concentrate is usually kept under cover during storage, there is seldom a problem due to oxidation from this source. The tailings, however, are disposed of in the open and are thus exposed to leaching by drainage water which may carry heavy metals into nearby streams, lakes and inlets. Tailings ponds are often formed by constructing a dam across a valley by using earth fill, waste rock or the coarse fraction (sands) from the tailings. This places the tailings directly in the path of the natural drainage of the area and can provide for a continuous flow of water through them. In the case of under-water disposal, little is known about the possible oxidation and subsequent release of soluble metals into the water body used for the discharge.

The most efficient concentration process is only successful in recovering from 90 to 95% of the valuable metals in the ore, and many mines also discharge most of the iron sulfide present in the ore with the tailings. This results in an effluent that contains an appreciable quantity of metal sulfides which are susceptible to oxidation and leaching by drainage water.

Processes Involved in the Formation of Acid Mine Drainage

The major problem of oxidation and leaching occurs on
the exposed ore surfaces in the open-pit itself and in the tailings. However, leaching of heavy metals will only occur under certain environmental conditions. The most important of these is probably the available surface area of the metal sulfides. Oxygen is required and this is provided by exposure to the atmosphere. These conditions occur both in the open-pit and in the tailings. In the open-pit the area of exposed mineral surface is much smaller than in the tailings but the concentration of metal sulfides is much higher. In the tailings the concentration of metals is generally low (except for iron) but this is compensated for by the much larger surface area of the finely ground waste material.

Hawley and Shizake (1971) outline the chemistry of acid mine drainage formation. They have found that it is only in tailings with a significant iron sulfide content that a chronic pollution problem will occur. Given that there are sufficient water and oxygen present, the following reaction takes place resulting in the production of ferrous sulfate and sulfuric acid:

\[ 2\text{FeS}_2 + 2\text{H}_2\text{O} + 7\text{O}_2 \rightarrow 2\text{FeSO}_4 + 2\text{H}_2\text{SO}_4 \]

This initial reaction takes place both in the tailings and on the ore surface in the open-pit. The products are then able to react in the presence of further oxygen:

\[ 4\text{FeSO}_4 + 2\text{H}_2\text{SO}_4 + \text{O}_2 \rightarrow 2\text{Fe}_2(\text{SO}_4)_3 + 2\text{H}_2\text{O} \]
The ferric sulfate formed in this reaction is then able to oxidize the other metals present in the ore-body and tailings. With chalcopyrite, for example, the following reaction may take place:

\[
\text{CuFeS}_2 + 2\text{Fe}_2(\text{SO}_4)_3 + \text{H}_2\text{O} + 3\text{O}_2 \rightarrow \text{CuSO}_4 + 5\text{FeSO}_4 + 2\text{H}_2\text{SO}_4
\]

These and other similar reactions involving whichever metal sulfides are present in the ore and tailings are to a considerable extent accelerated by the presence of the sulfur oxidizing bacteria \textit{Thiobacillus ferrooxidans} and \textit{T. thiooxidans}. The formation of acid mine drainage is therefore biological to a large degree. Once the oxidation of sulfides has produced a sufficiently acidic condition for the growth of the \textit{Thiobacillus sp.}, the rate of acid formation and of soluble heavy metal production is increased greatly. Even the most heavily polluted mine drainage provides a suitable environment for the growth of these bacteria. \textit{T. ferrooxidans} has been observed to tolerate levels of dissolved copper up to 12,000 ppm and of zinc up to 15,000 ppm. Most other heavy metals are also tolerated in much higher concentrations than those which are acutely harmful to all macroscopic forms of aquatic life. The optimum pH for the bacterial oxidation reactions is approximately 2.0, far below acceptable levels for aquatic life in general. These bacteria have been isolated from a number of locations where acid mine drainage has developed and there exists a considerable literature on their specific role in the oxidation of metal sulfides.
The production of acid mine drainage is a cumulative process since the ferric sulfate produced in the oxidation of ferrous sulfate is able to enter into further reactions involving other heavy metal sulfides. These other sulfides of copper, zinc, lead, etc. are also oxidized directly in aqueous solution as are the iron sulfides. All these reactions result in the production of sulfuric acid which creates an acidic solution in which heavy metal ions are highly soluble. An exception to this is lead which generally forms an insoluble sulfate and is therefore present at low levels in water draining from mining areas. The production of soluble and therefore leachable heavy metal salts can be expected to continue until virtually all of the sulfides that are exposed to atmospheric oxygen or to oxygen-bearing water have been converted into sulfates. In many cases this process may continue for decades following the abandonment of a mine-site. The process is therefore cumulative in the broader geographical sense as the acid load that must be carried by the environment will increase as the number of abandoned mining properties increases.

The rapid rate of growth in the mining industry in British Columbia may therefore be expected to create a considerable long-term problem of heavy metal pollution, the only solution to which may be the application of preventative measures from the onset of mining activity. If a mine and its disposal system are not designed with the possible oxidation
of metal sulfides and the natural drainage patterns of the area in mind, there is little that can be done to correct the problem once it reaches chronic proportions. Methods for the prevention and alleviation of acid mine drainage will be discussed later in this chapter.

**The Natural Levels of Heavy Metals in Fresh and Salt Water**

An analysis of most natural fresh waters and of all sea-water will indicate that all the heavy metals are present in solution. This is due to the natural weathering process which carries the metals from watersheds and discharges them into the oceans. The concentration of metals in any natural water depends to a large degree upon their concentration in the geological formations which are exposed to seepage water in the watershed from which it originates. It can be expected, therefore, that in an area where the soil has been formed from rock that has a high concentration of a particular metal that the water from it will also have a relatively high concentration of the metal.

One of the most difficult problems associated with estimating the effects of various concentrations of heavy metals on aquatic organisms is the determination of the chemical form in which the metal occurs in different waters. Water from a particular watershed passes through a number of environments on its way to the sea and each of these may favor a different
chemical state in the various heavy metals. Each situation, from seepage water in the soil, to runoff water in streams, rivers and lakes, to the highly saline conditions of the ocean, subjects the metals carried from the site of weathering to varying temperature, pH, hardness, oxygen concentration and salinity. Depending upon the physical and chemical nature of the water, the metals may be present as soluble sulfates or as insoluble hydroxides, silicates, or carbonates. Each metal exhibits different threshold levels for the conversion from one chemical form into another, and they may also tend to form complexes or chelation products with organic matter that is present in the water. Drainage that is rich in organic matter such as humic acids (as a result of drainage through a bog, for example) could be expected to contain a large fraction of heavy metals in a complexed form. Drainage that contains little organic matter would contain the metals in a simpler form, either as soluble salts or as insoluble particulates.

The significance of these varying physical and chemical factors lies in the fact that aquatic life is differentially effected by a given heavy metal depending upon the chemical form in which it is present. Generally speaking, the dissolved forms are the most toxic, while the insoluble and complexed forms are less so. High levels of heavy metals are toxic in any form, however, so the problem is one of degree more than one of kind.
Heavy Metals in the Ocean and Coastal Waters

Seawater has been found to contain all the elements in the earth's crust. Some of these are present in large amounts but most are found in concentrations of less than 1.0 mg/l (ppm) and many at less than 0.001 mg/l (1.0 µg/l). The open ocean, where the chemical composition is far more consistent than in either coastal areas or fresh waters, has been found to have the following average concentrations of heavy metals (Grill, 1971):

- Copper .................. 0.003 mg/l
- Zinc ..................... 0.010 mg/l
- Iron ...................... 0.010 mg/l
- Lead ...................... 0.0001 mg/l
- Cadmium .................. 0.0001 mg/l
- Mercury ................... 0.00003 mg/l
- Molybdenum ............... 0.010 mg/l
- Silver ..................... 0.0003 mg/l
- Gold ...................... 0.000004 mg/l.

There will be considerable variation from these figures in coastal areas depending on the volume of water draining from the land, the geology of the area, and many factors related to soil type and climate. A survey of the values found in coastal areas, particularly for copper, will serve to illustrate the range of concentrations that can be expected for the heavy metals.
At Woods Hole, Mass. Galtsoff (1943) found from 8.4-30.2 ug/l copper while in the Bahamas he observed levels from 1.0-8.3 ug/l. Buch (1944) found from 2.0-8.0 ug/l in water samples from the Baltic Sea while Meyer (1938) found from 5.7-22.0 ug/l in the same area. In Tokyo Bay, Japan, measurements made by Morita (1950) indicated levels of copper from 1.0-5.7 ug/l. Noddack and Noddack (1939) reported copper at a concentration of 4.0 ug/l in samples from the Zoology Station at Kristineburg, Sweden. At Friday Harbor in the San Juan Islands the copper levels were found to range from 0.7-1.9 ug/l (Chow and Thompson, 1952). Later work at Friday Harbor (Chow and Thompson, 1954) showed that the level of copper is not static but has a regular annual pattern with a maximum concentration in the summer and a minimum concentration in the winter (see Fig. 2). It would seem probable that the concentration of copper in a given coastal area is strongly related to the volume of runoff water draining into it. If one assumes that the rate of weathering is similar in different areas, it is clear that the large runoff experienced in the Pacific Northwest will dilute the copper considerably before it reaches an estuary. The level of copper found in the waters of British Columbia inlets (Howe Sound and Burrard Inlet) and in the Strait of Georgia are far below the average world level for coastal water. This is presumably caused by the high annual precipitation and the resulting low levels of copper in river water.
Figure 2. Graph showing the seasonal fluctuation in sea-water copper concentration for the surface waters of San Juan Channel, Washington, U.S.A. (after Chew and Thompson, 1954).
entering these coastal areas.

A considerable amount of work has been done in order to determine the natural levels of iron in coastal waters. In reporting the data obtained in their analyses, most workers follow the practice of giving separate values for the particulate and the dissolved heavy metals. This is particularly important with iron since there is often a wide range of particulate concentrations while the dissolved concentrations remain relatively stable.

Working in Pacific Ocean coastal waters, Laevestu and Thompson (1958) found a mean value of 17.8 ug/l for dissolved iron and 114 ug/l for particulate iron. In Texas Bay mean values of 30.0 ug/l for dissolved iron and 200 ug/l for particulate iron were reported by Parker et al (1963). At a coastal station in Japan, Hashitani and Yamamoto (1959) found concentrations of dissolved iron ranging from 9.0-156.0 ug/l. Williams and Chan (1966) reported levels of dissolved iron from 1.0-39.0 ug/l at a coastal station in the Pacific Ocean.

The natural levels of molybdenum have been reported for a number of coastal and estuarine locations. Working in Japanese coastal waters, Sugawara and Okabe (1960) found that dissolved molybdenum concentrations varied from 9.6-12.7 ug/l. Burton (1969) reported levels from 7.1-10.5 ug/l in samples of Indian coastal and estuarine water. Western North Atlantic
coastal waters contained from 6.3-14.0 ug/1 (Young et al, 1959) while British coastal waters were found to contain from 12.0-16.0 ug/1 (Black and Mitchell, 1952). The Irish Sea is reported to have levels of dissolved molybdenum from 8.4-10.3 ug/1 (Chan and Riley, 1966; Riley and Taylor, 1968). Beak et al (1970) found molybdenum concentrations from 4.0-11.0 ug/1 in the waters of Rupert Inlet on Vancouver Island. These measurements were made before the Utah mine began to operate and indicate that the natural levels of molybdenum in Rupert Inlet are quite similar to those found in many other parts of the world.

Reports of the levels of heavy metals other than copper, iron and molybdenum are more difficult to obtain since much less work has been done on them in coastal areas. Two British studies involved the analysis of coastal waters for a number of elements including some of the heavy metals. Black and Mitchell (1952) report concentrations of dissolved zinc at 11.0 ug/1, silver at 2.9 ug/1, lead less than 8.0 ug/1 and molybdenum at 12.0 ug/1 in water taken 20 miles off Plymouth, England. Elderfield et al (1971) found levels of zinc at 8.8 ug/1, lead at 3.6 ug/1, copper at 3.0 ug/1, and cadmium at 0.76 ug/1 in seawater near the Conway River estuary in Wales.

Heavy Metals in Fresh Water

The heavy metal content of fresh waters is far more
variable than that of either open ocean or coastal areas. This is due largely to the lack of buffering capacity in fresh water which is provided by the dissolved salts in seawater. Whereas the pH of seawater tends to remain slightly alkaline despite the addition of great quantities of highly acidic waste (Arnold and Royce, 1960), a considerable range of pH is common in fresh water, largely determined by the geology, soil type, precipitation and temperature in the watershed. An area rich in limestone will tend to produce alkaline drainage, whereas a region in which there is a great deal of mineralization will tend to produce acidic drainage. It is not usual, however, for an undisturbed watershed to produce drainage that is acidic enough to create a condition that is toxic to aquatic life. Even in the most highly mineralized areas, such as those with potentially exploitable ore-bodies, the drainage water is generally only slightly acidic and the heavy metal content, although considerably higher than in non-mineralized areas, is generally low enough to permit the development of a normal community of organisms. Depending on the actual acidity or alkalinity of the water there will no doubt be some variation in the species composition of different lakes and streams with corresponding variations in productivity. This variation is relatively insignificant, however, when compared to the "biological desert" which is often produced by acid mine drainage as a result of mining activity.
It is quite understandable why it is unusual to find chronic heavy metal or acid pollution problems occurring naturally even in highly mineralized areas. The majority of mineral surfaces that were directly exposed to weathering during glaciation in British Columbia have been subjected to oxidation and leaching of the heavy metals contained therein for about 10,000 years. Soils and vegetation have developed over most of the area, protecting the land from erosion and therefore from the further exposure of fresh mineral surfaces. In most watersheds the oxidation process is taking place at a relatively slow rate and is releasing heavy metals at levels that can be tolerated by fresh water communities. In British Columbia, even though there are extensive areas of heavy metal mineralization, the extremely high runoff in much of the province results in relatively low concentrations in runoff water (Peterson et al, 1970).

Copper is generally present in a dissolved state at concentrations below 10.0 ug/1 in fresh water. Sprague and Carson (1964) report an average copper concentration of 1.3 ug/1 and a range of 0-8.0 ug/1 in an unpolluted section of the Miramichi River in New Brunswick. In Buttle Lake on Vancouver Island, the copper levels have been found to range from 3.0-6.0 ug/1 (Peterson et al, 1971).

Dissolved zinc is usually found at levels below
50.0 ug/1 in fresh water drainage. In the Miramichi River Sprague and Carson (1963) found an average concentration of 3.3 ug/1 and a range of 1.0-20.0 dissolved zinc. In Buttle Lake levels of zinc are reported at between 15.0 and 25.0 ug/1 (Peterson et al, 1970). An undisturbed tributary of the River Conway in Wales was found to contain zinc at an average level of 23.8 ug/1 (Elderfield et al, 1971). Livingstone (1963) states that the probable mean concentration of both dissolved and particulate zinc in all fresh waters in the United States is about 70.0 ug/1.

Iron is probably the most variable of the heavy metals in terms of both dissolved and particulate concentrations in fresh water. Minerals containing iron are much more common than are those of the other metals and only slightly acidic conditions are required to leach it from a watershed in a soluble form. Iron also has a strong affinity for organic materials and readily becomes complexed with them. These factors are illustrated well by a study of rivers which drain into the English Channel. The River Test which drains the chalk deposits of southern Hampshire, and is therefore alkaline, was found to contain 12.8 and 13.2 ug/1 dissolved iron at the two stations occupied. The River Beaulieu, however, which drains the heaths and bogs of the New Forest and is therefore acidic, was found to have concentrations of dissolved iron of 639 and 645 ug/1 (Head, 1971). The same variability can be expected for
particulate iron due to the ability of waters containing large amounts of humic acids to carry iron as organic complexes in colloidal solution.

Lead is rarely found in a dissolved form even in the most acidic environments. Unlike the other heavy metals, lead forms an insoluble sulfate (the mineral anglesite) as well as insoluble hydroxides, oxides and silicates. In Buttle Lake lead concentrations were found to be less than 2.0 ug/l and in most cases were not detectable (Peterson et al, 1971). Dissolved lead levels in the River Conway were reported at 4.5 ug/l average concentration (Elderfield et al, 1971).

The other heavy metals are generally present in only very low concentrations under natural conditions. Cadmium is usually found below 1.0 ug/l and is reported at 0.45 ug/l in an unpolluted section of the River Conway (Elderfield et al, 1971). Mercury has been measured at concentrations ranging from 0.05-2.0 ug/l in water samples from the Saale River in Europe (Livingstone, 1963). Both silver and gold would not be expected at concentrations above 1.0 ug/l in natural waters. In general, concentrations of cadmium, mercury, silver or gold that are above 1.0 ug/l should be considered anomalous and deserve investigation to determine the cause of such high values.
Biological Requirements for the Heavy Metals and Their Distribution in Aquatic Organisms

Despite the fact that many of the heavy metals are acutely toxic to most aquatic organisms at concentrations well below 1.0 mg/l (1000 ug/l), many of them are required by these same organisms for essential biochemical and physiological processes. There is therefore a minimum tolerable level as well as a maximum one for each of the heavy metals which are required by a particular organism.

Copper has been shown to have an important biochemical function as an enzyme activator, as a constituent of flavoprotein, and as an integral part of the hemocyanins found in certain molluscs. In the hemocyanins, copper replaces the role of iron found in hemoglobin in the transport of oxygen (Mahler, 1956). Zinc plays an important biochemical role, serving as an enzyme activator and as a constituent of metallo-protein enzymes such as carbonic anhydrase which catalyzes the conversion of carbon dioxide to carbonic acid (Keilin et al, 1940). Iron is a very essential micronutrient for all forms of aquatic life. It is a constituent of hemoglobin (porphyrin-bound iron) and has been identified in the cytochrome system of oysters where it is responsible for 80% of the respiratory activity (Kawai, 1959). There are no known biological functions involving lead, mercury, cadmium, silver or gold. For these metals,
therefore, it is possible that there is no minimum requirement and that their complete absence would have no detrimental effects on aquatic communities.

Perhaps the most fundamental problem between heavy metals and aquatic organisms lies in the ability of all organisms to concentrate metals in their tissues to levels that are far above those present in the surrounding water. The various metals are concentrated at different rates and to different equilibrium levels depending on the organism involved, the metal concentration in the water, and the temperature (which to a great extent determines the rate of metabolic activity of the organism). The toxicity of a particular metal is often determined by the extent to which its concentration is "magnified" through selective uptake rather than by the actual level of the metal in the aquatic environment. One approach to this problem is the experimental determination of the "concentration factor" for given combinations of metals and organisms. As there are many variables involved and as the metals may interact strongly to affect each others uptake, this method gives results which may describe only a limited number of actual situations but it does provide an estimate of the order of magnitude involved in biological concentration.

Black and Mitchell (1952) present data for the concentration factors (ratio of heavy metal content of fresh algae
to heavy metal content of water) for a number of intertidal algal species from British shores. These show a wide range and are much more strongly correlated with the heavy metal involved than with the species of algae. The concentration factor for molybdenum ranged from 2 for *Laminaria digitata* to a high of 15 for *Fucus spirilus*. These are very low values for concentration factors and indicate that molybdenum is only weakly accumulated against a concentration gradient in marine algae. For zinc, however, the concentration factor ranged from 400 in *Laminaria digitata* to 1,400 in *Ascophyllum nodosum*. If the ambient concentration of zinc was 10.0 ug/l in the intertidal seawater it would be concentrated to 14,000 ug/l or 14 mg/l in the algae *A. nodosum*.

Among the marine animals the molluscs show the strongest ability to concentrate heavy metals. Pringle et al (1968) conducted a laboratory investigation of the accumulation of a number of heavy metals in various estuarine molluscs. The eastern oyster, *Crassostrea virginica*, gave concentration factors of 226,000 for cadmium, 14,800 for copper, 6,700 for iron, 4,100 for lead and 148,000 for zinc. The soft shelled clam, *Mya arenaria*, had concentration factors of 800 for cadmium, 2,000 for copper, 41,000 for iron, 3,400 for lead, and 1,700 for zinc while the mussel, *Mytilus edulis*, showed 800 for cadmium, 1,150 for copper, 2,900 for iron, and 2,200 for zinc.
Most of the studies involving the determination of the heavy metal content of aquatic organisms have not dealt with the levels of the metals in the aquatic environment and therefore concentration factors have not been calculated. Riley and Segar (1970) and Segar et al (1971) have discussed the distribution of all the major elements and many of the minor ones in the tissues of marine organisms. Some of the heavy metals, iron in particular, vary considerably in their concentrations from species to species, even when the organisms involved belong to the same taxonomic class. In echinoderms (starfish, sea-urchins, etc.) the iron content of dried specimens ranged from 16 mg/kg to 1,800 mg/kg in the seven species analyzed. Cadmium ranged from 1.7-9.4 mg/kg, copper from 4.1-30 mg/kg, lead from 0.50-6.0 mg/kg, and zinc from 68-240 mg/kg dried weight. Two species of coelentarates (sea-anemones, jelly-fish, etc.) which were analyzed showed similar ranges and were also quite different in their heavy metal contents even though closely related taxonomically. The analysis of 12 species of molluscs showed significantly higher metal values than echinoderms and coelentarates. Iron content was found to range from 65-1, 500 mg/kg, cadmium from 1.2-73 mg/kg, copper from 3.0-150 mg/kg, lead from 1.2-40 mg/kg, and zinc from 91-540 mg/kg dried weight. McCance and Shackleton (1937) report similar levels for copper in marine gastropod molluscs. They found an average copper concentration of about 50.0 mg/kg in 16 species analyzed. Marks (1938) reports
a range of copper levels in molluscs from 9.7-560 mg/kg dried weight, somewhat higher than the values reported by the other analysts.

It can be seen from the above data that there is considerable interspecies variation in terms of heavy metal content. There may also be a great deal of intraspecies variation (Pringle et al, 1968). In the Pacific oyster, *Crassostrea gigas*, zinc has been found to range from 86-344 mg/kg wet weight, copper from 7.8-37.8 mg/kg, iron from 15.3-91.4 mg/kg, lead from 0.1-4.5 mg/kg, and cadmium from 0.2-2.1 mg/kg. Similarly wide ranges of concentration were reported for the eastern oyster, *C. virginica*, the soft shelled clam, *Mya arenaria*, and the northern quahaug, *Mercenaria mercenaria*. However it is difficult to interpret the significance of these ranges as the specimens were collected from many different areas. It is possible that much of the variability is due to different levels of the metals in the environment from which the organisms were collected.

A very useful application of data on the heavy metal content of aquatic organisms is to indicate heavy metal pollution. A slight increase in the level of metals in the environment will often result in a considerable magnification of the levels present in aquatic organisms, particularly those with high concentration factors.
The Toxicity of Heavy Metals to Aquatic Organisms

General Considerations

A large number of studies have concerned themselves with the lethal and sublethal effects of heavy metals on aquatic organisms. In order to achieve a controlled environment, most workers have conducted their research in laboratories. Field work has largely been restricted to the reporting of specific instances of fish mortalities and to more general observations regarding the effects of waste discharges on entire communities of organisms. A sufficient body of knowledge has been gathered, however, to determine many basic principles as to the nature of toxicity and the tolerance of communities of organisms to increases in heavy metal concentrations.

The toxicity of heavy metals is strongly related to their ability to form complexes with a wide variety of organic substances. Just as metals may be complexed with non-living organics such as humic acids in drainage water, so they may form complexes with living material that is exposed to water in which they are dissolved. Pringle et al (1968) attributes the toxic effect to the poisoning of enzyme systems. Copper, mercury and silver are known to have a strong affinity for amino, imino and sulfhydral groups which are often active sites on enzymes. It has therefore been postulated that the relative toxicity of a particular metal is related to the stability of
its organic chelates or complexes. This would indicate relative toxicities in the following order, from greatest to least: mercury, copper, lead, cobalt, zinc, cadmium, iron. This is at best only a rough estimate of relative toxicity, however, as it does not take into account the differential ability of organisms to detoxify and to exclude metals in their tissues.

The most common specific mode of toxic action of heavy metals is probably their ability to combine with cell membranes, thereby affecting the permeability of the membrane and inhibiting the transport of sodium, potassium, chlorine and organic substances across it. Different organisms have different types of tissues exposed directly to the environment. In most higher forms, and particularly in fish, the most sensitive exposed tissues are the gills which are responsible for the uptake of oxygen from the water. Carpenter (1924), studying lead pollution at Aberystwyth, concluded that the toxic action of heavy metals on fish was due to asphyxiation. The heavy metals were thought to combine with the mucus secretions produced by the gills, thereby preventing gaseous exchange and resulting eventually in death. Lloyd (1960), however, considers that the toxic action is caused by a breakdown of the gill epithelium and therefore the loss of tissues necessary for gaseous exchange. In either case the result is the loss of the ability to breathe adequately. In a recent study to determine the physiological effects of copper on winter flounders,
Pseudopleuronectes americanus, Baker (1969) reports that there are a number of sites of destructive action. High and medium levels of copper produced fatty metamorphosis of the liver, necrosis of the kidney, destruction of the hemopoetic tissue, and gross changes in gill structure. Low levels of copper produced vacuolation of the gill epithelium as well as other effects in the gill tissue. Shaw and Grushkin (1957) postulate that the primary mechanism for the toxic action involves the combination of heavy metal ions with sulfhydryl groups of important enzymes. This leads to the hypothesis that the metals which form the most insoluble sulfides will also be the most toxic. The order of toxicity predicted from this conclusion is as follows, from most to least toxic: mercury, silver, copper, lead, cadmium, zinc, cobalt, iron. Experimental toxicity studies on a number of test organisms and on enzyme extracts appear to partially verify this hypothesis.

The Toxicity of Specific Heavy Metals

The literature that deals with the toxic action of specific heavy metals on particular species of aquatic organisms is far too voluminous to present in a complete manner. The objective of this section will therefore be restricted to the identification of particularly sensitive species and to the heavy metals that present the greatest potential pollution problem from the mining industry.
A study conducted by Duncan (1970) provides a good review of heavy metal toxicities in general and outlines a number of considerations which are fundamental to the problem. The toxic action of heavy metals is enhanced by both increases in temperature and by lowering the water hardness (as measured by calcium carbonate (CaCO₃) concentration). Low dissolved oxygen concentrations increase metal toxicity by forcing the organism to pass more water over its gills, thereby exposing itself to additional metal and aggravating the situation. The toxicity is reduced by seawater as compared to fresh water, possibly due to the higher alkalinity of the former which causes a greater fraction of the metal to be present in an insoluble form. Both suspended solids and organic material tend to reduce metal toxicity through the formation of complexes and the absorption of metals onto particulate surfaces. Other useful review articles have been published by Duodoroff and Katz (1953), Huet (1950), McKee and Wolfe (1963), Lloyd (1965), and Dickenson (1968).

It has already been mentioned that the most important factor in determining the level at which a particular metal is toxic is the chemical form in which the metal is present. This in turn is determined by the nature of the water; the temperature, oxygen content, acidity and chemical composition. In terms of acute toxicity in particular, it is the dissolved or ionic forms of the metals which are the most toxic due to their
ability to form complexes with cell membranes and other cellular constituents. Metals which are already complexed with organic matter in the water, and those that are present as insoluble sulfides etc., are less toxic as they do not readily form such complexes. This does not mean that these chemical forms do not present a potential pollution problem, however. Organically bound metals and metals in the form of particulates may be ingested by aquatic organisms and may be concentrated to high levels in their tissues in the same manner as dissolved metals. This may prove to be as harmful in the long term to an organism or group of organisms as direct poisoning. When dealing with an entire biological community of organisms as they occur in nature, it is often sublethal effects caused by slow accumulation of toxic materials which bring about disruption and degradation of living systems. This subject will be dealt with more fully in the discussion of effluent standards for heavy metal discharges.

