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WATER QUALITY AND RECREATIONAL USE OF THE RIVER VALLEYS IN CALGARY

by

© ANNE D. B. DHANANI

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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Date Oct 2, 1981

ABSTRACT

The river valleys within the city of Calgary are a major resource for outdoor recreation. It is a policy of the City that recreation should be the primary use of the floodplains and thus the park system in these valleys, which is already quite extensive, is being expanded. However, parts of the floodplains are occupied by industries, municipal works and residential areas and the quality of river water is degraded by discharge of wastes and runoff into the rivers. For some years water quality has been a problem and has aroused protests from recreationists who use the rivers, notably fishermen. As the population of the city has grown, and the park area in the river valleys has been increased, water quality problems have become more significant and have come to the attention of more people.

It is the objective of the author of this thesis to determine the impact of water quality on recreational use of the rivers and adjoining land and to assess the constraints that this might impose on plans for future development. In order to understand the nature of the problem, the literature on the role of rivers and the nature of water pollution in urban areas is reviewed together with information on relationships between water quality and recreation. Further, the administrative and legislative background to water quality control is discussed. The availability of water resources for recreation in the Calgary area is discussed and related to demand for use of those resources in light of current trends in recreation demand and the rapid growth in population of the city. The actual water quality of the Calgary rivers is analysed and that information is used to assess ways in which water quality imposes (or may in future impose) limits on use of the river valleys for recreation.

It was concluded that there is a very significant degradation of river water quality, particularly in the Bow River in south-east Calgary and in Nose Creek. Poor water quality has a negative impact on recreation and is a limitation on further development of the river valleys for recreational use. In order to improve and expand outdoor recreational opportunities in the river valleys water quality must be improved. Steps are already being taken to upgrade the quality of effluent discharge into the Bow River from the municipal sewage treatment plants but the considerable increase in volume of discharge will partially offset the improvements instituted. Also the rapid urbanization of the

watersheds of the rivers will make water quality degradation by urban runoff, already significant, an ever increasing problem in the future unless a large-scale effort to control this source of pollution is undertaken.

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1. INTRODUCTION

1.1 The Problem

Since the Second World War (1939–45) there has been a great increase in demand for outdoor recreational opportunities and in particular for those based on water resources. In the United States the Outdoor Recreation Resources Review Commision conducted a nationwide survey in 1962 and found that ninety percent of Americans participate in outdoor recreation of some kind and that most of those seek recreation associated with water (O.R.R.R.C., 1962, p. 12). Boating and fishing were ranked among the top ten outdoor activities and swimming ranked second. In a 1974 study it was reported that swimming was becoming so popular that by 1980 more people would be going swimming than participating in any other outdoor activity (Bumgardner, Klar and Ghirin, 1980). A 1975 survey by Fisheries and Environment Canada showed that one in four Canadians participate in sport fishing (Jennings, 1979, p. 2). The popularity of fishing in Alberta itself is indicated by the fact that sales of angling licenses increased almost 40 percent between 1974 and 1977 (Jennings, 1979, p. 2).

This demand is most intense in urban areas where there is both a high density population and usually a relative scarcity of sites suitable for water-oriented outdoor recreation. At the same time it is in these areas that the problem of environmental degradation is most acute and that it is the most difficult to maintain a high quality of water and associated shorelands for recreational use. More than anywhere else, water bodies in or near urban areas serve a multiplicity of uses. They not only offer the economic benefits of industrial and domestic water supply and waste assimilation, but also can enhance the quality of life for the population in other ways: for example, they may serve as a resource base for recreational opportunities, provide a habitat for wildlife and enhance the aesthetic value of the urban scene. Further, urban rivers

> "...can serve as the environmental skeleton on which an entire community amenity of major proportions can be built". (United States Environmental Protection Agency, 1972, p. 12.)

However, the wide range of water uses makes potential for conflict and environmental degradation very great. The problems arising from water quality degradation are essentially ones of resource use conflict. One sector may derive economic benefit from the resource by using its capacity to assimilate waste, but in doing so these uses are also degrading the quality of that resource. This would not matter if water was not also needed by another sector for a different purpose, such as recreation, thus leading to conflict between resource users. This problem arises because of a limited supply of physical resources and inequality of resource distribution. For example, water resources for recreation are abundant in north-eastern Alberta, and relatively abundant in the Red Deer region, but are very limited in the Calgary area. This problem is exacerbated by the intensity of demand for water-based recreation opportunities in cities and aggravated further by rapid increases in demand due to the rapid growth of urban centres, as has occurred in Calgary. The latter makes planning for and allocation of resources difficult and there is consequently always a surplus of demand over supply. In these areas the limited supply of water resources and shoreline for outdoor recreation, which are both suitable and accessible, may lead to overuse and degradation of the resource which then results in lower quality recreation experiences (Shaw, 1978).

The city of Calgary has a river system with a high potential for recreational uses, but all the aforementioned problems come into play. Rapid urbanization of the watersheds of the Bow and Elbow Rivers has led to deterioration of water quality due principally to the discharge of municipal sanitary and storm sewage into the rivers. Also, in many areas public access to the rivers is restricted by private ownership of land or existing industrial land uses in the valleys make the river environment aesthetically displeasing. Concern over the degradation of this major resource has led to the development of the Calgary River Valleys Plan (released January 1981). The main objective in this study is to "encourage harmonious and diverse uses along the rivers and their tributaties", to "develop the rivers/creeks and valleys as a focal point of year round recreational activities" and to "maintain and enhance the existing distinctive characteristics of the riverine environment" (p. 1). The aim is to improve public access to the river banks, to expand and integrate the system of riverside pathways and to plan for appropriate use of the shorelands. Land use in the river valleys, accessibility and provision of facilities for outdoor recreation either on or adjacent to the rivers are thus the key considerations in this plan.[1]

Since it is planned that recreation will be a primary use of the river valleys it is important to ascertain the effects of water quality on such use. It is necessary to know what limitations water quality might impose on plans for development and, as a corollary, the effect that more intensive recreational use might have on water quality.

1.2 The Objective

The purpose of the author of this thesis is to investigate the relationship between water quality and recreational use of water resources and their shorelands, using the city of Calgary as the study area. The objective is to establish whether or not the present level of water quality in the rivers has any negative impact on recreational use, if so, what form it takes and how great it is. In view of the growth of the city and the City's policy to use the valleys for recreation it is also important to assess the constraints that water quality might present for these plans.

1.3 The Approach

The literature on water quality and recreation will be reviewed. In order to understand the conflicts that arise, the nature of water resources in urban areas and recreationists' perceptions of water quality must be understood. The legislative and administrative background to water quality control will also be discussed for it is important to know what methods are, or could be, used to protect and improve water quality in order to enhance recreational use.

The present and planned uses of the river valleys in Calgary will be examined and their role as an outdoor recreational resource assessed in relation to alternative opportunities and growth of the city. Data on a variety of water quality parameters will then be analysed in order to ascertain what problems might exist in relation to recreational use of the rivers and adjoining land. The combination of these two lines of enquiry will then enable an assessment to be made of both the present and potential impact of water quality conditions on recreational use of the river valleys. Particularly

[1]The Provincial Department was involved in this plan but withdrew its support in March 1980 when it became evident that it would essentially be a land use plan.

acute conflicts of use, specific problems and means of alleviating them will then be discussed and, finally, how they might be dealt with.

2. RIVERS, WATER POLLUTION AND RECREATION IN URBAN AREAS

2.1 Rivers in Urban Areas

Following an era of industrialization and great technological innovation with a concomitant degradation of environment, there seems now to be a greater awareness of environmental problems and of the need for maintenance and improvement of environmental quality (McPherson, 1968; Environment Canada, 1978; Whipple, 1977; Carroll, 1979; McMillan, 1979). People are not only more conscious of the quality of their own immediate environment but there is widespread feeling that man has a moral duty to preserve the environment for future generations.

However, the proportion of people living in urban areas is increasing steadily (Marcus and Detwyler, 1972) and thus, due to the intensity of human activity, it is where most people live that it is most difficult to maintain the quality of the environment at a desirable level (ORRRC, 1962; Whipple, 1977). Two of the environmental consequences of economic growth and urban expansion are an increase in water pollution and a decrease in available open space (McPherson, 1969; Whipple, 1977; Environment Views, 1980). This is particularly significant in view of the fact that concurrent with urbanization there have been great increases in disposable income, mobility, leisure time and education: all factors which have contributed to a formidable growth in demand for outdoor recreation opportunities. Due to the large concentration of population it is thus in urban areas that this demand is most intense and yet it is also here that natural resources for outdoor recreation are both in short supply and often degraded in quality (ORRRC,#4, 1962; Davidson et al., 1965). While extra-urban areas serve as major resources for outdoor recreation (for example, the Rocky Mountains in the case of Calgary), nevertheless, the largest proportion of leisure time is spent close to the home, that is in urban areas (ORRRC, 1962; Patmore, 1972). Thus potential resources for outdoor recreation within urban areas take on special significance because of their proximity to the potential users.

Many forms of outdoor recreation are dependent to some extent on water and shorelands. It is estimated that 75 percent of all outdoor recreation in Canada is water-oriented (Day and Parkes, 1978, p. 78) and the greatest percentage increases in participation are for these forms of recreation, swimming being the most popular and fastest growing (ORRRC, 1962; Hustins, 1973). The importance of this increase in recreation participation does not lie only in the psychological benefits of leisure time (Whipple, 1977), but also in economic benefits. For example, it is estimated that in 1975 Canadian anglers spent $900 million on food, lodging, transport and supplies, and another $940 million on boats, motors, vehicles and camping gear (Day and Parkes, 1978). Add to this the magnitude of employment in industries serving recreationists and the great importance of recreation to the economy becomes evident. Fishing and the supporting commercial and industrial activities it generates are directly dependent on the quality of fish life in our rivers and lakes. Likewise, in many activities (e.g. hiking and canoeing) much of the pleasure derived from the activity is associated with the presence of wildlife. The continued survival of wildlife populations depends partly on good quality water resources.

The outcome of this combination of factors, urbanization and increased demand for recreation, is that pressure for high quality outdoor recreational opportunities is particularly acute in cities. However, cities are usually established where fresh water is available for industry and domestic consumption, where rivers or their valleys may be used for transport, power generation and waste disposal: that is, where water resources are available for a variety of economic needs. It is, therefore, also in cities that there is the greatest competition for the use of water resources.

Man derives benefit from water resources and open space not only in terms of economics or the opportunity they present for recreation, but also from their aesthetic value. They provide "pleasant views from urban areas...a buffer against noise... a sense of urban identity" (Wurster quoted in McPherson, 1969, p. 160). Thus, "aesthetically pleasing water adds to the quality of human experience" (United States FWPCA, 1968, p.5) and is particularly valuable in cities because "diversity, be it ever so little, has a value in relieving stress" (Darling quoted in McPherson, 1969, p. 159). Thus, while the aesthetic value of good quality water resources is hard to assess, it is clear that such resources have a very important role to play in urban areas. In fact, their aesthetic value is probably more important than their direct value for water-based recreational activities, for it is pervasive and has an impact on all urban dwellers, recreationists and non-recreationists alike. However, as with recreation so too with aesthetics,

> "...the values that aesthetically pleasing water provides are most urgently needed where pollution problems are most difficult – in cities where population and industry are likely to be most heavily concentrated" (U.S. FWPCA, 1968, p. 5).

Rivers and river shorelands may provide many of these aesthetic benefits in urban areas, are ideal settings for many outdoor recreation pursuits and are often a haven for wildlife that would not otherwise live in an urban area (for example, the Inglewood Bird Sanctuary in Calgary, Plate 1). This latter benefit is especially great for city dwellers who frequently have little contact with natural environments.

However, as well as being magnets for recreationists, rivers their shorelands and valleys make attractive residential areas and are strategic economic locations (Shaw, 1978). River valleys are ideal for transport routes, frequently contain valuable gravel deposits, and are prime sites for industries requiring cooling water and a convenient stream for effluent discharge. Thus, the natural attributes of rivers and river valleys are endangered by encroachment and abuse by these other uses which are vital components of the economic functioning of cities. For these reasons, the city of Calgary is located in the Bow River valley. The location of the central business district in the floodplain and a major road paralleling the river are shown in Plate 2.

This diversity of water uses in urban areas means that diverse demands are put upon water within a confined space. Thus, "value conflicts...arise when a commodities-oriented economy develops the desire to restore and maintain its quality of life" (Barkley and Seckler, 1972, p. 51). This conflict may be between public and private groups, for example recreational fisherman and canoeists versus industries using a river for waste assimilation. It may also be intra-public conflict. That is, while on the one hand the public demands preservation of river valleys for recreational use, they also require new roads and sewage treatment plants in the same valleys and use of the rivers to dispose of their waste products (Edmonton Planning Department, 1974). Thus, while programmes to improve and enhance water quality will be of benefit to recreationists, the diversity of water uses means that

Plate 1 Inglewood Bird Sanctuary in summer

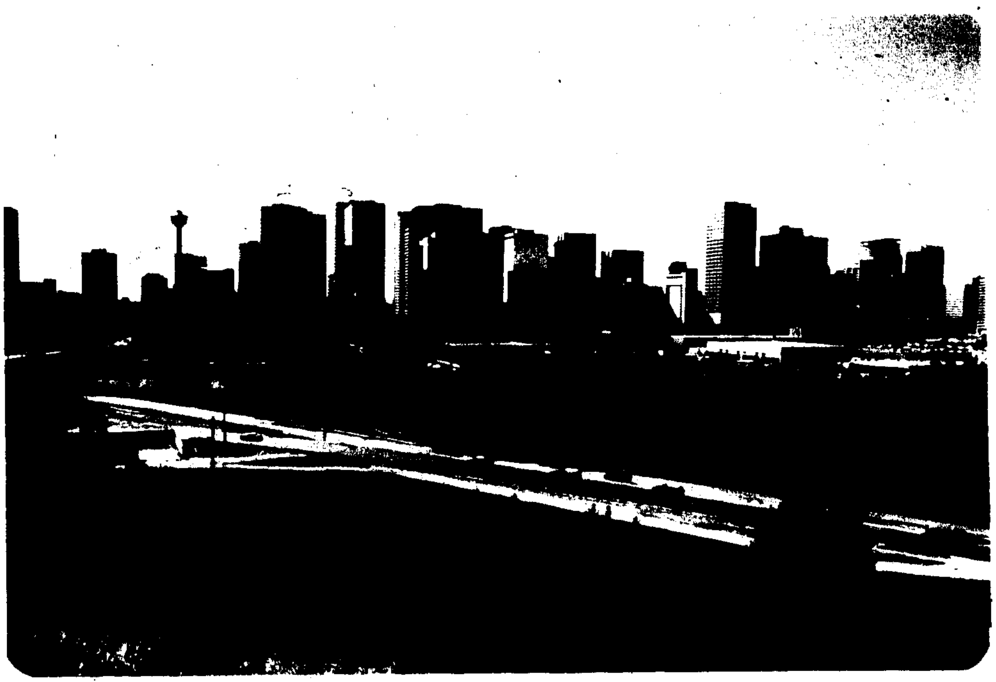

Plate 2 Downtown Calgary, the Bow River and Memorial Drive

"not all aims of pollution abatement can be served simultaneously without valuing some more highly than others and without confronting differences in human preferences" (G. White, 1971, p. 58)

For example, water with dissolved oxygen levels desirable for industrial purposes may be lethal to fish and thus disastrous to sport fishermen.

The great value of water resources for recreation and aesthetic enhancement, which does not contribute a tangible economic gain, has come to the forefront in recent years. However, very high quality water and shorelands are required for these uses and thus conflict often arises with, for example, industry which may both degrade the water quality and detract from the aesthetic value of the shores and valley. However, greater awareness of the value of open space and water resources in urban areas has led to the formulation of policies to protect these uses. That is, "Legitimate uses of streams change as the economy and affluence of the state change" (Illinois State, 1967, p. 169).

At the same time it is possible that recreational uses have benefited fortuitously from another state of affairs. That is, the increased competition for use of water resources has brought about realization of their true value and thus necessitated the formulation of policies and programmes to control their use and abuse.

"The increasing cost of water management and the competing demands for a finite supply mean that water has an economic value and, in the long term, cannot be treated as a free commodity." (Alberta Environment, Planning Division, undated)

A compromise has to be found between the costs of water pollution on the one hand (i.e. degradation of quality), and the costs of controlling that pollution on the other. Thus, while water-oriented recreation may in the past have been viewed as a fringe benefit of the existence of high quality water resources, it will be a primary beneficiary of improvement in water quality.

Nevertheless, in economic terms water has historically been regarded as a free resource, a 'common good', and as such is both undervalued and inefficiently used. While all other inputs to the production process have to be paid for, water for waste disposal is virtually free and thus is not subject to the same economizing measures as other resources.

"Naturally, if a resource is free, and if it contributes to the production of output in the industry, the firm will use all it possibly can. Even if the last amount of the resource contributes very little to the final output, at a price of zero, that amount will be used." (D. N. Dewees, 1972, p. 628).

In these circumstances "the resulting environmental quality quite naturally deviates from what the public would choose, since the public will is not reflected in private environmental decisions" (ibid.). This divergence between the public and private benefits and costs of water pollution and quality control make it necessary to impose from above a system of water allocation and quality control that will ensure both efficient and desirable use of water resources (Davidson et al., 1965). This is perhaps most essential when protection of water quality for public recreational use and general aesthetic value is concerned for provision of these amenities also operates outside the normal economic (market) system (Davidson et al., 1966; Barkley and Seckler, 1972; Wolman and Bonem, 1971). However, while this should lead to more equitable distribution of benefits of water resource use it is not a solution. The problem still remains of "the choice between investment for production of goods and services... and investment to enhance the aesthetic quality of rivers and lakes and the related landscape" (Wolman and Bonem, 1971, p. 35).

It can thus be seen that to assemble both water and associated land resources of a quality suitable for outdoor recreational activities can be very difficult in urban areas. In rapidly expanding cities such as Calgary there is often great pressure on both resources, thus creating considerable competition for recreational use. However, these problems are much more severe in old established areas where development of recreational potential may involve large scale urban renewal, land assembly and relocation of non-complementary uses.

Deciding which use will receive priority, whether of water or land, will depend on local circumstances but where competing uses are well-established they will often receive high priority or at least be difficult to remove (ORRRC, 1962). For example, "recreation uses of water in the United States have historically occupied an inferior position in practice and law relative to other uses" (US FWPCA, 1968, p. 7). In other words, recreation was often only considered an appropriate use if it did not interfere with other uses. "In a number of western states, recreation does not appear in the roster of 'beneficial uses' enumerated by statute" (ibid.). However, this situation has now changed dramatically because of a greater concern for the creative use of increased leisure time, because recreation is recognized as an important source of both physical and psychological well being and perhaps most important, it has become a multi million dollar industry with a major growth potential

Maintaining or enhancing the quality of water oriented recreation sites will entail water quality control, whether it be to improve the physical resource or to protect it against possible degradation by other users Objectives for water quality must be decided on, though in areas where there is already a problem and it is a question of imposing controls, given certain economic and political considerations, it may not be feasible to maintain water at a quality level suitable for all types of recreation Thus, the range of activities that may be pursued at a particular site may be restricted by water quality as well as by the natural physical characteristics of the site It is, therefore, important to know how quality affects the enjoyment of recreational activities

2.1.1 Effects of Urbanization on the Hydrologic Cycle

> "Of all land use changes affecting the hydrology of an area, urbanization is by far the most forceful" (Leopold, 1968, p 1)

First, the actual flow characteristics of streams are changed by urbanization of their watersheds These are determined by the extent to which a watershed has been covered by impervious surfaces and the efficiency of drainage. Impervious surfaces (buildings, streets, parking lots) prevent infiltration of precipitation into the soil and thus reduce soil moisture storage and groundwater recharge (Leopold, 1968; Thomas and Schneider, 1970). Instead of being channeled into these natural systems surface runoff is directed through drains and storm sewers to the receiving streams. The great efficiency of this man-made system means that storm runoff reaches these streams much faster under urbanization than under an agricultural or natural land use, with the result that flood peaks are much higher. For example, Leopold showed that

> "...for unsewered areas the difference between 0 and 100 percent impervious will increase peak discharge on the average 2.5 times. For areas that are 100 percent sewered, peak discharge... ratio increases to about eight for 100 percent impervious areas." (Leopold, 1968, p. 6)

Thus, under conditions of complete sewerage and a high degree of impervious cover the total volume of surface runoff and the frequency and magnitude of flooding increases, but groundwater recharge and thus the base flow of rivers is reduced. Stream channels tend to be enlarged by these increased flood flows, causing accelerated erosion of the banks and beds (Tucker, 1979). Hammer (1972, p. 39) studied this effect on 78 watersheds in Pennsylvania and came to the conclusion that channel enlargement effects depend on type of land use. He found that "the effect of impervious areas associated with detached houses is small", while "the effect of street and sidewalk area is large if the streets are sewered but otherwise small". However, for areas where impervious surfaces are large and more or less continuous the channel enlargement effect is very great, though with time the effect from residential areas tends to decrease (Hammer op.cit.)

. The volume of sediment yield from urban areas is also greatly increased over natural conditions (Tucker, 1979, Pierce, 1980). Wolman (1964) found that when an area is denuded of natural cover for construction the amount of sediment derived by erosion may be 20,000 to 40,000 times the amount derived from an equivalent area of farms and woodlands. This problem is thus of particular concern in a rapidly growing city such as Calgary where at any one time very large areas are denuded for street and highway construction, residential developments and central business district redevelopment. However, even without such intense construction activity, the difference in sediment yield between urbanized and unurbanized drainage basins was found by Leopold (1968) to be very great. He found that while "unurbanized drainage basins yield 200 to 500 tons per square mile per year", urbanized areas yield "from 1000 to more than 100,000 tons per square mile per year" (p. 11). However, this sediment yield in urban areas is very much dependent on current land use: when established (i.e. there is minimal construction activity), paved areas will yield less sediment than rural areas.

Under urbanization the aesthetic and recreational value of streams is often reduced. Channel enlargement causes bank erosion and destruction of vegetation; the addition of nutrients stimulates the growth of algae, which may then cause unpleasant odours, deplete oxygen concentrations and harm fish; finally, urban streams are often used as dumping grounds for all manner of rubbish. Another effect of urbanization is, thus, water quality degradation. While runoff from agricultural land adds nutrients and pesticides to rivers, that from urbanized areas adds a very wide array of contaminants to rivers which are used as receiving bodies for runoff and effluents. These include oil and grease, fertilizers, and sewage effluents. Furthermore, the contaminants in these discharges are usually much more concentrated than under agricultural or natural conditions.