The most common techniques for the determination of toxic levels of heavy metals are those which involve controlled mortality studies. The objective of such studies is usually the determination of the LC50 value which is defined as the concentration of a particular substance which results in the death of 50% of the test organisms over a given time period. The most commonly used time period is 96 hours but studies have been conducted using other time periods ranging from a few hours
to several weeks. Sprague (1969, 1970) gives a complete review of the methods employed and the interpretation of data from this type of bioassay. The usual procedure involves the exposure of test organisms to a wide range of concentrations of the toxic substance and the observation of the time required for 50% mortality of the organisms. The LC50 may be estimated from a graph which plots the median survival times against the concentrations.

Unfortunately this technique is often more convenient than it is meaningful as it does not take into account sublethal effects such as those that would interfere with growth, feeding behaviour and reproduction. The determination of these effects requires a great deal more time and effort but the results are much more meaningful in terms of their applicability to actual populations and communities of organisms. Another difficulty encountered in LC50 studies involves their application in arriving at standards for discharges containing such toxic substances as heavy metals. It would obviously be undesirable to permit the discharge of wastes containing a concentration of toxic material which is equal to the LC50 value. The problem is to determine how much lower than the LC50 value the standard should be set in order to avoid undesirable effects in an aquatic ecosystem. In practice this is often done somewhat arbitrarily by dividing the LC50 value by 10 or 100 or by some other number that makes the calculation quite simple. This
method has little biological validity and, although it can provide useful information as to the relative toxicity of a number of substances, it is certainly not sufficient for the determination of biologically meaningful standards.

Some progress has been made towards the improvement of these bioassay techniques. In a paper dealing with the effects of long-term exposures to copper on the growth, reproduction and survival of brook trout, *Salvelinus fontinalis*, McKim and Benoit (1971) incorporate sublethal as well as lethal effects into their study. They define the "maximum acceptable toxicant concentration" (MATC) as the highest toxicant concentration that has no adverse effects on the survival, growth and reproduction of the test organisms. This is determined by measuring the per cent survival, growth rate, number of females spawning, total number of eggs spawned and mean number of viable eggs spawned per female. Through statistical analyses the highest concentration of the toxicant which has no significant effect is determined and is used as the MATC. An "application factor" is then derived by dividing the MATC by the 96-hour LC50. If it is assumed that there is a constant ratio between the MATC and the LC50 for all aquatic organisms, it is then possible to calculate the maximum acceptable level for a particular toxicant by simply determining the LC50 for another species and multiplying it by the application factor.
Most of the studies involving heavy metal toxicities have concerned themselves with the acute effects of a single metal on a single test species. It is difficult to compare the results of one study with another for various reasons including the chemical form of the metal, the adequacy of experimental controls, and the variability of different species as regards their susceptibility to various toxicants. The approach here will be to report the results of a number of studies of each of the heavy metals individually.

Copper

The literature on copper toxicity is perhaps the most comprehensive as this metal is a common industrial pollutant and is toxic at relatively low levels. McKee and Wolfe (1963) report that copper concentrations ranging from 0.015-3.0 mg/l have been demonstrated as toxic to many kinds of fish, crustacea, mollusks, insects, phytoplankton, and zooplankton. Nielsen and Nielsen (1970) report that in simulated seawater an increase of only 0.001 mg/l copper concentration resulted in reduced growth of the uncellular algae, *Chlorella pyrenoidosa*. Working with the diatom, *Nitzschia palea*, Nielsen and Andersen (1970) found that 0.005 mg/l copper resulted in greater than 50% reduction in the rate of photosynthesis. Warnick and Bell (1969) report that 0.027 mg/l copper resulted in the complete immobilization of the crustacean, *Daphnia magna*. The growth
rate of the brown algae, *Laminaria digitata* was sharply reduced by 0.050 mg/l copper (Bryan, 1968), and Glendenning and North (1960) found that copper concentrations of 0.100 mg/l were sufficient to reduce the photosynthetic rate of the giant kelp, *Macrocystis pyrifera*, by 50%. Brown and Ahsanullah (1971) report that the brine shrimp, *Artemia salina*, was not affected by copper concentrations up to 1.00 mg/l while the polychaete worm, *Ophryotrocha labronica*, suffered a significant suppression of growth at levels of 0.050 mg/l. Pringle et al. (1968) found that copper concentrations above 0.020 mg/l were extremely toxic to the soft shelled clam, *Mya arenaria*, but were less so to the hard shelled clam, *Mercenaria mercenaria*. Pyefinch and Mott (1948) calculated at 24 hour LC50 value for copper on the barnacle, *Balanus balanoides*, at 0.320 mg/l and for the barnacle, *B. crenatus*, at 0.190 mg/l.

Tarzwell and Henderson (1960) found that the 96-hour LC50 for copper on rainbow trout, *Salmo gairdnerii*, was 0.050 mg/l in soft water but was 1.40 mg/l in hard water. Working with the fathead minnow, *Pimephales promelas*, Mount (1968) demonstrated that copper concentrations above 0.018 mg/l resulted in increased mortality and in decreased growth and fecundity. At concentrations above 0.032 mg/l copper was found to reduce the survival of the brook trout, *Salvelinus fontinalis*, and at concentrations above 0.017 mg/l was found to reduce growth and reproductive ability (McKim and Benoit, 1971). Sprague (1964)
reported that copper levels in excess of 0.048 mg/l resulted in increased mortality of juvenile Atlantic salmon, *Salmo salar*. In a later paper (Sprague and Ramsay, 1965) this value was reported to be 0.032 mg/l.

**Zinc**

As is true for many of the heavy metals, zinc is more toxic to fish and other aquatic life than it is to any other group of organisms. McKee and Wolfe (1963) report that levels of dissolved zinc from 0.1-1.0 mg/l have been demonstrated to be lethal to aquatic organisms in soft water, while up to 2.0 mg/l is often not toxic in hard water. This difference is attributed to the antagonistic action of calcium in hard water which reduces the metal's toxicity. The lowest lethal level of zinc reported in the literature is for the eggs and young of trout which were unable to survive at a concentration of 0.01 mg/l. McKee and Wolfe also report that 1.0 mg/l zinc is toxic to the pond snail, *Physa heterostropha* and that abnormally high levels of the metal are dangerous for oysters and many other shellfish.

Working with juvenile Atlantic salmon, Sprague (1964) found that the 96-hour LC50 for zinc in soft water was 0.60 mg/l. In a later paper Sprague and Ramsay (1965) report this level to be 0.42 mg/l and also found that the presence of copper in the test solution had a synergistic effect on the toxicity of
zinc. Bryan (1968) found that the growth of the brown algae *Laminaria digitata* was inhibited by a concentration of 0.10 mg/l zinc in seawater. Warnick and Bell (1969) report that the toxic threshold for *Daphnia magna* is 1.80 mg/l zinc and that for mayfly nymphs the corresponding value is 0.30 mg/l. In their studies of the giant kelp, *Macrocystis pyrifera*, Glendenning and North (1960) determined that a concentration of 10.0 mg/l zinc resulted in a 50% inactivation photosynthesis in the kelp fronds. Brown and Ahsanulla (1971) report that a concentration of 1.0 mg/l zinc resulted in 50% mortality of the polychaete worm *Ophryotrocha labronica*, in 13 hours. They also found that the growth rate of the brine shrimp, *Artemia salina*, was significantly suppressed by concentrations of zinc of 1.0 mg/l or higher.

**Iron**

The toxicity of iron has not been investigated as thoroughly as many of the other heavy metals. It is relatively insoluble in waters with a pH higher than 6.0 and if introduced into them as soluble salts it will precipitate out as insoluble hydroxides. In waters of low pH however, such as those created by acid mine drainage, iron becomes quite soluble and exhibits considerable toxic action to aquatic life. Furthermore, even in water with normal pH levels the deposition of iron hydroxide precipitates can cause serious irritation on the gills of fish and may cause blocking of the respiratory function.
McKee and Wolfe (1963) report that at a pH below 5.5 carp will not survive in a concentration of 0.9 mg/l iron and that 1.0-2.0 mg/l result in the death of pike, tench, and trout at similar pH values. An iron concentration of 5.0 mg/l resulted in the death of dogfish in 3 hours. McKee and Wolfe suggest that the probable upper limit for the survival of fish life is 50 mg/l iron in a dissolved form. They also report that of all the waters in the United States that support good fish fauna, 95 per cent of these have an iron content of less than 0.7 mg/l and 50 per cent have a content of less than 0.3 mg/l.

Lead

McKee and Wolfe report that levels of lead as low as 0.1 mg/l have been found lethal to various species of fish. For Coho salmon the 48-hour LC50 was found to be 0.34 mg/l lead. Anderson (1948) found that the toxic level of lead chloride for Daphnia magna was 1.25 mg/l. A significant suppression of growth rate was measured for the brine shrimp, Artemia salina, at lead concentrations above 5.0 mg/l. Jones (1938) lists concentrations of lead from 0.1-0.4 mg/l as the lethal levels for sticklebacks.

Cadmium

Cadmium is extremely toxic to all forms of aquatic life at very low levels. The threshold concentration of cadmium
chloride for immobilization of *Daphnia magna* in Lake Erie water was found to be less than 0.0026 mg/l, (McKee and Wolfe, 1963). Goldfish have been killed in 18 hours by a concentration of cadmium chloride of 0.0165 mg/l. Elser (1971) reports that the 96-hour LC50 for the sand shrimp, *Crangon septemspinosa* was observed at a cadmium concentration of 0.32 mg/l. Under the same experimental conditions the values reported for the hermit crab, *Pagurus longicarpus*, was 0.32 mg/l cadmium, for the common starfish, *Asterias forbesi*, 0.82 mg/l, and for the blue mussel, *Mytilus edulis*, 25.0 mg/l.

**Mercury**

Mercury is perhaps the most toxic of the common heavy metals. Anderson (1948) reports that a concentration of mercury of less than 0.006 mg/l was able to immobilize *Daphnia magna*. Malacea (1966) found that the 96-hour LC50 for bitterlings, gudgeon and minnows was 0.02-0.05 mg/l, while for carp it was found to be 0.05 mg/l. Vallin (1948) reports that a level of mercury of 0.02 mg/l was fatal to juvenile salmon in less than five days. Working with the stickleback, Jones (1939) reported a lethal level of 0.008 mg/l mercury.

**Silver**

Silver is similar in toxicity to cadmium and mercury, only trace amounts being required to produce harmful effects to
many organisms. Anderson (1948) found that the toxic level for \textit{Daphnia magna} was 0.0051 mg/l silver nitrate. The lethal level of silver for sticklebacks is reported to be 0.003 mg/l, (McKee and Wolfe, 1963) and for salmon fry the highest level tolerated was 0.04 mg/l.

\textbf{Recommended Standards for the Heavy Metal Content of Mine Drainage Water and Mine Effluent}

It is evident from the above review of heavy metal toxicity that although considerable work has been done in this area it is not possible to define with precision the maximum levels of heavy metals that would guarantee the survival of a specific organism or group of organisms. The large number of variables involved and the complexity of their interrelations requires that the criteria used to arrive at standards be quite general in nature and that various lethal and sublethal levels reported in the literature be used only as guidelines. The approach taken here will be largely biological in nature and the objective will be to provide heavy metal standards that will result in no significant harm either in species diversity or productivity in the community of organisms that is exposed to the effluent.

Any community of organisms is the result of adaptation through natural selection to a specific range of environmental
factors. For example, a population of mussels from one area may be adapted to an entirely different set of concentrations of metals than another population from another area. Some communities may therefore be much more susceptible to heavy metal poisoning than others. It is not possible, given the present state of knowledge, to predict with any accuracy the maximum levels that a particular community will tolerate. The axiom which follows from this is that it cannot be assumed that a community of organisms is capable of tolerating levels of any toxic substance in concentrations which are higher than those to which it has been exposed in its recent evolutionary history. Even if the community is at present exposed to lower concentrations than it has been in recent times (say within 100 generations) it will quite possibly retain sufficient "genetic memory" to withstand an increase to the former levels providing this is not done too rapidly. Peterson et al (1970) in discussing the levels of heavy metals in fish from lakes in British Columbia expresses this problem well:

There is a danger in comparing levels of these metals harmful to fish in other parts of the world to conditions found in British Columbia. The extremely high runoff in British Columbia has resulted in relatively low concentrations of heavy metals in its waters. Selective forces and acclimatization may have resulted in aquatic
organisms tolerant only to these relatively low levels of metals and consequently a concentration "normal" in other areas may be sufficient to produce harmful effects in some fishes in British Columbia. The problem is therefore one of assessing per cent changes in time within one system rather than comparing absolute values, one system to another, if we are to use these data in a biologically meaningful sense.

The major difficulty, therefore, in setting standards for the discharge of heavy metals is the variability in tolerance limits of the communities in the various receiving waters. It is quite possible that a community will tolerate some increase in metal levels that is outside its previous range of experience. It is not practically possible, however, to distinguish these communities from those that will not tolerate an increase. The most biologically sound practice, therefore, would be to discharge effluent with the same concentration of metals as are present in the receiving waters. This would require, in most areas, that the industrial process have no effect on heavy metal levels in the water taken in for concentrating or refining the ore or on the levels of metals in water that drains through the area disturbed by the mining operation. There is no doubt that persons representing the mining industry would view such a requirement as unrealistic.
as it would mean their effluent must be as clean as the water they take in for processing.

There is much to be said, from a practical standpoint, for the establishment of effluent standards that are uniform throughout the entire mining industry. This would simplify enforcement and would provide industry with a more equable system of requirements. The major weakness with uniform standards is that they do not take into account the variability of tolerance limits among different communities of organisms or of the natural levels of heavy metals in water. It is felt that this problem could be minimized by adopting the following approach:

1. Heavy metal standards must be set well below those levels that have been demonstrated to be harmful to aquatic life.

2. In combination with this the levels of metals in aquatic organisms in the receiving water must be monitored to determine any increase in the metal content of their tissues.

3. The receiving waters should also be monitored for any changes in population numbers and species diversity that may be caused by the effluent discharge.

With these principles in mind it is felt that the following levels of heavy metals should be established as maximum
concentrations in the effluent of the mining industry in British Columbia:

- Copper ...................... 0.020 mg/l
- Zinc ......................... 0.050 mg/l
- Iron ......................... 0.500 mg/l
- Lead ......................... 0.005 mg/l
- Cadmium ..................... 0.005 mg/l
- Mercury ..................... less than 0.0001 mg/l
- Silver ....................... 0.001 mg/l

A Review of the Effect of Mining on the Levels of Heavy Metals in Water at Various Locations in Canada

Although there are only a few publications in the literature dealing with the effect of mining in Canada on the levels of heavy metals in water, those that are available leave little doubt that the problem is a serious one and that it will continue to grow more serious if present practices are continued. Hawley and Shizake (1971) have reviewed this problem in connection with their studies of acid mine drainage situations in Ontario. They make a number of comments that illustrate the nature of the problem:

Without exception, when acid mine drainage type effluents were evident, the specific companies involved worked sulfide or sulfide-associated ores. Without exception, the ore-bodies contained
quantities of iron sulfide (in various minerological forms) and, without exception, the milling circuits serving these operations were such that the iron sulfides were rejected to the tailings areas as waste. Once in a tailings area, and after a varying period of time, iron sulfides react to form water soluble salts which, when discharged in the effluents from the tailings area, can affect stream chemistry and stream ecology. ... Acid mine drainage in Ontario is cumulative. Abandoned properties will continue to produce acid for decades. As the number of abandoned sulfide operations increases, the acid load that our environment must assimilate also increases. Thus, this is a problem of immediate concern which must be brought under effective control.

In their article they also present an analysis of a sample of seepage water from an abandoned tailings area in the Elliot Lake district. The water had a pH of 2.0 and contained 2,200 mg/l iron, 11.4 mg/l zinc, 3.6 mg/l copper, 0.67 mg/l lead and 0.05 mg/l cadmium. The sample of water that was analyzed was clear, colorless and sparkling in appearance when taken. By comparing the metal values found in the mine effluent with those reported toxic to aquatic organisms, it can be seen that
it is lethal to virtually all forms of aquatic life even if it were diluted by 100 times. The most prevalent type of mining in British Columbia involves the excavation of mineral sulfide ores such as those which have resulted in the problem of acid mine drainage in Ontario. Many ore-bodies in British Columbia also contain large amounts of iron sulfides, as for example the copper ore in the Highland Valley region which has an average iron content of 15% in the tailings (Dournovo, 1972), and the ore from the Churchill copper deposit in northeastern British Columbia which contains about 10% iron sulfide (Carr, 1971). The Utah copper deposit at Rupert Inlet also contains significant amounts of iron sulfide (Young, 1971).

A number of papers have been published dealing with the problem of heavy metal pollution in the Northwest Miramichi River in New Brunswick. The contamination in this river has been caused by an extensive copper and zinc mining operation on the Little South Tomogonops River which flows into the Miramichi. Sprague and Carson (1964) report that copper levels reached a maximum of 0.080 mg/l in a polluted section of the river as compared to a maximum of 0.008 mg/l in an unpolluted section. The lethal levels for fish were greatly exceeded for 20 miles downstream from the mine-site.

Working in the same area, Watson (1969) observed maximum copper levels of 10.0 mg/l and maximum zinc levels of
81.5 mg/l in the water of the Little South Tomogonops River immediately below the mine-site. The pH of the water in the river was found at times to reach a low of 3.2. Some interesting data were obtained in the same area by Besch and Roberts-Pichette (1970) in an attempt to determine the effect of copper-zinc pollution on stream-side vascular plants. The topography of the mine-site is such that the water draining from the open-pit enters a different tributary of the Miramichi than the water that drains through the tailings discharge area. It was found that the water draining from the open-pit was far higher in copper and zinc levels than that which was leaching through the tailings, the former containing up to 12.1 mg/l copper and up to 65.5 mg/l zinc, whereas the latter had up to 0.034 mg/l copper and up to 2.0 mg/l zinc. This illustrates the need to consider separately the heavy metal contamination from all exposed and disturbed areas in the mining operation. At the Utah mine, for example, the tailings are being discharged into deep water in Rupert Inlet and it has been suggested by the Company and the Department of Fisheries (now the Department of the Environment) that this will eliminate the possibility of heavy metal leaching. The open-pit area, however, will remain exposed to the atmosphere for the duration of mining and probably for a considerable time thereafter. It is quite possible that a serious leaching problem may develop from this source.
Besch and Roberts-Pichette report that the heavy metal pollution from the Little South Tomogonops River has resulted in complete elimination of vascular plants for a considerable distance below the mine-site resulting in barren gravel beds along the banks of the river. Pippy (1970) reports that there was a considerable fish-kill in the Miramichi from August 5 to 11, 1969, which he attributed to high levels of copper and zinc in the river at that time.

Browne and Butler (1970) reported heavy metal levels for mine water that drains from the Copper Cliff mine in the Sudbury district of Ontario. The sample analyzed contained 1.3 mg/l copper and 8.4 mg/l iron and had a pH of 4.7.

No references could be found in the literature to studies of the heavy metal levels in British Columbia waters affected by mining. It was determined that although many of the mining companies make such measurements for their own purposes, and that the Pollution Control Branch routinely monitors at least two sites for heavy metals, it is extremely difficult to obtain the data in a usable form. This is apparently due to the "confidential nature" of the data. One study, although it does not report concentrations in water, does indicate that the problem of heavy metal pollution from mining is present in British Columbia. Peterson et al (1970) have reported on the levels of metals in the livers of fish from a
number of lakes in British Columbia that receive discharges from mining operations. In Buttle Lake on Vancouver Island, fish livers were analyzed in 1966 prior to the opening of Western Mines' copper-lead-zinc mine. Copper levels were reported to average about 35.0 mg/kg wet weight and lead levels at about 0.6 mg/kg. In 1969, two years after the initiation of mining activity, the copper levels were found to have risen to an average of about 150 mg/kg and lead levels to about 2.5 mg/kg.

The most dramatic evidence of heavy metal pollution in British Columbia is reported by Peterson et al (1970) in their study of the mercury content of fish livers and muscles in a number of British Columbia lakes. In six lakes not affected by effluent from a mercury mine the mercury content ranged from a low of 0.01 mg/kg to a high of 0.95 mg/kg. In Pinchi Lake in central British Columbia, however, which receives the effluent from the Cominco mercury mine, the mercury content ranged from 0.10 mg/kg to 31.0 mg/kg with an average of about 5.0 mg/kg. The high levels of mercury in Pinchi Lake would not appear to be due entirely to natural leaching of exposed mercury mineralization. Some of the other lakes sampled were in watersheds that contain significant mercury mineralization. None of these showed mercury levels in fish comparable to those found in Pinchi Lake.
A Survey of Certain Mines in British Columbia
to Determine Their Effect on Heavy Metal Levels
in Some Associated Water Bodies

During the period from July 5 to July 12, 1972, a field trip was undertaken to study the impact of certain mines in southern British Columbia on the quality of some associated water bodies, and to document the visual effects of mining with 35mm color slide photography. Water samples were collected, wherever possible, at the various mine-sites. The sites visited ranged from very small abandoned shaft-mine operations, to the large-scale open-pit developments that are typical of the mines that have recently begun to operate.

The major objective of the water sampling program was the determination of evidence of heavy metal contamination of waters effected by mining activity. If significant increases in heavy metal levels were indicated by the survey, it could be concluded that the problem deserved further study and was worthy of the research effort involved in the case study of the Utah copper mine.
The heavy metal survey would also be useful in arriving at a prediction of the possible impact of the Utah copper mine on the water quality and biology of Rupert Inlet, into which its wastes are discharged.

It was not possible, due to limited time and financial resources, to carry out anything approaching a comprehensive water sampling program at the sites of mining activity that were visited. This would have required frequent sampling at each location chosen in order to account for seasonal fluctuations in heavy metal concentrations and a large number of locations would have to be sampled at each mine-site in order to obtain an overall estimate of the quantity of metals entering runoff water from the area.

The sampling which was undertaken was limited to a few samples collected on a single visit. The sample locations were chosen after a brief survey of the site and its environs.

Samples were taken from streams that were receiving drainage water directly from either the mill effluent (outfalls or tailings ponds) or the open-pit area.
In planning the field trip to the various mines, it was anticipated that there would be some difficulty in obtaining permission from the mine operators to enter the property due to the nature of the study. The mining companies are operating under a mineral lease that gives them the right to control access to the property and many of them have control gates at which the purpose of entry is questioned. Consideration was given to the possibility of obtaining written permission from the companies by means of a letter requesting that the author be permitted to enter the mine-site for the purpose of assessing the environmental impact of the operation.

This was not done, however, due to the previous experience of Mr. Bill Terry, SPEC Federation President, who had used this approach in attempting to gather information for use at the B.C. Pollution Control Branch Inquiry into Waste Discharges from the Mining Industry held on March 14, 1972. In a letter dated November 26, 1971, Mr. Terry asked the head offices of 29 mining companies for permission to enter their operations. Eleven replies were received, all of which denied the request for various reasons (against company policy, not in the company's interest, etc.). It subsequently
was concluded, therefore, that the best approach would be to enter the mine-site unannounced wherever possible and to take the risk of being asked to leave, hopefully after sufficient information had been gathered for the purpose of the field trip.

Methodology and Techniques Employed in Collecting and Analyzing Water Samples for Heavy Metal Content

Water samples from each of the mines visited were analyzed for copper, zinc, and iron concentrations using the Varion Techtron Model AA-5 atomic absorption spectrophotometer. Hollow cathode lamps for each metal were operated at the following wavelengths:

- Copper @ 324.75 mu
- Zinc @ 213.86 mu
- Iron @ 248.33 mu.

Commercially prepared standard solutions of 1000 mg/l were used to prepare more dilute standards against which the samples were compared.

The water samples were also analyzed for pH with the use of an Orion Ionanalzer Model 404 specific ion meter with a sensitivity of better than 0.1 of a pH unit. As the water samples were not analyzed in the field it is possible that some change in pH (and any of the other parameters measured) may have occurred during transfer to the laboratory. This is particularly possible for samples with an acidic pH in which
additional acid could be generated by oxidation of sulfides contained in the sample. It is felt, however, that this problem did not contribute to significant error in the pH values obtained. For example, a pH of 2.7 was found for tailings drainage water at the Sullivan mine at Kimberly. A letter from L.J. Nicholson (1972), Manager for Environmental Control for Cominco, reports a pH of 2.9 with a range from 2.7-3.1 for similar drainage water at the Sullivan mine.

Total conductivity of each sample was measured using a Radiometer Type CDM2e conductivity meter. Conductivity is an approximate measure of the total amount of dissolved ionic material in the water.

Water samples were collected in 1.0 litre polyethylene bottles. Polyethylene labware was used throughout the analyses in order to avoid contamination or absorption of metals that could result in errors. An exception to this was the use of a glass funnel for the filtration of water samples. All labware and the collection bottles were rinsed with 1:1 nitric acid and deionized water before use in order to avoid contamination. Deionized water was used for the preparation of all the heavy metal standards.

As soon as possible after collection (from 2-6 days) the water samples were vacuum filtered through a 0.45 micron filter in order to remove the particulates. The filtrates were
acidified to a pH of about 2 with a 1:1 solution of hydro­
chloric acid and deionized water in order to ensure the complete
dissolution of the metals in the sample. Before acidification
an aliquot of each sample was taken and analyzed for pH and
total conductivity.

Standards of 1.0 and 10.0 mg/l for the determination
of heavy metal concentrations were prepared from 1000 mg/l
stock solutions of copper, zinc and iron. These were used to
calibrate the spectrophotometer and the samples were analyzed
for one metal at a time, checking the calibration every two or
three sample analyses with the standard solutions. Some of the
samples collected at Britannia Beach (Stations 1, 2 and 3) were
analyzed twice using different standards for each of the two
analyses. For the first analysis the standards for each metal
were prepared separately and for the second the standards were
mixed to give one solution containing known amounts of all the
metals being measured. This procedure would determine any
interference that the other metals might have on the particular
metal being measured in the water sample. It was found that
there was no material difference (less that 5%) in the values
obtained through this variation in standard composition. The
values presented for metal concentrations were obtained by the
first procedure, that of using standards containing only the
metal being measured.

The method for the analysis of water samples was

**Results for Water Sample Analyses**

The results of the heavy metal, pH and conductivity analyses will be presented separately for each mine following a brief description of the mine and an explanation of the sample locations.

**Anaconda Copper Mine, Britannia Beach**

The Anaconda mine was studied in the greatest detail as it is the most accessible from Vancouver and is one of the most serious examples of heavy metal pollution in the province. The ore is a rich copper and zinc sulfide material which also contains a great deal of iron sulfide. Anaconda is a shaft mining operation and has been in production almost continuously for over 50 years. At present it has a capacity of 3,200 tons of ore per day. An elaborate network of shafts has been constructed with many of them extending far below sea-level. The main source of heavy metal pollution is from the drainage water that seeps through rock fissures into the shafts and must be pumped out to the surface. The drainage water is discharged
Figure 3. Outline map of the Britannia Beach region in Howe Sound showing the water sampling stations in Britannia Creek and along the shore of Howe Sound.
into Britannia Creek in at least two locations and is carried by the creek into Howe Sound where it is dispersed by currents in a predominantly northward direction along the eastern shores of the sound. Water samples were collected on January 7, 1972 at various locations in Britannia Creek and along the shore of Howe Sound (see Fig. 3). The results of the sample analyses are contained in the following table. Conductivity values are given in millimhos and metal concentrations are given in mg/l.

<table>
<thead>
<tr>
<th>Station</th>
<th>pH</th>
<th>Cond.</th>
<th>Cu</th>
<th>Zn</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.0</td>
<td>0.028</td>
<td>0.50</td>
<td>3.0</td>
<td>11.0</td>
</tr>
<tr>
<td>2</td>
<td>3.8</td>
<td>3.0</td>
<td>22.0</td>
<td>72.0</td>
<td>250</td>
</tr>
<tr>
<td>3</td>
<td>4.0</td>
<td>1.90</td>
<td>12.0</td>
<td>36.0</td>
<td>120</td>
</tr>
<tr>
<td>4</td>
<td>4.3</td>
<td>0.90</td>
<td>5.0</td>
<td>13.0</td>
<td>45</td>
</tr>
<tr>
<td>5</td>
<td>6.4</td>
<td>18.0</td>
<td>1.10</td>
<td>6.0</td>
<td>2.0</td>
</tr>
<tr>
<td>6</td>
<td>7.7</td>
<td>25.0</td>
<td>0.08</td>
<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>7</td>
<td>7.9</td>
<td>27.5</td>
<td>0.05</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>8</td>
<td>6.6</td>
<td>28.0</td>
<td>0.25</td>
<td>0.70</td>
<td>0.10</td>
</tr>
<tr>
<td>9</td>
<td>6.6</td>
<td>28.0</td>
<td>0.10</td>
<td>0.15</td>
<td>0.05</td>
</tr>
<tr>
<td>10</td>
<td>7.4</td>
<td>28.0</td>
<td>0.10</td>
<td>0.15</td>
<td>0.05</td>
</tr>
<tr>
<td>11</td>
<td>7.5</td>
<td>29.0</td>
<td>0.02</td>
<td>0.03</td>
<td>0.05</td>
</tr>
<tr>
<td>12</td>
<td>8.0</td>
<td>29.0</td>
<td>0.01</td>
<td>0.03</td>
<td>0.05</td>
</tr>
</tbody>
</table>

The concentrations of copper, zinc and iron found in the water flowing from the Anaconda mine leave no doubt that it has produced a serious acid mine drainage problem. The sample
taken at Station 2 (of the effluent water itself) has a higher concentration of both zinc and copper than at any other location in Canada that has been reported in the literature. The effluent is also very acidic, with a pH of 3.8 and results in a pH of about 4.0 in Britannia Creek. The conditions in the creek below the effluent discharge (and for a considerable distance above it, due to other discharge points upstream) are such that no macroscopic life forms are capable of surviving in it. Only specialized bacteria and other highly resistant microorganisms would be found in this water. The ocean water of Howe Sound is also seriously polluted for up to one half mile on either side of the mouth of Britannia Creek. Adjacent to the mouth of the creek there was no observable life in the intertidal zone with the exception of a thin film of unicellular green algae that was able to survive high in the intertidal zone.

Giant Mascot Mines Ltd., Hope

The Giant Mascot mine is a nickel and copper producing operation with a mill capacity of 1,500 tons per day. The tailings from the concentrator are pumped via a pipeline to the tailings disposal area which is a typical tailings dam built across a valley and filled in behind with the waste. The drainage water from the tailings area showed the visible symptoms of acid mine drainage with a distinct reddish discoloration due to iron precipitation from the water. About one minute after
stopping at the base of the tailings dam, the author was approached by an employee of the mining company (Giant Mascot was written on his hard-hat) who was most concerned that we not drink any of the water draining from the area. It is apparent that there is knowledge at a local level, at least, that the water is contaminated so as to be unfit for human consumption.

Three sampling stations were selected in the vicinity of the tailings disposal area. The first sample was of the tailings themselves as they entered the tailings pond. The second was of the drainage water that was seeping out at the base of the tailings dam. The third was of water above the tailings area and was apparently unaffected by the mine. Samples were collected on July 5, 1972 and the following results were obtained.

<table>
<thead>
<tr>
<th>Station</th>
<th>pH</th>
<th>Cond.</th>
<th>Cu</th>
<th>Zn</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.3</td>
<td>0.64</td>
<td>0.90</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>7.3</td>
<td>0.92</td>
<td>0.60</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>3</td>
<td>7.7</td>
<td>0.049</td>
<td>0.05</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

The analyses indicate that the tailings have a considerable effect on the level of copper in water draining from the area as the concentration of this metal in the tailings drainage is more than 10 times greater than in the water above the tailings area. The acidity of the tailings drainage is only slightly increased from 7.7 above the tailings to 7.3 below...
it. This may be due in part to the fact that the mine is still operating and the inherent acidity of the tailings is being masked by alkaline substances in the concentrator effluent. The levels of copper found in the drainage water indicate the beginning of a possibly serious heavy metal pollution problem and should be investigated more thoroughly in order to obtain a clear understanding of the extent of contamination and possible treatment methods.

The Highland Valley

The Highland Valley, midway between Ashcroft and Merritt in the southwestern interior of the province, is the site of the most extensive open-pit copper mining in British Columbia. Two large operations, Bethlehem Copper Corporation Ltd., with a mill capacity of 15,000 tons per day, and Lornex Mining Corporation, with a capacity of 38,000 tons per day, are presently in production, and a third mine, Valley Copper, with a projected capacity of 40,000 tons per day, is now being planned. Each of these mines has reserves of copper ore of over one billion tons. It was stated by an employee of Bethlehem Copper (Dournovo, 1972) that the Highland Valley contains an area approximately 16 miles by 40 miles within which the geology contains sufficient copper content (greater than 0.45% copper) to make it commercially exploitable by present mining methods. The implications of such a large area
being surface mined are difficult to predict, but if the state of the land that has already been mined is any indication of future conditions, it is likely that it will be made virtually useless for any other purpose. Gigantic piles of waste rock, thousands of acres scarred by clearing operations, and tremendous holes left from the open-pit operations dominate the landscape.

It was difficult to obtain water samples from this area. At the time of the visit the Lornex mine was shut down due to a strike. Because of this the mine-site was heavily guarded by both union and management personnel. Although the union members were willing to permit entry for the purpose of an environmental study, this was not the case with the management representatives. One water sample was obtained from the tailings pond immediately below the effluent discharge point. The results for the analysis of this sample, collected on July 6, 1972, were as follows:

<table>
<thead>
<tr>
<th>Station</th>
<th>pH</th>
<th>Cond.</th>
<th>Cu</th>
<th>Zn</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.7</td>
<td>0.020</td>
<td>0.12</td>
<td>0.03</td>
<td>0.01</td>
</tr>
</tbody>
</table>

The sample contained a copper concentration far above that which would be expected in water draining from an undisturbed area. The alkaline pH value is possibly due to the addition of lime in the mill flotation circuit and thereby into the tailings.

It was not possible to obtain any water samples at
the Bethlehem Copper mine. The only approach to the mine is by a road that is controlled by a gate that is manned by a company employee. Upon request the author was offered a tour of the mine-site under the guidance of company personnel. The tour included a look at one of the three open-pits, the mill building and one example of a reclamation experiment that was being attempted on overburden material. No photographs of the reclamation areas were permitted, however, and upon request the author was refused permission to see the tailings pond area or any of the other reclamation experiments that were said to be underway. The reclamation area that was seen was not very impressive and amounted to about one-half acre of mixed grasses on a levelled overburden dump. It was not possible to obtain information as to the amount of fertilizer required for this vegetation, even though the guide for the tour was the head of land reclamation for the company.

Fortunately the Highland Valley is probably one of the least likely areas in the province to develop a serious acid mine drainage problem. This is due to the very low rainfall of the area which will minimize the problem of leaching of heavy metals. The most serious problem in the Highland Valley is the possibility of massive land disturbance and the destruction of its usefulness for other purposes such as forestry, agriculture and recreation.
Brenda Mines Ltd., Peachland

Brenda Mines is a copper and molybdenum operation with a mill capacity of 24,000 tons of ore per day. In order to obtain samples of the tailings water it was necessary to ignore a number of signs that forbid entry to the area. Upon seeing the river that carries the tailings for about a mile from the concentrator to the tailings pond it became understandable that the company would not wish to have anyone see what they were doing. The water in the river was a thick grey slurry with a great deal of foam on the surface; it emitted a strong and objectionable odour. The vegetation along the banks of the river was all either dead or apparently dying. The analysis for a sample of the tailings water (Station 1) and of the drainage water from a nearby waste rock dump (Station 2), collected on July 7, 1972, produced the following results:

<table>
<thead>
<tr>
<th>Station</th>
<th>pH</th>
<th>Cond.</th>
<th>Cu</th>
<th>Zn</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.1</td>
<td>1.45</td>
<td>2.80</td>
<td>0.01</td>
<td>0.18</td>
</tr>
<tr>
<td>2</td>
<td>6.7</td>
<td>0.14</td>
<td>0.24</td>
<td>0.01</td>
<td>1.40</td>
</tr>
</tbody>
</table>

Both samples showed abnormally high levels of copper and iron and are indicative of a potentially serious heavy metal pollution problem. The high alkaline pH of the tailings, that would normally result in very low metal concentrations, is particularly interesting. The alkalinity of the tailings is possibly due to chemical added in the milling process.
Cominco Ltd. (Sullivan), Kimberly

The Sullivan mine at Kimberly is a silver, lead, zinc, and iron operation with a mill capacity of 11,000 tons of ore per day. Next to those at Copper Mountain mine at Princeton the tailings area is the most extensive in the province and is undoubtedly the most serious example of acid mine drainage in British Columbia. This is caused largely by the high concentration of iron in the ore. Most of the creeks receiving drainage from the area have no visible life in them and the vegetation along their banks is either absent or very unhealthy. Two samples of acid drainage were collected on July 10, 1972 at the base of the main tailings disposal area. Both locations showed typical symptoms of an acid drainage situation. The following results were obtained from the analyses of the samples:

<table>
<thead>
<tr>
<th>Sample</th>
<th>pH</th>
<th>Cond.</th>
<th>Cu</th>
<th>Zn</th>
<th>Fe</th>
<th>Cd</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.7</td>
<td>5.50</td>
<td>0.42</td>
<td>18.0</td>
<td>1350</td>
<td>0.27</td>
</tr>
<tr>
<td>2</td>
<td>2.7</td>
<td>5.30</td>
<td>0.54</td>
<td>17.0</td>
<td>1400</td>
<td>0.02</td>
</tr>
</tbody>
</table>

These water samples have the lowest pH of any found on the field trip. Both zinc and iron concentrations are at levels that indicate a very serious acid drainage problem and even copper, which is not among the metals mined at the Sullivan operation, is far above lethal levels for fish. Cadmium concentrations were also determined for these samples as it had been suggested
(in the SPEC brief to the Pollution Control Branch Inquiry into Waste Discharges from the Mining Industry) that this metal may be present in the Sullivan drainage water. In one of the samples it was present at a concentration of 0.27 mg/l. In natural waters cadmium is rarely present at concentrations higher than 0.001 mg/l and is therefore nearly 300 times as high in the drainage water than would be expected if there were no mining in the area. Cadmium is a particularly dangerous pollutant as it is extremely toxic to higher life forms, including humans, and is concentrated very efficiently by most organisms. Shimizu (1972) reports that the Kamioka Mine in Japan has resulted in an acid drainage situation that has caused serious cadmium pollution of the Jintsu River. As a result there have been over one hundred deaths attributed to cadmium poisoning (known in Japan as the Itai-Itai or Ouch-Ouch disease) and at present at least two hundred and eighty people are afflicted with the disease. It would seem to be a problem demanding immediate concern, therefore, and the Cominco operation should be thoroughly investigated in order to determine the extent of cadmium pollution.

Abandoned Mine at Moyie on Moyie Lake

A large pile of waste rock has been left by a small mining operation that was on the shore of Moyie Lake about 15 miles south of Cranbrook. A small volume of drainage water was
running from the base of the rock pile directly into the lake, and it had the appearance of acid mine drainage. It was not possible to determine the nature of the original ore but from the sample analysis it would seem likely that zinc was among the metals mined. A single water sample was collected on July 10, 1972 and it yielded the following results:

<table>
<thead>
<tr>
<th>Station</th>
<th>pH</th>
<th>Cond.</th>
<th>Cu</th>
<th>Zn</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.5</td>
<td>0.47</td>
<td>0.11</td>
<td>10.0</td>
<td>17.5</td>
</tr>
</tbody>
</table>

The sample of water was slightly acidic and contained a very high zinc concentration as well as a high iron concentration. The level of copper in the drainage water was also far higher than that which can be tolerated by many aquatic organisms. Fortunately the volume of runoff from the mined area appeared quite small and the lake is probably able to assimilate the heavy metal load without serious effects to the community of organisms living in it. The combination of many such discharges however, can lead to a serious problem and it would obviously be wise to avoid the creation of such conditions, no matter how small they may appear when viewed alone.

**Midway Mine, Aldridge**

The Midway Mine is a small abandoned shaft mine near Aldridge which is about 35 miles south of Cranbrook. A small volume of water with typical acid drainage characteristics was flowing from the shaft entrance and into a nearby stream. A
sample of this water was collected on July 10, 1972 and resulted in the following data:

<table>
<thead>
<tr>
<th>Station</th>
<th>pH</th>
<th>Cond.</th>
<th>Cu</th>
<th>Zn</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.7</td>
<td>0.56</td>
<td>0.04</td>
<td>1.20</td>
<td>28.0</td>
</tr>
</tbody>
</table>

The pH of the sample is quite low and indicated the beginning of a heavy metal pollution problem. Both iron and zinc are far above levels to be expected under natural conditions.

**Discussion and Conclusion**

It is apparent from the small number of mines visited and the few samples collected and analyzed that there is considerable heavy metal pollution in British Columbia, which in turn suggests that pollution control is not working effectively. If this is the case, it is likely that new mines will continue to generate conflicts unless the administration of pollution control and the overall decision-making process is improved. On this basis the detailed case history of the Utah copper mine was undertaken. All the water samples collected showed some increase in metal concentrations over those that would be expected under natural conditions, and many indicated that a serious acid mine drainage problem had developed. There are a number of other mines that deserve similar study but which, due to limitations in time and resources, were not included in the sampling program.

Notable among these are:

- Western Mines at Buttle Lake on Vancouver Island
- Wesfrob Mines at Tasu in the Queen Charlotte Is.
- Granduc Mines Ltd. at Stewart
- Granisle Copper Ltd. at Babine Lake
- Craigmont Mines Ltd. at Merritt
Texada Mines Ltd. on Texada Island
Churchill Copper Corp. on the Racing River
Similkameen Mining Corp. at Princeton.

All of these operations, judging from the results of the water sample analyses from the mines visited, are potential contributors to the heavy metal pollution problem.

A major objective of the water sampling program was to arrive at some prediction of the possible impact of the Utah copper mine on the levels of heavy metals in the water draining from the mine-site and in the waters of Rupert Inlet. It is difficult, due to the unique features of each mine-site, to state with any precision what the future conditions will be at a particular operation. It can be concluded with considerable certainty, however, that the Utah operation has the potential to produce serious heavy metal pollution of the water draining from the mine-site itself. The mine is operating in a region of high rainfall (80-100 inches annually) and the ore-body contains considerable iron sulfide as well as copper and molybdenum sulfides. It therefore has all the requirements necessary to produce an acid drainage condition with the resulting heavy metal pollution.

Whether this heavy metal load will result in degradation of the marine ecology of Rupert Inlet is less predictable, but if the Anaconda Copper Mine at Britannia Beach is a valid example to use in comparison with Utah, there is a good
possibility that in time (perhaps as long as 20-30 years) the acid drainage originating from the open-pit area and the waste rock dumps will cause a serious loss of species diversity and biological productivity at least along the shoreline adjacent to the mine.

A Brief Discussion of Techniques for the Prevention of Acid Mine Drainage

A great deal of research has been undertaken, particularly in relation to the situation brought about by coal mining in the Appalachians, in an effort to find a solution to the problem of acid drainage conditions caused by land disturbance due to mining. Much of this research has been directed towards the revegetation of the waste rock left behind after the excavation of ore has been completed. It is felt that the main weakness with this approach is that it is usually assumed that present mining techniques will continue to be employed and that the problem of reclamation is one of establishing vegetation on nutritionally sterile and often highly toxic waste material. This usually requires large amounts of fertilizer and a very specialized mixture of plant species. Fertilizer applications must be made frequently and possibly for many years after the initial planting in order to maintain a permanent cover of vegetation. Also, there is no indication that revegetation will be successful in preventing the formation of acid
mine drainage conditions. Drainage water is still able to seep through the tailings, the bulk of which are not affected by a surface layer of plant cover. This approach is therefore largely an aesthetic one and does not meet the requirement of reclaiming the land to its former productivity and usefulness.

In order to achieve a successful program of mine reclamation and acid drainage prevention it is necessary that the entire mining operation, from the outset of development, be carried out under certain conditions. It is felt that if the following guidelines were adhered to in the development of all surface mining operations, the problem of acid drainage would be all but completely eliminated and that the difficulties now encountered in revegetation programs would be largely overcome:

1. A detailed investigation of the soil and overburden profile of the entire area to be disturbed by the mining operation should be undertaken prior to the onset of any major land disturbance. This would provide knowledge of the relative fertility or toxicity of the various materials that must be removed from the site in order to extract the ore.

2. During the land clearing phase of the development all fertile soil should be placed in such a
way that it can be recovered at the end of the mining operation. Possibly the best method to achieve this would involve placing the soil in piles at the sides of the operation and stabilizing it by means of seeding to provide a cover of vegetation.

3. A survey of the entire area to be affected by the mining operation should be carried out in order to determine the natural surface and groundwater drainage patterns in the watershed being disturbed. The effects of mining on these drainage patterns should then be carried out in such a way as to minimize the number of individual drainage discharges running away from the disturbed area. Ideally this would involve planning the operation in such a way that all drainage from the pit area, the waste dumps, and the tailings area leaves the site at a common point. Any water that does leave the disturbed area could then be treated with little difficulty.

4. As far as possible all water draining from the mine-site and from the tailings pond should be recycled through the mill circuit during the time the mine is in operation. This would serve to
minimize the volume of water leaving the disturbed area and would greatly reduce any treatment costs if the drainage contained excessive levels of heavy metals.

5. Iron sulfide should be separated from the rest of the tailings, thus eliminating a principal cause of acid mine drainage. The iron sulfide could then either be shipped for refining to a smelter or could be disposed of under more controlled conditions than the tailings.

6. No underwater disposal of tailings, whether in lakes or inlets, should be permitted. This is an "out of sight - out of mind" approach to the waste disposal problem. If a serious pollution problem does develop as a result of underwater disposal, there is virtually nothing that can be done to correct it. Land disposal, on the other hand, leaves the tailings in an accessible location where polluted drainage water can be treated if necessary.

7. At the end of the mining operation the soil and overburden that was stockpiled should be returned to as large an area of the disturbed land as possible and revegetation should be carried
out on the entire area.

8. Provision should be made in the reclamation program of each mine for the continued treatment of any contaminated drainage water originating from the mine-site after the mine has ceased to operate.

If the preceding guidelines are followed it is likely that many potential acid drainage situations could be prevented from occurring. Only minimal changes in the technology presently being employed would be necessary. The cost of such measures would be small compared to the cost of attempting to correct an acid mine drainage condition after it had already reached chronic proportions.


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CHAPTER 4

THE UTAH CONTROVERSY - A CASE STUDY IN
THE ADMINISTRATION OF POLLUTION CONTROL

Introduction

Both Chapters two and three have indicated that the administration of pollution control in British Columbia is not functioning adequately.

To illuminate the shortcomings in the application of what would appear to be adequate legislation, a detailed case study was undertaken of what appeared to be a typical application for a pollution control permit for waste discharge from a heavy metal mine.
The Proposed Mineral Development

In 1965, Utah Construction and Mining Co., operating from their head office in San Francisco, acquired control of a group of mineral claims adjacent to the northern shore of Rupert Inlet on Vancouver Island. Subsequent exploratory drilling and excavation revealed an estimated reserve of 280 million tons of low grade copper-molybdenum ore. Development plans were announced in June, 1969, and called for an initial investment of 70 million dollars to establish ore concentrating facilities and to clear the mine-site in preparation for an open pit mining operation with a production rate of 33,000 tons per day beginning late in 1971. A major contract for sale of the concentrate was signed with the Mitsui Industrial Group of Japan in October, 1969. The mine would operate over a projected life-span of 21 years.

On October 2, 1969, an application was submitted to the Pollution Control Branch by Utah for a permit to discharge 9.3 million gallons per day of copper mine tailings into Rupert Inlet. The effluent would contain 32,000 tons per day of finely ground waste rock, and residual quantities of all
chemicals involved in the milling process. Some of the agents involved include sodium cyanide, zinc sulfate, amyl xanthate, fuel oil, lime, and various alcohols. The effluent would be discharged by means of a submerged pipeline which would transport the waste to a depth of 200 feet in central Rupert Inlet before its introduction into the water. It was hoped that this would eliminate the possibility of visible effects on surface water, as have occurred in similar operations when the tailings were introduced at the surface.

Rupert Inlet forms the most eastward extension of the inlet system of Quatsino Sound, which extends far into the northern end of Vancouver Island from the Pacific. It is typical of coastal fjords, being relatively long and narrow, with a deep basin which is cut off from the outer water by a shallow sill. Until the announcement of the Utah development, the public land around Rupert Inlet was managed as highly productive forest land. Some logging took place near the shore in the 1930's, but regeneration has long since returned the entire area to a state of semi-wilderness. The water in Rupert Inlet is clear and cold the year round and at present supports an abundance of marine life, including crabs, shrimp, clams, oysters and codfish which contribute considerably to the diet.
of local residents, particularly the inhabitants of the Quatsino Indian Reserve at the mouth of Quatsino Narrows.

The Decision Process

The Objectors

In response to Utah's application, within 30 days the Pollution Control Branch received some 150 written objections to the permit application, as allowed under the Pollution Control Act. The objectors included the Pacific Trollers Association, the United Fishermen and Allied Workers Union, various branches of the Society for Pollution and Environmental Control (S.P.E.C.), the Richmond Anti-Pollution Association (R.A.P.A.), and a large number of individuals, many of them members of the previous groups who objected as private citizens.

The majority of these submissions were subjective in nature and simply served to express the concern of the objector for the Branch's general approach to environmental problems. Many mentioned the massiveness of the proposed discharge and questioned the potential effects on a wild and beautiful area of the province. There were also a number of submissions that raised specific issues and put forward criticisms of the project of a more technical nature. Among these was a brief submitted by a group of four biologists and ecologists at the University of British Columbia. The points raised in this brief included the following:
1) The scale of the operation is outside the range of previous experience. The effects of such a tremendous amount of material ($6 \times 10^9$ cubic feet) on a small inlet cannot be adequately predicted.

2) The dynamics of water circulation in Rupert Inlet are not known. There may be vertical mixing which would bring the effluent to the surface. The effect of the tailings on the stability of the water profile is not known.

3) The exact chemical nature of the tailings cannot be predicted. In particular the concentrations of soluble heavy metal ions, including copper and zinc, are not known. The possibility of biological concentration of these heavy metals through the food chain has not been investigated.

4) The long term consequences of an increase in the turbidity of the inlet, should mixing occur, cannot be adequately predicted.

5) Because of the scale of the discharge, it is possible that undesirable effects may be far removed in both space and time from the projected period and area.

Perhaps the most detailed submission was that made by S.P.E.C. in which a considerable number of technical questions were presented. These included the following:

1. What effect will the mining operation have on the quality of runoff water entering Rupert Inlet as land drainage?
2. Will there be synergistic effects resulting from the combination of pulp mill effluent already entering Quatsino Sound at Port Alice and the proposed mine effluent?

3. To what extent will any substances in the effluent, e.g. copper, zinc, cyanide, be concentrated in the organisms present in Rupert Inlet?

4. Is there any assurance that the continuous discharge of the effluent will not result in long-term sublethal effects that may drastically alter the present community of organisms in the inlet?

The brief suggested that the Pollution Control Branch seek the advice of the many independent biologists, ecologists, engineers, economists, sociologists, and planners whose experience and information is seldom tapped by the decision-makers. The Group requested the Branch to take the following steps before making a final decision on the permit application:

1. Hold open, public hearings so that the widest possible expression of expert and lay opinion may be heard;

2. Actively encourage individuals to testify at such hearings;

3. Give full consideration to opinions expressed at such hearings in arriving at decisions;

4. Publish full proceedings of such hearings;

5. Publish reasons for arriving at decisions; and

6. Make all such publications freely and generously
available to the public.

At a later date a detailed outline for an ecological survey of Rupert Inlet, to be conducted before commencement of any mining operation and to continue throughout its operation, was submitted by S.P.E.C. to the Pollution Control Branch and to the Federal Fisheries Department.¹³

The Pollution Control Branch was faced with opposition to the Utah application from a wide base that included commercial fishermen, vocal anti-pollution organizations, sportsmen-conservationists, experts in the biological sciences, and many members of the general public. Final consideration of the permit application was therefore postponed indefinitely. On January 16, 1970 it was announced by the Minister of Lands, Forests and Water Resources that a study had been commissioned by The Water Resources Service in his department on the feasibility of dumping mine and mill wastes into fresh and salt water bodies.¹⁴ Although the Utah development was not mentioned as the object of the study, it seemed clear that it was directed toward this problem. The work would be conducted by B.C. Research, a non-profit organization specializing in industrial research. No original research would be carried out; the study would be a literature survey only.

Even before the study was completed it was clear that
it would not provide an adequate evaluation of the problems involved. A central criticism of the proposed effluent disposal system was its unprecedented size and nature. The existing literature contains few references that would be helpful in determining the feasibility of the Utah proposal. The restriction of the study to a literature survey excluded from consideration a number of local examples which are not reported in the literature but which are relevant to the Utah situation. The Anaconda Copper mine at Britannia Beach and the Western Mines copper-lead-zinc-silver mine at Buttle Lake are both examples of mines that discharge their effluent into bodies of water, although in smaller quantities than proposed by Utah. Both these mines are readily accessible for on-site inspection and undoubtably could have provided useful field information.

The main purpose of the study was to determine an acceptable procedure for waste disposal from an environmental point of view. It could therefore be expected that the authors of the report would be chosen with this objective in mind. This was not the case. There was no participation in the project by anyone whose field of study involved consideration of the total impact of large-scale industrial activity on the environment. The sole author of the report was a research scientist whose specialty is the microbiological leaching of sulfide ores. This expertise would undoubtedly be of significance in relation to the problem of acid leaching and heavy metal pollution, but is
hardly representative of the many considerations that require evaluation in determining the total environmental effect of the proposed waste disposal system. This problem was compounded by the fact that the author had been engaged for many years in work, at B.C. Research, conducted for the mining industry. Without in any way impugning the objectivity of the report's author, it can still be suggested that it would have been desirable, from the point of view of the objectors, to include someone in the study whose relationship with the mining industry was less direct.

Meanwhile both Utah and the objectors were making efforts to articulate their positions publicly. The Company pledged to undertake "extensive investigations of its proposals before they are put into operation". Meetings were held with various groups including the local Chamber of Commerce, at which Utah officials insisted that their method of disposal was the most desirable possible. The opposing views were expressed publicly and at meetings of the various objector groups.