2.2 Water Pollution in Urban Areas

2.2.1 Definitions of Water Pollution

It is this latter aspect of urbanization, water quality degradation, that is central to this thesis. However, since water quality is variable even under natural conditions and since degradation by man results in varying degrees of quality, it is no simple matter to determine at what point water may be classified as polluted. This is important to any discussion of the effects of water pollution for "in order to control pollution it is first necessary to define it and then to identify it" (Conover, 1970, p. 15).

To some people 'clean water' is that which is unaffected by man, but this definition is rather inadequate because sometimes 'natural' water is less than adequate for human needs and man can actually improve it (White, 1971, p. 59). Assessment of cleanliness involves human judgements and these will be not only subjective from an individual viewpoint, but also based on suitability for a particular use in a particular situation (White, op.cit.). 'Clean water', as opposed to 'natural' water, is thus best defined in the context of a certain use. A second definition of pollution and one that fits in with this requirement is that given by Egan :

> "something that is present in the wrong place at the wrong time in the wrong amount" (Egan, 1977, p. 100).

However, when a variety of conflicting activities are using the same water body this will not help resolve the question of whether or not that water is polluted. Nevertheless, it is more applicable and more helpful than the first definition for it does allow for the fact that a water quality deemed to be pollution in one set of circumstances may not be so considered in another situation.

A third definition incorporates the concept of human modification being central to pollution while also allowing for natural variations in quality and leaving open the possibility of differing user preferences.

> "A water is considered polluted when its composition or state is directly or indirectly modified by human activity to an extent such that it is less suitable for purposes it could have served in its natural state." (From a 1961 conference, quoted by T. R. Detwyler, 1971, p. 195)

This definition seems to be the most useful one in the context of river water quality in Calgary, for it is known that man-made causes account for the most serious pollution problems. However, this statement must be qualified: water may be 'polluted' by natural causes and thus, in another context, this definition might not be adequate. Nevertheless, it may still be said that, while

> "Natural water is not pure, ...most of what we call pollution today results from disposal of the waste products of civilization." (National Water Commission, 1973, p. 64)

2.2.2 Pollutant Sources in Urban Areas

Pollutant sources in urban areas are here divided into three categories: effluent from municipal sewage treatment plants, effluent from industry and effluent from storm runoff. The relative importance of each of these in any given area will vary with a large number of factors, including climate, the assimilative capacity of receiving streams and degree of industrialization. The city of Calgary is not heavily industrialized and so the main problem with regard to water pollution is usually seen as being sewage effluent. However, the magnitude of pollution by urban runoff is generally underestimated and receives less attention than is warranted, as will be shown.

The load of sewage carried to sewage treatment plants, under a system of separation of storm and sanitary sewage, includes a multitude of substances, but most notably: human wastes, food products, detergents and industrial effluents. While in some places raw sewage is discharged directly to rivers, in Calgary it undergoes primary and secondary levels of treatment. This entails screening out of large materials, settling out of inorganic solids such as sand and grit which is disposed of in sanitary landfills, primary clarification which is the settling out of organic and other suspended solids, then biological treatment. Biological treatment involves the mixing of sewage effluent with oxygen and the addition of micro-organisms which digest the organic content of the sewage. The sewage is then clarified once more to separate the wastewater from the sludge produced (which is then removed for further treatment and disposal), leaving a liquid effluent which, at the Calgary Bonnybrook Sewage Treatment Plant, has a biochemical oxygen demand and suspended solid concentration of about 20 mg./l.. With greater efficiencies expected to be achieved in the near future, these levels should be reduced to about 15 mg./l., representing 90 percent removal of biochemical oxygen demand and 93 percent removal of suspended solids (personal communication, B. Mackintosh). Under the expansion programme planned for the Bonnybrook Plant in 1983, the sewage will undergo 50 percent more primary clarification, about 50 percent more digestion and the removal of phosphorus by precipitation (B. Mackintosh).

Large industrial plants do not discharge their effluent into the sanitary sewage system but treat it (this depends on requirements) then discharge it directly to the receiving streams. In Calgary, the largest industries which discharge to the river are fertilizer plants and an oil refinery. These are industries which discharge wastewaters with high levels of suspended solids and chemical oxygen demand. In addition, while discharge from fertilizer plants has a heavy loading of nitrogen and phosphorus, that from oil refineries is particularly high in phenols, oil and grease.

As the point sources of water pollution are further controlled and treated the relative importance of non-point sources increases (Colston and Tafiri, 1975). This occurs because, not only is the proportion of pollution loading derived from runoff greater but it also then becomes evident that control of point sources of effluent discharge, on which control efforts have been focussed, is no longer sufficient to protect water quality. Indeed,

> "...there is considerable evidence that non-point sources of pollutants...which every year reach the water bodies we are trying to protect, may be as large or even larger than the point sources toward which virtually all of our multi-million dollar program is directed." (Hall, 1975, p. 20)

The significance of runoff to pollution in urban areas and the wide variety of pollutants it may contain has been demonstrated in a number of studies (DiGiano et al., 1975; Wiber and Hunter, 1975; Randall et al., 1975; McCuen, 1980).

However, it is also possible that the degree of pollution is related to size of drainage basin, being greater for smaller watersheds. Studies have shown that, for example, sediment load and B.O.D. are higher in smaller watersheds because of greater 'transport efficiency' and this may partially account for the high values recorded for urban runoff since many studies have been carried out on very small watersheds (Ragan, 1975). At the same time the degradation effect is greater in small streams because of the small volume of naturally flowing water (McCuen, 1980). This problem is compounded by the 'first flush' effect of storm runoff. That is, the pollutants in urban runoff are very concentrated because contaminants are washed off the surface in the early part of a storm (Pierce, 1980; Thornton, Kent, Nix and Bragg, 1980; Whipple, 1975). In fact, calculation of pollutant parameters (B.O.D., faecal coliforms, and others) for hypothetical street runoff showed "these to be frequently greater in magnitude than those in the raw influent to treatment plants" (Radziul, 1975, p. 13). This problem does not only occur in industrial or heavily developed areas. Hammer (1974, p. 53) demonstrated "an upward trend in most water quality parameters" for a suburbanizing basin in Pennsylvania. The results of these studies are of particular importance to Calgary. Here, very large sums of money are being spent to reduce point source pollution, while new residential and industrial subdivisions are being rapidly developed to accomodate a very rapidly growing urban population without any major effort to control pollution by surface runoff.

However, this pollutant source can be controlled by holding storm runoff in detention basins. This is particularly effective in settling out sediment and allowing bacteria to die off (Loijens, 1980). McCuen (1980) reports that for a study site in Maryland the average reduction in concentration of 11 water quality parameters was 60 percent. However, the efficiency of this system depends on detention time. As the volume of flow into the basin increases the detention time decreases, thus allowing less time for settling and die-off of pollutants (McCuen, 1980). Detention storage is also used to reduce the speed with which storm runoff reaches receiving streams and thus helps to alleviate the problems of elevated flood peaks, erosion and sediment transport described above.

The study described by Loijens is of particular interest to this thesis topic because the aim was to develop "the most cost-effective way of controlling pollutants so as to maintain and possibly enhance the recreational use of the Rideau waterway within the urban area" (op. cit. p. 54). Beaches along the river in Ottawa (the area of this study) have been closed to bathing either permanently or intermittently because of bacterial pollution. Although part of this problem was due to illegal sanitary sewer discharges and combined sewer overflows, urban storm runoff was found to be a significant source of some chemical pollutants and a very potent source of faecal index bacteria. The latter is of particular concern at bathing beaches and:

> "Bacterial pollution of the river during and after intense rainstorms from stormwater contains also high levels of index bacteria and attention has shifted to the treatment of stormwater runoff to control bacterial pollution." (Loijens, op.cit., p. 57)

Another point to be mentioned in a discussion of water quality is that in some circumstances pollution abatement may be a mixed blessing. For example, although the discharge of raw sewage causes a greater oxygen demand on the receiving water than treated sewage, it is sometimes the case that raw sewage actually causes less growth of undesirable blue-green algae than would primary treated sewage (Clarke, 1967).

There may even be advantages of pollution. Cultural eutrophication may lead to an increase in a fish population and even to bigger and better fish: a desirable outcome for fishing enthusiasts. However, if eutrophication continues apace other disadvantages may come into play and outweigh the former advantages. For example, excessive weed growth may lead to rafting and large beds of weeds may make access to parts of a river difficult for fishermen. There is also likely to be a decline in the quality of the fish flesh, thus making it unsuitable for consumption. This pattern of events has occurred in the Bow River downstream of Calgary. Considered one of the best trout streams in North America, cultural eutrophication did lead to an increase in the fish population but has now progressed to a stage where weed growth is causing serious concern among sports fishermen (Jennings, 1979) and many people do not eat the fish they catch.

2.3 Water Quality and Recreation

2.3.1 Some Definitions

Before embarking on a study of the effects of water quality on recreation it is useful to consider what is meant by recreation. Defining the word is not an easy task, for: "recreation is an enigma because while nearly everyone does it few agree on a definition" (United States E.P.A., 1972, p. 8). Nevertheless, a definition given by Driver seems to be a useful one; he describes it as "a particular type of human experience that finds its source in rewarding voluntary engagements during non-obligated time" (Driver, 1976). Charles Doell, on the other hand, has defined recreation as "the refreshment of the mind or body or both through some means which is in itself pleasureful...almost any activity or mental process may be recreation depending largely upon the attitude assumed in the approach to the process itself" (U.S. E.P.A., op.cit., p. 8)

In other words, recreation can be defined as an experience rather than merely as an activity and as such, aesthetics is very important to a high qualtity recreation experience.

An understanding of these concepts of recreation is important because, when evaluating water resources for recreation, it is not enough to look only at water quality and the physical capacity of the site to support activities. The quality of a recreation area is considerably enhanced by, for example, an interesting view, a natural setting or the presence of wildlife or birds. Often the satisfaction derived from an outdoor recreation experience may be increased simply by knowing, for example, that wildlife inhabit the area, even if they are not actually observed on any one occasion (United States FWPCA, 1968).

Likewise, there are various definitions of environment which may be held and this may lie behind controversy over what steps are necessary to ensure environmental protection. It would seem (to me) that to ensure preservation and enhancement of water resources, at a quality suitable for recreational use and aesthetic enjoyment, it would be better to take a broad view of what constitutes environment. Lafontaine has defined environment as

"the entity of the physical, chemical, biological and sociological circumstances, external to them, that living beings and especially man, encounter and that intervene in their present conditions and in their evolution either to promote them or to slacken or hinder them."(Lafontaine, 1977, p. 196)

Thus, aesthetic values are an important component of water quality objectives for recreational use. While such values are often protected by general standards, it was not until 1968 that aesthetics was added to the list of water uses to be protectd in the United States (Hines, 1971). However, if this broad definition of environment is taken, then aesthetic considerations and the value of recreation will be given greater weight in questions of environmental protection.

Nevertheless, aspects of water quality that affect health and comfort of recreationists are still important. However, where health protection is at issue differing opinions on a definition of health will lead to divergent assessments of what is necessary to protect it. The narrow view is, of course, simply that in order to protect the health of recreationists water should not contain any pathogenic organisms or any substances toxic to man. However, the World Health Organisation takes a broad view and defines health as "a state of complete physical, mental and social well-being and not only the absence of disease or disability" (Lafontaine, 1977, p. 196). Once more this brings us back to the importance of aesthetic factors as well as physical comfort and health in the assessment of suitability of a water body for recreational use.

2.3.2 Perception Studies

Since in the final analysis the actual usefulness of a water resource for recreational pursuits will depend on its perceived suitability by the users, it is important to know how they assess water quality and react to it. For this reason, studies which have examined recreationists' perceptions of water quality and the effects of poor quality on use will be reviewed.

Parkes (1974) interviewed beach users at four lakes of the Qu'Appelle Valley, Saskatchewan during the summer while also carrying out water quality sampling. He then compared responses to questions on water quality and levels of use between lakes and related this to the quality of the water. The general conclusions reached were that water quality was poor enough to cause a significant reduction of recreational use of the water and beaches at three out of four lakes; that lake users were aware of mounting concern over pollution generally and were becoming more aware of pollution in their immediate milieu. The fact that "the highest average amount of use in terms of primary water contact sports per user per season" was recorded at the lake with the best water quality and that users at this lake "recorded the least amount of activity reduction due to water quality problems", clearly demonstrates that water quality has a very significant impact on recreational use of a water resource.

These findings replicated those of Parkes's 1972 study of lake users and shoreline residents which showed that in all the areas studied there was reduction in some forms of water-oriented activities due to water quality degradation (Parkes, 1978). This also supported Coughlin (1972, p. 53) who found that :

> "The probability of using a stream site falls with increase in water pollution for nearly all activities."

However, in a Toronto study, Barker (1971) found that people swam in lake waters of very poor quality. They did so not because they were unaware of pollution, but despite the fact that they were aware of it. The apparent reasons for their continued patronage of beaches with poor water quality were related to the convenience factor and socio-economic variables giving rise to limited mobility. The same situation was also found to some extent in the Okanagan Valley (Canada – British Columbia Consultative Agreement, 1974). Investigation of water quality and use levels at several beaches indicated some negative response to low water quality but suggested that convenience might be a very important factor in beach use and that crowding might be a greater deterrent to use than poor water quality.

It has been found that users of low quality water are often willing to pay for an improvement. In the Saskatchewan study Parkes (1974) found that users at lakes with the poorest water quality were prepared to pay significant extra amounts to improve water quality. As might well be expected the quality of the water itself was not the only factor affecting willingness to pay. Other variables related to this willingness were income, time of season (this also has a bearing on water quality) and the amount of participation in water-oriented activities. An increase in any of these tended to increase the amount people were willing to pay. Of particular interest is the fact that he found willingness to pay for improved water quality among users of lakes that, over most of the period of study, met minimum provincial objectives for recreational use. This suggests that

> "...there is a discrepancy between the levels of water quality scientists consider acceptable for recreational use and those perceived by the user public" (Parkes, 1974, p. 111).

These findings on willingness to pay were replicated to some extent by David (1971). In a survey carried out in Wisconsin she found that people were reluctant to recommend increased public spending if they thought that the money would come out of their own pockets (in the form of taxes). However, given a list of projects for government funding they were prepared to reallocate funds from a number of other recipients to improve water quality.

Another important facet of these perception studies has been their elucidation of what the public perceives to be pollution. In his study Parkes found that over half the people interviewed mentioned algae as the most significant water quality problem. While this might well be related to the particular local situation, it is also indicative of viewpoint. David (1971), Nicholson and Mace (1975) and Bishop and Auckermann all questionned recreationists at lake sites, asking them to name water quality problems and to define pollution. The results were that, overwhelmingly, they mentioned the visual aspects of pollution, that is algae, scum, murky water and floating debris, while they did not spontaneously mention chemicals or toxic wastes.

It is also interesting to note that there were significant differences in the factors mentioned between types of recreationists (boaters, fishermen, swimmers) and between those using the water and those confining their activity to the shore (David, 1971). Bishop and Auckermann (1970) also showed that there were differences between user groups in the likelihood of terminating their use of a site due to a deterioration in perceived water quality. Their results showed that swimmers would be very likely to terminate use, fishermen would have a moderate to high probability of doing so, and sightseers a moderate probability, while boaters would be least likely to do so.

Coughlin (1975, p. 9) also noted that perception of water quality differs according to the use a person makes of a water body. He thus suggested that four discrete levels of water quality can be recognized by most people:

1. water clean enough for swimming and human consumption;
2. water clean enough to go fishing (that is, clean enough for native fish to live in), but not clean enough to swim in or drink;
3. water clean enough for boating only; and
4. water so foul that even boating is not pleasant.

In summary, therefore, the perception studies reviewed bring up several points of vital importance to both an assessment of the suitability of a water resource for recreational use and to public decision-making. These are:

1. the visual aspects of pollution are those most important to recreationists;
2. water of a quality which meets minimum government objectives may be considered poor by recreationists;
3. recreational use of a water resource usually declines with lowered water quality;
4. if alternative resources are lacking people will often use those with seriously degraded water quality;
5. the perception of water pollution and reduced use of a water resource because of pollution depend on the type of recreational use made of that resource.

2.3.3 Parameters for Evaluation of Water Resources for Recreation

In discussing water quality with regard to recreation it is usual to distinguish three levels of use:

1. direct contact;
2. indirect contact;
3. and non-contact or aesthetic use.

Direct contact recreation (also known as primary contact) may be defined as "activities in which there is prolonged and intimate contact with the water involving considerable risk of ingesting water in quantities sufficient to pose a significant health hazard" (United States FWPCA, 1968, p. 11). Indirect (or secondary) contact recreation involves "contact with water which is incidental or accidental and where possibility of ingesting appreciable amounts is minimal" (ibid.)

In accordance with these definitions, direct contact recreation includes such activities as swimming, wading, water skiing, windsurfing, skin and scuba diving. Activities considered to involve only indirect contact are usually boating, fishing and beach activities. The third category, non-contact recreation, takes in large tour boating, fishing from boats, recreation on land adjacent to water bodies and winter recreation on ice. However, there is good reason to believe that reclassification might be necessary. For example, kayaking frequently entails complete immersion of the body in the water and thus instead of coming under boating in the indirect contact category would be more appropriately classified as direct contact. Also, while some river reaches might not be suitable for swimming, in urban areas they will often be used by children playing. However, when referring to the different types of recreation the definitions given above will be used.

Factors influencing the recreational value of water may usefully be divided into two groups (United States EPA, 1972, p. 13):

1. those that endanger health or physical comfort;
2. those that render water aesthetically objectionable or unusable as a result of overfertilization.

The first group affects only direct contact recreational activities while the second affects all levels of use. Also, while types of water quality pollution that fall into the first group are usually invisible they may be accompanied by other visual aspects of pollution. Thus:

> "In most cases of gross micro-biological pollution of surface waters, there will be concomitant foreign substances of such magnitude as to cause the water to be aesthetically unacceptable." (United States EPA, 1972, p. 30)

For example, in the case of bacterial pollution it has often been found that at the same time floating sewage solids are present or that the addition of nutrients leads to increased algal or weed growth. Colour, taste, odour and turbidity may all render water unpleasant for recreational use and can also often be useful indicators of the presence of pollutants (Somers, 1977). For example, turbidity decreases the effectiveness of chlorination and thus may be used as an indicator of the possibility of a problem arising from this effect. Many pollutants, of course, cause a discoloration and unpleasant odour in the receiving water, particularly near outfalls. These parameters are thus important both through their direct impact on the aesthetic sensibilities of recreationists and also as indicators of chemical or biological pollution. Oil and grease on water are also unsightly and while large enough quantities could not be consumed by recreationists to have a toxic effect, they may cause obnoxious tastes and odours and endanger aquatic life (ORRRC #10, 1962).

There are three general water quality conditions that should be met for bathing waters: they should be aesthetically pleasing; they should contain no substance which is toxic upon ingestion or irritating to the skin; and they should be reasonably free of pathogenic organisms (Trewin, 1968; ShubenacadieStewiacke River Basin Board, 1978). However, the prime concern regarding water quality and water-based recreation is usually that of health.

Although epidemiological studies are lacking, some work has been done on trying to relate incidence of illness among swimmers to water quality. A series of studies has been done (Smith, Woolsey and Stevenson, 1951; Smith and Woolsey, 1952; and Smith and Woolsey, 1961; all reported on in United States EPA, 1972, p. 31) which demonstrated that there is a higher incidence of illness among swimmers than non-swimmers. The study of swimmers at a Lake Michigan beach (1951) showed a statistically significant increase in the incidence of illness among swimmers of poor water quality (mean total coliforms 2,300/100ml.). The 1952 study of the Ohio River showed that "swimming in river water having a median coliform density of 2,700 per 100 ml. appears to have caused a statistically significant increase in illness among swimmers". However, the third (1961) study on Long Island showed no relationship between illness and water quality. They also found that most of the ailments reported were of a minor nature not normally taken to a doctor.

An Environment Canada review of epidemiological studies (1972, p. 35) also indicated that illness does occur more frequently among swimmers than among non-swimmers. They found that eye, ear, nose and throat ailments represented 50 percent of recorded illness and gastro-intestinal 20 percent. This confirms Smith, Woolsey and Stevenson's earlier findings. It should be noted that the balance of ailments were skin irritations. Though usually of a minor nature, these can cause intense discomfort and were frequently reported as a most unpleasant consequence of swimming in the polluted waters of Lake Ontario (Simpson and Kamitakahara, 1971).

Further discomfort may be felt by swimmers or children playing in water because of the pH balance. Some waters are naturally alkaline or acidic and some are made so by the addition of chemicals but, whatever the reason, either condition can cause discomfort. The lacrimal fluid of the human eye has a normal pH of about 7.4 and a high buffering capacity can maintain it at this level until that capacity is exhausted. A deviation in the pH of swimming water may thus cause some discomfort and a large deviation will result in pain. However, natural waters rarely conform to the ideal level but the buffering capacity means that under average conditions a range from 6.5 to 8.3 can be tolerated (United States FWPCA, 1968, p. 16).

It has been stated that "many enteric diseases which may be transmitted through polluted beach water are endemic owing to other, more common methods of transmission" (ASCE, Public Health Activities Committee, 1963, p. 74). This thus obscures the incidence of infection contracted as a result of direct contact with polluted water, however this group came to

> "the inescapable conclusion that many people, particularly children, do develop enteric diseases each year as a result of swimming in polluted beach waters".

Both the longest standing, and the most commonly used, measure of water quality for health protection is the coliform standard. Both total coliform and faecal coliform bacteria counts are basic water quality parameters measured in stream monitoring.

However, faecal coliform counts are more reliable indicators of health hazard because, while total coliforms may come from a wide variety of sources, these originate only in the faeces of warm-blooded animals (including man). Other bacteria which are more reliable indicators of the presence of pathogenic organisms, are sometimes also monitored (eg. faecal streptococci). However, this is not standard practice for the water analysis techniques involved are more complicated, while the coliform count is a relatively easy parameter to measure and can thus be used by most monitoring agencies.

There has been a lot of controversy over the usefulness of coliform counts as indicators of health hazard because there is not a directly quantifiable relationship between concentration of coliform bacteria and of pathogenic organisms. There are many infections which are not transmitted by bacteria and it is likely that many enteric diseases, developed as a result of bathing in polluted water are due to protozoa and viruses (Krumbiegel in ASCE, Public Health Activities Committee, 1963, p. 64). Furthermore, some viruses may be more resistant to chlorine disinfection and persist longer in receiving waters than coliform bacteria (Whipple, 1977; Canada, Department of Health and Welfare, 1979). In these circumstances, conclusions based on coliform counts will result in underestimation of the health risk. On the other hand, coliforms are able to multiply in streams enriched with nutrients (Canada, Department of Health and Welfare, 1978, p. 14) and high coliform counts in these circumstances might then lead to overestimation of the presence of other organisms. Nevertheless, many are of the opinion that this test has stood the test of time well. While there is no conclusive evidence that violations of this standard have led to outbreaks of illness, at the same time conformance has certainly helped prevent such events (ASCE, 1963, p. 57).