It is important to note that during this period S.P.E.C. was active in "negotiating" with both officials of the Company, and with top level officials of the Federal Department of Fisheries Pacific Region. S.P.E.C. officers met with Fisheries Department personnel on December 5, 1969, to seek clarification of the Department's position and potential role in
the Utah decision process. They urged release of information used in compiling the Department's evaluation of possible effects of the Utah Development. The response was that some formal method of disclosing this information might be developed. However, ministerial approval would be required. S.P.E.C. emphasized that release of this information, provided it was based on sound research, could only serve to raise the Department in the estimation of the public.18

On December 18, 1969, S.P.E.C. officials met with Utah executive personnel. At this meeting the Company provided, upon request, a complete list of chemical additives to be used in the separation process. S.P.E.C. urged the Company to voluntarily undertake an ecological survey of the proposed discharge area to determine possible harmful effects. A draft memorandum of agreement prepared by S.P.E.C.'s Counsel that provided for such an ecological survey, with a research programme to be approved by S.P.E.C. and the Department of Fisheries and conducted at Utah's expense, was accepted for consideration by the Company.19 Subsequently, a public meeting was held January 18, 1970 at Rumble Beach by the local Chamber of Commerce in conjunction with Local 514, Pulp Sulphite and Paper Workers Union of the Rayonier Port Alice Mill. S.P.E.C. and Utah representatives, as well as Federal and Provincial legislators were invited. At the meeting Utah disclosed that it had engaged T.W. Beak Consultants to conduct an ecological
The following day a detailed plan for an ecological survey of the area, prepared for S.P.E.C. by Dr. John Stimson of the University of British Columbia, Institute of Animal Resource Ecology, was forwarded to Utah.

In the result, the Company neither entered into the research agreement proposed by S.P.E.C. nor specifically followed the S.P.E.C. ecological survey plan. However, it appears that the Group's efforts were at least partially responsible for the Company's decision to undertake its own study.

One incident which occurred during this period illustrates the problem of "best advantage" data interpretation that is common in developer-conservationist controversies. In planning the underwater disposal system it was assumed that the deep water in Rupert Inlet was stable and that there was no mixing of waters between deep and surface layers. On several occasions it was stated by Company representatives that, "A sill in Quatsino Narrows only 40 feet below the water surface will stop the tailings from spreading to other parts of the Sound... But there is practically no chance they would ever go so far. Below 70 feet there is no tidal turbulence in Rupert Arm"; and that "the water in Rupert Inlet is stratified into layers of differing density with tidal action affecting only the surface layers". It was inferred from this that the deep
water was stagnant and did not mix with the surface water. It was subsequently pointed out in an article in the local newspaper that the available oceanographic data suggested that the waters were indeed vertically mixed and therefore there was an exchange of water between deep and surface layers. The Company's response to this suggestion was rather interesting. They quickly accepted it as fact, implying that it was known from the beginning. It was now claimed that "it is important to us that this interchange occur as it will prevent any long-term buildup of toxic matter in the inlet". When the contradictory nature of these statements was pointed out in a second article, there was no further comment by the Company.

The Federal Fisheries Department

The Pollution Control Act requires the Director to seek the advice of the Comptroller of Water Rights as well as the provincial departments of Agriculture, Health, and Recreation and Conservation, before the permit is issued. A copy of the application is also forwarded as a matter of policy to the Federal Department of Fisheries, whose jurisdiction includes protection of the fisheries resource, particularly the Pacific Salmon that spawn in the many rivers and lakes near the British Columbia coast. The Federal Department may therefore participate in the decision-making process by recommending in cases where it is felt that the fishery may be adversely affected by the proposed disposal scheme, either that a permit not be
granted, or that protective conditions be attached to the permit. It is in the interest of both provincial authorities and permit applicants to seek this advice, since the Department of Fisheries is clearly authorized under the Fisheries Act\textsuperscript{31} to control the discharge of deleterious substances into waters frequented by fish.\textsuperscript{32}

In the case of the Utah development, the Department of Fisheries had taken an even more active role than is usual under the pollution-control permit-issuing process. The Department was directly involved in planning the disposal method prior to the permit application on October 2, 1969.\textsuperscript{33} Utah engineers had approached fisheries officials early in 1969 to obtain their advice and cooperation. It was apparently during these consultations that the decision was made to discharge the tailings underwater rather than on the land. Utah favoured underwater disposal from the beginning, presumably for economic reasons. The Department of Fisheries also felt that underwater disposal would be the most desirable method. This decision was based on the possibility of biological leaching of tailings if they were left exposed to atmospheric oxygen on land. The facts surrounding this decision throw considerable light on the problem of information quality and interpretation in the decision-making process.

It has been observed at many previous mining operations,
in particular the coal mines of the Appalachian region, that exposed mine waste is subject to oxidation by bacteria, primarily *Thiobacillus* spp., which convert insoluble sulfides such as copper sulfide into water soluble sulfates such as copper sulfate.\(^{34}\) The products of this bacterial action are extremely toxic to aquatic life. They have resulted in large fish kills and have rendered some 6,000 miles of rivers inhospitable to fish-life in the United States alone.\(^{35}\) It is known, therefore, that toxic acid mine drainage may result from land disposal of mine tailings due to the presence of atmospheric oxygen which is necessary for the bacterial oxidation mechanism. It was apparently felt by the Company and by Fisheries Department officials that underwater disposal would provide a solution to this problem. Subsequent oceanographic studies, however, tend to cast serious doubt on the correctness of this assumption, as shown below.

**The Deep Water Mixing Problem**

As mentioned previously, at the time of the permit application, the Company's public statements suggested that it was known that the deep water in Rupert Inlet did not mix with the surface water, and therefore the tailings would not be brought to the surface. It followed that the deep water would also be very low in dissolved oxygen, since it was not replaced

* For a more complete discussion of this problem, see Chapter 5.
periodically by fresh oxygenated water from the surface. It is only in the upper layers of water, due either to photosynthesis by phytoplankton, or to diffusion from the atmosphere, that oxygen is added to the marine system. Water that remains at depth for long periods gradually becomes low in dissolved oxygen as it is used up by the organisms living there.

When the permit application was filed, the provincial and federal departments involved were approached to determine their positions regarding the discharge. Both the Provincial Department of Recreation and Conservation\(^3\) and the Federal Department of Fisheries\(^3\) cited the existence of a stable water body and a low dissolved oxygen content in deep water as the primary reasons for the decision to employ underwater disposal.

There have been only two studies of Rupert Inlet which involved the collection of basic oceanographic data.\(^3\) One of these was conducted by the Fisheries Research Board of Canada and included the results of four oceanographic cruises in the Quatsino Sound area. In both of these studies, dissolved oxygen values from 50 to 75 per cent saturation at 400 foot depths were reported in Rupert Inlet. Dr. G.L. Pickard also reported high oxygen values in the deep water and states that this condition could not exist unless there was vertical mixing in the Inlet, with the deep waters being periodically replaced by surface water.\(^3\) The source of the information that led the
Department of Fisheries to the opposite conclusion regarding both oxygen content and water circulation is not clear. Certainly the Department's conclusion seems contrary to the results of the research done by the Fisheries Research Board, a main function of which is provision of information for use by the Department of Fisheries.

The existence of high dissolved oxygen levels in the deep water was pointed out to the Department of Fisheries in December, 1969. The position of the Department did not change as a result and remains the same even though the presumed low oxygen concentration was central to the reasoning put forward for underwater disposal. This decision had apparently become irreversible even in the face of documented technical information which indicated that the original assumptions were inaccurate.

There is another implication of high dissolved oxygen apart from its significance in determining the Inlet's water circulation. It was assumed that sulfide oxidizing bacteria would not be capable of operating on the tailings if they were placed underwater, particularly in water with a low oxygen content. However, it has been shown that there are also marine forms of *Thiobacillus*, and these are well adapted to underwater conditions. The high dissolved oxygen content in Rupert Inlet would almost certainly be sufficient for their growth. The tailings surface could provide a substrate which
would support a large population of these organisms resulting in the release of soluble heavy metal ions into the marine environment.

Public Participation

"Processing" the Objections

On July 3, 1970 the 150 objectors were informed by the Pollution Control Branch that the B.C. Research study on "The Disposal of Mining and Milling Wastes With Particular Reference to Underwater Disposal" had been completed. The report recommended that tailings from ore concentrators should be placed in deep water wherever possible. Since this is what Utah intended to do, the effect of the report was to support the Company's position. It is difficult to understand the reasoning behind the conclusions in the study. Not one reference was cited which indicated that the proposed method of disposal had been employed successfully at any other mine. This was probably due to the unprecedented and therefore undocumented nature of the proposed disposal system.

The form letter to each of the objectors dated July 3, 1970, which announced the report's completion, enclosed an abstract and advised that a limited number of copies of the report were available at Pollution Control Branch offices on a two week loan basis. The letter continued:

In order that all available data relative to the
application set out above can be considered at this time, and in the event you wish to support your original submission further, documented written briefs based on technical data which supports your position will be received and considered. In order to expedite this matter, these briefs must be received in this office no later than August 3, 1970.44

The majority of the objectors felt that their original submission had sufficiently expressed their concern and opposition. Some, like S.P.E.C., reviewed the report, and concluded that since it was merely a literature survey, it added nothing that called for further comment. Therefore, most objectors decided that they did not wish to submit further material and did not respond to the letter.

On September 4, 1970 all but four of the 150 objectors received a form letter from the Director that read in part as follows:

I have noted that you did not respond to our letter of July 3, 1970 in the allotted time and you are advised therefore in accordance with subsection 4 of section 13 of the Pollution Control Act (1967) that your objection (if you intended your original letter to be an objection) does not warrant a hearing.45
Subsection 4 of section 13 states that:

The Director shall decide in his sole discretion, whether or not the objection will be the subject of a hearing, and shall notify the objector of this decision.\textsuperscript{46}

It appears that the basis upon which the Director exercised this discretion was whether or not further material had been filed in response to his July 3 letter, even though there was no indication in that letter that failure to do so would result in an objector being excluded from the decision-making process. In fact, at least one objector who did file further material received the same form letter dated September 4, 1970.\textsuperscript{47} In the same letter the objectors were informed that:

You may be interested to know that a hearing will be held in Kinsmen Recreation Hall, near Port Hardy Airport at 8:30 a.m. on September 16, 1970 to hear those who replied to our letter of July 3, 1970. The procedure for the hearing will be determined and announced by the Director at the commencement of the hearing.\textsuperscript{48}

Subsequently, it was disclosed that only four objectors had been named to make representations at the hearing. These were: a housewife and a pulp and paper worker, both from Duncan, B.C., a retired gentleman from North Vancouver, and the Pacific Salmon Society, an association representing the interest
primarily of sports fishermen and marina operators. None of these objectors had included technical briefs with their submissions, and none had first hand knowledge of the Quatsino Sound area. The reply of the Pacific Salmon Society to the July 3rd letter had merely stated that:

The Pacific Salmon Society is not able to submit a detailed brief, as suggested, within the time limit of August 3rd, 1970.

At this point then, further participation in the permit decision process had been denied to the most directly concerned and knowledgeable individuals and organizations. In particular, groups likely to be very directly affected by the grant of the permit such as the Pacific Trollers Association and the United Fishermen and Allied Workers Union, were not permitted to make public representations. These groups represent the commercial fishermen whose livelihoods depend upon salmon runs such as that of the Marble River which flows into Rupert Inlet.

In response to their exclusion from the hearing, S.P.E.C., the largest and most vocal of the anti-pollution groups, sent an open telegram to the Pollution Control Branch which read in part:

If you wish to hold a public hearing on Utah,
please consult a lawyer to find out what that
means. If you do not wish to hold a public hearing on Utah, you will find yourself in a court of law.51

By this time one of the reasons for the agency decision to hold a public hearing on the Utah application had become clear. In an interview, the Director disclosed that he was following the procedure outlined, as a result of a B.C. Supreme Court decision handed down in May, 1970, in which Mr. Justice Wootton had criticized him for failing to act "in a judicial manner" on a permit application by Hooker Chemicals Ltd. of Nanaimo.52 In both the Hooker Chemicals case53 and the earlier case of Western Mines Ltd. (NPL) v. Greater Campbell River Water District,54 decisions of the Director on permit applications were quashed on the ground of failure to allow objectors to properly substantiate their objections, and therefore failure to act in accordance with the principles of natural justice.55 Since these cases have elaborated the procedural requirements for dealing with objections under the Act, they must be examined in detail, and the Director's procedure on the Utah application considered in light of them.

In Western Mines Ltd. v. Greater Campbell River Water District56 an objection had been filed by the Water District, which held an appropriation licence under the Water Act,57 to the company's application for a permit to dump mine-mill waste
into a fresh-water lake, source of the river from which the District drew its water supply. After receipt of the objection was acknowledged by the Pollution Control Board, the District retained the B.C. Research Council to prepare a report on the possible effect on its water supply of the Company's proposed discharge. There was no further communication between the District and the Board until the Board wrote to the District's solicitors informing them that their objection had been considered and "dismissed", and that permits were being issued to Western Mines Ltd.

The District immediately moved for a writ of Certiorari to quash the permits. At trial, the application was dismissed on the ground that the Board, in determining permit applications, exercised an administrative as opposed to a judicial function. A purely administrative body has no duty to provide adequate notice or an opportunity to be heard to a party affected by its decision; and in any event Certiorari lies only to a tribunal that exercises judicial functions.

However, this decision was reversed on appeal. The majority of the British Columbia Court of Appeal (Davey and Branca, J.J.A.) held that while the Pollution Control Board is an administrative body, procedurally it might, at certain stages of its process, be required to act judicially. The provisions of the Act allowing persons whose rights would be affected by
the granting of a permit to file objections show that the Board must proceed in a judicial manner in considering these objections.⁶³ Although section 17(2) of the Pollution Control Act⁶⁴ allows the Board to decide "in its sole discretion whether or not the objection will be the subject of a hearing", this does not mean that the objector can be denied a reasonable opportunity to support his objection informally, by written submissions for example, if a hearing is denied. The section, said Davey, J.A.,

confers a right to make an effective objection and that means, surely, the right to have the objection considered by the Board. This in turn implies a reasonable opportunity to support the objection by representations so that the Board may rule upon it intelligently. Anything less makes the statutory right to file an objection illusory and farcical.⁶⁵

Following this decision, and apparently in response to the wave of public concern about the quality of the province's environment generated by the Western Mines controversy, the Pollution Control Act⁶⁶ was repealed and re-enacted as the Pollution Control Act, 1967.⁶⁷ Provision was made for appointment of a Director to be responsible for administration of the Act, including the permit issuing process.⁶⁸ To the Board was left the task of advising the Minister on policy matters,
undertaking investigations at the request of the Minister, and acting as appeal tribunal from decisions of the Director.

Important changes were made in the objection provisions. Section 17(1) was replaced by the subsection outlined previously that limited the right to file objections with the Director on permit applications to:

Any person who has an interest in land or who is an applicant for or the holder of a permit or licence issued under this Act or the Water Act, who claims not the land or any interest under such permit or would be affected by the granting of a permit...

However, a new subsection was added that allowed any person who fell outside the specified class to file an objection with the Pollution Control Board, which must then decide "whether the public interest requires that the Director take the objection into consideration in making his decision."

It was under this subsection that an objection was filed in March of 1970 by Lawrence Jones, a commercial fisherman, to an application by Hooker Chemicals Ltd. of Nanaimo to discharge chemical wastes into Georgia Strait. Without any further communication, the Director informed Jones that his objection would not be the subject of a hearing. A writ of Certiorari was then sought to quash the Director's decision
denying a hearing. The action was brought with the backing of the Nanaimo Branch of the Society for Pollution and Environmental Control. The S.P.E.C. group had also filed an objection, however it was felt that the more readily identifiable economic interest of the fisherman made him a better plaintiff.

Wootton, J. held that the Director fell into error by making his decision not to hold a hearing on the objection without first supplying Jones with the technical material filed in support of the application, and giving him an opportunity to consider that material and reply to it. Before making his decision not to grant a hearing, the Director was required to proceed in the manner outlined by Davey, J.A. in the Western Mines Case, i.e. "(allow) the objectors to know the essentials of the case they have to meet and a reasonable time in which to support the objections, at least informally, by material and submissions..." Therefore, the Director's order was quashed, and the matter referred back to the Pollution Control Branch.

The Hooker Chemicals case is particularly useful from the public participation standpoint because viva voce evidence as to Pollution Control Branch procedure was given by the Director. In cross examination by counsel for Jones, Mr. Venables explained the manner in which objections by members of the public are dealt with by the Branch. This became important in the case because Jones had addressed his objection to the
Director, rather than to the Board as section 13(6) would seem to require. There was some question, therefore, whether the objection was properly made under the provisions of the Act.

In answer to a question whether he had accepted a letter by an owner of water-front property located two miles from the Hooker Chemical plant as an objection properly lodged under section 13 of the Pollution Control Act, the Director replied:

I take cognizance of all evidence before me whether it is in the form of an objection or otherwise.

Later in the cross-examination the following exchange took place:

39 Q Yes. Now, Mr. Venables, I understand that in addition you gave in your evidence that you took into consideration any objections that were filed by - from other sources to the Board, is that correct?

A I don't believe I put it that way.

40 Q I see.

A We take some of these objections that are actually filed or written to the Minister or to the Chairman of the Board; there is quite a lot of confusion about the Board's position, etc., and they end up on our desk.

41 Q Yes.

A - officially accepted, and we recognize them.
42 Q So this is again where you are exercising your discretion, is it not, to recognize any person who writes, whether it be to the Minister, to the Board, to you as the Director, to whoever it is, so long as there is an objection to the application for the permit you will then look at it then and consider it a properly-filed objection?

A That is right, but can I qualify that?

43 Q Yes.

A This is fine in appreciation of the fact that we are working within 30 days, and the fact that everybody doesn't know the act. By writing back and forth we feel that does nothing but create confusion and that they are misdirecting their correspondence; so in the light of those facts, what you say is correct.77

The practice of the Branch seems quite clearly to be recognition and consideration of all objections whether filed by persons having an interest under section 13(2) or by other persons entitled only to object to the Board under section 13(6). Persons in the latter class are accorded status as objectors by the Director without the Board first determining whether the public interest requires that the Director consider their objections. The effect of this practice78, coupled with the decision in the case, was to accord members of the public a
wider opportunity to participate in the decision process than might be strictly necessary on a narrower interpretation of the legislation.\textsuperscript{79}

While acknowledging the Director's sole discretion as to hearings on objections, the tenor of the judgement suggests that hearings would be desirable in many cases.\textsuperscript{80} Wootton, J. also strongly suggested that the Director should establish a procedure that would ensure that the requirements of notice and opportunity to consider and respond are properly met.\textsuperscript{81} He also recommended that when the Director denies a hearing on an objection, he should clearly notify the objector of his right to appeal that decision.\textsuperscript{82}

With the Utah controversy boiling around him when the Hooker Chemicals judgement was handed down, the Director was quick to heed the judicial advice. Unfortunately, something was lost in his interpretation of Wootton, J.'s suggestions, as the hearing procedure adopted by the Director on the Utah application amply demonstrates.

On the face, then, the Utah hearing appeared designed to satisfy the apprehended legal requirement of holding a hearing, while at the same time effectively limiting both the presentation of relevant technical information and the range of public participation. On September 14 the scheduled hearing was postponed indefinitely when the Director developed a sore throat.\textsuperscript{83}
Opposition to the discharge of effluent into the inlet had been voiced early in the Summer of 1970 by the Board of the Regional District of Mount Waddington, which is the local government of northern Vancouver Island. At a meeting of the Board on August 3, 1970, it was resolved that the regional district "can't condone the method of waste disposal proposed by Utah Construction and Mining Co. in their operation at Rupert Inlet". The Board also expressed the desire to participate in any public hearing that might be held on the permit application. As a result of their exclusion from the hearing scheduled for September 16, the Board expressed criticism of the manner in which the matter was being handled by the Pollution Control Branch. At a meeting of the Board on September 21, the Chairman stated,

If it's public and open no one is suspicious, but when they hold private meetings about things like this you can't blame people if they treat it with the suspicion that something underhanded is being done. I think it's noteworthy that nobody from this area, none of the municipalities or anyone else, was asked to appear to the hearing.

On November 6, 1970 the four official objectors were informed that the hearing had been rescheduled for December 2 in Port Hardy. Each objector would be permitted the assistance
of one technical advisor who would be included as a participant at the hearing.

Meanwhile, the delay of over one year in the granting of the Pollution Control Permit had not been reflected in any delay by the company in developing the mine-site. Clearing had begun in January, 1970, three months after it had become apparent that there was considerable opposition to the proposed disposal scheme. By the fall of 1970, the Company had cleared over 1000 acres of timber, begun excavation and removal of over-burden, installed a deep-sea wharf to receive construction materials, and commenced construction of the main mill building as well as many smaller structures.

Approvals for these activities had been obtained from a number of Federal and Provincial agencies. Approval under the Federal Navigable Waters Protection Act was required to construct the wharf facilities.\textsuperscript{87} Certificates of work were filed with the provincial Mines Branch as required by the Mineral Act\textsuperscript{88}, along with a reclamation plan as required by the Mines Regulation Act.\textsuperscript{89} In addition, a permit allowing diversion of water for processing purposes had been obtained from the Comptroller of Water Rights,\textsuperscript{90} and a high voltage power service had been installed by the Crown Corporation B.C. Hydro and Power Authority.\textsuperscript{91} All of these regulatory hurdles had been cleared before any hearing on the Pollution Control Permit
application was held. Over 350 men were permanently employed at the mine site.

The company management was well aware that the operation of the mine could not begin unless a permit was obtained. The Minister of Municipal Affairs, himself a member of the Pollution Control Board, was asked why Utah was permitted to develop the mine site before obtaining a permit. He replied that "work that is now going ahead is being done on the company's own responsibility". However, it seems unlikely that the company would invest 30 million dollars in building concentrating facilities if it foresaw any real possibility of failure to obtain a permit. In fact, the Director himself interviewed just prior to the hearing conceded that it was obvious that the development would go ahead and that the only question was what technical disposal requirements would be imposed. At the hearing, in response to a question by Mrs. Elaine Price, one of the recognized objectors, whether it is "... fair to presume that Utah started its operation assuming it would get a permit?": R.O. Wheaton, Utah administrative manager replied: "Yes, that is fair to assume."

One week before the hearing an event occurred that was perhaps the most dramatic public response in the entire Utah affair. A petition which protested the "arbitrary action" of the Pollution Control Branch in refusing to allow S.P.E.C.
and other groups to object publicly, was signed by 241 of the 350 employees engaged in the construction of the Utah mill site. The Chairman of the Petition Committee stated that:

It's a very important issue, one which could have serious effects on all of us and could be a danger to our children and grand-children. We feel there could be a danger of pollution to Rupert Inlet and the fact that the Board refuses to hear S.P.E.C.'s brief makes us feel this more strongly.

Such an unprecedented show of environmental awareness on the part of union members who depend directly on the mine's construction, is indicative of the wide base of public opposition to the project. It also suggests extreme lack of public confidence in the ability of the Pollution Control Branch to work effectively toward the goal of improved environmental quality.

The Hearing

The hearing on the Utah application was held as scheduled on December 2, 1970 in Port Hardy. Although the objectors were permitted only one advisor each, and did not formally have the right to counsel, the Utah representative was supported by three technical advisors, a senior company official from San Francisco, and two lawyers including senior counsel.

Through S.P.E.C. the lay objectors had obtained three
advisors: a marine biologist from Simon Fraser University, an oceanographer from the University of British Columbia, and a member of the U.B.C. Law Faculty. The Pacific Salmon Society was represented by a PhD. Ecology student who had shortly before become a member of the Society and who acted as his own technical advisor. The Pollution Control Branch had helpfully provided the objectors (on the day of the hearing) with a list of "suggested questions", apparently culled from the rejected objections, intended to aid in cross-examination of company officials. S.P.E.C. officials organized tactics meetings of the recognized objectors and their technical advisors prior to the hearing, and the Society assumed the cost of accommodation and transportation to Port Hardy for three of the objectors and their advisors.

When the Pollution Control Branch hearing opened, Mr. Venables, the Director, made a short opening statement in which he outlined the scheme and operation of the Pollution Control Act, and indicated the purpose of the hearing that day. He made it clear that so far as the Pollution Control Branch was concerned, the applicant must give adequate assurance that the works contemplated by the application will not cause pollution. He then stated that the Act empowers him to determine his own procedure, and proceeded to outline for the first time the procedure to be followed at the hearing. Generally, the format was that the applicant, Utah Construction and Mining Company,
would present its application first, followed by cross-examination by the four recognized objectors and/or their advisors. Following cross-examination, the objectors would make their presentations, and themselves submit to cross-examination by the Company representative or his counsel. Next, questions from the public in the hall would be allowed to any of the sworn witnesses, whether Company representatives or objectors. Finally there would be a closing statement by the applicant and cross-examination of the applicant and its advisors by members of the panel which consisted of the Director, his counsel, and three Pollution Control Branch members, two of whom were engineers and the third a PhD. biologist.

The brief presented by the Company in support of its application was lengthy and contained preliminary studies of currents, density profiles, and bottom fauna. It became apparent, however, through the cross-examination by the objectors and the presentation of their briefs, that the studies which had been done were not conclusive in answering the fundamental ecological problems involved. Sweeping generalizations as to the effluent's harmlessness had been made on very limited observations. In particular:

(1) The possibility of biological concentration of heavy metals was not even considered in the Company's lengthy brief. The fact that accumulation of copper and lead has occurred in fish near a similar tailings outflow at Buttle Lake
on Vancouver Island suggests that the authors of the brief were either unaware of basic biological considerations, or simply avoided discussion of the subject.\textsuperscript{99}

(2) The possibility of bacterial oxidation of heavy metal sulfides in the marine environment was not considered in the brief. The implications of this possibility on the eventual levels of soluble heavy metals in the Inlet deserve at least preliminary investigation.

(3) The extent of possible heavy metal pollution resulting from the exposure of the ore surfaces in the open pit was not discussed in the Company's brief.

(4) The only investigation of direct toxicity of the effluent to marine organisms was a 96 hour test involving coho salmon fry in a 100 per cent concentration of simulated tailings water.\textsuperscript{100} The fact that these tests were not carried out by the accepted method adds to the many inherent limitations of 96 hour tests.\textsuperscript{101} No tests were conducted on organisms most likely to be affected such as clams, crabs, phytoplankton, etc. No tests were carried out on any organisms to indicate possible sub-lethal effects of the effluent.

(5) The limited tidal current measurements made by B.C. Research on behalf of the Company indicated that "deep water currents do occur" in Rupert Inlet.\textsuperscript{102} This conclusion was not favourable to the Company as it indicated that bottom scouring and vertical mixing may occur. These actions would
tend to bring the tailings into surface waters. At the hearing the authors of this study were not represented. Instead the Company engaged an independent consultant to reinterpret the B.C. Research data. Whereas the conclusion of the B.C. Research study was "data are insufficient to document reliably any current patterns", the Utah consultant concluded that "current measurements are adequate to indicate the general strength and character of the currents". These conclusions were both made on the basis of the same observations taken during the B.C. Research study.

(6) The biological survey of Rupert Inlet was designed to favour the Company's contention that there was not significant marine life in the inlet. Nearly all samples taken were of the bottom sediments below 100 foot depths. The report concluded that "benthic productivity in the deep central basin of Rupert Inlet is not high". No attempt was made to estimate primary productivity in the Inlet and no samples were taken in the more productive intertidal and euphotic zones. The production of commercially valuable species of crabs, shrimp and bottom fish was not considered in the brief.

(7) The report presented on the measurement of density profiles in Rupert Inlet concluded that "density stratification exists through the entire water column within Rupert Inlet". The only actual measurements made were taken on one day, June 17, 1970, and were reported for only two stations in Rupert Inlet.
The generality of the conclusion is obviously not justified, given the limitations of the data in both space and time.

It was clear from the reaction of Utah's consultants that they had not expected serious questioning of both the limitations of their data base and their lack of consideration for the biological components of the marine system. A member of the press who attended the hearing reported that the objectors "had the harried Utah experts scurrying to their records for additional data in support of their application. The impression created was that Utah's proposed system of monitoring the effect on marine life of the tailings would be inadequate, and that Utah had not been convincing in claiming that the discharge would not create excessive turbidity of surface waters."  