While coliform counts are considered to be reliable indicators of the effectiveness of the disinfection process for sewage, the United States Environmental Protection Agency has proposed that a measure of chlorine residual also be used. It has been shown that, where turbidity is low and the pH level is suitable, the presence of a chlorine residual indicates that no pathogens are present. The conditions required to make this measurement valid do considerably restrict its usefulness but, where the requirements are met, it could be a reliable water quality parameter for health protection.

It may frequently be the case, however, that water will contain no substances that might be detrimental to health but still be unsuitable for use on aesthetic grounds alone. The primary sensor of water quality is the eye and it has been found repeatedly (Barker, 1971; Davis, 1971; Parkes, 1974; Nicholson, 1975) that it is the visual aspects of pollution on which users base their assessments of water quality. At a minimun, water should be free of floating substances or suspended solids, particularly of sewage origin, and also free of objectionable colour due to industrial discharges (Kneese and Bower, 1968). Odour is also very important and offensive to both recreationists engaged in activities in or on the water and to those enjoying the shoreline. This may originate from sewage or industrial effluents, being a particular problem at outfalls, or may be caused by decaying aquatic growths when these are overabundant.

For indirect contact recreation, standards and objectives are usually less stringent than for direct contact uses because there is less chance of hazard to health and contact is not so intimate. However, these other aesthetic factors are equally important to both indirect and direct contact users of water. They are also very important to non-contact users, for example those picnicing in a park adjacent to a river. However, poor water quality will probably have less impact on these users because of the distance between the water and the observer and because water quality does not physically affect their activities except when, for example, odours are extremely foul.

Nutrient enrichment of recreational water bodies is a major problem in Canada and is usually related to phosphorus concentrations (Day and Parkes, 1978). Although nutrients do not pollute water directly, they have an impact on all forms of recreation through the stimulation of excessive slime and weed growths. Swimming, of course, would not be contemplated in water with a heavy growth of algae or weeds though boaters are more tolerant of such conditions. Nevertheless, they may incur problems because heavy weed growth not only obscures the bottom and any hazardous obstructions but may also hinder movement of boats. The impact on recreational fishing is also considerable whether conducted from boats or the shore. Excessive weed growth may impede access to favoured fishing spots and will often also detract from any scenic quality. Decaying algae and weeds in water may exert a large biochemical oxygen demand, deplete oxygen concentrations and cause unpleasant odours, while those washed up on beaches may not only cause odours but also be unsightly. There are thus also secondary effects of eutrophication. Seasonal depletion of dissolved oxygen levels may affect the fish population, species diversity may be reduced and favoured species may decline in numbers.

Indeed, the degree of reduction in species diversity of fish is a good indicator of the degree of water pollution (United States EPA, 1972, p.35; Shubenacadie–Stewiacke River Basin Board, 1978, p. 106). Water quality requirements for support of aquatic life are in some cases higher than for recreation. "The value of water for fishing ...can be reduced or destroyed by waste discharges which do not render the water repulsive or even necessarily unattractive to human beings" (Kneese and Bower, 1968, p. 32). For example, an occasional lowering in the oxygen concentration in water may not affect recreational use if it is short–lived, but just one instance of anoxia can have disastrous effects on a fish population. Turbidity is also important to fish for high levels caused by sediment load may settle and make stream bottoms and banks unsuitable for aquatic growth. This will also have an effect on photosynthesis by reducing the amount of light that penetrates water, this in turn may affect oxygen levels and thus also fish life. "Sediment from stream straightening during construction caused 94 percent reduction of catchable–size trout in Flint Creek, Montana" (ORRRC, Report 10, 1962, p. 15). Such high turbidity will, however, also be aesthetically unattractive to recreationists, whether fishermen or not. The health and species diversity of fish are important both to recreational fishermen and to other recreationists who derive pleasure from seeing them. It is thus recommended that

> "All surface waters should contribute to the support of life forms of aesthetic value" (U.S. FWPCA, 1968, p. 5).

Of course, the ideal swimming water (not to be confused with the swimming environment) is found in an artificial pool of suitable size with a good shore and bottom, where the water is clear, free of pathogenic substances and at a suitable temperature. Any natural body of water then, which is used for swimming will be a compromise between the ideal conditions of water quality and possibly polluted conditions. However, a high quality natural environment adds aesthetic satisfaction to all forms of recreational activities. Thus water quality parameters that reflect aesthetic quality as well as standards of health and safety are vitally important to any evaluation of water resources for recreational use.

2.4 Administrative and Legislative Background to Water Quality Control

2.4.1 Administration

Many parts of Canada, and in particular Alberta, for the first time "have the ability and the hope of attaining large-scale industrial development and the jobs, the urban amenities, the material goods and the pollution that go with it" (Carroll, 1979, p. 21). However, an increased awareness of and concern for environmental quality, coupled with a rapid growth in participation in outdoor recreation, has also been noted. This combination of circumstances leads to conflict over use of water resources. In the past the recreational use of water resources was accorded little value in Canada. Due to the vastness of the country's natural resources, when conflict arose, recreation could always be accommodated elsewhere and anyway since the benefits from recreation are largely intangible and difficult to quantify, it was not regarded as a beneficial use of water. (Pearse, 1968).

However, since it is now official policy that "water management and water resource development is ultimately aimed at protecting and improving the social and economic welfare of Canadians" (Fisheries and Environment Canada, 1978, p. 89) more weight is given to the preservation and enhancement of aesthetic and recreation values. Thus, two basic principles of objective setting, as put forward by Environment Canada, are:

1. "Objectives must include environmental requirements, as well as requirements for human consumption and use"; and
2. "Where natural conditions are suitable, all bodies of water should be of sufficiently high quality to permit safe direct body contact". (Environment Canada, 1979, p. 3)

Thus: "Policy and administrative changes have been made to adjust pollution control measures to changing stream usage" (Illinois State, 1967, p. 169).

Differences between approaches to water quality control stem from differences of philosophy: that is, varying views as to the aims of water quality control and who should be responsible for it. For example, there are differences of opinion on whether water quality objectives should be designed to protect current uses or to enhance water quality and allow for possible uses. According to Hines (1971, p. 236) "standards must be designed not only to preserve but to enhance the quality of the waters regulated" and provision should be made for potential future use as well as present and intended uses.

If an economic approach is taken to setting water quality objectives and regulations then a judgement has to be made as to where the balance between costs and benefits lie. For, as complete removal of pollutants is approached costs mount at an increasing rate and from an economic point of view "choice of quality level must depend on cost of achieving that level" (Kneese and Bower, 1968). This has been the rationale underlying many water quality standards. For example, with regard to the United States Environmental Protection Agency it has been stated that "we are ... concerned with attainability, and so we want to make sure that a standard is reasonable and practical in the sense of achieving it" (Robeck, 1974, p. 27). In other words, attainability is an important consideration in setting standards and attainability usually depends on economic considerations. While this might be lauded as a pragmatic approach, it is not necessarily the best way of ensuring environmental quality. While it is certainly true that the economic benefits of water pollution should be taken into account, a judgement must be made as to what levels of pollution we are willing to tolerate. An economic approach to standards of environmental quality is more likely to be taken by those who derive benefit from the use of water for waste discharge. Others removed from the possibility of costs of pollution control, are more likely to favour a policy of non-degradation and to place more importance on the benefits of high quality water for non-economic uses. However, whatever the viewpoint, pollution control programmes should be based on the protection of riverine systems rather than ease of administration and attainment (Ackermann, 1978). In fact, improvement in water quality depends to a large extent on the recognition of the social, and even economic, value of recreational use of water:

> "Since...the benefits from water quality improvements to municipal and industrial water users appear to be small, recreation plays a critical role in determining which programmes of water quality improvement are justifiable" (Howe, 1971, p. 132).

These differing viewpoints may also arise partly from differing time-scales under condideration. For example, although less regulation of effluent discharge may encourage economic growth in the shortterm, water quality degradation may eventually have the opposite effect. That is, while industries may be located where clean water is abundant for supply and waste disposal, degradation of the water might lead to the necessity of piping water from some distance away, thus increasing costs to users (Barkley and Seckler, 1972). Also, it is easier and cheaper to prevent water pollution in the first instance than to clean it up after the fact.

If the aim of water quality control is to protect potential uses as well as present uses of a water body then more attention is likely to be paid to the potential value of water resources for recreational use and aesthetic enhancement. The National Technical Advisory Committee on Water Quality Criteria to the United States Federal Water Pollution Control Federation recommended that standards should be used to "provide for and enhance general recreation use" and to "provide special protection for the recreation user where significant body contact with water is involved" while "surface waters should be suitable for use in secondary contact recreation... without reference to official designation of recreation as a water use" (United States FWPCA, 1968, p. 8).

It should also be borne in mind that while direct contact recreation may not be regarded as a water use in some locations, the water will often be used for wading and paddling by children. In this case parameters and objectives used in assessing water quality for primary contact use should be applied. This is especially the case in small urban streams of shallow depth which are particularly attractive spots for children at play, for example the Elbow River and Fish Creek in Calgary. It has been said that

> "...surface waters – wherever there are people – have recreational potential, (and) are likely to be used for recreation even i[illegible]sly polluted, and provide increased recreation value as quality improves" [illegible]WPCA, 1968, p. 9).

Thus, even minor water resources may take on some importance for recreational use in densely populated areas. Even when water quality is generally good, it should be remembered that in urban areas a great number of storm drains may empty into small water courses and the addition of storm runoff may have a considerable short–term impact on the quality of small volumes of water.

Even when the aims of water quality control are clearly defined , arriving at a set of numerical objectives for quality is not straight–forward. Gysin, in his discussion of water quality standards in Switzerland said that :

> "...some parameters are based on scientific fact but most are taken from experience or are the result of negotiations between the authorities and interested parties or stem from existing legislation of other countries" (Gysin, 1977, p. 181).

Effluent standards in particular are often a result of negotiation between industry and government rather than scientific evaluation (Gysin, ibid.). Effluent standards for petroleum refineries and fertilizer plants in Alberta, for example, have been arrived at as a result of a joint review by industry and government (Alberta Environemnt, Water Quality Branch, 1976). Negotiation and industry participation in decision making are practices to be encouraged in principal, they do leave the possibility open that pressure might be exerted on the government to be more lenient in standard setting. That is, where feasibility of compliance is a consideration this may lead to dispute and a compromise more favourable to industrial dischargers than to other water users, for example, recreationists.

Gysin's statement raises yet another issue in the setting of water quality standards, that of adopting those set by other agencies. This seems to be very common practice, however, as pointed out by Pomeroy and Orlob:

> "Mere availability of values, whether authoritative and defensible or not, is not alone sufficient to justify their use. They may derive more from the perpetuation of subjective judgements over years of professional lassitude than from considered evaluation of the real impact of quality change on beneficial use." (Pomeroy and Orlob, 1967).

While adopting the water quality standards of another country or agency may be quite legitimate in many circumstances, if done routinely it does make the validity of standards set much more questionable and leaves the possibility open of inappropriate standards being set. This adopting of standards has been true of the Canadian federal and provincial governments (Somers, 1977, p. 226), though the publication of Guidelines for Surface Water Quality (Environment Canada, 1979) has been an extensive review of water quality objectives. This document, intended "to provide to water managers the scientific basis for formulating water quality objectives" is "based upon the best available information relevant to Canadian surface waters" (op. cit., pages iii and v).

There is then the question of whether a set of objectives should be applied nationally or whether it is better to establish local standards. In Canada, a multiplicity of water uses coupled with a great variability in natural surface water quality mean that any national standard might not be appropriate throughout the country (Canadian Council of

Resource Ministers, 1978; Environment Canada, 1972).

> "Any attempt to write a national standard for even surface water in Canada would either permit the pollution or the deterioration of certain waters or would place impossible demands for water quality control on other waters which do not meet high quality standards even in their natural state" (Environment Canada, op. cit. p. 3; see also Somers, 1977).

Thus, Environment Canada water quality objectives are guidelines to recommended minimum levels for the establishment of local objectives by each province.

In efforts at pollution abatement authorities use standards and objectives to maintain or acheive a certain environmental quality. These may be either receiving water standards or effluent standards. The former apply to the water into which effluents are discharged and apply to the net effect of the discharge of effluent on the receiving water body. The latter, however, apply to the actual discharge before it mixes with the receiving water. Receiving water standards and objectives are thus implicitly linked to a recognition of the desirability of using water bodies to dilute wastes. This assumption is not implicit in the use of effluent standards.

There are advantages and disadvantages to both these systems. When receiving water standards are applied an individual discharger might be releasing a highly contaminated effluent, but, to meet the standards set, if the volume of the receiving water is great and thus its dilution capacity large, he might not need to treat the effluent. Thus, even if standards or objectives for water quality are never violated, it might well be that some industry is freely discharging highly contaminated wastes into the environment. One way of inducing dischargers to consider the external costs of using water as a medium for waste disposal is to impose effluent standards. The burden of pollution is thus put on the polluter and whatever the dilution and assimilative capacity of the receiving water body the effluent must meet certain requirements. Since use of water resources for waste disposal is regarded as a property right, both local governments and private industries see the use of effluent fees as impinging on their property rights and forcing them to pay for a resource which had been free (McMillan, 1979).

The Canada Water Act and the Fisheries Act do indeed provide for the establishment of effluent standards and charges (Fisheries and Environment Canada, 1978,; McMillan, 1979), and in Alberta effluents from major industries are already monitored and discharge licenses required. However, an actual fee schedule is much more imposing, particularly if the discharger cannot negotiate the quantity and quality of effluent discharged, as is now the case. Nevertheless, in Canada, heavy reliance is placed on the use of objectives for receiving waters and the use of subsidies and taxes to induce desired behaviour by dischargers (Dorcey and Fox, 1974).

However, it should be noted that regulation of effluent discharges does not necessarily ensure that water quality degradation will not occur for the volume of treated effluent could be very great. Improvement in quality of present effluents will be offset by the increased quantity that is an inevitable consequence of increased population, urbanization and industrialization (Illinois State, 1967). For example it is estimated that in the USA the amount of BOD discharged by municipal treatment plants has remained constant since 1957, despite additional treatment capacity and improved plant design. "The increase in pollution loading collected by the sewers...was sufficient to offset the improvements in treatment effectiveness" (Whipple, 1977, p. 7). It is thus clear that a combination of both effluent standards and receiving water objectives is essential to an effective programme for protection of water quality (Nemetz and Drechsler, 1980).

Since this discussion revolves around the use of objectives and standards for water quality control and assessment the meaning of these terms will be clarified. The terms 'objective' and 'standard' are often confused and used interchangeably, however, the term 'standard' should properly be used to describe a value of a water quality parameter which is established by statutory authority for measuring water quality (Environment Canada, 1979; Clarke, 1967). An objective, on the other hand, is

> "a designated concentration of a constituent that when not exceeded, will protect an organism, a community of organisms, a prescribed water use, or a designated multiple-purpose water use with an adequate degree of safety." (Environement Canada, 1979, p. 2).

Neither should standards and objectives be confused with criteria. These are standards of reference based on scientific evaluation of cause-effect relationships. Thus a criterion is not a prescribed limit or goal but may be used to assess water quality suitability for a particular use (Lafontaine, 1977; Environment Canada, 1972 and 1979).

Problems also arise, however, if it is not clearly stated what type of objective or standard is being discussed. For example, this might be a level which is never to be exceeded or which is not to be exceeded as either an average or a median. If these statistical measures are used then it should also be stated over what period of time or to what number of samples the measurement should apply.

Objectives may sometimes be descriptive rather than quantitiative. This is often the case with protection of aesthetic quality and may be more appropriate to parameters which are subject to wide variations under natural conditions (United States FWPCA, 1968). However, this does allow for considerable latitude of interpretation which may be undesirable (Bishop and Auckermann, 1970), so it is useful to cite an ideal standard or a range of deviation from natural conditions. For example, the parameters suspended solids, turbidity, temperature and colour are subject to wide variations in Alberta due to natural conditions and so it is appropriate that in Alberta Surface Water Quality Objectives a range of deviation is used rather than a precise value.

The way in which an objective or standard is applied will thus depend on the individual parameter and the type of water use. For example, where water quality for fish life is in question a limit set as 'never to be exceeded' is appropriate because just one incident of anoxia or toxicity can do immense damage. When a standard or objective is being set for a chemical which is only found in natural waters as a result of pollution it would be reasonable to set a standard of 'none' or 'less than' the level of sensitivity of the laboratory measurements. With coliform counts, which tend to vary greatly, it is impractical to set an upper limit never to be exceeded so it is more usual to set a limit which is not to be exceeded more than a certain percentage of the time. Furthermore, in this case it is more meaningful to set a median value as the standard rather than a mean because the former is less dependent on extreme values.

2.4.2 Legislation

Since protecting water quality in order to enhance the environment and provide maximum recreational benefits involves governmental regulation, the legislative background to water quality control will be discussed.

2.4.2.1 Canada

Under the British North America Act of 1867, most responsibility for management of natural resources is vested in the provincial governments (Tinney, 1972; Carroll, 1979). As far as water quality is concerned "because pollution primarily affects property rights, the provincial governments must be regarded as having primary legislative responsibility" (Emond, 1972, p. 655). According to Emond the federal responsibility for pollution control should include the establishment of minimum standards to protect the economic and social well-being of Canadians, while provincial governments should be concerned with upgrading these standards and finding solutions to particular problems. Thus "the Federal Government Organization Act in 1970...established the authority to adopt objectives and standards relating to environmental quality and to control pollution" (Environment Canada, 1979, p. 1). However, these are not legally required standards but

> "water quality use-objectives that...allow water managers to readily identify the water quality requirements which can then be stated on a basin-by-basin basis" (ibid., p. 1).

The 1970 Canada Water Act was acclaimed as an innovative and important advance in environmental policy (McMillan, 1979) for it included "provision for basin management programmes, regionally determined water quality standards, and the potential for use of effluent charges" (ibid., p. 52). This Act was "designed to facilitate a co-ordinated and comprehensive approach to water resource management" (ibid., p. 56). Thus Part 1 provides for the establishment of intergovernmental committees on water resource management, while Part 2 enables federal and provincial governments to establish water quality management agencies "...to restore, preserve and enhance the water quality level..." (Canada Water Act, p. 3; and see Tinney, 1972). The plan of this part

> "is to recommend (a) water quality standards and a timetable for their acheivement, (b) waste treatment requirements and charges levied for treatment in the agency's facilities, (c) the quantities and types of wastes which may be deposited in the area's waters and the effluent discharge fees to be paid for use of the water. ...Once a water quality management programme is implemented, it is an offence to deposit wastes contrary to the provisions of the programme" (ibid., p. 57).

No water quality management agencies have been set up as provided for under Part 2 (Canada Water Act, 1980, p. 17; McMillan, 1979, p. 59) though a number of federal-provincial agreements and implementation programmes provided for under Part 1 have been established, some with water quality as the major concern; for example, the Great Lakes, Okanagan and Qu'Appelle agreements (ibid., p. 18). McMillan (1979) suggests that the reasons for this are institutional. That is, planning agreements are acceptable to provincial and local governments but "the closer the planning gets toward implementing recommendations the greater the concern of existing authorities for the maintenance or enhancement of their own positions" (ibid. p. 59) and water quality management under Part 2 clearly requires implementation authority. Also, since the authorities consider that they can carry out their programmes under Part 1, they see no need to establish new authorities under Part 2.

However, the federal government is

> "committed to... the application of national effluent regulations and guidelines to control pollution discharges at source" and "committed to the view that those who use the water resource ... should bear the costs of pollution control" (Fisheries and Environment Canada, 1978, policies 3 and 7).

Thus, since regional water quality management agencies have not been created nor effluent standards implemented and since the federal government's powers under Part 1 of the Act (which has been implemented) are limited, the federal government has used the Canada Fisheries Act to implement its policies. Since fisheries come under federal control the government is using this act to establish effluent standards and guidelines and to ensure protection of water quality (McMillan, 1979).

Part 3 of the Act is rather different because it is strictly regulatory in contrast to the other parts where taxes and charges are used as disincentives to implement policies. This deals with a specific problem: reducing the nutrient input to water bodies by control of the phosphorus content in detergents and arose because of public concern for eutrophication of water resources. Part 4 gives powers of enforcement by allowing the establishment of inspectors, levying of fines and issuance of orders to refrain. Thus, while the Canada Water Act provisions for comprehensive planning have been adopted readily, those for water quality management under Part 2 of the Act have been effectively avoided because they necessitiated the establishment of new authorities and introduction of new regulations.

2.4.2.2 Alberta

In Alberta, responsibility for pollution control and water quality monitoring lies with the Department of Environment. Within the department this comes under the jurisdiction of the two divisions of the Water Qual;ity Branch. The Standards and Approvals Division is responsible for setting standards and issueing licenses while the Pollution Control Division is responsible for enforcement. In 1977 the Standards and Approvals Division issued 'Surface Water Quality Objectives' for Alberta. These were developed in association with Saskatchewan and Manitoba under the Prairie Provinces Water Board and are

> "minimum water quality guidelines which would allow the most sensitive use. ...The numerical values...represent a goal which should be achieved or surpassed" (Alberta Environment, Standards and Approvals Division, 1977, p 3).

In Alberta waste water effluent guidelines have been established under the Clean Water Act for fertilizer plants and petroleum refineries (Alberta Environment, 1976a and 1976b). These were developed jointly by government and industry and "define minimum acceptable levels for waste water treatment...consistent with good operating practices and environmental protection" (Alberta Environment, 1976b). Thus, the Alberta government's policy is that pollution must be controlled at source but

> "The assimilative or self-purification capacity of watercourses must be regarded as a natural resource that is legitimate to use" (Alberta Environemnt, Planning Division, undated).

2.4.2.3 United States

In the United States, the passing of the Water Quality Act of 1965 was a landmark in the history of water quality standards and control. The Act required that states adopt water quality standards and a plan for implementation and enforcement, established the Federal Water Pollution Control Adiminstration, and set up a programme of grants to improve control and treatment of waste discharges (Noble and Finley in Pavoni, 1977). "Thus, the concept of water quality standards was introduced into water pollution control legislation for the first time" (ibid., p. 8).

However, in 1972 the policy was changed by amendment to the the Water Pollution Control Act. This shifted the emphasis of pollution control from monitoring and improving receiving water quality to the control of pollution at source by the requirement that certain minimum levels of treatment be applied to effluents (Scholl, Heaney and Huber, 1980). The objective of this non-degradation policy is "the restoration and maintenance of the chemical and biological integrity of the nation's water's" (Bregman, in Gehm and Bregman, 1976, p. 780). By aiming at non-degradation of, rather than minimum standards for, receiving waters, water of a quality better than current standards is protected from degradation and it is no longer implicit that assimilative capacity of a stream may be used to its utmost (Moore, 1978). However, implementation of a programme such as this is very difficult for, while the EPA has authority to enforce the law, many states are not in a position to ensure that all municipalities provide 'best practibable treatment technology' and industries 'best available technology economicaaly acheivable' by 1983. This arises because, not only are the terms 'practicable' and 'economically acheivable' open to different interpretations but data on water quality are sparse and unreliable in many states, making it difficult to judge compliance or non-compliance with the regulations. Conversely, lack of data makes it very easy for alleged polluters to contest a charge laid against them. Thus, the passing of bills and regulations is but one step in water quality control, for their effectiveness depends on successful implementation programmes.