It should be noted though that the technical dialogue was carried on almost entirely by the Utah consultants and the scientific advisors of the recognized objectors. The reading by the objectors of their previously submitted briefs was largely a formality, since the briefs dealt mainly with the more general question of overall environmental quality standards for the area, and the need for pre-development planning. Several of the briefs pointed out that lay objectors could not and should not be expected to produce technical information. Nevertheless, it was technical information only that interested the hearing panel, and a number of questions raised by objectors
in cross-examination that involved policy issues were quickly
ruled out of order by the Director. At the end of the day the hearing was adjourned sine
die pending the outcome of appeals that had been filed by
both S.P.E.C. and R.A.P.A. with the Pollution Control Board under
the Pollution Control Act internal appeal procedure. Both
groups felt that they had been unjustly excluded from the
December 2 hearing, and were determined to be heard in a public
forum.

Pollution Control Board Appeal

Following the letter from the Pollution Control Branch
dated November 6, 1970, S.P.E.C., along with the Richmond Anti-
Pollution Association, had decided to appeal the Director's
decision to exclude them from the Port Hardy hearing, to the
Pollution Control Board. In his letter, the Director had
specifically indicated that he considered his decision to hold a
hearing and to hear the persons listed, to be an appealable
order under the Act. In providing this information, he appeared
to be following the suggestion made by Wootton, J. in Reapplica-
tion of Hooker Chemicals (Nanaimo) Ltd. Again the Director
seemed to respond directly to the judicial criticism levied in
the Hooker Chemicals Case.

Both groups forwarded notices of appeal to the
Director of Pollution Control with covering letters requesting
postponement of the hearing scheduled for December 2nd, 1970 pending the outcome of the appeal.\textsuperscript{111} The notices of appeal were also served on Mr. F.S. McKinnon, Chairman of the Pollution Control Board.\textsuperscript{112}

Two main grounds were urged in the similar notices of appeal filed by the two groups, namely:

(1) that the procedure followed by the Director deprived the groups of their rights to natural justice and fair treatment under the Pollution Control Act because inadequate notice was given of the consequences of failure to reply to the Director's letter of July 3rd, 1970. It was made clear by the Director only afterward that response to the letter was a prerequisite to further participation in the decision process; and

(2) that the venue of the hearing was inappropriate because, as the Pollution Control Branch well knew, many of the objectors were located in the lower mainland region of British Columbia. Transportation to Port Hardy from the Vancouver area is costly, and as became clear during the hearing, accommodation in Port Hardy is inadequate for large numbers of objectors.\textsuperscript{113} They suggested that their objections were meritorious and that the public interest requires the Director to take their objections into consideration in reaching his decision on the permit application.

The Director's reply stated in part:
Your attention is ... directed to sub-section 7 of section 12 of the Pollution Control Act, 1967, which states: "No appeal shall act as a stay of execution" and accordingly you are advised that the hearing on the application from Utah Construction and Mining Company will be held as scheduled at Port Hardy on December 2nd, 1970.¹¹⁴

Following adjournment of the Port Hardy hearing, the appeals were heard by the Pollution Control Board¹¹⁵ in Victoria on December 8, 1970. The first presentation was made by the agent of the Richmond Anti-Pollution Association, who argued that the Association had been unfairly discriminated against in that it had not been chosen by the Director to appear as an objector at the Port Hardy hearing; that the Association was not given a proper opportunity to be heard in support of its objection; and that the location of the hearing at Port Hardy was inappropriate since many of the objectors, including R.A.P.A., were located in the Vancouver area and accommodation at Port Hardy was limited.¹¹⁶ Strong reliance was placed on the Director's failure to provide proper notice of the consequences of failure to reply to his letter of July 3rd.¹¹⁷ Also, since new material in support of the application, including the T.W. Beak Consultants report,¹¹⁸ had come forward at the hearing, he argued that failure to allow R.A.P.A. a proper opportunity to respond to this material resulted in a denial of
natural justice within the principles laid down in Western Mines Limited v. Greater Campbell River Water District, and Re Application of Hooker Chemicals (Nanaimo) Ltd. Apart from the strict legal argument, he emphasized that R.A.P.A. should not have been excluded from the hearing for two reasons: first, it had demonstrated by its actions that it is an interested and responsible organization, and if given an opportunity to respond to the new information submitted by the Company at the hearing, it may provide valuable new insights; and second, public confidence in the administration of the Pollution Control Act is undermined when an organization representing a significant segment of the public is excluded from an agency hearing.

S.P.E.C.'s counsel then presented the appeal on behalf of that group. He incorporated by reference the legal argument with respect to notice and hearing that had been submitted on behalf of the Richmond Anti-Pollution Association, then outlined S.P.E.C.'s involvement in the permit application process, and indicated the range of technical and scientific experts available to S.P.E.C. He also stated that S.P.E.C. had additional technical information to present in an appropriate public forum.

Lands, Forests and Water Resources Minister, Ray Williston, one of the Pollution Control Board members, entered the hearing room approximately half way through the argument presented on behalf of the Richmond Anti-Pollution Association.
Later he addressed some comments to the group representatives. In particular, he told them that appeals and procedural wrangles were simply time wasted. No formal hearings or procedures should be necessary. If groups have information, he said, they should simply send their briefs to the Director, and to the press.122

The Board's decision on the appeals was rendered the following day. Each group received identical written reasons as follows:

The Appeal is disallowed; however, in view of the fact that the appellants state that they have certain new technical information available regarding the application by the Utah Mining and Construction Company, the appellants are requested, if they so wish, to forward this information, in writing, to the Director of Pollution Control, within thirty days of the date of this order, and the Director of Pollution Control is instructed not to make any decision regarding the said application before he has considered the aforesaid information.123

This decision left the groups facing something of a dilemma. On the one hand, the opportunity to file further material could be construed as a limited victory. However, it
was felt that any response at this point would be accorded little weight, and in any event it would have a lesser impact than it would if presented at a public hearing and adequately publicized. Also, there was reason to believe that the members of the Pollution Control Board, none of them legally trained, had simply failed to appreciate the weight of the arguments based upon failure to provide adequate notice and a full and fair opportunity to be heard at the hearing. If further technical material were filed as allowed by the Order, there was fear that the main point relating to the hearing might be taken to have been waived by the groups. There was of course a further appeal to the Supreme Court (or to the Cabinet) within thirty days following the Board's Order, but many group members felt that since the permit was likely to be granted very shortly, a more effective action might be one for a writ of Certiorari to quash the ultimate decision to grant the permit. Since the issues in an appeal to the Supreme Court under s. 12 of the Act, and in subsequent certiorari proceedings, would be substantially the same, the possibility of waiver again became a real danger if the latter course were adopted.

In the result, two of the possibilities were covered. R.A.P.A. filed a further technical brief within the thirty day period, while S.P.E.C.'s Executive Director simply wrote a long letter to the Director of Pollution Control reiterating the group's position on its failure to be heard, and otherwise
did nothing more.

Resulting Policy and Procedural Changes

Permit Conditions

On January 20, 1971 the public hearing was formally closed by the Director. The following day Utah Construction and Mining Co. was issued a permit by the Pollution Control Branch to dispose of 9.3 million gallons of copper mine waste daily into Rupert Inlet. The disposal system was to be no different from that originally proposed by the Company. The permit did however contain a number of specific requirements that the Director of Pollution Control termed "stringent anti-pollution safeguards". Among these were requirements that:

1. The Permittee shall not fail to secure tenure to land sufficient and suitable for a tailings disposal pond on or before December 31, 1973, or prior to discharge, whichever date is the sooner.
2. The Permittee (shall) ... design and construct an emergency tailings pond to acceptable engineering standards and such shall be maintained in good repair throughout the life of the permit.
3. The Permittee shall not fail, prior to commencement to discharge, to post security in an acceptable form in the amount of $1,500,000.00 for a period of five (5) operating years after discharge commences.
The security or a portion thereof will be subject to forfeiture should the Permittee fail to comply with an order of the Director to construct an alternate or modified system of treatment and/or discharge.

4. The Permittee shall engage an independent agent or organization to set up and conduct a two-phase sampling and surveillance program which will be carried on for at least five (5) operating years after discharge commences – all subject to approval by the Director ...

(a) to ascertain the natural conditions in the receiving environment through monitoring the variations in physical-chemical-biological characteristics of Rupert Inlet, Holberg Inlet, Quatsino Narrows and related waters...

((b)) to ascertain the effects of the effluent discharged into the receiving environment through monitoring of the physical-chemical-biological characteristics of Rupert Inlet, Holberg Inlet, Quatsino Narrows and related waters.

Despite their initial appearance the first two requirements do not represent any significant change in the original disposal plan. The Company already had control of far
more land than would be necessary for land disposal of the
tailings. The construction of an emergency tailings pond
was proposed long before the granting of the permit. The
Company had included it in plans of the mine prepared prior to
the public hearing.\textsuperscript{131} Presumably it was considered necessary
in the event of a failure in the underwater disposal system.
Diversion of the tailings to the emergency pond would allow
the mill to continue operations while repairs were made to
the system.

One requirement not contemplated by the Company in
its proposal was the posting of the bond as security against
construction of the tailings pond. However, there is no
reason to believe that the Company would not build the tailings
pond if it were not required to post the bond.

At the time the permit was issued it was uncertain
whether this security would be available as compensation for
damage to the Inlet caused by the effluent. The permit states
only that the security is posted against failure to construct
an alternate or modified disposal system on the order of the
Director.

A meeting of the Pacific Salmon Society on February
20, 1971, was attended by the Minister of Municipal Affairs who
was at the time also a member of the Pollution Control Board.
The question of compensation for damages was put to him at the
meeting and he promised to write an answer to it on his return to the capital. In his letter, however, he simply restated the terms of the permit and did not address himself to the questions asked. It would seem probable, therefore, that the security is not intended as compensation for any damage that results in the Inlet from the effluent discharge.

The emergency tailings pond will be built on the shore of Rupert Inlet, using an island near the shore as one wall of the dam. It will therefore be of little use to place the tailings in it should problems arise as a result of their disposal in the Inlet, since drainage from the emergency pond would be directly into the Inlet. A shift to using the pond would merely move the tailings from one part of the Inlet to another.

The fourth provision of the permit, that requires the Company to undertake a program of biological monitoring, is an indication of some advance in pollution control policy. Although the disposal system will be no different from that originally proposed, there is now the possibility that damage to the Inlet will be identified before it becomes serious. There is no guarantee, however, that a monitoring system will be successful in avoiding any undesirable effects of the discharge. If, for example, copper is found to accumulate in some organisms through food-chain concentration or some other mechanism, it is possible
that there will be a considerable delay from the time of introduction of the tailings until significant amounts of copper appear in animal tissue. In this situation, contamination may continue to grow worse even after the discharge of tailings has been stopped. It is possible that laboratory experimentation aimed at determining the accumulation rates of heavy metals in marine organisms would assist in the understanding of these problems. At present there is no indication that research of this nature will be attempted.

In order to comply with the requirement of an independent agent to set up the biological monitoring program, Utah approached the University of British Columbia through the Mineral Engineering Department. This resulted in an agreement between Utah and U.B.C., approved by the U.B.C. Board of Governors, for a monitoring program covering the period March 1, 1971 to August 31, 1972. The supervisor of the program is Professor J.B. Evans, Head of the Department of Mineral Engineering. The cost to Utah of the U.B.C. assistance for the initial period will be $40,500. Total cost of the program will be substantially more since a large part of the actual data collection and analysis will be carried out by commercial consultants and Utah employees. The main functions of the U.B.C. Committee are design of the program and interpretation of the data.
The pollution control permit issued to Utah states that:

Prior to and for the first year after commencing to discharge, data collected during each quarter shall be tabulated and submitted quarterly to the Director;

and also that the independent agent must:

Submit comprehensive reports containing the tabulated data of the sampling and surveillance program. The data is to be interpreted and submitted to the Director in such a form that it may be published. The first report shall be submitted approximately at the time of, but prior to commencement to discharge and at annual intervals thereafter.\(^{134}\)

The permit does not specifically state that the results of the program will be published and made available to the public; but the Branch appears to have committed itself verbally to this policy.\(^{135}\)

An important consideration is the composition of the committee in terms of the academic disciplines represented. At present, the three main areas of study represented are Mineral Engineering, Geology, and Oceanography, with four members from each of these departments. This composition suggests that there is a serious risk of repeating the
inadequacies of the report produced by B.C. Research when that organization was commissioned to conduct the study into the feasibility of discharging mine wastes into water bodies. In that case a specialist in microbiology was given the entire task of determining the most ecologically acceptable disposal method. In the case of the advisory committee, it appears that the task of directing a biological monitoring program has been assigned to a group in which engineers and physical scientists greatly outnumber life scientists.

The two biologists on the committee are both from the Institute of Oceanography; one a specialist in marine phytoplankton, the other in marine zooplankton. Because of the particular structure of the departments at U.B.C., there is no one on the committee whose specialty involves fish and other members of the nekton (free swimming organisms). These areas of study are well represented in the Department of Zoology, but this department was not directly involved in the consultations that led to the formation of the committee. This is regrettable as their full participation would probably have enhanced the committee's ability to interpret the biological data on which recommendations to the Director will be based.

The Environment and Land Use Act

The Utah controversy has also resulted in enactment
of a new statute by the British Columbia Legislature, designed to ensure consideration of environmental impact in use and development of public land and resources. The Environment and Land Use Act\textsuperscript{136} authorizes establishment of a Cabinet Committee empowered to formulate and recommend programs to foster increased public environmental concern and awareness; ensure consideration of environmental factors in land use and resource development, and minimize consequential environmental damage; and prepare reports and make recommendations to the Lieutenant-Governor-in-Council relating to environmental problems in the development and use of land and other natural resources.\textsuperscript{137} The Committee may also appoint technical committees, engage consultants, and hold public inquiries when it deems an inquiry necessary to properly determine any matter within its jurisdiction.\textsuperscript{138}

This Committee appears to be the direct result of a rather surprising policy statement by Lands, Forests and Water Resources Minister, Ray Williston, following granting of the Utah permit. He stated in the Legislature that in future, large extractive resource developments would not be allowed to proceed until pollution control approval had been obtained. This, he said quite candidly, would prevent a repeat of the Utah situation where massive capital investment by the Company prior to permit approval had created overwhelming economic imperatives that could be set against the environmental concerns raised during the permit application process.\textsuperscript{139} He emphasized that
these go-ahead approval procedures would include evaluation by technical experts and public hearings. Mr. Williston's original statement suggested that the existing Cabinet Land Use Committee, recently established under the Land Act, would be charged with these duties; however, it was subsequently decided to introduce separate legislation.

Environmental groups were generally encouraged by the government move to deal with this problem; however, they directed strong criticism at the legislation itself. They were particularly concerned that the Act does not guarantee that public hearings will be held before major developments are undertaken. The Committee is merely given a discretion whether or not to hold hearings. They also pointed out that there is no requirement that notice of proposed developments or adequate information as to their nature, be given to the public before Committee deliberations commence. Nor is there any machinery by which interested persons can register their concern by filing objections, as they can under the Pollution Control Act.

Clearly it is desirable to formalize the kind of decision that must have been taken de facto in Cabinet with regard to the Utah development before application was made for the Pollution Control permit. However, the Environment and Land Use Act makes it clear that the go-ahead decision is still to be made in Cabinet, with no guarantee of public participation, or
even public notice. Does this amount to an acknowledgement that the Pollution Control Act permit application process is merely housekeeping - concerned only with technical means of minimizing environmental damage? If so, the limited avenues for public participation developed under the Pollution Control Act become meaningless and effective public participation will now depend, in effect, upon Cabinet fiat.\textsuperscript{142}

**Challenging the Permit: the Piatocka Case**

Following the granting of the permit on January 20, 1971, S.P.E.C. and R.A.P.A. officials were disappointed, though not altogether surprised. They felt that their efforts may have resulted in slightly more onerous permit conditions than would otherwise have been the case. But, the issue seemed too fraught with possibilities to be allowed to cool; and there remained the Supreme Court, a route that had previously proven successful in the Hooker Chemicals Case.\textsuperscript{143}

Therefore, on May 3, 1971, with S.P.E.C. support, a *certiorari* action to quash the Utah permit was commenced in the Supreme Court of British Columbia by Paul Piatocka. Mr. Piatocka was a commercial fisherman who had fished in the area of Rupert Inlet and Quatsino Sound for some 15 years. He was also one of the 72 fishermen who had signed the brief that S.P.E.C. had enclosed with its original objection.

The grounds set out in the notice of motion were
substantially those argued on the appeal to the Board.\textsuperscript{144} An additional ground was that the Director exceeded his jurisdiction in deciding to issue the permit by considering an irrelevant matter, namely, the investment of some $30 million in the property by Utah. In effect, it was alleged that this fact had forced pre-judgment of the issue upon the Director.\textsuperscript{145}

Three preliminary objections were raised by counsel for the Attorney-General and the Director. These were:

(1) that the applicant lacked status to file an objection under the Pollution Control Act;

(2) that the applicant had failed to exhaust his internal remedies, since he had not taken the statutory appeal to the Pollution Control Board; and

(3) that the material filed in support of the applicant's notice of motion was insufficient.

Following a three day hearing, June 11, 14 and 15, 1971, on the preliminary objections, Aikins, J. reserved, and on September 15, 1971, handed down a written judgement.\textsuperscript{146} He dismissed the action, upholding the first preliminary objection: that Piatocka lacked standing under the Pollution Control Act because he had not filed a valid objection to the Utah permit application.

Aikins J.'s decision seems questionable on strictly
legal grounds; and completely unsatisfactory from a broader social standpoint. The case significantly reduces opportunities for effective public participation under the Pollution Control Act from the high water mark reached following the Hooker Chemicals Case. However, in one important respect the decision may be helpful to aspiring public participants in future permit applications. This will be discussed below following examination of Aikins, J.'s reasoning.

His Lordship concluded that a key question was whether the Director could validate an "ineffective objection" by considering it, even though the Board had not reviewed it and made a determination under s. 13(6) that the "public interest required" the Director to consider it. This may seem a little odd, since the reason that the Board had not made a determination under s. 13(6) was that the Board and Director had previously established a policy that all objections to permit applications should be forwarded to the Director. This policy was followed in the Utah application. The Board did not make a formal determination on any of the non-s. 13(2) objections, including that of Piatocka. Therefore, if Aikins, J. is correct in his conclusion that

(A)n 'effective objection' must be such by statute and the Director cannot by inviting a brief, or by treating an objection as if it were an 'effective objection', give it a status which it
then every one of the 150-odd "public interest objections" was invalid. Since the mine-site was remote Crown Land, it is unlikely that there were any property owners or licence holders who could have validly filed an objection with the Director under s. 13(2). The result is that there were no valid objections at all. The exchange of correspondence with the objectors by P.C.B. officials and the Port Hardy hearing were therefore entirely *ex gracia*, as counsel for the Director so eloquently argued at the Supreme Court hearing.152

The Court was concerned that to find a duty to act judicially on the Director in respect of Piatocka's objection would be to "validate" the objection; and to validate the objection would be to allow the Pollution Control Authorities, by establishing a variant policy, to "amend" the objection provisions of the Pollution Control Act.153 This does not necessarily follow. The duty to act judicially is an element of the more general common law principle of natural justice. This principle was imported by the common law whenever a matter arose for decision that affected the rights or interests of an individual.154 These obligations can be excluded by appropriately drafted statutory provisions. Section 13(4) of the Act may have done this, subject to the limitations placed by the *Western Mines*155 and *Hooker Chemicals*156 cases, if the Director had decided to rely on it and hold no hearing. But there is
also authority for the proposition that a decision-maker must act judicially when he accords a hearing, even if under his governing legislation he is not obliged to do so.157 This means that interested parties must be provided with relevant information and given a fair opportunity to be heard. "Fair", it is submitted, means to be heard orally at a formal hearing if that privilege has been accorded to other similarly affected persons.

But even if natural justice does not require participation by all affected persons if a formal hearing is held, it is still arguable that the exchange of correspondence amounted to an informal hearing within the Western Mines principle.158 If so, the duty to act judicially arose with respect to Piatocka and continued when new materials (especially the T.W. Beak Report) were introduced at the formal hearing on December 2nd, in Port Hardy.

Aikins, J. also rejected the argument that the Director was estopped from denying that he was without authority to deal with Piatocka's objection. He said:

As to Estoppel, the applicant was not a qualified objector; he did not change his position, nor was his position as such affected in any way by the Director treating him as if he were a qualified objector. There was no prejudice to the applicant. I can see no sound basis for the argument given
The difficulty is that this reasoning allows the Director to shelter behind his own informal procedural modifications. This problem suggests that the estoppel argument should at least have received more attention from the Court. There is a well-recognized distinction between a situation in which the effect of the alleged representation is to confer a spurious jurisdiction upon a judicial officer or tribunal, and one in which the representation involves a "mere irregularity of procedure". It is arguable that this case, involving as it does a procedural modification by the Board and Director, falls into the latter class, one that will support an estoppel. The detriment to Piatocka can be found in his failure to obtain a determination from the Board as a result of being misled into believing that it was unnecessary to do so. The ultimate result was that he was unable to make further representations regarding the protection of his livelihood - the Rupert Inlet fishery.

The result in the case from the environmental groups' point of view is disappointing, but it is not altogether unfavourable. The decision means that it is now clear that the Board must consider and pass upon section 13(6) objections. However, the Board is not an operational body; rather it is more closely akin to an interdepartmental committee with policy and planning responsibilities that meets from time to time. It is
likely to find itself completely unable to deal with the
mountains of objections that can be expected on future contro­
versial permit applications. The decision, therefore, may well
result in a full re-examination of the objection and hearing
procedures under the Act and clarification of the right of
members of the public to participate in the decision process.

Conclusion

How did the activities of the Environmental Action
groups affect the decision on the Utah application? Can any
effects on the Pollution Control decision process as a result
of their efforts be identified? Is the B.C. legislative and
and administrative framework adequate to ensure effective
citizen and group participation in pollution control decisions?
What is the role of the courts? Obviously no very clear answers
can be given; but after full review of the Utah controversy,
some general observations can be made.

Several effects of the Environmental Action groups' activities on the decision can be identified. S.P.E.C. was able,
by recruiting and briefing independent technical experts, to
seriously challenge the type and quality of the information upon
which certain conclusions in the Utah proposal were based, as
well as to suggest and develop alternatives. S.P.E.C. was able
to do this even though it was technically excluded from the
hearing and forced to work informally through its individual
members, and through other parts of the decision process, such as the internal appeal to the Board.

In addition, the activities of S.P.E.C., R.A.P.A. and assorted individuals resulted in the Utah application being widely publicized. This massive publicity, that featured strong criticism of the Pollution Control authorities, appears to have been at least partly responsible for sensitizing the issue and forcing the decision to hold a public hearing.

It is impossible to say what the result would have been in the absence of the activities of the Groups. But, perhaps some indication of the Groups' effectiveness is the fact that the Utah permit conditions included several "firsts". The performance bond requirement was the first for an industrial plant. Biological monitoring requirements had been included in previous permits, but none were so detailed and comprehensive as that specified for Utah.\textsuperscript{162}

The experience of the Groups also highlights a number of problems inherent in the existing pollution control legislation and policies.

1. The Pollution Control Act and regulations are misleading as to the nature and effect of decisions by the Director to issue permits. The Director does not decide the first order question of whether or not the development should go ahead at all; he
merely makes second order decisions on the technical acceptability of the effluent disposal systems proposed. He considers that this is the limit of his authority under the Act and has even gone so far as to suggest that the Act does not permit him to consider the public interest when dealing with permit applications.\(^{163}\)

However, while the Director does not make the go-ahead decision, nevertheless his permit does confirm and give legal authority to the decision taken previously at the higher departmental level, and occasionally in Cabinet. His position may be the unhappy one of buffer between Cabinet and outraged public on politically sensitive environmental issues such as the Utah Mine proposal. But, in any event, his decisions on effluent quality and quantity conditions in permits for individual plants in certain areas ultimately add up to overall water quality standards for that area. Therefore, no matter how vehemently the Director denies it, he does in fact make policy with respect to receiving water quality.

The problem is that the legislation appears to the groups and individuals to give the Director authority to "control pollution". In dealings with the
Director and proceedings before him they therefore direct their concern and comment at the question of whether the plant should be built at all (over which the Director has no authority) and to the question of receiving water standards that ought to prevail in the area having regard to competing resource uses, etc. (which the Director denies he has authority to consider in permit applications). They simply cannot understand why the inquiry must be limited essentially to quibbles about the operation and effects of the technology proposed; and in any event, without expert assistance they are incapable of responding effectively to these issues. It is little wonder that skepticism about the entire process rapidly develops among citizen objectors.

The real decisions are made at higher levels, and it is obvious that discretionary statutes like the Environmental Land Use Act do not guarantee effective public involvement in these decisions.

2. As framed, the Pollution Control Act makes invocation of the process and formulation of issues the sole preserve of the polluter or potential polluter. The Pollution Control Branch decision process can be initiated only by an application for
a permit submitted to the Director according to the procedures laid down in the Act and regulations. No interested individual, whether he has property likely to be affected or not, can formally raise the matter with the Director until the polluter has prepared its proposal and submitted its application. Before filing, the proposal that is the subject of the application will have been carefully planned and designed to raise mainly narrow technical issues related to the feasibility of the system proposed, and possibly scientific issues related to obvious potential environmental effects.

In addition, the applicant may already have acquired a kind of pre-emptive right to discharge his waste by obtaining approvals under other statutes and investing substantial sums of money. Objectors are always placed in the position of meeting the polluter on his own terms.

3. The opportunities for public participation provided by the legislation and the relevant policies of the Branch and Board are still too narrow to allow meaningful public involvement in the decision process. Participation as direct objectors is limited to persons having land or a permit or water
licence likely to be affected. In areas of substantial crown land, no such persons may exist. Other objectors must file with the Board, and must obtain a favourable public interest determination to even get their objections before the Director. All of this is quite apart from oral public hearings, which are in all cases within the sole discretion of the Director. Few hearings on objections are held, and they appear to be held only in situations where the issue has become too politically sensitive for the Director. Public hearings may in fact be used mainly as a safety valve by the Director when public pressure makes his buffer position untenable.

The internal appeal procedure in the Pollution Control Act proved largely futile as a means of widening public participation in the Utah application. It is likely to remain so until members of the Pollution Control Board acquire a proper understanding of their responsibilities in conducting these judicial proceedings under the Act.

4. Better information must be conveyed to objectors, and this must be done earlier in the process to allow sufficient lead time for analysis and response. In the Utah decision process, the major
Utah technical brief was received by the four recognized objectors only one week before the Port Hardy hearing. The Director must at least recognize this difficulty, since mimeographed "suggested questions" were distributed to them at the hearing, and they were encouraged to ask questions to clarify the nature and implications of the Utah proposal. In other words, the Branch used the hearing itself as a means of conveying information to the objectors, information without which they were unable to adequately support their objections. Clearly this is not good enough.

Legal actions in the courts have had some impact in opening the pollution control decision process to representation of a wider range of interests. The Western Mines\textsuperscript{165} and Hooker Chemicals\textsuperscript{166} cases have established that even where an oral hearing is denied, the Director must meet certain minimal procedural standards in dealing with objectors. He must provide the objectors with the information submitted by the applicant in support of his application, and must allow them a reasonable time to examine this material and to comment on it.