2.4.2.4 Comparison Between Canada and the United States

In the United States water quality is controlled by the federal government through a non-degradation policy and the use of standards. In contrast, while the Canadian federal government is committed to control of pollution at source, primary responsibility for water resources in Canada lies with the provinces and so the federal government has issued objectives for receiving waters to be used as guidelines by provincial governments and enforced some regulation of effluent discharge through the Fisheries Act for which it has responsibility. Also, effluent standards in Canada are usually negotiable between government and industry and thus more flexible than in the United States where negotiation does not usually occur (McMillan, 1979).

3. THE STUDY AREA AND ITS PRESENT USES

3.1 Background Information

Calgary was founded in 1875 by the establishment of a Northwest Mounted Police fort at the confluence of the Bow and Elbow Rivers in southern Alberta. The Bow River valley, which penetrates well into the Rocky Mountains and opens out into the prairies at Calgary, was chosen as the route for the first railway line through the mountains. The city started growing steadily as a service centre for the rich agricultural hinterland and as a transportation centre following the arrival of the Canadian Pacific Railway line in 1883 (Baines, 1973, p. 18). While the Bow River itself was never important for navigation because of its swift current, log rafts were used to float farm equipment down from the mountains and into the prairies (Benthin, 1977).

In the 1880's logs were floated down both the Bow and Elbow Rivers (Dawson, 1885) and the Bow became prominent as a logging river when the Eau Claire Company of Wisconsin obtained rights to timber along the Bow, Kananaskis and Spray Rivers. In 1886 the Eau Claire sawmill was built on the banks of the Bow in Calgary near Centre Street and log drives were conducted each year until 1944. This same company also started the Calgary Iron Works and with a water wheel provided the first source of electrical power to the city (Calgary Herald, August 28, 1980) in the evenings when it was not needed by the planing mill. River flooding was a problem for the company so they built a dam just above the present Louise Bridge and diverted water into a channel along the south bank (now Prince's Island Park) to carry logs to the mill and water to the generators. However, the first major power project on the Bow River was the Horseshoe Falls plant at Seebe built by the Calgary Power and Transmission Company and completed in 1911. Since then the same company, now Trans Alta Utilities, has built a whole series of dams for hydro-electric power generation in the Bow basin.

Oil was found in the Turner valley in the 1920's and since 1947 Calgary has experienced phenomenal growth as a centre for the oil and gas industry. Two oil refineries were built in Calgary though now only the Gulf Asphalt Plant remains on the site of the old British American refinery. The city is now the Canadian headquarters of most smaller oil companies and the Canadian exploration headquarters for major companies with corporate head offices elsewhere. The city has consequently emerged as a major financial centre and the expanding employment market has led to rapid growth in the construction and service industries.

On January 1 1980 the population was 553,170 (that is double the 1963 figure) and at medium fertility and immigration rates it is projected to reach 1 million in the year 2001 (City of Calgary, Planning Department, 1979). The phenomenal population growth has entailed rapid urbanization of the watersheds of the Calgary rivers. This has been concurrent with the rapid increase of participation in outdoor recreation (O.R.R.R.C., 1962) and has thus led to an even more rapid increase in demand for these recreational opportunities than has occurred in most places. This demand has grown more for water-based recreational activities than for any other type (op. cit.) and in a questionnaire conducted for a report "The Recreational Needs and Preferences of the Citizens of Calgary" (Rethink Inc., 1980) swimming topped the list of services for which the public would like to see an increase. The river valley system is a resource of great value for the provision of this type of recreation and it is the policy of the City of Calgary to develop it as a parkland system (PR 13, 1973).

3.2 The Bow River Basin

The Bow River basin, with a drainage area of 10100 square kilometres (3900 square miles) just above the Fish Creek confluence at the south-east extremity of the city, has its head waters in the Rocky Mountains to the west with a maximum elevation of 3627 metres (11,900 feet) in peaks on the continental divide (Figure 1). This upper part of the basin is delineated by the front range of the Rockies from where the river flows through the foothills, an area of ranching and agriculture, to Calgary and the plains. Much of the flow in the Bow River thus has as its source the glaciers and snowfields of the mountains. River flow peaks in June with a mean monthly discharge of 8,574 c.f.s. (1911-1979)[2] while winter flow is very low from November to April with the lowest mean monthly discharge of 1517 c.f.s. (1911-1979) recorded for February.[3] Flow has been very variable in the past with the mean monthly discharge for June varying from a

[2]All streamflow measurements are given in imperial units, as used by the Water Survey of Canada until 1979, the period covered in this thesis.
[3]Figures given for station 05BH004 at the Langevin Bridge.

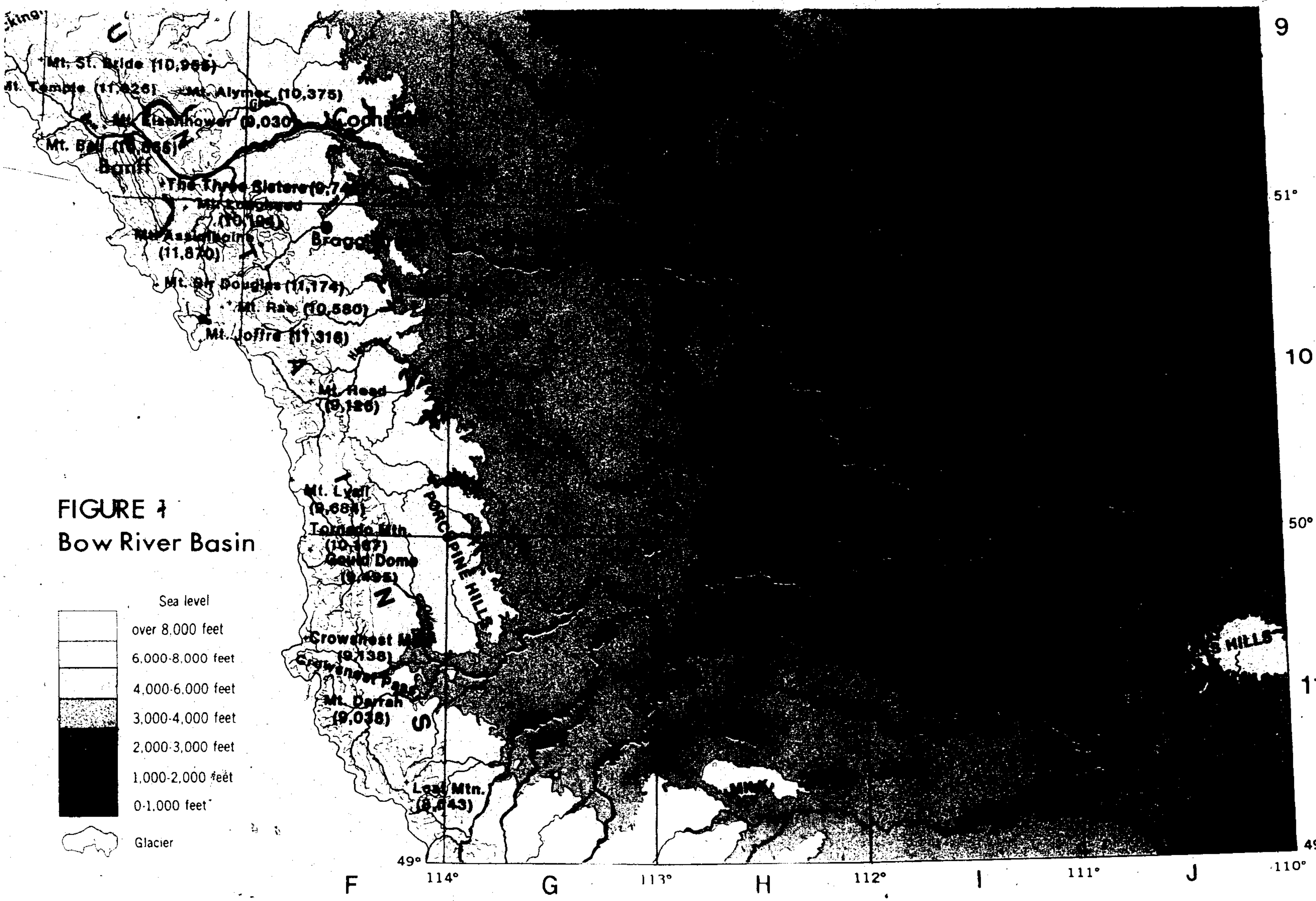

FIGURE 4
Bow River Basin

low of 4,270 c.f.s. in 1926 to a high of 16,700 c.f.s. in 1923, a year in which flooding occurred in the Bow basin. However, upstream storage has reduced the range in average monthly flows. For the period 1930-1978 the average June flow was 7954 c.f.s. and the February flow 1783 c.f.s..

The maximum daily discharge of the Bow River on record is for June 3 1932 when a flow of 41,100 c.f.s. was recorded and resulted in very serious flooding of parts of the city. A similar flow on June 3 1929 also resulted in widespread flooding. Most of the floods during this period were the result of a combination of factors: heavy rainfall over the foothills and front ranges caused by northward intrusion of marine tropical air; high temperatures causing rapid snowmelt, often coupled with high ground moisture levels and occurring in the peak runoff season. In the case of the 1929 and 1932 floods these conditions were aggravated by the fact that peak flow on both the Bow and Elbow Rivers at Calgary occurred simultaneously. These, however, are not necessarily the largest floods to have occurred in Calgary. Reports of flooding before stream gauging began, indicate that the largest and most devasting flood happened in 1897 and that a previous one in 1879 might have been just as big. Another in 1902 also caused extensive damage. However, since that time a large number of reservoirs have been built on the Bow basin above Calgary and the river is now controlled for hydro-power generation. Eight reservoirs constructed between 1909 and 1954 now provide 318,000 c.f.s. of live storage. The newest and lowest dam, Bearspaw on the Bow just outside the Calgary city limits, is a terminal reservoir designed to even out the river flow and also to reduce the hazard of winter flooding due to ice-jams, generate a little hydro-power, and now is also used to supply water to the city.

This damming of the river has changed streamflow patterns, decreasing summer flows and increasing winter flows. Mean monthly discharge for June in the years 1911-1929 was 10,338 c.f.s. compared to 7,954 for 1930-1979, a considerable reduction in summer peak discharge. Conversely, the mean flow for February increased from 1,045 c.f.s. for 1911-1929 to 1,783 since 1930 (figures calculated from Environment Canada, Inland Waters Directorate, Surface Water Data). Although the Bow River is dammed for the purpose of power generation, this degree of control may also have reduced the risk of spring and early summer flooding. However, the lack of any significant flooding since 1932 might also be due simply to the lack of the right combination of natural factors as described. It is surmised (Nelson and Byrne, 1966) that fires and land clearing, which accompanied the building of the railway through the Rocky Mountains and exploitation of natural resources in the Bow Valley in the late nineteenth century and early twentieth century, indirectly led to the occurrence of large floods during that period by accelerating runoff. However, since previous flooding has been caused by heavy rainfall over the foothills and front ranges, the significance of this factor is doubtful (A. H. Laycock, personal communication).

The main tributary of the Bow River in or above Calgary is the Elbow with a drainage area of 1269 square kilometres (490 square miles) and its headwaters in the mountains and foothills to the west. The Elbow has a pattern of flow very similar to that of the Bow River with a mean June discharge of 807 c.f.s. below Glenmore Dam (1933–1979) and a winter low of a mean January discharge of 74.6 c.f.s. (1933–1979). This compares to flows of 1261.9 and 115 c.f.s. for the years 1911–1929. The Elbow within the city of Calgary has been controlled by the Glenmore Dam since 1932. Damage caused by flooding in that year would have been even greater had not the reservoir been empty following construction. However, the water level is kept very high and so its capacity to reduce flood flows is very low (Alberta Environment, Planning Division, 1980). The mean total annual discharge before the dam was built was 289,550 acre feet (1911–1930) while the post-dam mean (1935–1976) is 195,609 acre feet.

Nose Creek, with a drainage basin of just 894 square kilometres (345 square miles), enters the Bow just east of the Elbow confluence in central Calgary. This is a small creek flowing from the north, through Airdrie, to Calgary and has not been controlled though it is channelized in parts. Streamflow data are only available for the years 1911–1919 and 1972–1978 and only for the months of March to October. These show a mean total annual discharge of 6970 acre feet (1973–1976) with a mean monthly peak of 52.9 c.f.s. in July. The maximum daily discharge on record is 946 c.f.s. on May 18 1917 and the flow often ceases altogether. The flow in this creek is thus very variable and flashy, that is, it responds very quickly to storm events and in a very short time a trickle of water can turn into a torrent. With increasing development of the watershed this characteristic is probably becoming more pronounced and could lead to accelerated erosion of the stream banks.

Fish Creek has a small drainage basin, just 165 square miles, which drains the agricultural land and the easternmost part of the foothills south-west of Calgary flowing into the Bow River near the southern limit of the city. Very little streamflow data is available for this section and that which is includes the years 1915 and 1916 when rainfall was unusually high. Due to the lower altitudes, snowmelt in the headwaters occurs earlier than in the Bow and Elbow basins and thus peak streamflow is in April and May. Despite the small size of the drainage basin, Fish Creek has a total annual discharge of 20,000 acre feet compared to only 7,000 for Nose Creek. Also, while the flow in Fish Creek diminishes rapidly from July, in Nose Creek it declines only slowly.

3.3 Recreational Opportunities in the Calgary Region

The prime recreational resource of the Calgary region is the Rocky Mountains. Just 120 kilometres (seventy-five miles) west of Calgary is the entrance to Banff National Park. Originating with a 26 square kilometre (10 square mile) reserve around hot sulphur springs which was taken over by the federal government in 1885, Banff, Canada's first national park, now covers 6640 square kilometres (2,564 square miles). Banff and the other mountain parks which border onto it offer unparalleled opportunities for recreational pursuits: in summer, camping, fishing, canoeing, hiking and sight-seeing; in winter, both downhill and cross-country skiing and snowshoeing. In the front ranges are located the Forest Reserves and Kananaskis Country (incorporating Kananaskis Provincial Park) which offer much the same opportunities as the national parks but hunting and snowmobiling are also allowed. The proximity of the city to these mountains is considered by many to be the prime attribute of its desirability and the mountains exert a strong pull on both tourists and Albertans.

Nearer to the city, the foothills have areas suitable for hunting and camping, rivers for canoeing and fishing and just west of the city are Bragg Creek and Big Hill Springs Provincial Parks. The former has facilities for the activities already listed and also an extensive system of cross-country ski trails, while the latter is essentially an area for family picnics and walks.

All these recreation areas discussed lie to the west of Calgary and it is thus to the west that most people look for outdoor recreation opportunities. However, to the east of the city on the prairies there are opportunities for canoeing and fishing on the Bow River and its tributaries. In the 1920's the Bow downstream from Calgary became popular with American and European millionaires for trophy rainbow trout fishing (Benthin, 1977) and it is still a highly prized trout stream. In an article on the Bow River entitled "The Finest Day of Fly Fishing We've Ever Had in Our Lives" it was written:

> "...never in my life before have I seen so many large fish surface feeding regularly for a four hour period on a challenging flat water trout river."[4]

However, this publicity for the Bow is two-pronged because the author also mentioned the extensive weed cover and noted that

> "The only negative we know about this fishing is that the river is highly enriched by a nearby city. There is no odour to the stream and it is a clear beautiful river, but we are given to understand that the flavour of the fish is not very desirable and herein may lie the secret to why the Bow River is so abundantly full of heavy fish."

Just 8 kilometres (5 miles) east of the city is Chestermere Lake. This reservoir of 276 hectares (682 acres), formed by a dam on the Western Irrigation District Canal, has a sailing club on its shore and is also used for windsurfing. However, public access is limited by the encirclement of the lake with private residences

> "At Chestermere Lake...the only things more common than ducks are the no-trespassing signs posted by residents...in order to keep away public who have few alternatives for shore-based recreation pursuits." (Shaw, 1978, p. 181).

There is a 1.5 hectare (4 acre) public park with a boat launching ramp and picnic tables at the head of the reservoir, but the water is too cold for swimming[5]. The canal itself is also used for canoeing and rowing.

The city of Calgary is thus unusually well-endowed with extra-urban recreation areas. However, although the mountains have water resources of the highest quality in terms of rivers, lakes and reservoirs, these are unsuitable for direct contact activities such as swimming because of swift currents in the rivers and very low water temperatures in all water bodies. In addition, there are problems of use conflict at hydro-power reservoirs, such as fluctuating water levels and denuded shorelines

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[4]This appeared in a newsletter of the Orvis Company of Vermont, U.S.A., tackle-makers, March 1979, vol.14, no. 2, p. 16.
[5]In 1980 this area was closed for rehabilitation.

(Benfield, 1975, p. 36). More important, however, although the mountain areas are within a day's outing of Calgary, they remain out of reach for regular recreational use to many urban dwellers: that is, the less mobile and the less affluent.

In the more immediate vicinity of the city there is an almost complete lack of water bodies that can be used for recreational activities such as boating and swimming or as areas for picnicing and walking. For these reasons, the best possible use must be made of natural resources within the city to satisfy demand for outdoor recreational opportunities and the river valley system in Calgary is an invaluable resource for this type of use. There are, however, plans to develop part of the shore of Bearspaw Reservoir at the city limits in the north-west as a Provincial Park to serve, primarily, the city of Calgary. This will in effect be a continuation of the Calgary river parks system, as is Fish Creek Park in the south.

3.4 Recreational Use of the River Valleys in Calgary

The potential for flooding on the Bow and Elbow Rivers[6] has led to the zoning of a large part of the floodplains for open space. At a flow of 80,000 c.f.s. above the Elbow River, or 110,000 c.f.s. below it, (the estimated size of the 1897 flood) which has a 70 year return period the flood plain of the Bow River comprises 2,136 hectares (5,278 acres) of which 641 hectares (1,585 acres) is the floodway (Montreal Engineering, 1973). Of this total 1,682 hectares (4,156 acres) are open space. This use of the floodplain[7] serves several purposes: it helps to reduce the magnitude of flood damage; it protects the value of the rivers as an aesthetically pleasing focus for the city; retains the riverbanks for recreational use and allows the preservation of natural areas along the river (Lombard North Group Ltd, 1973). However, large areas of floodplain are privately owned. Thus land acquisition by the City is necessary to implement this policy. In the Calgary River Valleys Plan (November, 1980, p. 61) land recommended for acquisition is identified. The total area is 486.89 hectares (817 acres) comprising 155.84 hectares

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[6]For more information see: Alberta Environment *Elbow River Flood Study - Interim Report* 1980; Montreal Engineering Company Limited, for Alberta Environment, *City of Calgary Flood Study*, 1973; Lombard North Group Limited, *Bow River Impact Study*, 1973.

[7] Construction is allowed in this floodplain but it must conform to special building regulations.

(385.2 acres) along the Bow River and 331.05 hectares (817 acres) along Nose and West Nose Creek. Land acquisition on this scale is very expensive (the estimated cost is $57 million plus) and requires considerable time. In the case of the Elbow River, 43 percent of the floodplain is developed, compared to only 22 percent for the Bow River (Calgary Planning Department, 1980). Most of this development is residential and so potential for land acquisition for extension of the park system is severely restricted here.

The network of river valleys is an extensive and valuable resource for outdoor recreational use, though the development of this use probably arose originally more by necessity than by any explicit planning decision in favour of recreation. However, it is now an official policy of the City of Calgary [8]

> "...to develop a total linked system of open space with the river valleys as the major focal point... This open space will consist primarily of the floodway lands, undevelopable escarpments and significant natural landscape features. ...the intention is not to preserve all land in its natural state, but instead to develop parks for all levels of use." (City of Calgary, Parks/Recreation Department, 1977, p. 37)

Most of the parks are linked by a pedestrian and cyclist pathway. There should be a pathway all along the Bow River by 1981 and the goal is to have pathways along both banks of all rivers.

3.4.1 Bow River

The Bow River winds through the city for 39 kilometres (24 miles) from the north-west to the south-east with many islands and gravel bars which are exposed at low water. The cold temperature and swift current of the Bow River make it unsuitable, in fact dangerous, for swimming and paddling but it is used for fishing and boating (canoes, kayaks, rubber dinghies). More important, it is an essential component of Calgary's public park system, much of which lies adjacent to the rivers (Figure 2). In terms of the number of users, this role as an aesthetically pleasing backdrop to the parks, used by many people for a wide variety of activities from picnicing to cycling, is much more important than actual use of the water.