The Hooker Chemicals case had an additional impact, since it was the decision and the judicial criticism in that case that apparently played a large part in inducing the Director to hold a formal hearing on the Utah application. It seems,
therefore, that legal action to challenge pollution control decisions may have a leverage effect beyond the actual legal requirements laid down by the decisions in particular cases. This effect likely stems from the administrators' perception of judicial decisions in the light of sensitivities in their decision process and its political underpinning.

However, there are still very serious constraints on the effectiveness of these legal actions. The most important factor is the narrow technical approach of the courts, which is re-enforced by traditional Canadian judicial conservatism and reluctance to appear to 'legislate'. The *Piatocka Case* is an excellent example. That case clearly illustrates the danger of being obliged to rely entirely on procedural grounds to achieve broader environmental objectives. The earlier *Western Mines* and *Hooker Chemicals* cases were of little precedential value in *Piatocka* since, while in result they had the effect of recognizing the public interest in pollution control decisions, and the necessity for wide public participation, they really turned on procedural matters. Unfortunately the same procedural points were not directly in issue in the *Piatocka* case, even though *Piatocka* raised the same wider social issues of public interest and participation in environmental decisions.

The result in the *Piatocka case* appears to have narrowed opportunities for public participation in proceedings
under the Pollution Control Act. However, the procedure has at least been clarified, and the possibility of a heavy burden upon the Board in making numerous public interest determinations on objections may force a full review of the decision process under the Act.

Two final comments relate to scientific and technical issues in permit applications. At the time of the Utah application, the B.C. Pollution Control Branch was ill-equipped to handle biological and biochemical issues. Its entire expertise lay in the physical and applied science areas - mainly engineering. Some of the resulting problems in evaluating issues with large biological components have been documented above in the Utah application. Life scientists have since been added to the Branch staff; and in fact the Hearing Panel in Port Hardy included one recently-appointed biologist. However, the proportion of engineers on the Branch staff continues to be rather large. 168

The Utah application also illustrates the fact that basic scientific issues relating to environmental effects are often not resolved at all in permit applications. If objectors and Branch are well informed and armed with the necessary expertise, possibilities will be raised and hypotheses advanced, but that is about all. Any opinions ventured will always be carefully qualified.
The result is that these possibilities are left to be tested by the actual construction and operation of the proposed facility. In the case of the Utah development, a thorough on-going monitoring and surveillance program was required by the Pollution Control Branch. Serious environmental effects might be detected and remedied in time. But the possibility of a major ecological crisis developing in the Inlet in a short time cannot be ruled out; nor can the possibility of cumulative poisoning or contamination of essential food chain organisms. Certainly serious consideration should be given by the pollution control authorities to requiring further biological studies as a precondition to development. In a sense, the question is who should bear the onus of showing that serious environmental damage is or is not likely? Pre-development studies or pilot project requirements would throw the onus on the developer, where, it is suggested, it should be. Post-development monitoring requirements on the other hand, really leave the burden on the interested and affected public, even though the developer may in fact bear the cost of monitoring and data interpretation.

It has been clearly demonstrated in the preceding case history that the decision-making process did not adequately consider information that was necessary to any prediction of the possible effects of Utah's mine tailings on Rupert Inlet. Perhaps the two most critical factors contributing to this inadequacy were the Pollution Control Branch's decision to
exclude the most knowledgeable participants from the public hearing, and Utah's reluctance to investigate the patterns of water movement in Rupert Inlet.

In order to investigate empirically the actual patterns of water movement in Rupert Inlet, the author undertook a program of on-site oceanographic research. The results of this research are reported in the following chapter.
Footnotes for Chapter 4

1  North Island Gazette, October 29, 1969, at 1.

2  Application for a Permit under the Pollution Control Act, 1967, filed with the Pollution Control Branch October 2, 1969, signed by R.O. Wheaton, Administrative Manager, Utah Construction and Mining Co: North Island Gazette, October 29, 1969, at 15.

3  Brief of Utah Construction and Mining Co. in support of its application for a permit under the Pollution Control Act, 1967, Appendix 1.

4  The Vancouver Province, December 1, 1970 at 21.

5  Pollution Control Act, ss. 13(2); 13(6).

6  S.P.E.C. at this time was the largest anti-pollution society in British Columbia, with a central organization and some 30 branches throughout the province (plus several in other provinces) and a membership of approximately 8,000.

7  R.A.P.A. is a relatively small ratepayers association formed by concerned residents of the Municipality of Richmond which occupies an island at the mouth of the Fraser River. Its situation has made Richmond the recipient of the domestic and industrial waste of several dozen upstream communities, including the City of Vancouver.

8  Brief dated November 28, 1969, filed with the Pollution Control Board as an objection to Utah permit application and signed by:

   C.S. Holling, Director, Institute of Animal Resource Ecology, University of British Columbia.

   P.A. Larkin, Acting Head, Department of Zoology, University of British Columbia.

   Ian E. Efford, Director, Marion Lake Project, Canadian International Biological Programme.
See J.L. Pickard, "Oceanographic Characteristics of Inlets of Vancouver Island, British Columbia", 20 J. Fish. Res. Bd. Canada 1109-1144 (1962);


See Society for Pollution and Environmental Control, "Utah Affair - November, 1969", Introspect 12-30, Special Report Edition, (Spring 1970). The S.P.E.C. objection was on its face, filed on behalf of 72 fishermen (whose signatures were attached) with an opinion provided by Dr. A.L. Turnbull of the Department of Biological Sciences, Simon Fraser University, appended. The idea of course was to produce an objection by persons more
clearly affected in a purely economic sense. However, as a result of this tactic there was later some doubt as to whether the central S.P.E.C. body itself was a properly qualified objector under section 13 of the Pollution Control Act. Several S.P.E.C. branches including Port Alice, and Malahat-Cowichan did file timely direct objections.


19 *Id.*, at 17-18. The memorandum of agreement proposed was as follows:

MEMORANDUM OF AGREEMENT

between

UTAH CONSTRUCTION & MINING CO. LTD.

and

THE SOCIETY FOR POLLUTION AND ENVIRONMENTAL CONTROL (SPEC)

TERMS OF REFERENCE:

Utah is a mining corporation presently initiating a project to mine and concentrate ore at Rupert Inlet, Vancouver Island, B.C.

SPEC is a Society incorporated under the Societies Act in B.C. concerned with the advancement of ecological science.
The parties agree that the public interest will be advanced by provisions of an ecological survey of the Rupert Inlet area to be put in hand before commencement of concentrated operation as a foundation for review at some subsequent date, after the mine has been operating for a period. Utah will pay for the entire cost of the survey provided the same shall not exceed an amount to be negotiated among Utah, SPEC, and officials of the Department of Fisheries of Canada. It is intended that SPEC shall offer a design for the survey and organize the same. It is intended that the Department of Fisheries shall be approached and requested to undertake approval of a survey design and administration of the survey itself. The Department will also be asked to contribute its facilities to carrying out the survey work. It is further intended that in order to carry out the survey an executive committee be struck having one representative each from Utah, SPEC, and the Department of Fisheries. It is further intended that the committee shall at an appropriate time, authorize publication of the interim report setting out the findings of the survey and containing recommendations with regard to the ecological state and future condition of the Rupert Inlet area.

In consideration of the premises, and in particular, in consideration of the payment of the cost of the survey by Utah, and design of the program by SPEC, the parties hereto agree as follows:

1. Utah will accept that program of survey which is designed by SPEC, approved as to conditions and limits by the Department of Fisheries and agreed to as to total costs by Utah.

2. SPEC will furnish to Utah and to the Department of Fisheries, a program design not later than the 15th day of January, A.D. 1970.

3. This entire agreement is subject to obtaining of agreement to participate by the Department of Fisheries.

4. Neither the survey itself nor the report issued subsequent thereto shall be considered binding on any party to this agreement, and in particular, no recommendations contained in any such report are to be considered binding on Utah.

5. The parties agree that Utah shall be considered the initiating party of the ecological survey provided for herein.

6. Utah shall provide, at an early date, guidelines as to
what conditions of accounting for costs incurred during the progress of the program shall be regarded as acceptable by Utah.

7. This agreement does not provide for a subsequent second stage to the survey after the plant has been in operation for a period; it is intended that this matter be left open to future negotiation.

8. Utah will co-operate, in so far as it may reasonably be able to, in providing access to property owned or controlled by Utah in the Rupert Inlet area for the purpose of carrying out the survey.

9. This agreement is to be effected without prejudice to the rights of any party with respect to any proceedings initiated under the Pollution Control Act of British Columbia. The putting in hand of the program shall not be construed as an admission by Utah with respect to any permit applied for under the said act.

10. This memorandum is intended to comprise the substance of the agreement between the parties, and it is agreed that such further or other conditions as may reasonably be required by solicitors acting for either of the parties may be advised shall be reduced to writing and executed by the parties as the occasion may arise.

On behalf of UTAH (not signed)

On behalf of SPEC (not signed)

20 Id., at 21; Vancouver Sun, January 19, 1970, at 10.

21 Id., at 21-24.

22 The Group was particularly concerned by the fact that it could not discover the details of the proposed studies from either the company or the Department of Fisheries. The Fisheries Department replied only that "it would appear that many of the features described in your survey plan have been included in
(The Company's) plans and ... there are several additional features which we regard to be important which will also be included" (Letter to Dr. Robin Harger, S.P.E.C. Vice President from W.R. Hourston, Director of Fisheries, Pacific Region, dated February 5, 1970). S.P.E.C. was also unable to obtain assurance from the Department that the completed study would be made available to the public: see Introspect, supra note 54, at 24-26.

23 As noted in the February 5, 1970 letter from W.R. Hourston to R. Harger, (supra, note 58) the Company's survey contained "many of the features of the S.P.E.C. plan." Earlier one of the Company officials had referred to the possibility of "courtesy studies" being conducted: see letter to M.E. Pratt of Utah from G.F. Culhane, Chairman S.P.E.C. Legal Committee, dated February 10, 1970; Introspect, supra, note 54 at 26.


26 See Waldichuk, supra, note 45;

Pickard, supra, note 45;


29 Pollution Control Act, s. 5(4).


32 Id., s. 33.

33 Personal Communication, from Mr. Leslie Edgeworth, Federal Department of Fisheries, to P.A. Moore, December 14, 1970.

34 See H.L. Ehrlick, "Observation on Microbial Association With Some Mineral Sulfides", in, M.L. Jensen Ed., Biogeochemistry of
Sulphur Isotopes, (Proceedings of a National Science Foundation Symposium, Yale University, April 12-14, 1962).


36 Personal communication, Hon. Ken Kiernan, British Columbia Minister of Recreation and Conservation, to Dr. J.P. Kimmins, dated November 9, 1969.

37 Personal communication, Mr. Ken Jackson, Federal Department of Fisheries, to P.A. Moore, dated November 9, 1969.

38 See Pickard, supra, note 45; Waldichuk, supra, note 45.

39 Personal communication, Dr. G.L. Pickard, Director, Institute of Oceanography, University of B.C., to P.A. Moore, dated December 2, 1969.

40 Personal communication, Mr. Ken Jackson, Federal Department of Fisheries, to P.A. Moore, dated December 8, 1969.

41 See p. 14 supra.


43 See D.W. Duncan, The Disposal of Mining and Milling Wastes With Particular Reference to Underwater Disposal, Study

44 Letter from W.N. Venables, Director Pollution Control Branch to Pacific Salmon Society; also to Dr. J.P. Kimmins, dated July 3, 1970. Emphasis added.

45 Letter from Pollution Control Branch to Dr. J.P. Kimmins, dated September 4, 1970.

46 Pollution Control Act, s. 13(4).

47 The Malahat-Cowichan Branch of the Society for Pollution and Environmental Control. However, the group had in the meantime changed its name to "Duncan S.P.E.C.", and had filed further material in response to the Director's July 3, 1970 letter under that name. This was disclosed later at the hearing of the S.P.E.C. - R.A.P.A. appeal to the Pollution Control Board, heard December 8, 1970 (infra, p. 31): Vancouver Sun, December 10, 1970, at 2.

48 Supra, note 43.

49 By coincidence the three individuals were all members of S.P.E.C.

50 Letter, Pacific Salmon Society to W.N. Venables, Director Pollution Control Branch, dated July 26, 1970.

51 Vancouver Province, September 10, 1970.

52 Vancouver Sun, September 10, 1970.


55 The principle concerns basic procedural fairness, and is sometimes said generally to involve first, an unbiased decision-maker, and second, adequate notice and a fair opportunity for interested parties to be heard. There is general agreement on the futility of attempts to extract any very precise definitions
from the Canadian cases. See generally Robert F. Reid, Administrative Law and Practice, 209-218 (1971).


57 R.S.B.C. 1960, c. 405.

58 Under the predecessor statute (The Pollution Control Act, R.S.B.C. 1960, c. 289) the Board was the sole decision-maker.

59 The trial judgment dated October 14, 1966 is unreported. (Vancouver Registry No. X844/66., Dryer, J.).

60 The authorities are legion. See Robert F. Reid, Administrative Law and Practice 159, 167-170 (1971). However, the characterization of the Board's function as administrative was questionable, particularly since the recent landmark English case, Ridge v. Baldwin, (1963) 2 All. E.R. 66, (1963) 2 W.L.R. 935, was not cited to the court.


62 Id., at 706.

63 Id., at 707.

64 R.S.B.C. 1960, c. 289.

65 Id., at 708.


67 S.B.C., 1967, c. 34.

68 Id., ss. 2, 10.

69 Id., ss. 4, 12.

70 Id., s. 13(2).

71 Id., s. 13(6).

72 Re Application of Hooker Chemicals (Nanaimo) Ltd., (1970)

73 Re Application of Hooker Chemicals Nanaimo Ltd., supra note 110, hearing transcript, cross-examination of W.N. Venables, Director, Pollution Control Branch, 26-29, (questions 44-57).

74 Supra note 67, at 359.

75 Supra note 53, at 707.

76 Hearing Transcript, supra note 106, at 18. (questions 1-3).

77 Id., at 25-26.

78 This informal modification of the statutory objection procedure was approved by Wootton, J. who stated at 357 (75 W.W.R.):

> I must conclude that the applicant had the right to have his application heard because the Director indicated that he considered the objection of the applicant as a valid one.

79 This has since been considerably qualified by the decision in the case that arose from the Utah controversy: see p. 42 infra.

80 A Vancouver Sun editorial, (July 18, 1971, at 4), expressed the hope that this suggestion would be acted upon by the agency or by the legislature:

> We would like to think this is a fateful judgment for the people of B.C. We would like to think that the government will show proper respect for the court's belief that 'There must be some machinery whereby the public having an interest in the matter should have an opportunity of objecting to the granting of permits' (per Wootton, J. at 75 W.W.R. 357).

81 Supra note 67, at 360.

82 Ibid.

North Island Gazette, August 12, 1970, at 1.


Letter, Pollution Control Branch to Pacific Salmon Society, dated November 6, 1970. The excluded objectors received copies of this letter as well.

Navigable Waters Protection Act, R.S.C. 1970, C.N-19, s.5. as am. 1968-69 c. 15 s. 3(1)(2).

Mineral Act, R.S.B.C. 1960 c. 244 as amended s. 51.

Mines Regulation Act, R.S.B.C. 1960 c. 242 s. 11, as am. 1967, c. 25, s. 11, 1968, c. 18, s. 2.

Water Act, R.S.B.C. 1960, c. 405 as amended ss. 8, 9.

See B.C. Hydro and Power Authority Act, S.B.C. 1964, c.7.


Vancouver Sun, December 3, 1970 at 22.

North Island Gazette, December 2, 1970.

Material distributed to objectors in Port Hardy, December 2, 1970.

Brief of Utah Construction and Mining Co. in support of its application for a permit under the Pollution Control Act, 1967.


Vancouver Sun, January 20, 1971 at - and see G.R. Peterson, "Heavy Metal Content of Some Fresh Water Fish of British Columbia". Department of Recreation and Conservation, Fish and
It is usual in 96 hour tests to arrive at an estimate of the median lethal concentration (LC50) which is the concentration of the toxic material which results in the death of 50% of the test organisms in a 96 hour period. It is then usual to set the standards for the particular toxic substances many times lower than this value. The tests run for Utah only established that there was 0% mortality of the test organisms at 100% concentration of the simulated effluent. It may be that the LC50 is at only double the concentration of the toxic substances present in the tailings and therefore the tailings would contain more toxic material than would generally be considered acceptable: See J.B. Sprague, "Measurement of Pollutant Toxicity to Fish: I. Bioassay Methods For Acute Toxicity", Water Research, Review Paper, 793-821 (Pergamon Press 1969).
Supra note 67.

Letters, Richmond Anti-Pollution Association (Mrs. S.V. Boyce, Secretary) dated November 17, 1970; and Canadian Scientific Pollution and Environmental Control Society (S.P.E.C.), dated November 19, 1970, to W.N. Venables, Director Pollution Control Branch.

Letters, Richmond Anti-Pollution Association, dated November 17, 1970; and Canadian Scientific Pollution and Environmental Control Society, dated November 20, 1970, to F.S. McKinnon, Chairman, Pollution Control Board.


Similar letters, W.N. Venables, Director, to J. Marunchak, Communications Director, Canadian Scientific Pollution and Environmental Control Society, and to Mrs. S.V. Boyce, Secretary Richmond Anti-Pollution Association, both dated November 20, 1970.

Six of the 10 Board members were present:

F.S. McKinnon, Chairman (Retired Deputy Minister of Forest Service).

The Hon. R.G. Williston, Minister of Lands, Forests, and Water Resources.

V. Raudsepp, Deputy Minister of Water Resources.

R.G. McMynn, Director, Commercial Fisheries Branch, Department of Recreation and Conservation.

J.W. Peck, Chief Inspector of Mines, Inspection Branch, Department of Mines and Petroleum Resources.

Dr. C.J.G. Mackenzie, Associate Professor, Director, Division of Public Health Practice, Department of Health Care and Epidemiology, University of B.C., Vancouver.

Other members of the Board were:

The Hon. D.R.J. Campbell, Minister of Municipal Affairs.

The Hon. R.R. Loffmark, Minister of Health Services and Hospital Insurance.
Dr. J.A. Taylor, Deputy Minister of Health, Health Branch.

J.S. Allin, Department of Agriculture.

The suggestion here was really that the Utah application raised issues of concern throughout the province and that interested persons from other parts of the province should be heard in as convenient a manner as possible. Therefore a second hearing in a Lower Mainland location, or in Victoria, might be necessary.

The result was a hearing that gave neither Port Hardy area residents, nor concerned individuals and groups elsewhere in the province a proper and convenient opportunity to be heard. The four outside objectors were heard to the exclusion of local residents.

Form letter, Pollution Control Branch to Utah objectors, dated July 3, 1970, see note 79, supra.

Supra note 97.

Supra note 53.

Supra note 67.

Richmond Anti-Pollution Association, Memorandum of Argument, at 9-10.

Vancouver Sun, December 8, 1970, at 20.

Letters, F.S. McKinnon to Richmond Anti-Pollution Association, and Canadian Scientific Pollution and Environmental Control Society dated December 9, 1970. A Vancouver Sun report of December 10, 1970, at 2, noted that "The Board's decision... follows a suggestion made by Resources Minister Ray Williston at the appeal that anyone with technical objections to Pollution Control applications should simply hand them to the Director and to newspapers instead of involving time and money in hearings and appeals".

Pollution Control Act, s. 12(1)(c).

Letter (and attached brief), Robert T. Franson for the Richmond Anti-Pollution Association, to the Director, dated January 6, 1971.

Vancouver Sun, January 21, 1971, at 1.


See Vancouver Sun, January 21, 1971 at 1. The report of the permit grant appeared on the same day as an account of Throne Speech highlights from the opening of the British Columbia Legislature. One of these highlights was a promise to introduce measures to enhance environmental protection. The result was a very effective page 1 juxtaposition of headlines: "TOP PRIORITY PLEDGED TO B.C.'S ENVIRONMENT" and "UTAH GETS OKAY FOR INLET DUMPING".

Vancouver Province, January 21, 1971 at 1.


Brief of Utah Construction and Mining Co. in support of its application for a permit under the Pollution Control Act, 1967, Appendix 2.

Letter, Dan Campbell, Minister of Municipal Affairs to Lloyd Stewart, President, Pacific Salmon Society, dated March 30, 1971.


Letter of transmittal from Director of Pollution Control to Utah Construction and Mining Co., dated Jan. 20, 1971. Attached to Pollution Control Branch Provisional Permit No. 379-P.

Personal communication, A.J. Chmelauskas, Chief Engineer, Pollution Control Branch. It is interesting to note that the requirement for the first report to be submitted before commencing to discharge was ignored by Utah and apparently overlooked by the Branch. The mine began to discharge in late October, 1971. As of January, 1972 the report had not been submitted.

S.B.C. 1971, c.
137 Id., s. 3.

138 Id., s. 4.


140 Ibid.; see Land Act, S.B.C. 1970, c. 17, s. 84; B.C. Reg. 185/70.


142 The fiat is taken seriously in British Columbia, one of the few remaining Canadian jurisdictions in which the fiat of the Lieutenant-Governor in Council is still a prerequisite to most direct legal action against the Crown in right of the Province: see Crown Procedure Act, R.S.B.C. 1960, c. 89.

143 Supra note 50.

144 Supra note 72.

145 See Notice of Motion para. (f) and supporting affidavit of Paul Piatocka, para. 22.

146 Re Piatocka and Utah Construction and Mining Company, (1971) 21 D.L.R. (3'd) 87 (B.C.S.C.) During the three months between the hearing on June 11, 14 and 15, 1971, and the date of judgment, construction at the Utah site continued unabated.

147 Supra note 50.

148 Supra note 139, at 95.

149 Supra note 77.

150 Affidavit of Alben Joseph Chemelauskas, Chief Engineer of the British Columbia Pollution Control Branch, dated June 10, 1971, but not formally filed in the action.

151 Supra note 139, at 95-96.

152 Writer's notes from Hearing, June 14, 1971.
153 Supra note 139 at 95.


155 Supra note 54.

156 Supra note 53.

157 The following statement appears in Robert F. Reid, Administrative Law and Practice (1st ed., 1971) at 21:

There is authority to the effect that even though a hearing is not required, one who embarks on it must conform to the rules of natural justice, despite an apparently absolute discretion and the exercise of power classified as administrative,


158 Supra note 54 at 708 per Davey, J.A.

159 Supra note 146 at 96.


There are many matters which public authorities can now delegate to their officers. If an officer, acting within the scope of his ostensible authority, makes a representation on which another acts, then a public authority may be bound by it, just as much as a private concern would be... It was a matter within the ostensible authority of the planning officer and being acted on, it is binding on the council.
In Re Fertile Belt No. 183 and Peters, (1915) W.W.R. 103 (Sask. Q.B.), a Provincial weed inspector who gave notice not in compliance with governing statute was held to be estopped.

162 Interview with A.J. Chemelauskas, Chief Engineer, Pollution Control Branch, June 15, 1971.

163 The Vancouver Province, Friday, June 11, 1971, at 8.

164 See note 125, supra. The Director has stated that "(The Act) is essentially a waste control act. That is, it recognizes that there must be some discharge of waste in the air, land and water ... And if it is too narrow, then there are democratic processes to take care of that": The Vancouver Province, supra, note 201.

165 supra note 54.

166 supra note 53.

167 supra note 146.

168 At present 33 members of the Branch staff are classified as engineers, 16 as technicians and engineering assistants, and 7 as biologists: Question answered in the Legislature by R.G. Williston, Votes and Proceedings of the Legislative Assembly of British Columbia 10-12, (February 4, 1972).
CHAPTER 5

THE PHYSICAL OCEANOGRAPHY OF RUPERT INLET ON VANCOUVER ISLAND
WITH CRITICAL COMMENTS ON ITS USE FOR THE DISPOSAL OF MINE TAILINGS BY UTAH CONSTRUCTION AND MINING COMPANY

Introduction

As explained in Chapter 4, it was decided by the Pollution Control Branch, in the face of considerable public opposition, that the Utah mine would be permitted to discharge 9.3 million gallons, containing 32,000 tons of mine tailings, per day into Rupert Inlet. In defending its application for a permit to do so, the Company contended that the tailings discharge would not result in any undesirable effects on the water quality of the inlet or on its ecology. The central point of their argument was the assertion that the deep waters of Rupert Inlet were not affected by tidal currents and that the tailings would therefore settle directly to the bottom without causing an increase in the turbidity of the water in the inlet.

In this section of the thesis, the Company's arguments are explored more fully and their assumptions regarding the suitability of Rupert Inlet as a receiving site for the tailings
Figure 1. Map showing the location of Quatsino Sound on Vancouver Island.
Figure 2. Map showing the location of Rupert Inlet in Quatsino Sound on Vancouver Island.
from their mining operation are critically examined. The principal objectives of the experimental work reported in this chapter were the investigation of the patterns of water movement in the inlet using standard oceanographic equipment, and the prediction and tracing of the movements of the tailings in the inlet after the discharge began. The study was also intended to show the feasibility of testing the assumptions underlying the granting of Utah's pollution control permit.

**Description of the Study Area**

Rupert Inlet is located at the northern end of Vancouver Island and forms the most eastward extension of the inlet system of Quatsino Sound (see Figs. 1 and 2). Rupert Inlet is about five miles in length and is a little over one mile wide at the widest point. It is a typical fjord type of inlet with an extensive tidal estuary at its head and a shallow sill at its mouth. It is about 170 metres (90 fathoms) deep at the deepest point, which is adjacent to the mouth and about one-half mile from Quatsino Narrows, which forms the sill. Rupert Inlet is continuous with Holberg Inlet which runs to the northwest, the two being joined at their deepest points. (Fig. 2 shows the approximate depths in fathoms at various locations in Quatsino Sound.)

Rupert Inlet is unusual amongst fjords in one important respect. In all other fjords on the British Columbia coast most of the fresh water drainage from the land enters the inlet at its head and travels on the surface for the full
length of the inlet to its mouth and thence to the sea. In Rupert Inlet, however, the main freshwater runoff is from the Marble River which enters the inlet almost at its mouth near Quatsino Narrows. The freshwater runoff into the head of the inlet is far less than that from the Marble River due to the small area of the watershed feeding the former and the relatively large area of the latter. The input of fresh water from the land can be an important factor in determining the circulation of water in an inlet. The full significance of this unique feature will be discussed later in the context of the oceanographic data collected for Rupert Inlet.

The Oceanography of Rupert Inlet as Described by Utah Prior to Their Application for a Pollution Control Permit

As outlined in Chapter 4, it was the Company's intention to dispose of their tailings by means of a submerged pipeline that would carry them to a depth of 150 feet and discharge them on the bottom of the inlet about a quarter of a mile from the shoreline. In an effort to convince the federal and provincial authorities and the general public that their disposal scheme was the most desirable possible, the Utah management found it necessary to put forward an hypothesis regarding the movement of water in Rupert Inlet.

To this end, an article was placed in the December 10, 1969 issue of the North Island Gazette (the local newspaper for
the area in which the mine was planning to operate) with the headline "Utah Officials Say No Danger in Mine Effluent". The article contained a summary of a statement by Utah's Administrative Manager, Mr. Bob Wheaton, who said that:

A sill in Quatsino Narrows only forty feet below the water surface will stop the spread of tailings to other parts of the sound, but there is practically no chance they would ever go so far. **Below 70 feet there is no tidal turbulence in Rupert Arm** ...

... We feel confident the tailings will go down and stay there. (Emphasis added)

The North Island Gazette of January 21, 1970 went on to quote Mr. Wheaton as stating that:

**The water in Rupert Inlet is stratified into layers of differing density with tidal action affecting only the surface layers.**

It was also stated in both these articles that the Company had the support of the Federal Fisheries Department and was assured by its "expert consultants" that the statements concerning the circulation of water in Rupert Inlet were correct. In essence, the Company was maintaining that there were no currents in the deep waters of the inlet and that the tailings would therefore settle without any disturbance to the bottom of the inlet. Here their only effect would be the annihilation of the inlet's deep water benthic community which the Company contended would not result in any undesirable effects on the water quality or ecology
of the inlet. This was further emphasized in the Company's brief (Anonymous, 1970) to the Pollution Control Branch hearing in Port Hardy on December 2, 1970 where it was predicted that the tailings:

will coalesce and form a density current, on the order of two feet to ten feet in thickness, which will flow down the sloping bed of Rupert Inlet and come to a rest in the deepest portion of the inlet.

This statement implies that there would be no increase in the turbidity of the water in Rupert Inlet above a depth of ten feet from the bottom. This was the position taken by Utah in all its communications with the government agencies and the public and it was strongly supported by the "expert consultants" that the Company hired to defend its application for a Pollution Control Permit at the Port Hardy hearing.

Oceanographic Data on Rupert Inlet Which Were Available at the Time the Permit Application was Made

Until the time of the application by Utah for a Pollution Control Permit, there had been very little basic oceanographic work carried out in Rupert Inlet. It is in a relatively isolated location and had never in the past been used as a receiving body for industrial waste. The data that had been collected were very useful, however, despite their limitations (lack of replication, few sampling stations) as they gave
an indication of the general pattern of water circulation in the inlet. In a paper on the oceanographic characteristics of the inlets on Vancouver Island, Pickard (1963) commented that:

In Holberg and Rupert it had been anticipated that the shallow sill of Quatsino Narrows separating them from Neroutsos would result in stagnation and low dissolved oxygen values. It will be seen (from the data) that this was not the case. In fact, apart from the deepest sample at the head of Holberg, the water in the two inlets was remarkably uniform from top to bottom with the highest oxygen values at 100 metres of all the Vancouver Island inlets except Sidney and Millar Channel. (Emphasis added)

The concentration of dissolved oxygen in a body of water is often a very useful diagnostic indicator of the general pattern of water circulation. Oxygen is introduced into a water body only at the surface where it is absorbed from the atmosphere or near the surface as a by-product of photosynthesis by phytoplankton and benthic algae. There is no input of oxygen into a water body below the euphotic zone. It is necessary to assume, therefore, that deep water which contains an appreciable amount of dissolved oxygen (similar to surface water values) was at some time in the past at the surface and has moved into a deeper location. As oxygen is consumed by the organisms in the deep water, it would become
depleted over a period of time and the water would become stagnant unless freshly oxygenated water from the surface replaced it. The high oxygen levels in Rupert Inlet therefore suggest very strongly that the water in the inlet is circulating to some degree, and that the deep waters are being replaced periodically by water nearer the surface.

The only other data available on the oceanography of Rupert Inlet at the time of the permit application was that collected by the Fisheries Research Board of Canada in a series of three oceanographic cruises to the area in August, 1957; November, 1962; and August, 1967 (Waldichuk et al, 1968). All the data collected indicated a high oxygen concentration in the deep waters of the inlet. For example, on the 16th of August, 1957 the water at 100 metres in central Rupert Inlet had an oxygen concentration of 6.51 mg/l which represents 70.1% of the saturation value at the in situ salinity and temperature and at one atmosphere pressure. In addition the vertical temperature and salinity profiles of the inlet indicate that the water is very uniform from near the surface all the way to the bottom. Only in the top 5 metres was there an appreciable increase in temperature, whereas below this depth the temperature never varied more than 1°C from top to bottom. This lack of layering or stratification is a strong indication that the water is being mixed by currents. This is supported further by the fact that the data were collected in mid or late summer when stratification
is most likely to take place due to heating of the surface waters. The limitations of the data left open the possibility that stratification did exist during the winter due to fresh water runoff from the land, but as there were no data, this could not be assumed for the purpose of justifying the Company's disposal plans.

It can be seen from this review of the data available at the time of the permit application, that anyone who had analyzed it for the purpose of determining something about the circulation of water in Rupert Inlet should have come to the opposite conclusion from that used by Utah representatives in rationalizing their plans to the government and the public. It can only be assumed that the Company officials were unaware of the data, that they chose to interpret the data differently, or that they had little concern for the facts of the matter and gave a higher priority to pushing their plans ahead than to a correct understanding of the circulation of water in Rupert Inlet.

The oceanographic data for Rupert Inlet discussed above were readily available to anyone requesting it at the time that Utah was planning its tailings disposal system. In particular, the data from the Fisheries Research Board should have been accessible to the Company. The Fisheries Research Board is the research arm of the Federal Fisheries Department and part of its function is the provision of information for use
by the Fisheries Department. As the Fisheries Department was working closely with Utah during the planning of the disposal system, one might conclude that the Department was also unaware of the data that had been collected by its own research personnel.

**Oceanographic Data for Rupert Inlet That Have Been Obtained Since the Permit Application**

After Utah applied for a pollution control permit, and particularly after the public hearing in Port Hardy, there was a great deal of research undertaken in Rupert Inlet. Most of this was aimed at establishing baseline data in order that any effects of the tailings discharge on the inlet could be determined after the disposal began. Unfortunately, very few of the studies were directed at establishing the pattern of water circulation in the inlet. There were two exceptions, however, that did pertain to this question. A report prepared for Utah by B.C. Research (Howard, 1970) was the only attempt to date (March, 1973) at measuring current velocities at various depths in Rupert Inlet. Current speed and direction were measured at two points, one at the deepest part of the inlet near Quatsino Narrows, and the other in mid-channel off the mine-site. The report concluded that "deep water currents do occur" in the waters of Rupert Inlet, particularly at the station nearest to Quatsino Narrows. Current speeds of up to 1.00 knot were reported at 490 feet at this location, a very rapid movement for
water at such a great depth. The maximum current velocities in
the deep water were found to occur in conjunction with the
incoming tidal flow through Quatsino Narrows. This indicates
that the currents are caused by the tides and that the water
entering the inlet is not remaining on the surface as suggested
by the Company but is for some reason "diving" into the deeper
waters as it flows through the narrows. (As explained in
Chapter 3, the Utah representatives went to some length to
discredit the findings of this report at the Pollution Control
Branch hearing in Port Hardy on December 2, 1970.)

The other research related to deep water currents was
carried out by a research team from the Federal Department of
Fisheries and was led by Mr. Darcy Goyette, a pollution biolo­
gist with the Department. He found (Goyette, 1971) through
the use of electronic depth sounding equipment, that the bottom
of Rupert Inlet was surprisingly free of sediment at its deepest
point near Quatsino Narrows. In the absence of currents it
would be expected that there would be a considerable deposit of
sedimentary material at this location. Firstly, because it is
the deepest part of the inlet and as the rest of the inlet does
have a layer of sediment on the bottom, it could be expected
that gravity would ensure some deposit there. Secondly, because
the water flowing from the Marble River fans out right above
this area, it would be expected to deposit its sediment load on
the bottom of the inlet at this point. A plausible explanation
of this unusual situation would be that deep water currents occur as a result of the tidal flow through Quatsino Narrows. The lack of sediment can be attributed to the scouring action of the currents as they flow over the bottom. This would tend to carry any sediment further up the inlet until the current velocity decreased to the point where the sediment particles could settle out on the bottom.

The oceanographic data that have been collected by various researchers since the permit application indicate that there are deep water currents in the inlet, thus supporting the conclusions drawn from the data that was available before the application. Despite this indication that Rupert Inlet would be a poor location to dump millions of tons of finely ground mine waste, these findings had no effect on Utah's disposal plans.

**The Significance of Temperature Measurement in Oceanography**

The density of seawater is determined by just three factors: temperature, salinity and pressure. An increase in temperature results in a decrease in density and an increase in salinity results in an increase in density. There is also a slight increase in density with depth (i.e. pressure). The pattern of density distribution in any waterbody can be determined by measuring the temperature and salinity at a number of points, computing its density at each point from a table, and interpolating between the points in order to obtain a two or
even three dimensional representation.

The distribution of density in a waterbody is commonly used in oceanography to determine the general pattern of water circulation. An example would be useful to illustrate this technique. Given a typical fjord type of inlet with a deep basin separated from the outside water by a shallow sill, it would be possible to measure temperatures and salinities at various depths at two stations, one inside and one outside the sill. From these values the density can be calculated and plotted on a longitudinal vertical section through the two stations (see Figs. 3a and 3b). Isopycnals (lines joining points of equal density) can then be interpolated between the two stations (density is expressed as $\delta t$, as calculated from temperature and salinity by means of a table). The main current flows between these two stations would then be along the isobars because the water tends to remain within its own density stratum rather than moving into water of lesser or greater density. For example, on an incoming tide the surface waters moving into the inlet from the ocean would tend to move to a level in the inlet where the water was of equivalent density. Figures 3a and 3b illustrate the current patterns that would be expected from two different types of density distribution. In Figure 3a the density distribution is the same on both sides of the sill and so the water entering the inlet would be expected to remain on the surface. In Figure 3b the water in the inlet is less dense
Figures 3a and 3b. Diagrams of a longitudinal cross-section through a hypothetical coastal fjord inlet. Isobars are shown as dotted lines and arrows show the probable direction of current flow over the sill on an incoming tide for the two patterns of density distribution.
than that outside and the incoming water would therefore flow downwards as it enters the inlet until it reaches its own density level. This is an oversimplified model, but the same principle may usefully be applied to more complex situations.

The temperature distribution of a waterbody may be summarized in a series of vertical profiles which are obtained by measuring the temperature at various depths (often continuously) from individual surface stations. A major feature of vertical temperature profiles is the thermocline, a region of the profile over which temperature exhibits relatively rapid change with depth. A sharp thermocline is indicative of a waterbody with strong stratification and a tendency to remain stable in the thermocline region. One would not expect any large exchange between the water above the thermocline and that below it. Conversely, a temperature profile with little or no thermocline may be indicative of a waterbody without much stratification and, in the absence of a halocline, may be expected to be mixed from top to bottom. Exceptions to the above situation are possible, however, if there is a strong enough halocline (salinity gradient) to offset the effect of temperature on density. This may be the case in inlets when large freshwater runoffs reduce the salinity of surface waters considerably.

The above example can be further illustrated with data
that were collected during an oceanographic cruise carried out by the University of B.C. Institute of Oceanography in March, 1971 (Leblond, 1971). Temperature and salinity measurements were made at a number of locations in and around Rupert Inlet. One of these stations was immediately outside Quatsino Narrows, and another was just inside the narrows in the deepest part of Rupert Inlet. Figures 4a, 4b and 4c show the values found for temperature, salinity and density at Stations R1 and R2 during an incoming tide on March 6, 1971. These graphical representations show that both the temperature and salinity of the deep water in Rupert Inlet have values equal to that of the water at about 15 metres depth outside the narrows. This indicates that the deep water in the inlet probably originated as water outside the sill of the narrows which is also about 15 metres deep. If one assumes that water coming into the inlet follows the lines of equal density shown in Figure 4c, it would appear that the water does indeed "dive" as it enters the inlet, at least at the time of year during which these data were collected. It should also be noted that the density of the water at sill depth outside the sill and that in the inlet appears to be equivalent in both temperature and salinity values. The fact that the deep water in the inlet is equivalent in both these values to the water at sill depth outside, is further indication that it is part of the same water mass and that the deep water in the inlet is a result of a flow of water through Quatsino Narrows which
Figures 4a, 4b, and 4c. Diagrams showing longitudinal cross-section of Quatsino Narrows and Rupert Inlet. Isopleths of temperature, salinity, and density are shown as dotted lines between stations R1 and R2 for March 5 and 6, 1971. (LeBlond.)
then flows downwards into Rupert Inlet.

Methodology and Techniques Employed by the Author

In Temperature Measurement in Rupert Inlet

In order to provide a complete understanding of the pattern of water movement in Rupert Inlet, it would be necessary to measure many parameters, including temperature, salinity, dissolved oxygen and currents. This would have to be done at frequent intervals and at a number of stations and depths over a period of one year and preferably for two or three years, in order to be more sure that a representative year had been sampled. This was not possible due to limited time and resources and it was therefore necessary to limit the data collection to temperature. Turbidity, which was also measured, was useful in supporting some of the hypotheses related to current patterns but this was not the principal purpose for measuring this parameter. The results of the turbidity measurement will be discussed in a following section. It was felt that of all the parameters that could be measured, temperature would be the least difficult and it would provide much information of value in determining possible patterns of water movement. This would include:

1. The annual fluctuation of the thermocline and the nature and depth of the thermocline.
2. The presence or absence of a horizontal stratification of the water due to a strong
thermocline. If there is a strong thermocline all year it could indicate that the surface waters are separated from the deep waters below the thermocline (assuming there is no strong halocline).

3. The stability of the deep waters with respect to temperature. If the deep waters exhibit a constant temperature throughout the year, it would indicate that they are stable and do not mix with surface waters. If the temperature of the deep waters changes seasonally, it is likely that they are being replaced periodically.

The instrument used for temperature measurement was a standard bathythermograph, Model No. OC-2/S, obtained from the Kahl Scientific Instrument Corporation in San Diego, California. The instrument contains both temperature and pressure (depth) sensitive elements and provides a range of temperature from -2 to 30°C and of depth from 0 to 140 metres. The temperature information is recorded by means of a stylus that produces a continuous trace of temperature versus depth on a gold-coated glass slide within the instrument. For each temperature profile a new glass slide is used and upon completion of the measurement it is removed from the instrument, marked for the time, date and station, and stored in a plastic slide container. The temperature trace is interpreted by means of a slide holder
that superimposes a grid of temperature versus depth over the slide, providing data for continuous temperature profiles with depth.

The bathythermograph was lowered into the water by means of a 12 Volt battery-powered winch that was constructed by the author and was fixed to the stern of the research boat (a 21-foot cabin-cruiser powered by an inboard marine engine). Figure 5 shows the locations of the stations at which vertical temperature profiles were taken. Measurements were taken at these stations on five different occasions: February 4 and 5, 1971; April 26 and 27, 1971; July 21 and 22, 1971; December 1-3, 1971; and April 10, 1972. The results of these measurements are reported in full in Appendix A of the thesis.

Results of the Temperature Studies in Rupert Inlet

The first impression obtained from the temperature profiles (Appendix A) is that the water in Rupert Inlet is remarkably uniform from very close to the surface right to the bottom at all stations. At no station on any of the dates sampled was there a variation of greater than 1°C from a depth of 10 metres to the bottom. Another obvious feature is the lack of a strong stratification of the water near the surface into distinct horizontal layers. Even for the July, 1971 readings there is only a very shallow (about 2 - 5 metres) layer of
Figure 6a. Temperature profiles for February and July of 1963 at a station in Kamloops Lake, (After Ward, 1964).

Figure 6b. Temperature profiles for December and July at Station R7 in Roseport Inlet (1971).
warming water on the surface and there is no indication that the water is stabilized into distinct layers. If the water were indeed vertically stable, it is likely that by July there would have been sufficient solar heating of the surface waters to produce a relatively deep surface layer of warmer water. A comparison with a waterbody in which there is a strong seasonal thermocline will serve to illustrate this point. Figure 6a shows the vertical temperature profiles for Kamloops Lake (Ward, 1964) in January and July of 1963. This can be compared to Figure 6b that shows the vertical temperature profiles for comparable times (February and July of 1971) for Station R7 in Rupert Inlet (see Fig. 5 for the location of Station R7). It can be seen from these illustrations that whereas Kamloops Lake develops a distinct surface layer of warmer water in the summer, this is not the case for Rupert Inlet. This feature of the vertical distribution of temperature in Rupert Inlet is further indication that the water is undergoing some form of vertical circulation rather than remaining stable throughout the year.

By far the most significant feature of the temperature profiles collected in Rupert Inlet is the seasonal variation of temperature in the deep waters. It can be seen, by referring again to Figures 6a and 6b, that there is a considerable increase in water temperature from the top to the bottom of the water column in Rupert Inlet, whereas in Kamloops Lake the seasonal variation is restricted to the surface while the deep waters
remain at a constant temperature throughout the year. The significance of the variability in deep water temperature in Rupert Inlet is the fact that this pattern of temperature change could not take place in a body of water in which there was no vertical circulation. In a body of water the inputs of heat for warming the water are received through the surface (geothermal heating from the bottom is insignificant). Because of this the water is heated from the surface downwards, eventually resulting in a warmer, less dense layer of water at the top of the water column. The water beneath this layer does not receive any of this heat from solar radiation because it is all absorbed by water within a few metres of the surface. In a stable waterbody the deep water (below about 50 metres) would therefore be expected to remain at a more or less constant temperature throughout the year. In Rupert Inlet, however, there is a difference of about 4 - 6°C between the February and July water temperatures in the deep water. The water in Rupert Inlet apparently warmed up by the same amount at 120 metres as it did at 15 metres. The same pattern of warming throughout the water column can be seen for all the stations in the inlet. Figure 7 gives a more complete picture of the seasonal variation in water temperature for Station R7 in Rupert Inlet. It can be seen that the deep water temperature rises in the summer and falls in the winter months. This process apparently takes place rather gradually as the April, 1971 measurements indicate a
Figure 7. Seasonal variation of temperature profiles at Station R7 in Rupert Inlet.
temperature at 100 metres of about 8°C which is intermediate between the February temperature of about 6°C and the July temperature of about 12°C. In December of 1971 it can be seen that the deep water temperature had once again returned to about 6°C.

The seasonal fluctuation of deep water temperatures in Rupert Inlet has only one plausible explanation. The only mechanism by which the temperature of the deep waters in the inlet could increase and decrease seasonally throughout the entire water column would be the continual or at least frequent replacement of the deep water by water from, at or near the surface. There is no other means by which the deep water could gain or lose heat in sufficient amounts to cause such a change in temperature. The data for temperature in Rupert Inlet is therefore quite conclusive, particularly in conjunction with the other oceanographic data presented previously, in establishing that significant vertical mixing takes place in the inlet. Contrary to Utah's theory that the deep water was stable and not mixing with the surface water, it would appear that there is almost complete seasonal exchange of the deep water with replacement by warmer surface waters in the summer and by cooler surface waters in the winter.

It may be added that the pattern of water temperatures found by the author in Rupert Inlet coincides well with those
recorded by the Pre-Operational Phase of Utah's Environmental Control Program (Evans, 1972). In this publication, however, there is no attempt to interpret the data in terms of its implications for water circulation in the inlet. The report was prepared by the chairman of the U.B.C. advisory committee which was set up as an independent agent to supervise the environmental monitoring program required by the Company's pollution control permit (see Chapter 3). It contains a great deal of useful background information on the inlet prior to the commencement of tailings discharge from the mine. However, it is unfortunate that the report contains the same weakness as all the other research that has been carried out by the Company. There is simply no attempt to determine directly or to infer from the temperature and salinity values, the pattern of water circulation in the inlet. It is obviously fundamental to the prediction of the impact of the tailings on the inlet to arrive at some hypothesis concerning water circulation. The fact that the Company has avoided investigating this question leads one to believe that they are not anxious to know about it. This attitude on the part of a major corporation involved in primary resource extraction can only lead to errors in judgement by themselves, the government, and other groups involved in their regulation.

In conclusion, the results of temperature measurement in Rupert Inlet can be summarized as follows:
1. The water temperatures are very uniform from very near the surface to the bottom at all deep water stations in Rupert Inlet at any one time of the year. Surface heating in the summer and surface cooling in the winter are confined to the top few metres of the water column.

2. There is no sharp thermocline separating the water into distinct horizontal layers of differing density at any time of the year during which samples were taken.

3. The pattern of seasonal temperature variation in the deep water indicates that there is frequent and perhaps continual vertical circulation throughout the water column in Rupert Inlet.

4. Utah's interpretation of the oceanographic conditions in Rupert Inlet was both superficial and incorrect.

The Significance of Turbidity Measurement in Oceanography and its Application in Rupert Inlet

Turbidity measurement has been used by a number of investigators in basic oceanographic research. One application has been in deep sea and coastal research as a means of tracing water currents and determining general patterns of water circulation. In using turbidity as a diagnostic feature in oceanography, it is assumed that the separate "sources" of water for
each waterbody will have a characteristic turbidity and, because of this, water masses can be distinguished from each other on the basis of this parameter. In its most basic form, turbidity is simply the measurement of the relative ability of the water to absorb light. The light absorption properties of water are determined by a number of factors. Basically, anything that is in the water that will reflect (scatter) or absorb electromagnetic radiation in the visible spectrum contributes to its turbidity. This would include all particulate solid matter as well as dissolved substances that absorb light. River sediment would be among the former while dissolved substances that discolor the water such as humic acids draining from the land are among the latter mentioned substances contributing to light absorption. It must be emphasized that the turbidity value for a particular water mass cannot be converted directly to a quantitative expression of the concentration of suspended solids (particulates) in that water. This would be the case if all suspended matter was identical in particle size, chemical composition, and optical properties, and if there were no dissolved substances that absorbed light in the water. In fact, however, there is considerable variability both within and among different water masses. Turbidity values are therefore only rough quantitative expressions of the suspended matter in the water being measured.

The turbidity of water can be expressed as an
attenuation coefficient which is defined by the equation:

\[ I = I_0 e^{-\alpha L} \]

Where \( I_0 \) is the intensity of light at its source, \( I \) is the intensity of light after it has passed through the water being measured, \( e \) is the exponential function (\( \log e \) equals 2.3 \( \log_{10} \)), \( \alpha \) (alpha) is the attenuation coefficient, and \( L \) is the distance (path length) over which the light travels through the water. The attenuation coefficient (also known as the extinction coefficient or simply as "alpha") is expressed in reciprocal metres (metres \(^{-1}\)) when the path length \( L \) is expressed in metres.

The use of turbidity measurement as a means of indicating the distribution of individual water masses in a body of water is best described by Jerlov (1968). His book on optical oceanography is the most complete work on the subject and many examples of the application of light absorbtion measurements are presented in it. The diagnostic features of vertical turbidity profiles are presented in a paper by Joseph (1955), a brief review of which will be sufficient to indicate the manner in which turbidity measurement can be applied to oceanographic research. It has been found that waterbodies that are stratified into horizontal layers of differing density show a marked increase in turbidity at the interface of the layers. Figure 8a is an example of this situation and shows that the water (in this case of the North Sea) is stratified into two distinct layers with a sharp discontinuity at about 38 metres
Figure 8a. Turbidity and temperature profiles from a station in the North Sea, (After Joseph, 1955).

Figure 8b. Turbidity and temperature profiles from a station on the Dogger Bank, (After Joseph, 1955).
depth. The corresponding vertical temperature profile has been superimposed on the graph in order to illustrate the fact that the turbidity increase coincides with the thermocline. On the other hand, if there is no marked turbidity change in the water column, it can usually be assumed that the waters are well mixed, i.e. relatively homogeneous. Figure 8b is an example of a turbidity profile from the Dogger Bank and shows a homogeneous distribution from top to bottom. The temperature profile is again included and as would be expected, there is no evidence of a thermocline.

One other diagnostic feature of vertical turbidity profiles deserves mention. It has been found (Joseph, 1955) that there is a sharp increase in turbidity near the bottom in areas where there are strong ocean or tidal currents. This turbidity increase is apparently the result of bottom sediments that are picked up by the currents and carried along with them. The existence of such a turbidity increase at the bottom of a vertical turbidity profile is therefore an indication that there are currents affecting the bottom waters at that location.

The Design and Construction of a Transmissometer

For the Measurement of Turbidity in Rupert Inlet

In order to obtain the relevant information on turbidity in Rupert Inlet, it was necessary to collect the data as continuous vertical profiles. This was because most of the
diagnostic features of turbidity profiles are related to the rate of change of turbidity with depth rather than with its absolute value at any one depth. This can only be achieved by an instrument that measures the turbidity directly as it passes through the water column. The alternative method is to collect water samples in sampling bottles from various depths in the water column and to analyze them for turbidity at the surface in a laboratory. This is a much more convenient method (it was the method used for the preoperational phase of Utah's environmental monitoring program) as it eliminates the need to employ underwater optics and electronics. Its weakness, however, is that it only provides a very discontinuous representation of the turbidity. Because of this, it is probable that many of the significant features of the profile would not be recorded thus making interpretation and comparison difficult. It was necessary, therefore, to use a transmissometer (otherwise known as a turbidity-meter, a transparency-meter, a light attenuation meter, an alpha meter, a hydrophotometer or a turbidimeter) that provided data in a continuous form.

A simplified diagram of the instrument employed is shown in Figure 9. It was designed and constructed by the author after reference to Briggs and Morris (1971); Duchrow and Everhart (1971); Fukuda (1958); Inoue, Nishizawa and Fukuda (1955); Jerlov (1953, 1955, 1957, 1959, 1968); Jones and Wills (1956); and Joseph (1955). A great deal of help was also
FIGURE 9. DIAGRAM OF TRANSMISSOMETER CONSTRUCTED FOR USE IN RUPERT INLET.
The transmissometer consists of two water-tight cylinders that are aligned on an axis by means of three stainless steel rods. In one of the cylinders is a 12 Volt incandescent bulb that supplies the light source for turbidity measurement. The light is placed so that the filament is at the focal point of a double convex lens (focal length 44 mm., diameter 46 mm.) that is placed between the bulb and a ½-inch thick glass window at the end of the cylinder. Behind the bulb is a light-dependent resistor (photocell) that acts as a reference for the photocell in the other cylinder. The double convex lens provides a parallel beam of light that passes through the glass window and into the water where it travels for 60 cm. through the water. It then enters another glass window and into the second water-tight cylinder. Upon entering the cylinder, the light passes through a lens identical to the one in the first cylinder which focuses the light through a pinhole in a partition. This assures that only light which is parallel to the axis of the instrument is able to pass through the pinhole and onto the photocell that is placed about 30 cm. behind it, thus preventing all other light from being recorded. The two photocells are connected in a bridge circuit that serves to produce a relative rather than an absolute reading of the light intensity reaching the photocell in the second cylinder. In this way
any fluctuation in the light intensity of the 12 Volt bulb is compensated for.

The power for the instrument was provided by a 12 Volt lead-acid battery on board the research boat. The battery was connected to a waterproof connector on the instrument by means of a 4-wire neoprene-coated cable of 160 metres length. Two of the wires provided the circuit for the 12 Volt bulb and two of the wires, after passing through resistors to adjust the current, provided the power for the photocells. The turbidity was recorded on the surface by a Rustrak Model No. 2146 miniature chart recorder that was powered from a separate 12 Volt battery and had a range of sensitivity from 0-100 micro-amperes. The current was adjusted to calibrate the instrument by means of a combination of fixed and variable resistors in a control panel in order that turbidities ranging from 100 to 0% transmission of light corresponded to current values from 0 to 100 micro-amps. The calibration procedure was identical to that employed by Jones and Wills (1956). The turbidity reading was recorded on Rustrak Style N chart paper and provides a continuous trace of the per cent transmission of light across the 60 cm. path length.

The transmissometer was lowered into the water by means of the 12 Volt battery-powered winch on board the research boat. It was attached to the winch with a 3/16 inch stainless
steel cable. The 4-wire electric cable was lowered and raised by hand and was coiled in a container on deck when not in use. The depth of the instrument was recorded by means of an "event" marker on the recorder, which was operated manually.

All external parts of the instrument were of either acrylic plastic (Plexiglass) or stainless steel in order to avoid corrosion problems. The Plexiglass cylinders were painted black inside and taped with black plastic electricians tape on the outside in order to prevent extraneous light from entering the interior of the instrument. Black Plexiglass baffles were placed along the supports between the two cylinders for the same purpose.