The Bow River links a variety of recreation areas. These include parks designed for high intensity use, such as Bowness Park with its funfair and a lagoon for canoeing and ice-skating, and the Calgary Zoo on St. George's Island; others such as the Pearce

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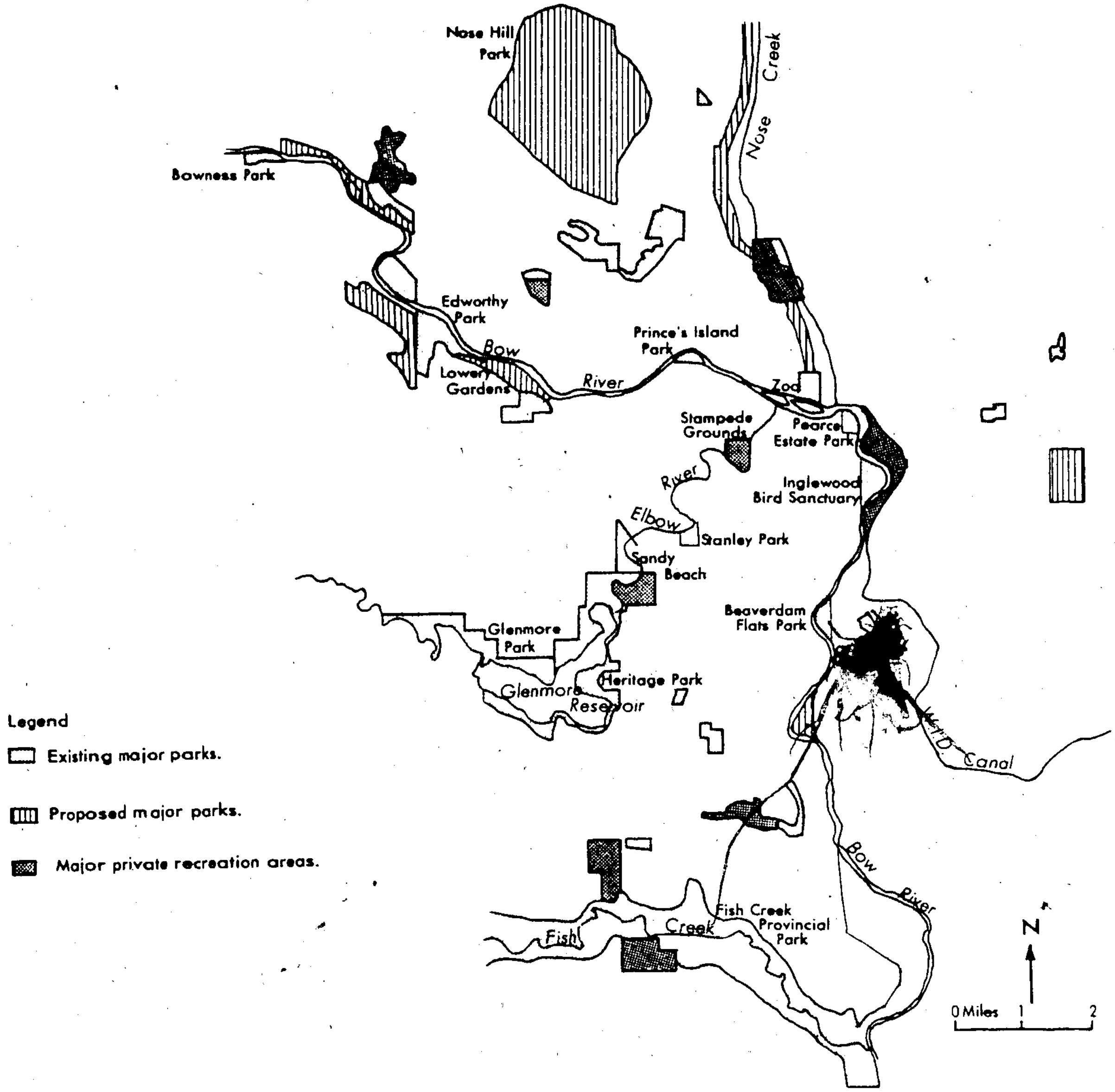
[8] PR 13, Calgary Master Plan, 1973.

FIGURE 2 Calgary - Parks



Source: The City of Calgary, Parks / Recreation Dept., 1977

Estate Park and Edworthy Park which are for less intensive use; then also Lowery Gardens and Inglewood Bird Sanctuary which are preserved as natural areas. The latter is one of the few natural areas in the park system: lagoons formed by side channels and islands of the Bow River are a haven for waterfowl[9] who inhabit the area in large numbers and use it as a staging post on migration routes (Plates 1 and 3). Prince's Island Park also stands out in this system for, due to its proximity to the downtown core, in summer it is visited in the lunch hour by many office workers and thus is very intensively used. South of the bird sanctuary the river flows through the industrial part of the city and the only park between there and Fish Creek Provincial Park at the southern end of the city is Beaverdam Flats Park.

There are plans to develop Carburn Park along the Bow River south of Glenmore Trail which will be adjacent to the future community of Riverbend (under construction) and will help fill the gap in the park system that exists in the south-east. The form that this development will take has not yet been decided but it will cover 36 hectares (90 acres) or more and include a natural lagoon which could be used for canoeing or model boating. Development of this park will help to open up this scenic stretch of the Bow River to which public access is now blocked by industrial and construction sites. The other proposal for expanding the park system along the Bow River is the development of Bowmont Flats which lies on the left bank of the river to the east of 85 Street N.W.. Opening up to the public this flat area at the base of the escarpment, presently used for gravel washing and nursery operations, will allow the continuation of the pathway along the river to 85 Street.

3.4.2 Elbow River

The Elbow River flows through the Sarcee Reserve into the 425 hectare (1,050 acre) Glenmore Reservoir in south-west Calgary, the main source of the city's water supply. However, this reservoir is also very valuable for the visual amenity it affords and as a base for water sports and is a focus, in fact a raison d'etre, for a very large area of parkland that borders onto it. The Weaselhead area at the head of the reservoir is a natural area used for walking, cycling and cross-country skiing; Glenmore Park on the

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[9]Up until 1975 216 species of birds were recorded (Bird, 1974).

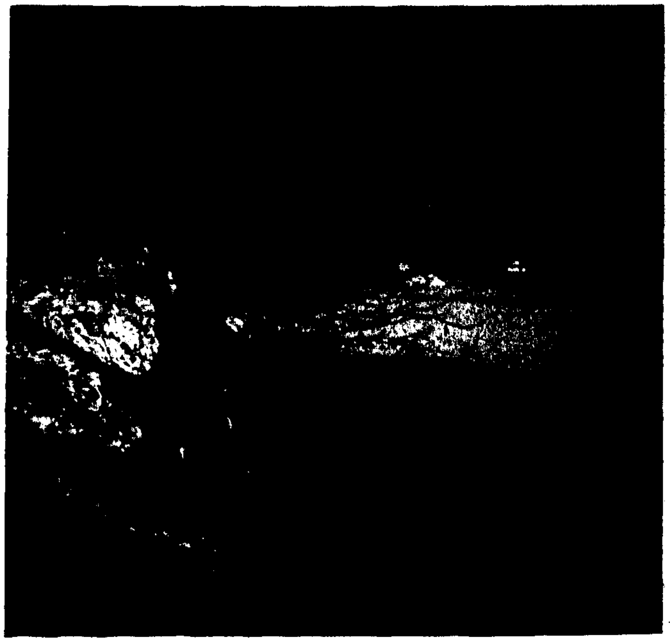

Plate 3 Inglewood Bird Sanctuary in winter

Plate 4 Sailing boats at Glenmore Reservoir

north side has picnic facilities, a fitness track and canoe rentals; on the east side there are public docks for sailing boats (Plate 4) and Heritage Park (a reconstruction of a pioneer village); and on the south shore is the Calgary Sailing Club. This reservoir is thus one of Calgary's greatest recreational resources and without it these parks would be greatly reduced in amenity value, not to mention the adjacent residential areas which derive so much of their land value from its proximity.

Downstream of the dam the river has incised a valley which is at first deep and narrow. In this reach some areas on the inside of meanders are used as parks (Sandy Beach) while others are proposed for this use (Calgary Planning Department, Calgary River Valleys Plan, 1980) and one is occupied by the Calgary Golf and Country Club. The Elbow then flows through residential areas with small parks at various stages (Figure 2) and both the water and shorelands are used extensively for recreation where not privately owned. In winter the riverside pathway serves as a cross-country ski trail and in summer it is heavily used by walkers and cyclists. Recreational use is most intensive at Sandy Beach (a picnic area) and at Stanley Park (open air swimming pool and picnic facilities) where, in particular, the river is used by children paddling, fishing and floating on tyres and in rubber dinghies. On 19 hectares (47 acres) at the confluence of the Bow and Elbow Rivers is Fort Calgary. On the site of the original Northwest Mounted Police post, this is the latest addition to the river park system and includes a museum and reconstruction of the layout of the original fort. While most of the land around the Elbow River is developed, there is vacant land on the left bank to the north of the dam, which has been proposed as parkland and a possible site for a swimming lagoon (City of Calgary, 1980; CH2M Hill, 1980). In addition, Lindsay Park, the site of the old C.N.R. yards in the Erlton district, has been reclaimed recently and an indoor aquatic centre is being planned for the site.

3.4.3 Nose Creek

The Nose Creek valley has been used heretofore as a transportation corridor and for light industrial development, but plans have been drawn up for a linear regional park along the creek (Figure 2).[10] While the obstacles to be overcome in this development (aesthetic quality of the valley and the physical obstructions of the roads and the railway, Plate 5) are considerable the plan has great merit because the north-east quadrant of Calgary is very deficient in open space[11] while its population is expanding rapidly. Community meetings and questionnaires conducted for the 1980 study showed strong support for this type of development (P.E.R.C., 1980), which will include an extensive trail system with activity centres linking up with the Bow River pathway system.

3.4.4 Fish Creek

The Fish Creek valley has gradually been acquired by the province and developed as a provincial park serving an urban population. The park extends from the mouth of the creek upstream to the western city limits and has been preserved as a natural area with a very extensive trail system for pedestrians, cyclists, cross-country skiers and horseback riders. There are also picnic areas and a swimming lagoon, Lake Sikome, at the southeast end of the park. This is the only swimming facility of its kind in the city and so is very popular and might well be copied elsewhere. The creek itself is too small to be used for most water-based activities but it is used extensively by children paddling (Plate 6).

3.4.5 Western Irrigation District Canal

The Western Irrigation District Canal takes wate[illegible] ne Bow River at the weir by the Pearce Estate Park east of the zoo and conveys it to [illegible]hestermere Lake. The canal, which varies from 61 to 183 metres (200 to 600 feet) in width passes through residential, industrial and eventually agriculatural areas. While the canal is used in summer by canoeists and in winter by cross-country skiers and snowmobilers, there is a lot of undeveloped potential to enhance and extend present uses. A hard top pathway has recently been constructed alongside the northernmost section of the canal and a fence put up to prevent further scarring of the escarpment by motorcyclists. Further improvements of this kind would increase the recreational resources of south-east Calgary and provide direct access to the river path network for this segment of the city.

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[10] Walker, Newby & Assoc., *Nose Creek Valley Concept Plan*, 1976 and Professional Environmental Recreation Consultants, *Nose Creek Valley Master Plan*, 1980.
[11] In 1976 it was 1,000 acres short of the standard. Walker, Newby & Assoc. op. cit.

Plate 5 Nose Creek in autumn, north Calgary

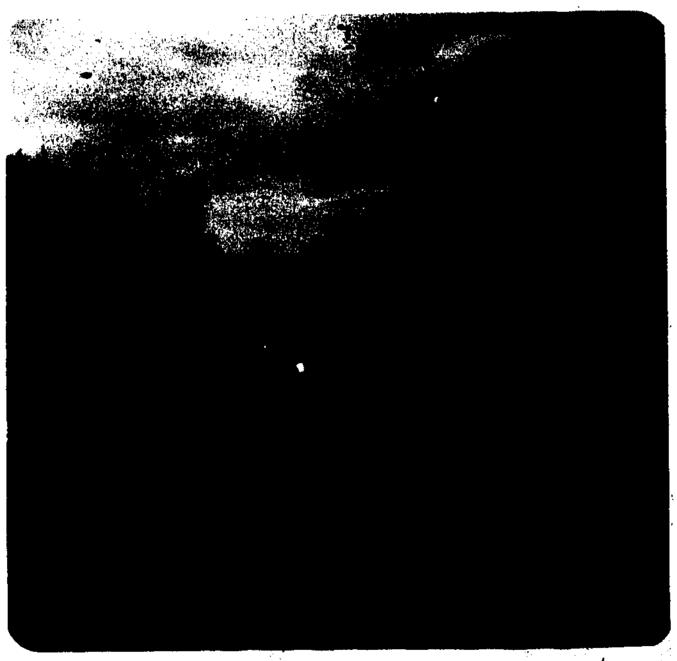

Plate 6 Children playing near the mouth of Fish Creek.
Sampling Station T11

3.5 Non-Recreational Use of the River Valleys

From the industrial land use map (Figure 3) it is clear that the river valleys in Calgary do not serve solely as a recreational resource. Despite the evident disadvantages of locating in the floodplain, the downtown core of the city and some residential areas are located very close to the Bow River on low lying ground (Plate 2). The valleys also serve as transportation corridors: for example, Memorial Drive, which is a major artery, follows the Bow River and Deerfoot Trail (Highway 2) is in the Nose Creek valley while C.P.R. lines use both of these. The location of the city in a bend of the Bow River and at the confluence with several tributaries means that there are numerous bridges straddling these rivers and rapid population growth with the consequent increase in traffic has necessitated the construction of a number of new ones.[12] Gravel extraction has also been done in various parts of the Bow valley in the past, notably Montgomery Flats (to be Bowmont Flats Park), Lowery Gardens and the south-east area, though some of these sites have now been reclaimed.

The water of the Bow River is used to supply major industrial plants in the south-east part of the city and a weir diverts water into an irrigation canal which serves the Western Irrigation District. Municipal water supply is drawn off both the Bow and Elbow Rivers. The Glenmore Dam on the Elbow in south-west Calgary, which was completed in 1932, impounds the Glenmore Reservoir with a capacity of 22,830 acre feet (Alberta Environment, Planning Division, 1980). Since that date this has been the main source of water for the city and a large treatment plant is adjacent to the dam. The Bearspaw Dam on the Bow River was built in 1954 by Trans Alta Utilities (formerly Calgary Power) and is now also used to supply water (about 35%) to the city. A treatment plant is located to the east of the dam and trunklines supply water to the north-west part of the city and also connect with the Glenmore system.

A very important non-recreational use of the rivers themselves, especially with regard to this thesis topic, is that of wastewater assimilation. Two large fertilizer plants, the Gulf Asphalt Plant and several other industries in the south-east are licensed by the provincial government to discharge treated effluent directly into the Bow River. Smaller industrial operations, for example the meat packing plants, pre-treat their water then

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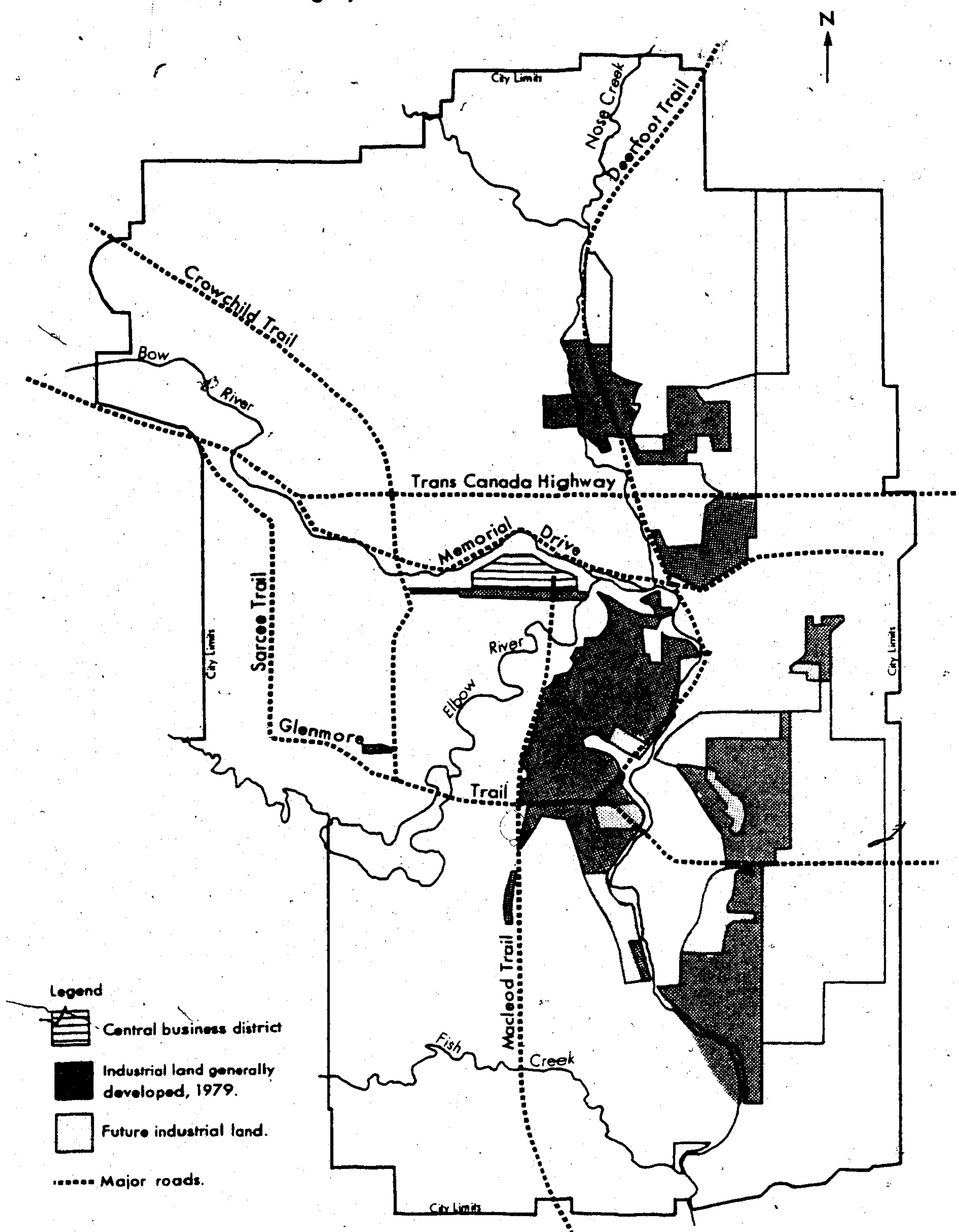
[12]In 1980 work was started on the construction of two new bridges over the Bow River.

FIGURE 3 Calgary - Industrial Land Use



Source: The City of Calgary, Business Development Dept., January 1980.

discharge it into the sanitary sewer system. The city has separate sanitary and storm sewer systems so there is also a very large number of storm water outfalls into the rivers:

- 127 into the Bow
- 77 into the Elbow
- 52 into Nose Creek
- 26 into Glenmore Reservoir
- 10 into Fish Creek
- 3 into Beddington Creek
- 295 in total into the rivers[13].

The advantage of a separate system is that the sewage treatment plants do not have a sudden and very large inflow at peak runoff times. The benefits of this are that they do not have to be designed to take a large, but infrequent, load and the treatment system is never bypassed (which would allow untreated sanitary sewage to go direcly into the river) as sometimes happens with a combined system. However, the disadvantage is that storm runoff passes untreated into the receiving water (Plate 7) and it has been shown that even runoff from residential areas can seriously degrade the quality of the receiving stream (Hammer, 1974). Furthermore, the swiftness with which runoff from impervious surfaces reaches a stream through the storm drainage system means that the discharge of that stream is increased beyond naturally occurring levels. In a small creek this can lead to channel widening and bank erosion (Hammer, 1972) and this has happened in Nose Creek. However, storm water detention ponds are used in some sections of the city (four in total) and there are plans to build more of these. With this system, suspended solids are settled out and B.O.D., nutrients and bacteria levels reduced before the runoff water reaches the stream and peak flow is reduced.

The city has two sewage treatment plants. The Bonnybrook Plant in east Calgary was originally built in the 1930's with primary treatment facilities but was upgraded to secondary in 1970 when it became apparent that the river could not assimilate the volume of waste imposed on it by a rapidly growing city. This plant treats 80% of the sanitary sewage, serving the town of Airdrie as well as most of Calgary and discharges

[13]Information supplied by City of Calgary, Engineering Dept., Sewers Division. In addition there are outfalls into the irrigation canal and into storm water detention ponds.

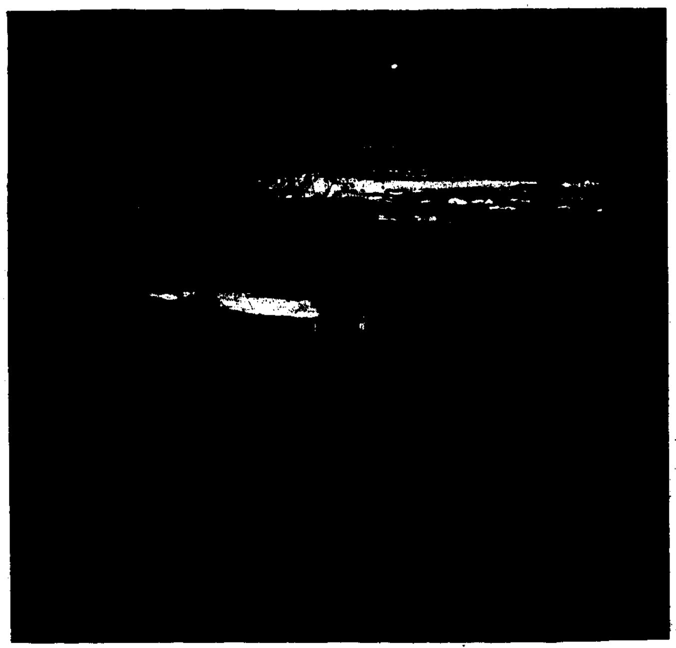


Plate 7 Storm sewer discharging into the Bow River

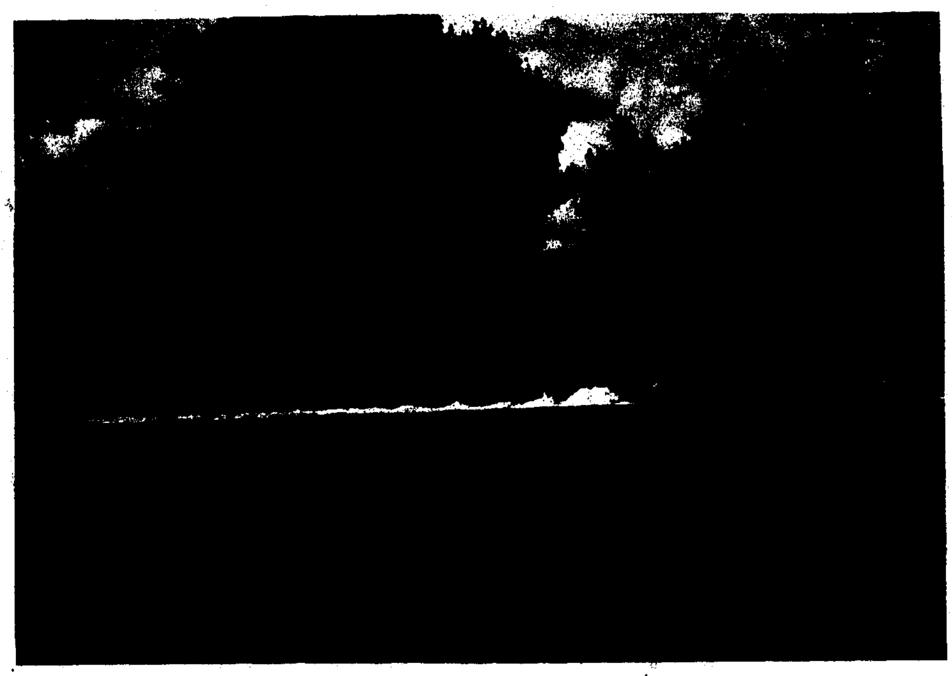


Plate 8 Effluent discharge from Bonnybrook Sewage Treatment Plant

effluent into the Bow River (Plate 8). Its design capacity is 72 million gallons per day though the average flow through is 65 (personal communication, B. Mackintosh Plant Chemist). There is a diurnal variation in this volume of effluent discharged and also a seasonal variation. In winter the volume of wastewater entering the plant sometimes increases as a result of infiltration of groundwater into the trunklines downtown and along the river when river ice causes the groundwater to rise. The plant is licensed to discharge effluent with 25 p.p.m. biochemical oxygen demand and 25 p.p.m. suspended solids, but these levels are gradually being improved.