The water pressure at 150 metres is approximately 200 pounds per square inch. In order to ensure that the cylinders were water-tight, rubber O-rings were used on all sealed surfaces at both ends of the cylinders and on the glass windows. The 2-wire electric cable running between the two cylinders was fitted at both ends with waterproof connectors.

Presentation of Turbidity Data for Rupert Inlet

The measurement of turbidity in Rupert Inlet was carried out for two distinct but related purposes. Firstly, it was hoped that turbidity data would be helpful in corroborating the evidence obtained from temperature measurement and the other
information available for the inlet. The presence or absence of a sharp discontinuity in turbidity values, the seasonal range of turbidity values and the presence or absence of an increase in turbidity near the bottom would all be useful in interpreting the oceanographic situation in the inlet. Secondly, and most important, it would be possible to determine the extent of distribution of Utah's mine tailings in Rupert Inlet after the dumping had begun. The natural levels of turbidity were measured periodically for about a year before the mine began to discharge its waste into the inlet and were then measured periodically for about a year after the discharge began.

The bulk of the mine waste is composed of finely ground rock. A large increase from the average natural levels of turbidity in the water column would therefore indicate the presence of tailings in it. It could also be assumed that wherever the particulate matter from the tailings was identified by turbidity measurement, the dissolved substances in the waste would also be present.

It happens far too frequently in developments involving environmental disturbance that there are no background (baseline) data collected before the development begins. As a result, even if data are collected after a disturbance has taken place, there is nothing to compare them with in order to
arrive at an estimate of the magnitude of environmental change that has taken place. The Utah mine offered an opportunity to conduct a study without this limitation, since it was possible to initiate the research on Rupert Inlet over one year before the mine began its waste discharge. It was also possible in the case of the Utah mine to test a specific hypothesis. This hypothesis was supplied by the mining company itself in its rationalization of the tailings disposal system. Simply stated, the hypothesis would read:

there will be no measurable increase in the average natural background levels of turbidity in Rupert Inlet above a depth of ten feet from the bottom as a result of Utah's tailings disposal system.

The monitoring of turbidity in the inlet was therefore all that was necessary to arrive at either confirmation or rejection of the hypothesis.

Turbidity profiles in Rupert Inlet were obtained for the same stations as for the temperature profiles (see Fig. 5). Another station, designated N1, and situated at the mouth of Neroutsos Inlet in mid-channel (see Fig. 2) was also sampled for turbidity. Turbidity was measured at these stations on seven occasions: November 2 and 3, 1970; February 4-6, 1971; April 26 and 27, 1971; July 21 and 22, 1971; December 1-3, 1971;
April 10 and 11, 1972; and September 18 and 19, 1972. The first four of these occurred before the mine began its waste discharge while the other three occurred after the discharge began. The results of these measurements are presented in full in Appendix B of the thesis.

In order to provide a more graphic visual representation of the turbidity data, the vertical profiles obtained for each replication were combined to yield vertical longitudinal sections of the turbidity pattern in Rupert Inlet. These diagrams will be used in the text in order to illustrate the description and interpretation of the turbidity data. On these diagrams the turbidity values are expressed as the attenuation coefficient as calculated from the light absorption values obtained directly from the transmissometer.

Before the discharge of tailings began, most of the water in Rupert Inlet was of very low turbidity and was very uniform with respect to both space and time. All four of the replications revealed that most of the water in the inlet had an attenuation coefficient between 0.13 and 0.15 m$^{-1}$. This corresponds to a range of light absorption from about 7 to 10% over the 60 cm. path length of water being sampled. There was no discernible pattern of seasonal variation in most of the water in the inlet.

The vertical profiles of turbidity presented in
Appendix B indicate that with the exception of two stations (Stations R1 and R2 on February 5, 1971) there was no evidence of horizontal layering of the water at any of the stations during any of the sampling dates. The two exceptions are probably due to a high freshwater runoff from the rivers at the head of Rupert Inlet. This would result in the higher turbidity values found in the surface waters throughout the inlet on this occasion. A local resident of the area verified this fact by stating that there had been over one week of heavy rains immediately prior to the February, 1971 field trip (Hole, 1971). It was therefore concluded that the typical vertical turbidity profile in Rupert Inlet was more similar to the example shown in Figure 8b than that shown in Figure 8a. The turbidity profiles support the conclusion that the water in the inlet is not stratified into distinct horizontal layers.

Although most of the water in Rupert Inlet had a very low and very uniform turbidity, a number of distinct regions of higher and more variable turbidity were observed. These were all found to occur either near the surface or near the bottom of the inlet with the highest readings either right on the surface or right on the bottom. An analysis of these regions of higher turbidity will serve to illustrate some of the natural patterns of water movement in the inlet.

Beginning with the longitudinal vertical section for
November 2 and 3, 1970 (see Fig. 10) it is evident that there is a region of higher turbidity near the bottom of the inlet from a depth of about 130 metres to the bottom. The turbidity is greatest on the bottom (with an attenuation coefficient of greater than 0.35 m\(^{-1}\)) and becomes lower as one travels upward to the 130 metre depth where it is about 0.15 m\(^{-1}\). This is the type of turbidity pattern described by Joseph (1955) and as discussed previously it is often indicative of deep water currents. The increased turbidity could be caused by a scouring and consequent mixing of the bottom sediments into the deeper water.

There were also two distinct regions of higher turbidity in the surface waters of the inlet during the November, 1970 sampling. One of these is centred around Station R11 and is almost certainly due to the sediment load in the runoff water from the Marble River (see Fig. 5 for the location of the Marble River). The other region of higher turbidity is centred around Station R5. As there are no major streams entering the inlet at this location and as the excavations and clearing for the mine-site had already begun when the first readings were taken, it was concluded that this region of higher turbidity was caused by the initial work on the mine development. It could be observed visually at this time that the surface waters adjacent to the mine-site were highly discolored by sediment-laden surface runoff that was originating from the land being
disturbed for the establishment of the mine.

The turbidity pattern for February 4-6, 1971 showed the highest surface turbidity for any of the sample replications carried out before the mine began to discharge its tailings (see Fig. 11). The reason for the high values (up to $0.90 \text{ m}^{-1}$ at the surface at Station R11) was most probably the very heavy rainfall that occurred in the area immediately prior to the sampling. There were two distinct areas of surface turbidity; one centred around Station R11 and another that appears to originate at the head of the inlet. The first was the result of runoff water from the Marble River and was the most turbid of the two regions. The second was most probably the result of runoff from the two creeks at the head of the inlet (Waukwaas Creek and Coetwaus Creek). It is interesting to note that there was a slight increase in turbidity of the deep water below Stations R1, R2 and R3. This was probably caused by sediment that is settling out of the runoff water as it enters the inlet from the two creeks. There was no indication of any surface turbidity caused by the mine-site clearing operations during this sampling period.

The longitudinal vertical section for April 26 and 27, 1971 shows only one significant region of higher turbidity water on the surface (see Fig. 12). This is located between Stations R5 and R9. This higher turbidity was attributed to
QUATSINO NARROWS

RUPERT INLET

STATION

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170

DEPTH (METERS)

0.20
0.17
0.15
0.25
0.40

> 0.13

ATTENUATION COEFFICIENT (α) IN M⁻¹

α ≥ 0.40 SHADeD LIGHTLY
α ≥ 1.00 SHADeD DARKLY

DATE: JULY 21 & 22, 1971
the land clearing operations leading to the development of the Utah mine. Just as during the November, 1970 field trip, the sediment-laden water was seen to be entering the inlet as runoff from the mine-site.

The surface water turbidity as a result of the Marble River runoff is apparent in the vertical longitudinal section shown for July 21 and 22, 1971 (see Fig. 13). This region was again centred around Station R11.

The regions of highest turbidity for this time of year were both centred around Station R5, one region being at the surface and the other at the bottom of the inlet. At the time these measurements were made there was a great deal of overburden being dumped into the inlet as a result of stripping the waste from the top of the ore-body at the mine-site. Part of the overburden material was being used to construct the causeways from the shore of the inlet out to Narrow Island to form the emergency tailings pond (see Fig. 5). Part of the material was apparently being disposed of by simply dumping it into the inlet. It was concluded that the surface turbidity centred around Station R5 was a direct result of this overburden dumping. It is also highly probable that the bottom turbidity centred around Station R5 was caused by the overburden dumping and a resulting flow of the heavier particulate matter down the side of the inlet along the bottom.
In summary, the turbidity of most of the water in Rupert Inlet was very low and very uniform throughout the year before the discharge of tailings began. It was consistently observed that there was a large region of water between the surface and the bottom that had a turbidity of less than 0.15 m$^{-1}$. This is in contrast to the situation that has been observed in Bute and Jervis Inlets on the British Columbia mainland where there is a large variation in the turbidity of the entire waterbody from the winter to the summer (Pickard and Giovando, 1960). This is caused by sediment entering these inlets from the melting of glaciers in the summer. In Jervis Inlet, for example, the maximum surface water turbidity ranged from a low of 0.75 m$^{-1}$ in February of 1958 to a high of 10 m$^{-1}$ in June of the same year. A similar situation was observed in Bute Inlet for the same months in 1958.

The Utah mine began to discharge its tailings into Rupert Inlet sometime in October of 1971. As had been planned, it was discharged from a submerged pipeline on the bottom at a depth of 150 feet and at a distance of about 1200 feet from the shore of the inlet. Figure 14 shows the vertical longitudinal section of turbidity for December 1-3, 1971, about one and one-half months after the discharge of tailings began. It is apparent from only a brief inspection of the turbidity pattern observed during this sampling that the tailings discharge had
resulted in a dramatic increase of the turbidity of all the water in Rupert Inlet. This change can be assumed to have taken place in the short time between the initiation of the discharge and the time of turbidity sampling. Before the input of tailings began there had been a region of water, comprising the greater part of the water in the inlet, with turbidity values below 0.15 m\(^{-1}\). One and one-half months after the discharge began most of the water in the inlet had turbidity values higher than 0.30 m\(^{-1}\) and the lowest turbidity value recorded in the entire inlet was 0.22 m\(^{-1}\). Approximately one year prior to this sampling, in November, 1970, the highest surface turbidity recorded was 0.25 m\(^{-1}\) (see Fig. 10). In December, 1971 the highest surface turbidity was 0.68 m\(^{-1}\) and represents an increase to about 150% of that of the previous year. In November, 1970 the highest bottom turbidity was 0.38 m\(^{-1}\) while in December, 1971 it was 3.60 m\(^{-1}\) or an increase to about 1000% of that of the previous year.

The pattern of turbidity distribution for December 1-3, 1971 leaves no doubt that there is a flow of water over the Quatsino Narrows sill and into the deep waters of Rupert Inlet. A distinct band of water of relatively low turbidity appears to have intruded into the turbid "cloud" caused by the tailings discharge. The longitudinal vertical sections for April 10 and 11, 1972 and for September 18 and 19, 1972 (see Figs. 15
VERTICAL LONGITUDINAL SECTION OF TURBIDITY IN RUPERT INLET

FIGURE 15

ATTENUATION COEFFICIENT ($\alpha$) IN $\text{m}^{-1}$

- $\alpha > 0.40$ shaded lightly
- $\alpha > 1.00$ shaded darkly

DATE: APRIL 10, 1972

QUATSINO NARROWS

RUPERT INLET

STATION

DEPTH (METERS)
VERTICAL LONGITUDINAL SECTION THROUGH RUPERT INLET

DATE: SEPTEMBER 18 & 19, 1972

ATTENUATION COEFFICIENT ($\alpha$) IN m$^{-1}$

$\alpha \geq 0.40$ SHADeD LIGHTLY
$\alpha \geq 1.00$ SHADeD DARKLY

QUATSING NARROWS

RUPERT INLET

STATION

ON1 R11 R10 R9 R8 R7 R6 R5 R4 R3 R2 R1

DEPTH (METERS)

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170

0.20 0.30 0.50 0.70 1.0

FARLINGS DISCHARGE

0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90

0.10 0.18

$\geq 0.17$

$\geq 0.10$

$\geq 0.07$

$\geq 0.04$

$\geq 0.02$

$\geq 0.01$
and 16) show that the tailings cloud is being pushed towards the head of the inlet by the currents flowing down over the sill. This displacement of the tailings by deep water currents is resulting in an upward movement of the turbidity cloud in the vicinity of Stations R5 and R6.

All three of the sample replications that were made after the mine began to discharge its tailings indicate that the turbidity of the water in Rupert Inlet has been increased throughout the entire waterbody. It is therefore necessary to reject the hypothesis, as stated by the Utah representatives, that the tailings discharge would result in no increase in the turbidity of the water above a depth of ten feet from the bottom.

Conclusions

The vertical temperature and turbidity profiles collected in Rupert Inlet for the period from November, 1970 to September, 1972 are sufficient, in conjunction with the data collected from other sources, to arrive at conclusions regarding the objectives of the oceanographic study. Firstly, the temperature data, in conjunction with the turbidity data, leave no doubt that there is a circulation of the water throughout the entire waterbody of Rupert Inlet. There is no distinct horizontal stratification of the water and it is therefore probable that the circulation is continuous from the surface to
the bottom of the inlet. Secondly, the turbidity data alone is conclusive in proving that the tailings are not settling directly to the bottom of the inlet as was predicted by the mining company and supported by the Federal Fisheries Department. The turbidity profiles indicate that the tailings have resulted in an increase in the turbidity of the entire inlet with the greatest increase occurring from the bottom to a depth of about 50 metres. In addition, the turbidity patterns observed in the inlet after the discharge began indicate that the deep water currents are the result of a flow of water over the sill of Quatsino Narrows and down into the deep waters of the inlet.

By using all the information that has been presented regarding the oceanographic features of Rupert Inlet, it is possible to arrive at a general model of the circulation of water in the inlet. It seems likely that the driving force for this circulation is the rapid flow of water (up to velocities of about 6 knots) that enters the inlet through Quatsino Narrows on an incoming tide. The water is well mixed as a result of its rapid flow through the narrows and is generally colder and more saline (and therefore has greater density) than the water on the surface of Rupert Inlet. Perhaps of greatest significance is the fact that the fresh water flow from the Marble River enters the inlet in such a way as to produce a layer of low salinity (low density) water immediately in the
Figure 17. Diagram of a vertical longitudinal section of Rupert Inlet showing the possible deep water current patterns caused by the tidal flow of water through Quatsino Narrows.
path of the tidal flow through Quatsino Narrows. It is therefore possible that the "diving" of the water flowing in through the narrows is enhanced by the downward deflection caused by its contact with this layer of low density runoff water. The downward flow of water as it enters the inlet results in the displacement of some of the deep water that is already in the inlet. The deep water is in this manner gradually replaced by the tidal flow entering the inlet. The displaced deep waters are eventually pushed to the surface of the inlet and are carried out through Quatsino Narrows on the outgoing tidal flow (see Fig. 17).

This hypothetical model of water circulation in Rupert Inlet is further verified by a number of visual observations that were made during the field trips to collect oceanographic data. On an incoming tide there was often a prominent "tide rip" forming an arc just off the entrance to Quatsino Narrows. The incoming water was moving rapidly (3-4 knots) on the narrows side of the tide rip, whereas the water on the inlet side of the tide rip was moving very slowly up the inlet (about $\frac{1}{2}$ knot). The incoming water appeared to be flowing beneath the surface water of the inlet.

On one field trip in particular (July 21, 1971), an observation was made that quite positively demonstrated the existence of deep water currents in the inlet. While lowering
Figure 13. Diagram showing the angle of the winch-line observed at Station R9 on July 21, 1971, indicating the presence of deep water currents.
the transmissometer at Station R9 there was a wind blowing from
the southwest at a velocity of about 5 miles per hour. This
resulted in a noticeable drifting of the research boat up the
inlet. Under these conditions, and if the water was not moving
(i.e. no currents), one would expect the winchline on which the
transmissometer was lowered to go down at an angle such as that
shown by the dotted line in Figure 18. This was only the case in
the top 10-15 metres of the water, however. From a depth of
about 15 metres of the water to about 50 metres the winchline re-
mained relatively vertical. This would indicate that the water
between these depths was moving up the inlet at a velocity equal
to the research boat and therefore at a higher velocity than the
surface water. Below 50 metres and down to a depth of about 100
metres the angle of the winchline changed even further (see Fig.
18). The only plausible conclusion is that the water between
these depths was travelling up the inlet at a higher velocity
than that of the research vessel. Below a depth of 100 metres
the winchline gradually became nearly vertical again, indicating
that the velocity of the deep water currents was decreasing
below this depth. These observations were made about one hour
after high water (calculated from the Canadian Tide and Current
Tables, 1971). It is therefore probable that the deep water
currents indicated by the angle of the winchline were the
result of the tidal flow through Quatsino Narrows.

Observations were also made of surface upwelling of
water at various locations in the inlet. This was often seen to occur near Hankin Point (see Fig. 5) where at times the water appeared to be "boiling" due to the high velocity of the upwelling current. Less intense but more extensive upwelling was frequently observed right off the mine-site in the vicinity of Stations R5 and R6. This was most probably the result of deep water displacement by the flow of water entering the inlet through Quatsino Narrows.

The decision to permit Utah to discharge its mine tailings into the deep waters of Rupert Inlet was to a certain extent based upon the report commissioned by the Water Resources Service of the British Columbia Government to B.C. Research (Duncan, 1970). This report contained the following recommendation:

Where possible, and where reuse value is considered minimal, tailings should be disposed of at depth in deep bodies of water.

The report goes on, however, to recommend that:

Underwater disposal should not be permitted where settling characteristics of the tailings, or underwater currents, preclude rapid and complete settlement.

It is therefore the conclusion of the thesis that Utah's method of mine tailings disposal is environmentally undesirable, as
described in the B.C. Research study, as it has resulted in a dramatic increase in the turbidity of all the water in Rupert Inlet. This situation has occurred despite the large body of evidence that was available prior to the discharge from which it was possible to predict the present condition of the inlet. It was argued by the company, despite the absence of supporting evidence regarding the oceanographic condition of the inlet, that this situation would not develop. It can therefore be concluded, on the basis of the evidence presented in this chapter, that either:

1. an error in judgement was made on the part of the Company and the government agencies involved in the approval of the Company's disposal plans, or:

2. the Company and possibly the government agencies acted with little or no regard for the environmental consequences of the mine waste disposal and decided to minimize or to ignore the information that was presented to them.

Whichever of the above possibilities is the case, there is no doubt that Rupert Inlet has been affected far more seriously by the tailings discharge than was originally anticipated by the Pollution Control Branch when it granted a pollution control permit to the mining company. It is therefore
the recommendation of this thesis that the underwater disposal of mine tailings into Rupert Inlet cease and that a suitable means of land disposal, as outlined in Chapter 5, be adopted at the Island Copper Mine operated by Utah Construction and Mining Company.
Bibliography for Chapter 5


CONCLUSION

The preceding chapters have presented in some detail many of the legal, economic, administrative and environmental problems encountered in resource-use decision-making.

The thesis has demonstrated that the major weakness in the present process by which resource-use conflicts are resolved is the lack of consideration of information regarding the environmental impact of resource developments. This is due partially to an actual scarcity of information, but is also because of the reluctance of corporate and government decision-makers to take this information into consideration.

The experimental work carried out for the thesis (Chapters 3 and 5) was intended to provide information necessary to an evaluation of the environmental desirability of Utah's tailings disposal system. In summary, the data collected indicated that:

1. The water in Rupert Inlet is well mixed from top to bottom as a result of the tidal flow through Quatsino Narrows. The temperature data collected in the inlet indicate that the entire waterbody is being replaced as a result of frequent or perhaps continual displacement by warmer water in the summer and cooler water in the winter which is flowing into
the inlet through the narrows and replacing the deep waters of the inlet. In addition, the presence of increased turbidity near the bottom of the inlet, probably caused by sediment scouring, and the results of the limited current measurements carried out by B.C. Research, indicate that there are relatively strong currents in the deep waters of Rupert Inlet.

2. The turbidity measurements carried out in Rupert Inlet indicate that prior to the commencement of Utah's tailings discharge the turbidity of most of the water in Rupert Inlet was very low and very uniform throughout the year. On all of the four replications of turbidity measurement carried out in the year prior to tailings discharge it was found that most of the water in the inlet had a turbidity value (attenuation coefficient) of less than 0.15 m\(^{-1}\).

The turbidity measurements carried out after the commencement of tailings discharge indicate that the turbidity of the entire waterbody in Rupert Inlet has been greatly increased by the introduction of the tailings. One and one-half months after the discharge began the lowest turbidity value recorded
in the inlet was 0.22 m$^{-1}$. The highest turbidity recorded in the deep water of the inlet before the discharge began was 0.38 m$^{-1}$. One and one-half months after Utah began discharging tailings the highest turbidity value recorded in the deep water was 3.60 m$^{-1}$ which represents an increase to about 1000% of pre-discharge values.

3. The analysis of water samples collected at a number of active and abandoned mine-sites in British Columbia indicate that there is considerable heavy metal pollution of water that drains through areas which have been disturbed by mining operations. This was particularly true of mining operations that have been in production for many years such as the Anaconda Copper mine at Britannia and the Sullivan mine operated by Cominco at Kimberly. The fact that heavy metal pollution has resulted from mining operations that are comparable in many respects to the Utah mine at Rupert Inlet suggests that in time this mine will also create serious heavy metal pollution of the water draining from the open-pit.

A major objective of the experimental work carried out in Rupert Inlet and at other mine-sites in the province was to
demonstrate that it was possible, given very limited financial and material resources, to obtain information necessary to the prediction of the probable environmental impact of the tailings discharge and land disturbance from the Utah mine. In order to illustrate the relative success of the experimental work in fulfilling this objective, it would be useful to compare the results obtained with those presented in the report of the environmental monitoring program set up by Utah in compliance with its pollution control permit (Evans, 1972).

The Utah monitoring program was successful in collecting a large amount of background data for Rupert Inlet. In particular, the data for the heavy metal content of aquatic organisms was presented in a manner that will make it possible to compare them with heavy metal data collected after the mine began to operate.

Despite the fact that a large amount of useful data was assembled during the Utah monitoring program, the most outstanding feature of the report on pre-operational conditions in Rupert Inlet is the absence of background data that are essential to the determination of the suitability of the inlet for the disposal of mine wastes. In particular, the report was lacking in that it failed to include the following information:
1. There was no data presented in the report on the nature and composition of intertidal plant and animal species. The most probable effect of heavy metal pollution from land drainage would be the reduction or elimination of intertidal organisms (as is the case at the Anaconda Copper mine at Britannia Beach). A study of the intertidal flora and fauna was therefore essential to the determination of the post-operational effects of the mining operation.

2. There was no attempt to interpret the unusual sediment distribution on the bottom of Rupert Inlet. The fact that the deepest part of the inlet is virtually free of sediment leads to the possibility that deep water currents resulting from the tidal flow through Quatsino Narrows are preventing the deposition of sediment there.

3. While the report did contain data on the resident fish populations in the inlet, it made no reference to the important commercial species such as salmon and herring. Rupert Inlet is the only major spawning river for spring salmon (chinook) in Quatsino Sound. It is therefore essential that a complete inventory of these species
be taken if a complete understanding of the inlet's ecology is to be attained.

4. The most outstanding weakness of the report is the lack of any attempt to determine the circulation of water in Rupert Inlet. The central argument put forward for the use of the inlet for waste disposal was the hypothesis that the deep waters of the inlet were not affected by currents and were not mixing with the surface waters. It would therefore seem central to any pre-operational monitoring program that this hypothesis be tested by the collection and interpretation of temperature, salinity, oxygen and current data. In fact, there was no attempt at current measurement and the temperature, salinity and oxygen data collected were not sufficient to arrive at an interpretation of water circulation in the inlet.

In comparing the two programs, it is sufficient to state that while the Utah program was unsuccessful in providing the necessary data on which to evaluate Rupert Inlet's desirability as a receptacle for mine wastes, the author was able to demonstrate that the deep waters of the inlet were circulating and that the tailings would not settle directly to
the bottom. The author's study was also successful in proving conclusively that the introduction of the mine tailings was indeed responsible for an increase in the turbidity of the water in Rupert Inlet. As of the date of this writing there has been no data released by Utah on the effects of the tailings discharge on the turbidity of the inlet, despite the fact that this data is being collected routinely as part of the monitoring program (Evans, 1972).

The pre-operational phase of the Utah monitoring program was carried out at a total cost of $225,000 of which $30,000 was for capital equipment, $40,000 was for operating supplies and labour, and $155,000 was for consultants and purchased services (Evans, Ellis, and Pelletier, 1972). The projected cost per annum for the post-operational monitoring program is in excess of $100,000. The Company's pollution control permit requires that the monitoring program be carried on for at least five years after the commencement to discharge tailings and it will therefore result in a total expenditure in excess of $750,000. The personnel required for the Utah monitoring program included 12 faculty members from the University of British Columbia, from the University of Victoria, a full-time staff of research workers at the mine-site, and numerous workers engaged part-time in data collection and sample analysis.

The experimental work carried out by the author
during the three years from 1969 to 1972 was done at a total cost of about $12,200 of which $9,000 was for living expenses while studying at the University of B.C. as a graduate student, $2,000 was for equipment and operating supplies, and $1,200 was for travel expenses to and from the mine-site. (This cost does not include any estimate for the voluntary services provided by the author's friends who accompanied him as research assistants on the field trips. Even if all such additional expenses were included, the total cost would certainly be less than $25,000.)

The Utah monitoring program was, of course, far more involved and required more sophisticated equipment than did the author's experimental work in Rupert Inlet. On this basis a comparison of the total costs of the two projects is invalid, as they were not similar in their objectives. It is interesting, however, that even though the Utah program required such a large expenditure of funds that it was not successful in generating information that was absolutely essential to satisfy the objectives of an environmental monitoring program.

The information generated by the author's experimental work in Rupert Inlet was presented to both the Pollution Control Branch (Chmelaushas, 1971) and to the U.B.C. advisory committee (Evans, 1972). Despite the fact that the information presented indicated the existence of deep water circulation in the inlet, there was no change in either the Pollution Control
Branch's policy towards the waste disposal or in the advisory committee's monitoring program. This demonstrates the fact that even when the information necessary to a desirable decision is available, there is often a reluctance on the part of decision-makers to consider it. The weakness of the decision-making process is therefore more directly related to the attitudes of the people involved and to the structure and function of the institutions involved, than it is to the quality of the information being considered.

The solution to this problem will require legislation to restructure and redefine the functions of the government agencies involved in the decision-making process. This will necessarily result in a redefining of the relationship between resource developers, whether they be individuals, corporations, municipalities, etc., and the government.

A great deal of further research will be required in order to arrive at suitable legislation and in order to generate the technical information necessary for future resource-use decisions.

This thesis has demonstrated that the present decision-making process is inadequate to deal with the environmental problems encountered in large scale resource developments. It must be hoped that this research will be continued and expanded, and will result in a more socially beneficial and less environmentally damaging use of natural resources.
Bibliography for Conclusion


APPENDIX A

BATHYTERMOMGRAPH DATA FOR RUPERT INLET

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TEMPERATURE (°C)

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DATE: DEC. 2
TIME: 13:30

STATION: R4
DATE: DEC. 2
TIME: 12:00

STATION: R5
DATE: DEC. 1
TIME: 15:30

STATION: R6
DATE: DEC. 1
TIME: 15:00

STATION: R7
DATE: DEC. 1
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BATHYTERMOMOGRAPH DATA

APRIL 10, 1972
APPENDIX B

TRANSMISSOMETER DATA FOR RUPERT INLET

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TRANSMISSOMETER DATA  NOVEMBER 2 & 3, 1970

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TRANSMISSOMETER DATA

APRIL 26 & 27, 1971

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TRANSMISSOMETER DATA JULY 21 & 22, 1971

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