The city has recently embarked on an expansion programme which will increase the plant capacity to 100 million gallons per day and will incorporate tertiary treatment. Under this system there will be 50% more primary clarification and digestion and 97% of phosphorus will be removed (personal communication, B. Mackintosh). This compares with 30% removal of phosphorus at present and will be accomplished by the use of alum which causes phosphorus to precipitate. The phosphorus content of the effluent, the main source of which is human and household waste, is the largest single cause of water quality degradation in the Bow River so this improvement in the treatment system is a major (and extremely expensive[14]), step towards alleviating the quality problem of the Bow River.

In the 1950's primary treatment plants were also built at Fish Creek and Ogden. In the spring of 1975 the Ogden Plant was taken out of service and the flow passed to the Fish Creek Plant. Daily peak flows to the Fish Creek Plant later increased to such a level that bypassing raw sewage to the river soon would have become unavoidable. It was then decided to build a new, expanded secondary treatment plant on the same site. This was especially necessary because the province also raised the standards for effluent discharge and in winter oxygen depletion of the water under ice cover brought levels very close to the minimum criterion of 5 mg./l. (Reid, Crowther & Partners Ltd., 1975). There was also a marked deterioration in other aspects of water quality below the Fish Creek outfall and the creation of Fish Creek Park made this problem all the more critical.

In April 1980 the secondary treatment plant was put on line and now serves the area roughly south of Glenmore Trail on the west side of the Bow River and as far north

[14]The total cost is estimated at 100 million dollars of which 14 million will be for phosphorus removal (Environment Views, vol. 3, no. 1, 1980, p. 23).

as Forest Lawn on the east side. This thus includes a very large proportion of the industrial sector of the city (Figure 3). The effluent is discharged into the Bow River within Fish Creek Provincial Park and thus effluent quality is of special concern to recreationists. It is probable, however, that in the future the City of Calgary will go ahead with a programme to upgrade this facility to include phosphorus removal.

4. WATER QUALITY IN THE CALGARY RIVERS

4.1 Introduction

The data used for the following analysis of water quality was that available through Naquadat (the national water quality data computer retrieval system) and was supplied by the Water Quality Branch of Alberta Environment. The information is comprised of the results of water quality monitoring programmes carried out by the federal and provincial governments between 1970 and 1979.[15] However, since many of these programmes are short–term and undertaken for a specific purpose, the data are patchy with respect to both chronological continuity and the range of parameters for which the samples were tested. Bearing in mind these inadequacies, the data were analysed and compared to both federal and provincial surface water quality objectives in order to both identify those parameters which might not meet desirable levels and to understand both the causes and consequences of degraded water quality.

The variation in quantity and type of data available causes difficulties in our analysing water quality. For example, situations arise in comparing sampling data where over a hundred values of a given parameter have been recorded at one station but only a few, or even none, at another station. This makes sound comparison difficult and so where three or less values are available they are not shown in the figures or used in the analysis and if a small sample may account for an anomaly this is mentioned. In the figures, sampling stations between which data are unavailable or based on very small sample sizes are joined by a dashed line. This situation causes gaps in the data when seasonal variations are analysed because there may not always be enough samples to give a representative mean value for every month. However, concern over Bow River water quality has sparked more intensive monitoring programmes, for example, in 1979 a five week intensive study of coliform bacteria counts in Calgary was undertaken which is invaluable to this type of study. The choice of water quality parameters for analysis was made in accordance with the discussion in Chapter 2 of the relevance of certain factors to the recreational use of rivers and adjoining land. While a very wide range of parameters might warrant analysis in an exhaustive study it was decided here to consider

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[15]Results of water sampling since 1979 are not yet available through Naquadat.

only those of immediate and well-established relevance to recreationists and for which reasonably reliable data were available. Thus heavy metals, including mercury, have been omitted from the study. While there is a potential problem of biological magnification and occurrence in fish, and recreational fishing is very important in the study area, analytical techniques used in the past for detection of mercury in water are now questionned and therefore data available are not considered valid. Nevertheless, available data were analysed for 8 sampling stations. This revealed that in very few cases had levels risen above the Environment Canada objective level but in many cases the detection limit of the test method was above the Alberta objective, so whether or not levels exceeded that is unknown[16].

The water quality parameters selected for analysis are thus:

1. temperature, as it directly affects the use of water for bodily contact recreation activities and for support of fish life;
2. pH as it affects both fish life and the comfort of recreationists in contact with water;
3. dissolved oxygen and biochemical oxygen demand, because of the importance of the former to fish and the sanitary status of a river and the relationship of both to the discharge of sewage;
4. turbidity because of the negative visual impact of turbid waters and the possibility of transmission of bacteria with sediments derived from surface runoff;
5. colour, odour, oil and grease for their visual and olefactory impact and also because they frequently reflect less than desirable quality with regard to other parameters;
6. coliform bacteria because of the potential for transmission of disease to recreationists in contact with water ;
7. phosphorus because of the impact of nutrient loading on growth of aquatic plants.

These measures of water quality have been analysed for 20 sampling stations on the Bow River from the mountains to the mouth and for 11 stations on those streams tributary at Calgary (Table 1 and Figure 4). In this way it should be

[16]In the 1950's the CIL plant discharged a lot of mercury to the Bow River and this also infiltrated into gravel deposits, however, mercury contamination is no longer considered a problem. Personal communication, K. Exner, Pollution Control Division, Water Quality Branch, Alberta Environment, Calgary.

TABLE 1

Water Quality Sampling Stations

BOW RIVER

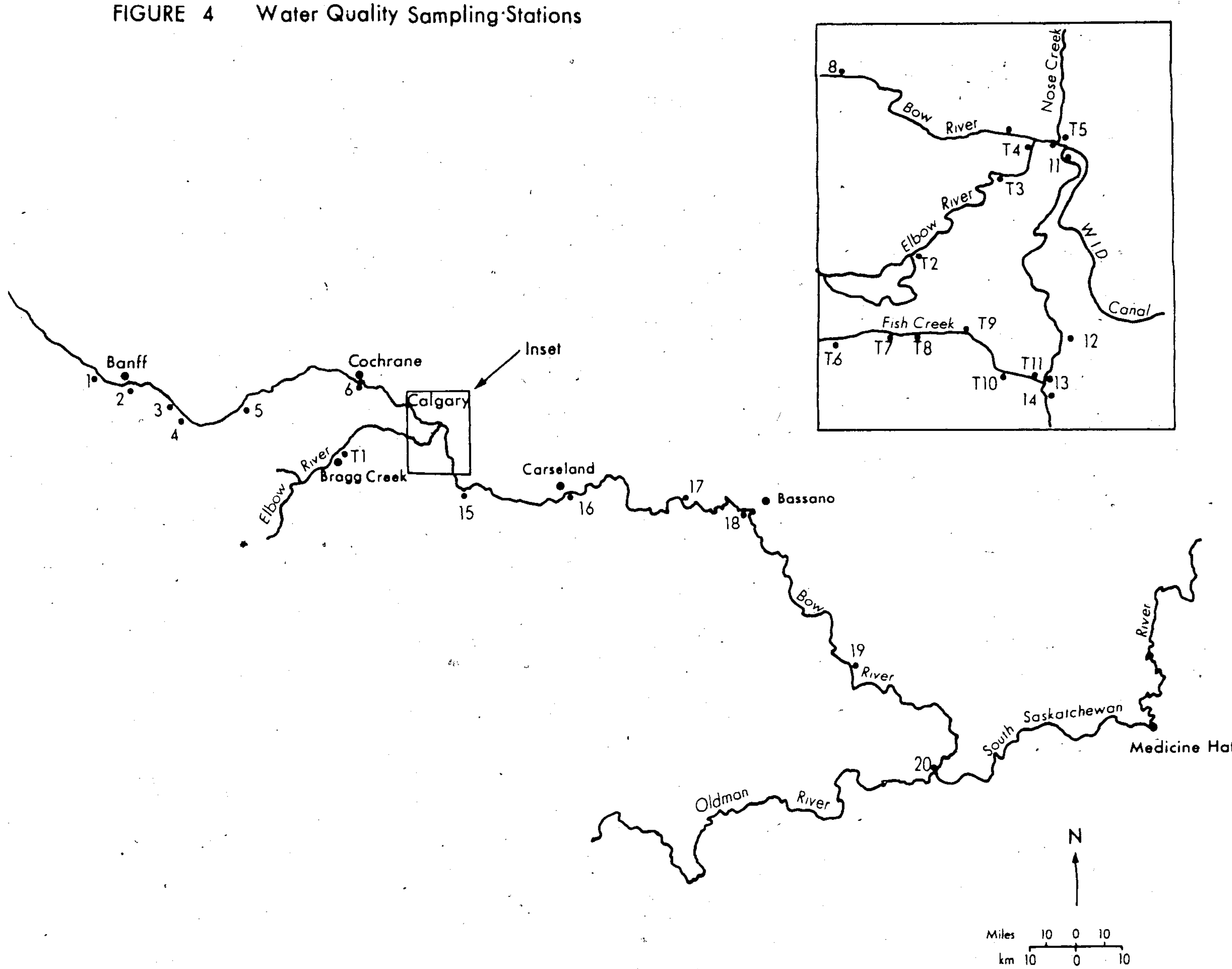
Station Number	Naquadat Station Number Federal	Provincial	Location
1		AT05BB2010	Five Mile Bridge, Banff
2	AL05BB0002	AT05BB2020	Banff Bridge
3	AL05BD0002	AL05BD0002	Below Spray River
4	AL05BE0013	AT05BE2040	Canmore
5	AL05BE0006		Near Seebe
6	AL05BH0017	AT05BH2080	Cochrane
7	AL05BH0001	AT05BH2090	Bearspaw Dam
8	AL05BH0020	AT05BH2100	Calgary 85 St. bridge
9	AL05BH0018		Edmonton Trail Bridge
10	AL05BH0019		CPR bridge E. of St. George's Isl.
11	AL05BH0007	AT05BH2140	Cushing Bridge
12		AT05BM2148	Intermittent Channel
13		AT05BM2149	50 yds above Fish Creek
14		AT05BM2159	200 yds below Fish Creek
15		AT05BM2160	Stiers Ranch
16	AL05BM0002	AT05BM2220	Carseland
17	AL05BM0009	AT05BM2230	Cluny
18	AL05BM0001		Bassano Dam
19	AL05BN0002	AT05BN2250	Scandia
20	AL05BN0001	AT05BN2270	Near the mouth

TABLE 1 (continued)

TRIBUTARIES

Station Number	Naquadat Station Number Federal	Naquadat Station Number Provincial	Location
T1	AL05BJ0003		Elbow R. at Bragg Creek
T2	AL05BJ0001	AT05BH2120	Elbow R. below Glenmore Dam
T3		AT05BH2130	Elbow R. at Stampede Park
T4		AT05BH2135	Elbow R. at 9 Avenue bridge
T5		AT05BH2110	Nose Creek near mouth
T6		AT05BK2151	Fish Creek at 37 Street
T7		AT05BK2153	Fish Creek
T8		AT05BK2155	Fish Creek at Elbow Drive
T9		AT05BK2156	Fish Creek at Highway 2
T10		AT05BK2157	Fish Creek near park buildings
T11		AT05BM2158	Fish Creek near mouth

FIGURE 4 Water Quality Sampling Stations



possible to elucidate any spatial variations through the basin which may be necessary to an understanding of water quality in the city of Calgary. Seasonal variations were also examined on order to better understand those factors which influence or determine water quality.

4.2 Analysis of Data

4.2.1 Temperature

Temperature is a prime factor in determining the suitability of a water body for direct contact recreational activities. While immersion of the body in water at a temperature over 35 degrees C for extended periods of time may be dangerous (Environment Canada, 1979, p. 59), in Alberta we are more concerned with the lower limit of suitability. Swimmers in water colder than 15 degrees C for more than an hour risk hypothermia and death and thus water must be consistently warmer than this if it is to be used for recreational activities such as swimming. However, for activities in which body contact with the water is limited the importance of temperature lies in secondary effects, such as its influence on the biological productivity of the water body and the species composition of the fish population.

The temperature of water is determined primarily by climatic regime but also by local topography, river dynamics and man's intervention. The climate of southern Alberta is mid-latitude continental, that is with long, cold winters and short, but warm, summers and so water is usually cold because the summer is neither hot enough nor long enough to allow for any great warming. Furthermore, the headwaters of the Bow River lie in the permanent snowfields of the Rocky Mountains and those of the Elbow in the front ranges so the water in these rivers is very cold at source and since the Bow, in particular, is a swift flowing mountain stream, the water remains cold. Man may cause an increase in water temperature by adding heated effluent to the stream, by reducing velocity or holding water in shallow areas which allows greater warming by the sun and the settling out of high albedo sediments. Conversely, the water temperature of a stream may be lowered downstream of a dam by the release of water from the bottom of a reservoir where it is usually very cold. Since both the Bow and Elbow Rivers are dammed, this effect is likely to apply here and may be very significant in the case of the Elbow River which is very small and is also used intensively in the summer by children paddling.

The maximum recorded temperature for each monitoring station on the Bow River and tributaries is shown in Figures 5 and 6. As expected, the water attains higher temperatures downstream in the plains (stations 15–20) than upstream in the mountains (1–4), however, while most of the maximums surpass the recommended minimum of 15 degrees C that temperature might only be maintained for short periods of time. Analysis of seasonal variations in temperature for the Bow River at Cushing Bridge, Calgary (station 11, Figure 7) showed that in August alone was the mean temperature greater than 15 degrees C.[17] The same pattern emerged for the Elbow River (Figure 8) though it also appears that the Elbow may warm up earlier due to its small volume and shallow depth. Needless to say, the maximum recorded temperature of 19 degrees C in Calgary, and even the maximum for the entire Bow River (26.7 degrees C near the mouth) are well below the recommended maximum for more than short-term body immersion (35 degrees C). While warmer temperatures no doubt occur from time to time, undetected by stream monitoring because of both temporal and spatial variations, the general conclusion must be that these streams are too cold for direct contact recreation activities except in very shallow or lagoon areas.

4.2.2 pH

pH is a measure of the hydrogen ion concentration in solution in water and is an indication of the balance between acids and bases. Measured on a scale of 0 to 14, 7 indicates neutrality while values below this indicate acidity and those above alkalinity. This scale is, however, logarithmic so a change of one unit is a tenfold change in hydrogen ion concentration. The pH of natural fresh waters ranges from 4 to 9 and in Alberta Surface Water Quality Objectives (1977) it is stated that it should fall in the range of 6.5 to 8.5 but not be altered by more than 0.5 units. Environment Canada has specific standards for recreation: these are an absolute minimum and maximum c 6 and 9 respectively and an objective for direct contact recreation that pH should be in the range of 6.5 to 8.3.

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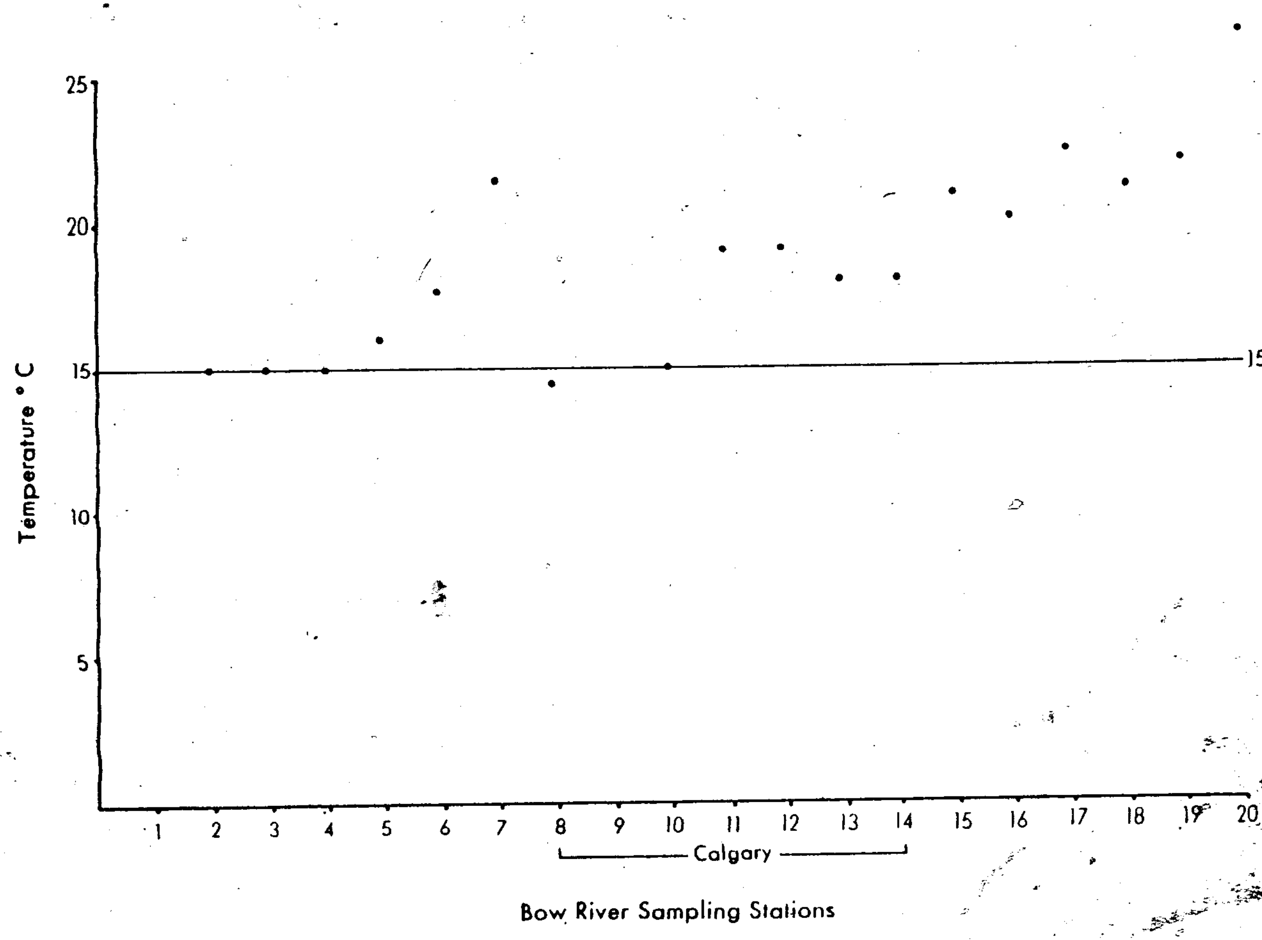
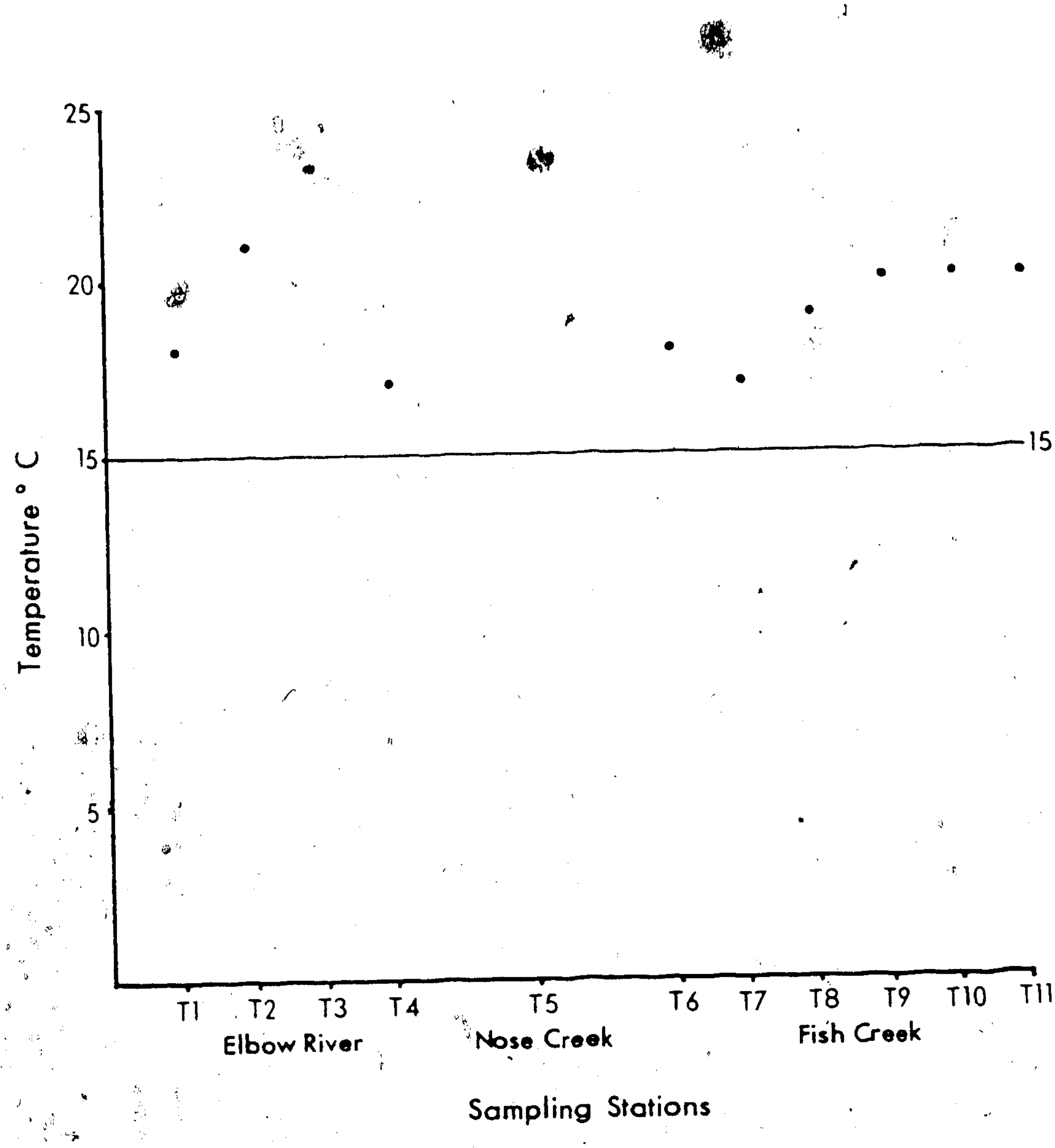
[17] The very small sample size for each month means that the mean value may differ significantly from the true mean but it can be taken as an indication of seasonal variation.

FIGURE 5 Temperature Maximums - Bow River



Source: Naquadat data supplied by Alberta Environment

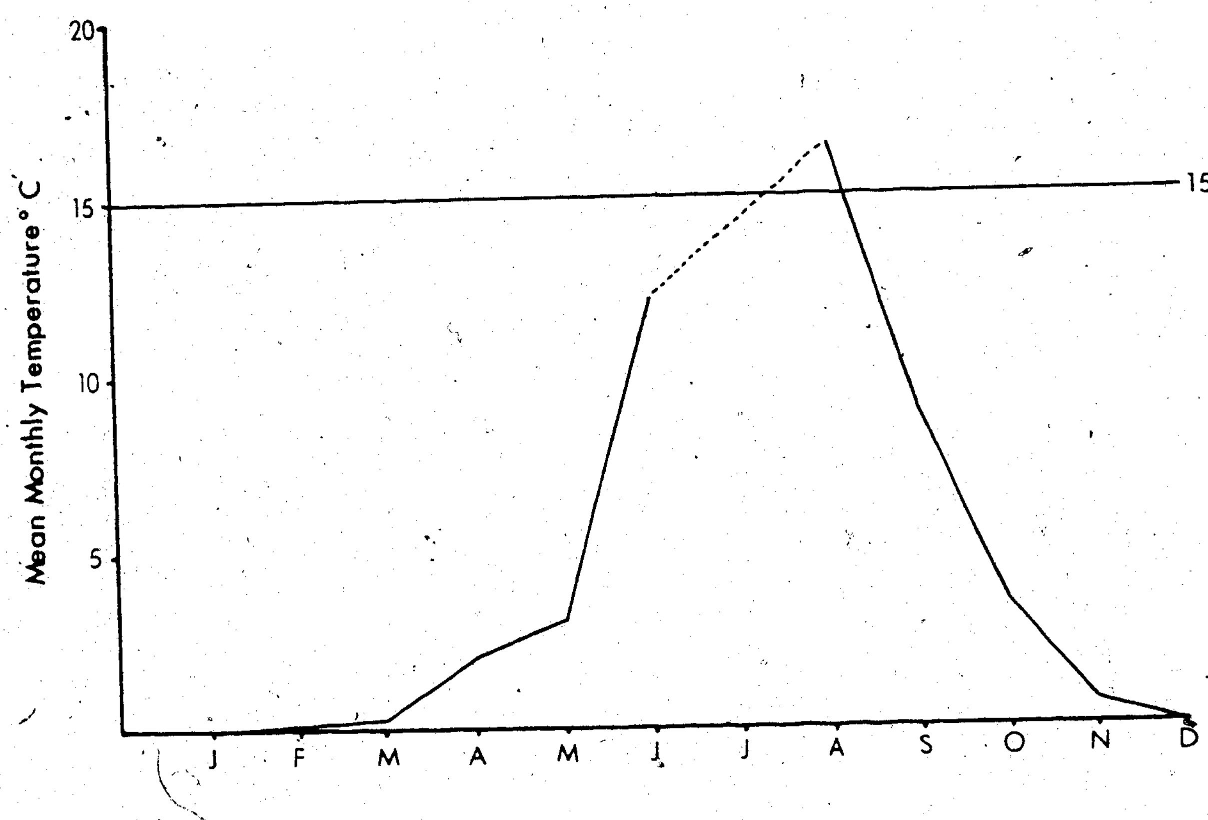
FIGURE 6 Temperature Maximums- Tributaries



Source: Naquadat data supplied by Alberta Environment

FIGURE 7 Temperature- Seasonal Variation

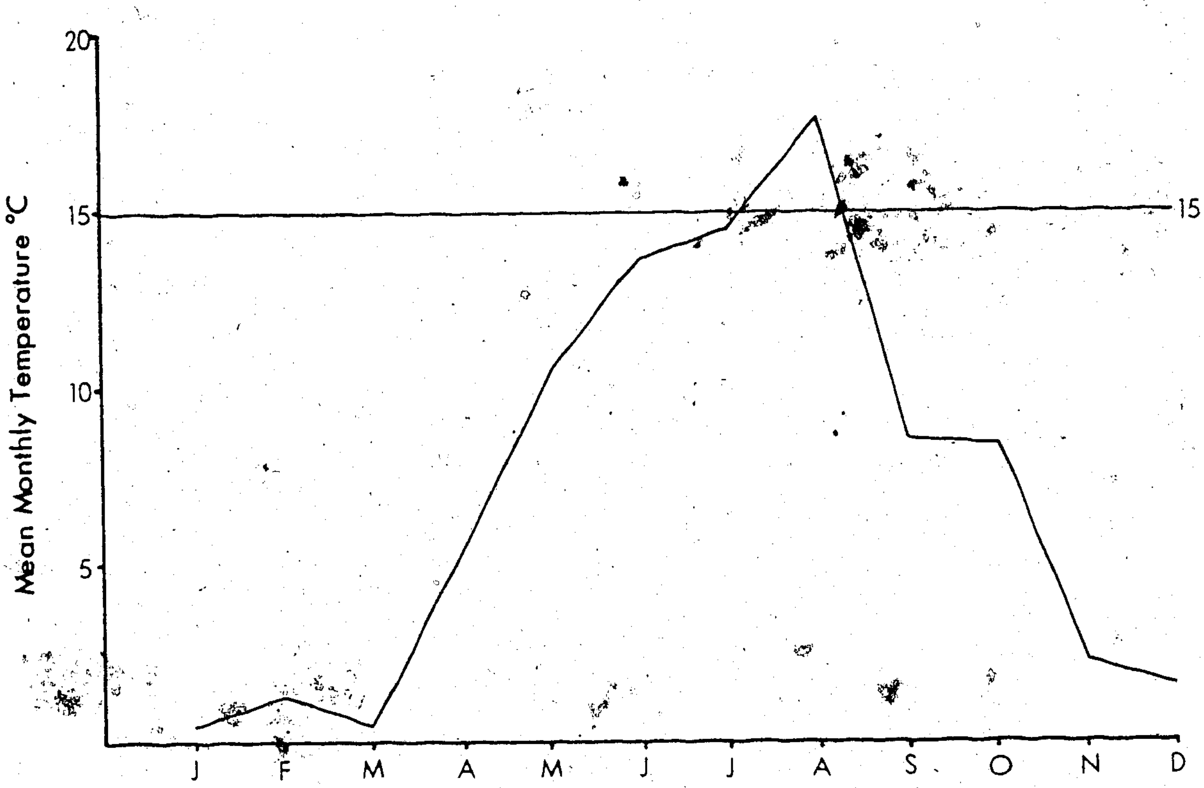
Sampling Station 11



Source: Naquadat data supplied by Alberta Environment

FIGURE 8 Temperature - Seasonal Variation

Sampling Station T2

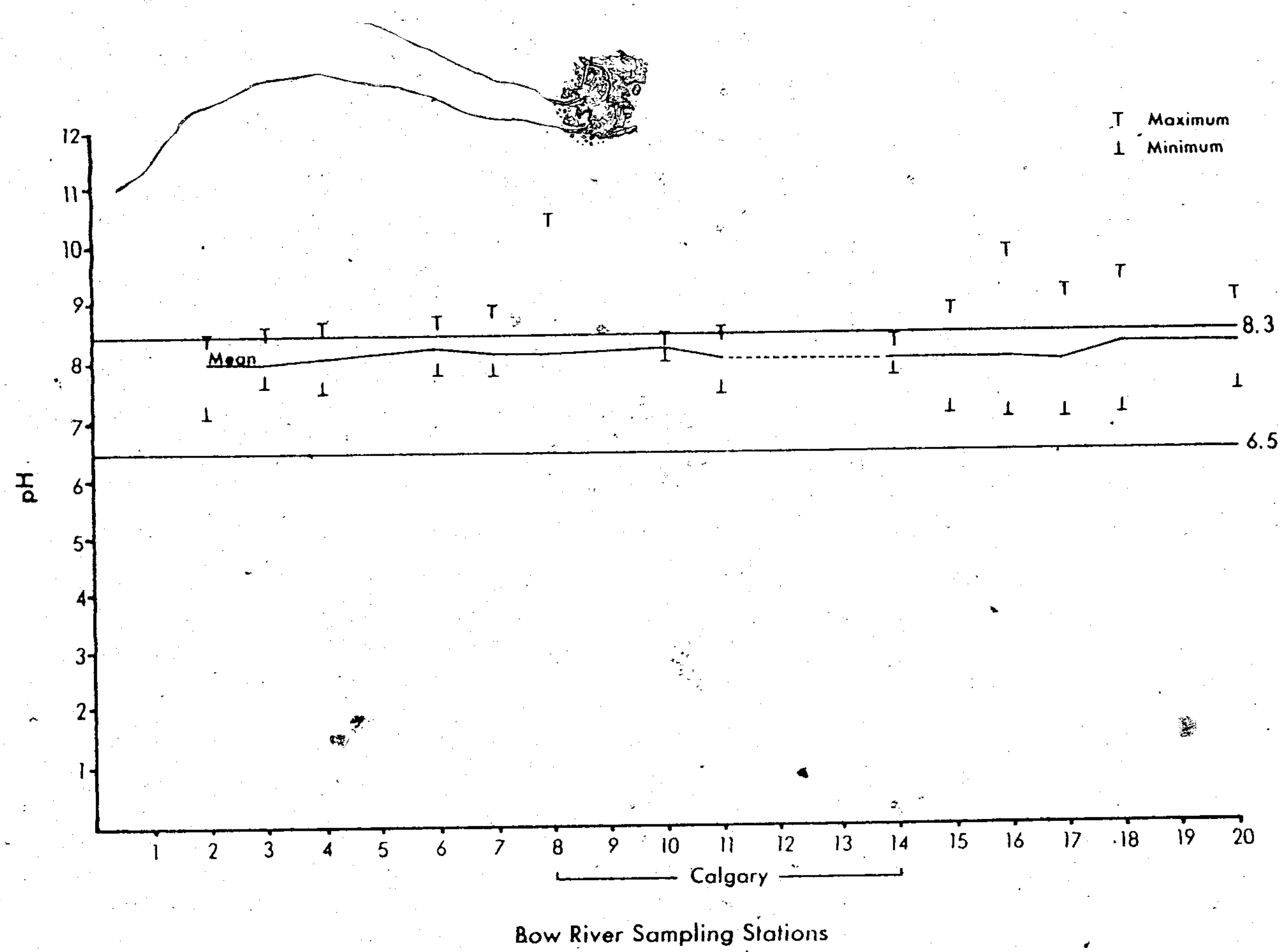


Source: Naquadat data supplied by Alberta Environment

The pH of water may be increased by the presence of carbonates, bicarbonates and hydroxides while free mineral acids and carbonic acids may lower it. Industrial wastes which have not been neutralized are a common source of these and may thus cause water acidity. The Headwaters of the Bow River lie in predominantly limestone mountains. Thus carbonates from this source increase the pH of river water. In the prairies of western Canada Canada, water is usually alkaline because solonetzic soils and saline groundwater often contribute salts to surface waters, while high evaporation rates result in greater concentrations. The importance of the pH measure to assessment of water quality lies in the fact that it can affect the availability of nutrients and the toxicity of many trace elements and, more important, the species composition of the aquatic environment. The latter is of importance to both the aesthetics of a water body and to the quality of sport fishing. Also important in the context of this thesis is the fact that the occurrence of pH values outside the recommended range may be detrimental to the enjoyment of direct contact recreational activities because of eye irritation. The pH of the lacrimal fluid of the human eye is 7.4 but, in most cases, the buffering capacity of this fluid allows contact with water at a pH of 6.5 to 8.3 to be tolerated without irritation (U.S. Environmental Protection Agency, 1972). Deviation outside this range is, however, likely to cause discomfort to most people, and thus pH is especially important in areas where people swim or children play in shallow water (for example, the Elbow River, Fish Creek and various lagoons and side channels of the Bow).

The mean and the range of values for pH in the Bow River are shown in Figure 9. It is clear that in no case does the water quality fall below either the Environment Canada absolute minimum or the objective minimum and, in fact, no value of less than 7 (neutrality) is recorded. While the mean remains relatively constant throughout the Bow basin, the range of values does tend to be greater downstream from Calgary in the prairies (in particular, the maximums are significantly higher), than upstream in the mountains and foothills. There is thus little variation in average conditions through the basin, and the fact that deviation about the mean is much greater in the lower part might well be attributed to natural variation. The tendency to greater alkalinity downstream from Calgary is probably a result of the hotter, drier climate with consequently high evaporation rates, the occurrence of alkaline soils and addition of saline groundwater.

FIGURE 9 pH - Bow River



Source: Naquadat data supplied by Alberta Environment

While pH values do not fall below suggested standards and all means are within the objective range, maximum values rise well above the upper limit recommended by Environment Canada (1979). In fact, the maximum recorded value of every sampling station exceeds 8.3 pH units (the Environment Canada objective) and at least equals the stated Alberta objective of 8.5. Furthermore, at half of the sampling locations the maximum recorded value exceeds the absolute maximum suggested by Environment Canada (1979). In view of the source area of the Bow River (as discussed) this is to be expected.

Within the City of Calgary station 8 is anomalous in having a very high maximum value. It is the only sample of a total of 57 for which the pH is greater than 9 and, while three other samples are recorded which are equal to the stated objective of Alberta Environment (1977), no others exceed it. This single large value may therefore be interpreted as a single chance or unusual occurrence. Nevertheless, although mean values at all Calgary stations fall within recommended limits, the maximum values are all greater than 8.3 and at least equal the Alberta Environment objective of 8.5.

pH values for the tributary streams at Calgary are shown in Figure 10 and from this there appears to be very little variation either between or within stations and all means are less than 8.5. Otherwise, conditions are similar to those in the Bow River; values occur toward the more alkaline end of the scale and, while no maximums are greater than 9, all but one either equal or exceed 8.5.

In summary, the water of the Bow River and tributaries tends to be slightly alkaline (mainly due to climatic and soil factors and the predominance of limestone in the mountains) but all mean values fall within the range of the Alberta Water Quality Objectives and from the data analysed there does not seem to be a serious problem. However, it is possible that at times pH does rise to levels that would cause discomfort to the eyes of recreationists.[18]

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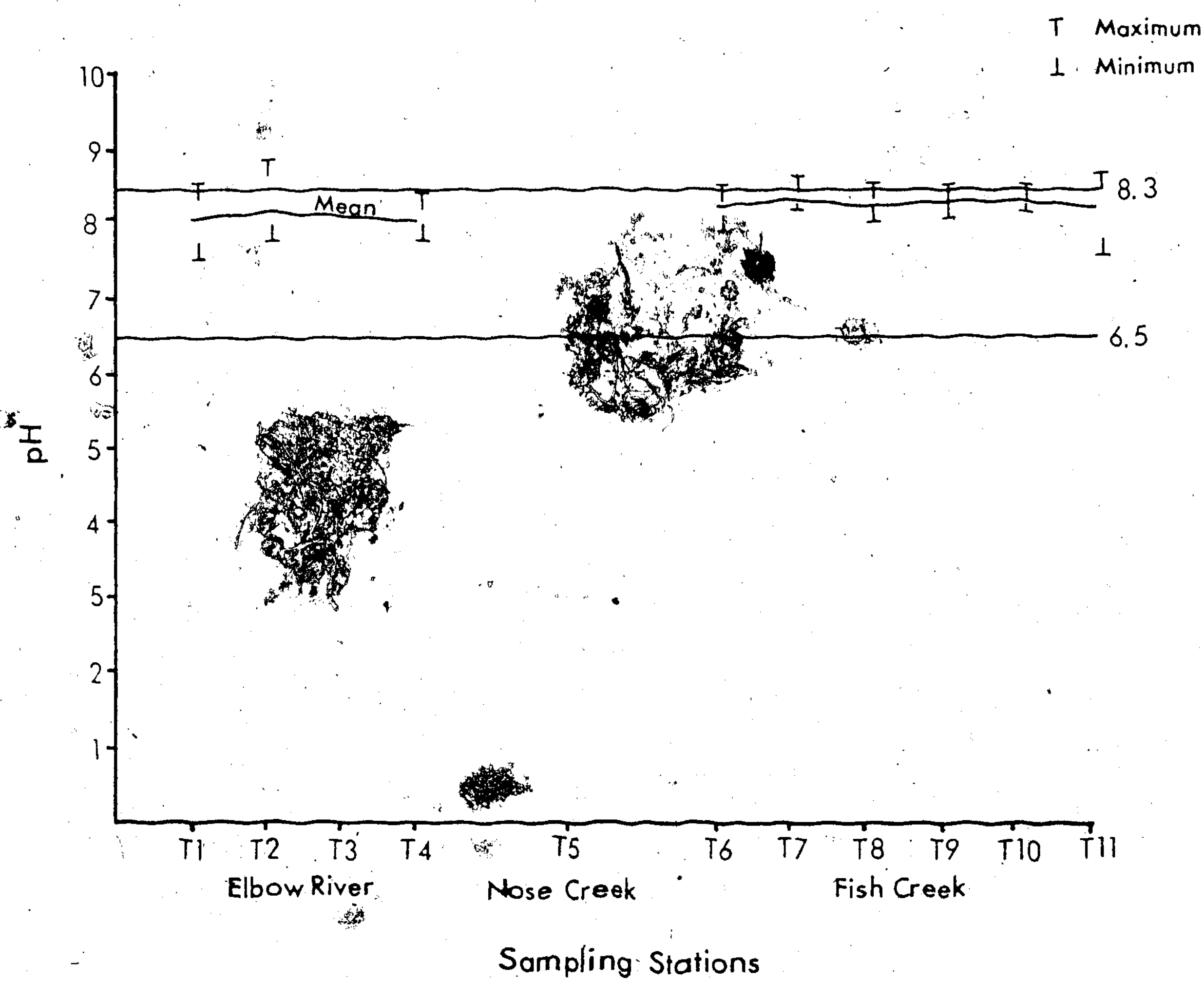
[18] Analysis of the available data did not give any evidence of seasonally determined variations.

FIGURE 10 pH - Tributaries



Source: Naquadat data supplied by Alberta Environment

4.2.3 Dissolved Oxygen and Biochemical Oxygen Demand

Dissolved oxygen in water may be derived either from the atmosphere or from photosynthesis by aquatic plants and is found dissolved in natural surface waters at typical concentrations of between 5 and 10 mg./l. (Environment Canada, 1979). The amount occurring varies with temperature, salinity, turbulence and atmospheric pressure (decreasing with altitude). At the altitude of Calgary (3,440 feet) an oxygen concentration of 5 mg./l. represents a saturation level of 38 percent at 0 degrees C. The concentration is also subject to diurnal and seasonal fluctuations which are due in part to variations of temperature, photosynthetic activity and river discharge. There is a normal 'sag' in oxygen levels in daytime due to warming of the water by the sun but this is made up at night when oxygen is redissolved from the air. However, when nutrient concentrations are high algae tend to multiply and, even if they are not abundant enough to constitute a physical nuisance, they may cause a reversal in the diurnal oxygen pattern. Photosynthesis by the algae in daytime releases oxygen into the water but respiration at night consumes it, thus causing the night time 'sag'. The eventual decay of algae imposes a heavy oxygen demand and may cause a longer lasting seasonal 'sag'.

Even a short-term night-time oxygen sag in summer may have serious consequences for fish populations.Although fish may become accustomed to low oxygen levels if exposed to them gradually (Shubencadie-Stewiacke River Basin Board, 1978, p. 41) sudden lowering of levels below about 5mg./l. are fatal to most species. A fish kill was reported near Bassano, downstream from Calgary, in July 1979 (Calgary Herald, 17/9/79) and, although the cause was not confirmed, it was surmised to have been a lethal combination of factors. Streamflow in July was unusually low (3,637 c.f.s. compared to a long term mean of 7,190 c.f.s. for 1908-1979), water temperatures in this reach of the Bow rose to 27 degrees C and algae were abundant, which factors combined together make a hostile environment for fish.

The water quality parameter known as biochemical oxygen demand is a measure of the amount of oxygen required to oxidize the organic matter in water by aerobic microbial decomposition to a stable inorganic form. B.O.D. is usually measured as the amount of oxygen consumed over 5 days at a temperature of 20 degrees C (B.O.D.5). Thus it is a measure of oxygen consumed but cannot indicate the presence of organics not consumed, nor account for the effect of materials which may inhibit microbial decay. B.O.D. therefore, is not a pollutant in itself but is an indicator of organic pollution and the potential for reducing the dissolved oxygen content of water.

An increase in biochemical oxygen demand may be imposed by man either directly by the addition of oxygen demanding substances, for example municipal, agricultural and pulp and paper wastes, or indirectly by the addition of nutrients which stimulate aquatic growth which then in turn impose an oxygen demand at night or when they decay. Thus, variations in oxygen demand may be either temporal (diurnal and/or seasonal) or spatial in type, as when wastes such as these are added to a particular reach of the river. For example, the Bonnybrook Sewage Treatment Plant in Calgary discharges effluent with a B.O.D. of about 20 into the Bow River (personal communication, B. Mackintosh). In 1977 this was estimated to represent a B.O.D. load of 2,982 Kg./day from the Bonnybrook plant and 5,794 Kg./day from the Fish Creek plant[19]. This causes a noticeable increase in B.O.D. downstream from these plants (Figure 11) which is coupled with a very significant oxygen sag (Figure 12). It is thus important to bear in mind first, that the relationship between B.O.D. and D.O. is usually asymmetrical: that is, while B.O.D. levels may influence D.O. levels the inverse does not usually apply. Secondly, the relationship between the two is inverse: that is, an increase in B.O.D. has the potential to cause a decrease in D.O.,though this will not always occur due to the complexity of causal factors.

To give a general overview of conditions in the study area, the data will be discussed first with regard to spatial variation. The mean and range of values for B.O.D. at each sampling station on the Bow River between Banff Park and the confluence with the South Saskatchewan River are shown in Figure 11. The dominant characteristic of the resultant graph is the trend for B.O.D. to increase with distance downstream, and a secondary one that the range in B.O.D. for individual locations is greatest in the lower reaches of the basin. It should be especially noted that the marked upward trend in the graph begins within the City of Calgary between sampling station 11, Cushing Bridge, and number 13, just above the confluence with Fish Creek, that is in the reach of the river into which the effluent from the sewage treatment plants and industries is discharged.

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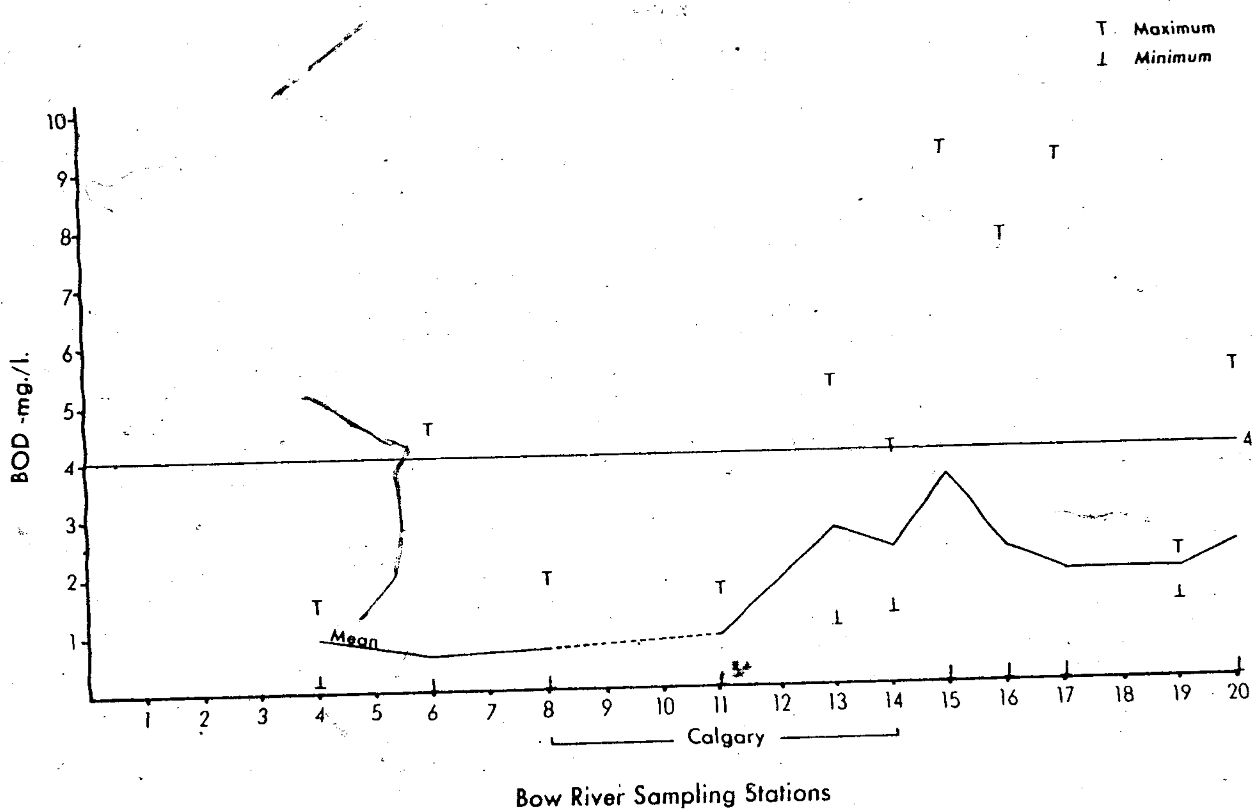
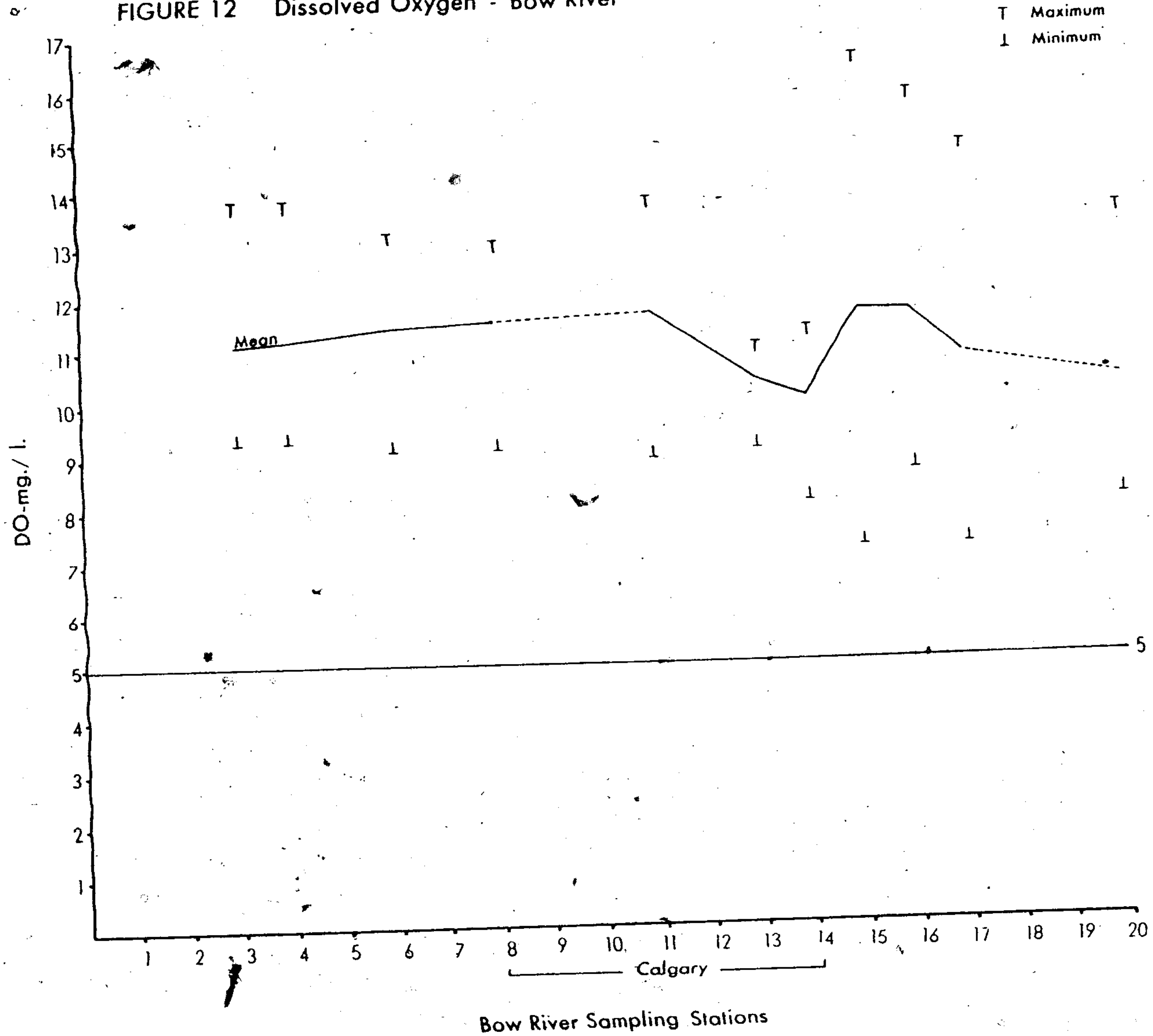
[19]Since that time secondary treatment has been instituted at Fish Creek (April 1980) thus drastically reducing the load.

FIGURE 11 Biochemical Oxygen Demand - Bow River



Source: Naquadat data supplied by Alberta Environment

FIGURE 12 Dissolved Oxygen - Bow River



Source: Naquadat data supplied by Alberta Environment

Dissolved oxygen levels, shown in Figure 12, show the opposite trend to that of Figure 11, for dissolved oxygen concentration tends to decrease with distance downstream. Though this is a logical relationship, the connection is not necessarily straightforward. The dip in the graph between stations 11 and 15 might be an anomaly attributable to the small sample size for stations 13 and 14, or it might indeed represent a depletion of oxygen due to the addition of oxygen demanding municipal wastes which is then followed by a recovery downstream. While the former is a plausible explanation, comparison with Figure 11 and the information given in Chapter 3 make the latter the likely explanation. This problem can only be solved by the analysis of a greater volume of data than is at present available.

Waters with B.O.D. levels less than 4 mg./l. are generally considered clean (Environment Canada, 1979, p. 32) while those with levels above 10 mg./l. are considered significantly polluted because of the large amounts of degradable organic materials which they must contain. For values in between these, whether or not the water would be considered polluted depends on the source of the oxygen demand because these levels could occur naturally. Despite the characteristics described above, mean B.O.D. at all stations on the Bow River is less than 4 mg./l. and, although maximums rise above this level, in no case do they exceed 10 mg./l.. On this basis the water would be classified as clean or slightly polluted. Furthermore, variations notwithstanding, concentration of dissolved oxygen is high throughout the river and even the lowest values recorded are well above the 5 mg./l. given in Alberta Surface Water Quality Objectives 1977 as the level below which it should not be allowed to fall.

However, the levels of B.O.D. and D.O. described above are no reason for complacency. B.O.D. does sometimes exceed 4 in the City of Calgary and downstream and, although dissolved oxygen concentrations are high, there is a definite trend for minimum values to be markedly lower in southeastern Calgary and downstream than upstream of the city. In other words, although the situation with regard to these parameters is not yet serious, there are, by the standards given, very clear indications of degradation which should give cause for concern. While few examples from the tributaries have been measured for B.O.D. and D.O., the data available indicate high levels of dissolved oxygen with mean values ranging from 8.7 to 13.2 mg./l.. The data on biochemical oxygen demand suggest that this is not a problem in the tributaries in the City of Calgary for only one value is recorded which exceeds the Environment Canada clean water level of 4 mg./l. and this is 4.1 mg./l. recorded on the Elbow River at Bragg Creek to the west of the city.

Since the factors influencing B.O.D. and D.O. concentrations in water are subject to significant seasonal variations it is important that these two parameters be analysed on a seasonal basis, both to throw light on how they might be influenced by the factors described above and also to determine what implications such seasonal variations might have for recreation. In order to do this four sampling stations have been chosen for detailed analysis. These are number 8 on the Bow River in north-west Calgary, number 11 at Cushing Bridge not far upstream from the Bonnybrook Sewage Treatment Plant outfall, number 15 just outside the southern city limits and number 16 at Carseland downstream from Calgary (Figure 4). The first two are thus above the sewage plant outfalls while the latter two are below both these outfalls and all the city's stormwater outfalls.[20] This is important because the sewage treatment plants are the single greatest contributors to BOD in the river. If it can be shown that the impact on water quality is very significant, then a prime recommendation will be that effluent quality at these sources be improved. Since stations 8 and 11 and, separately, 15 and 16 display very similar characteristics to each other but markedly different from the other pair they will be discussed as pairs; 8 and 11 will be referred to as upstream locations and 15 and 16 as downstream locations.

In Figure 13 it is shown that the upstream range of B.O.D. values is very narrow and consistently low (0-2.5 mg./l.) and that there is no difference between summer and winter. However, while the range of D.O. levels is not very great either (8-14 mg./l.) there is a marked contrast between summer and winter, with the higher D.O. concentrations occurring in winter. At the downstream locations (Figure 14) there is a wide range of B.O.D. levels (0-8 mg./l.) and also some difference between summer and winter for the higher values tend to occur in the latter season. D.O. levels downstream do not differ significantly in range (7-16.5 mg./l.) from those found upstream but they do not have the same seasonal variation.

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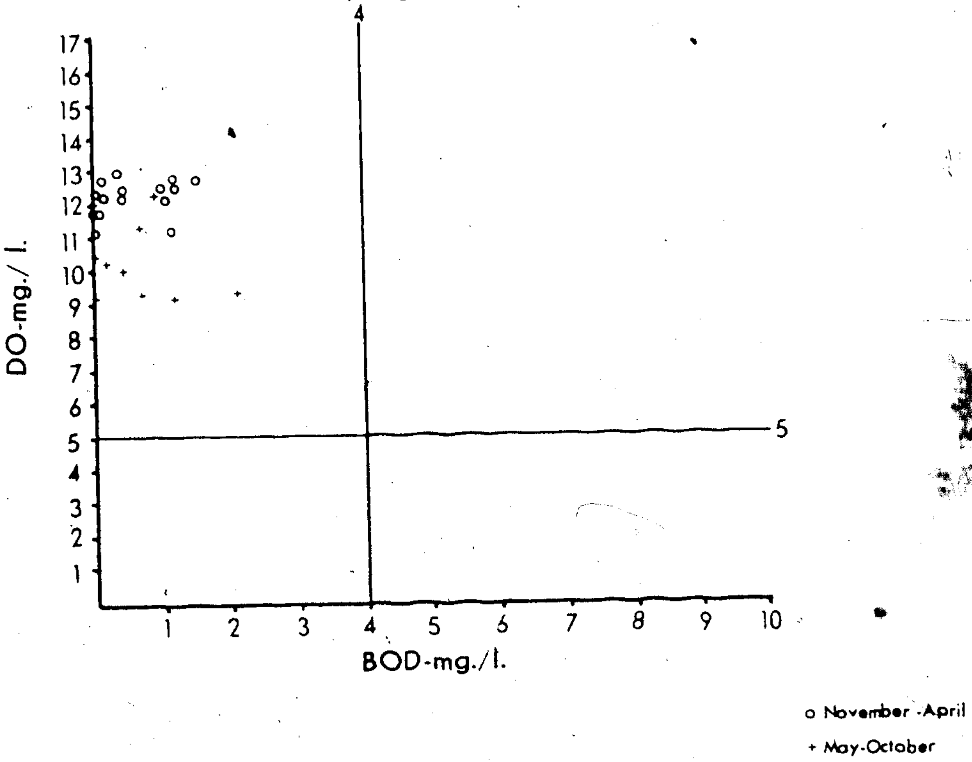
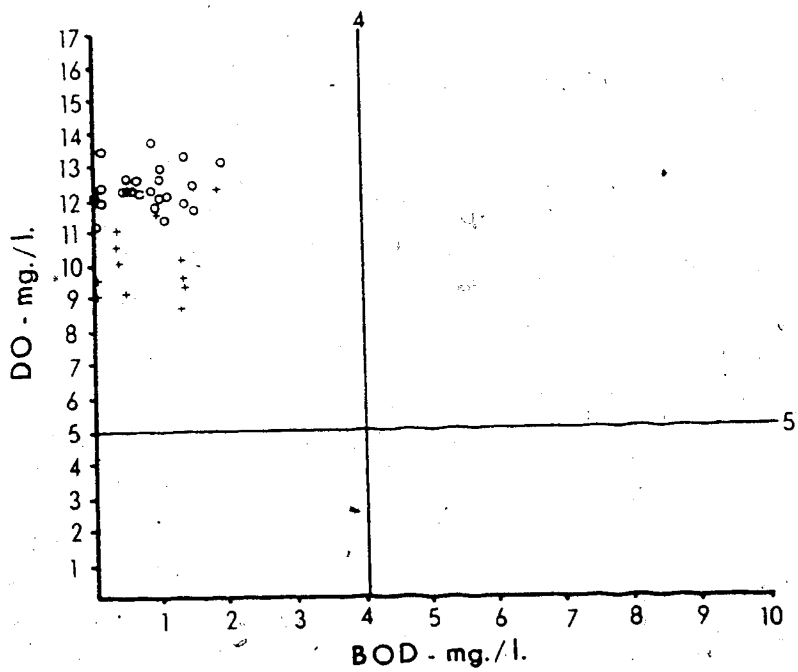
[20]Insufficient samples were available for the stations downstream from the sewage treatment plant outfalls but within the city.

FIGURE 13 Dissolved Oxygen and Biochemical Oxygen Demand

Sampling Station 8



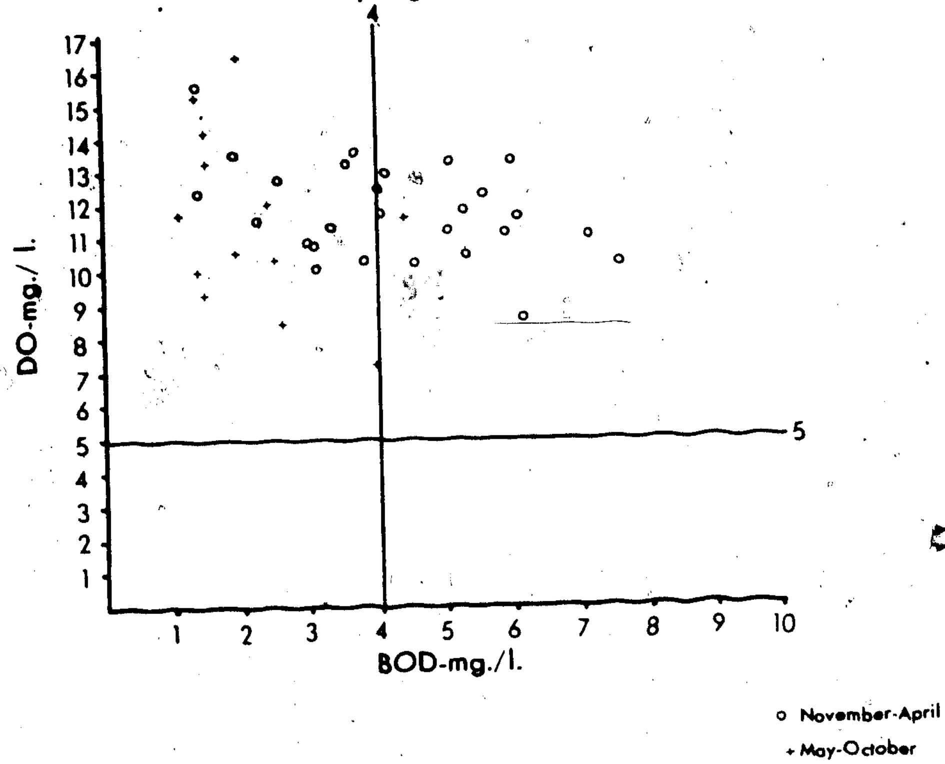
Sampling Station 11



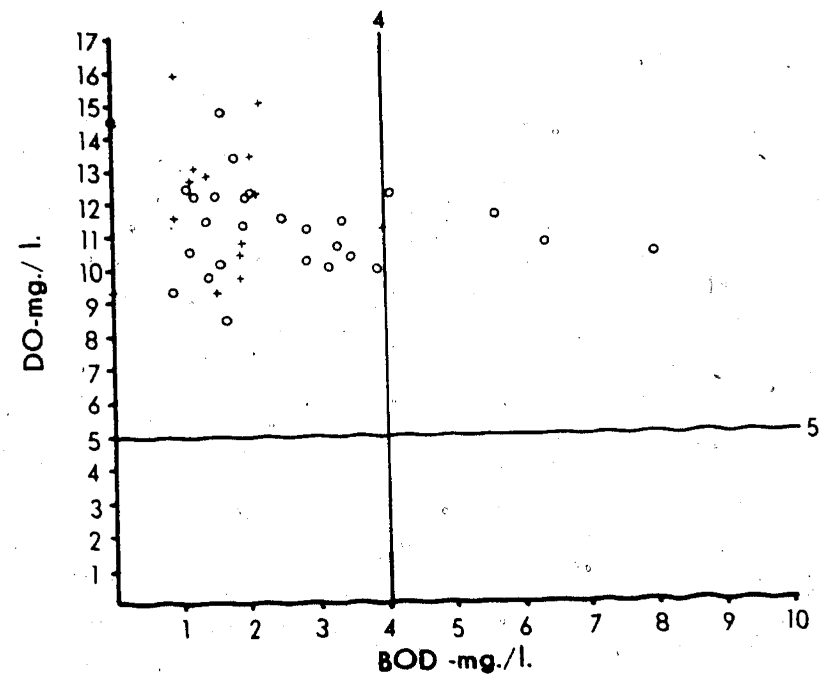
Source: Naquadat data supplied by Alberta Environment

FIGURE 14 Dissolved Oxygen and Biochemical Oxygen Demand

Sampling Station 15



Sampling Station 16



Source: Naquadat data supplied by Alberta Environment

As indicated, a major influence on B.O.D. levels in the Bow River at Calgary is the input of municipal sewage effluent. While sanitary sewage effluent from the treatment plants is fairly constant throughout the year (diurnal and small seasonal variations do occur, see Chapter 3), the runoff collected in storm sewers is subject to seasonal variations being higher in spring, at snowmelt time, and during summer rains[21]. The oxygen demand of decomposition processes at work on vegetational matter is at a peak in late summer and fall when the summer's growth of aquatic plants starts to die off.

B.O.D. is also influenced by volume of streamflow because of the dilution effect of water. Discharge of the Bow River at Calgary starts to increase in April from very low winter flows, rapidly reaches peak flow in June and then slowly declines to low flow again in October. This factor is quite important because the seasonal change in river discharge is very pronounced. The mean monthly flows for the period of record show an increase of almost six times between February and June. However, this has been reduced by control of the river for hydro-power and the same figure for the years 1930–1979 is four and a half times. From this information one would expect B.O.D. to be very significantly lower in summer than in winter (all other things being equal). This is not borne out by the data displayed in Figure 15 for upstream locations, but it is borne out by that in Figure 16 which indicate a marked decrease in B.O.D. at downstream stations during the summer months, particularly at station 15. The increase from October onwards at this station is due to the very low river flows at that time coupled with the presence of decomposing organic matter from summer growth. This pattern is not, however, duplicated at the upstream locations. While the inverse is in fact true and B.O.D. increases in summer (earlier at Cushing Bridge than at 85 Street Bridge) the increase is only slight, for B.O.D. levels at these locations are quite consistently low throughout the year. This slight increase is probably insignificant and might well dissappear with a greater number of samples. It would thus appear that dilution only becomes a relevant factor when B.O.D. levels are higher (the river at these stations is not subject to large biochemical oxygen demands from decomposing algae).

Seasonal change in temperature also affects B.O.D. for while the cold winters inhibit aquatic growth this increases markedly with warm summer temperatures (water

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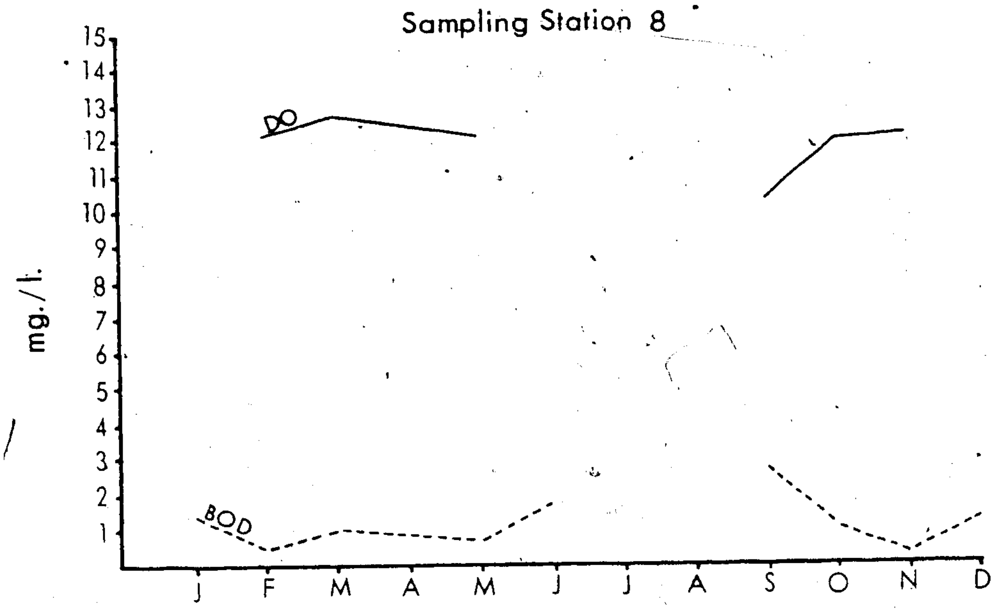
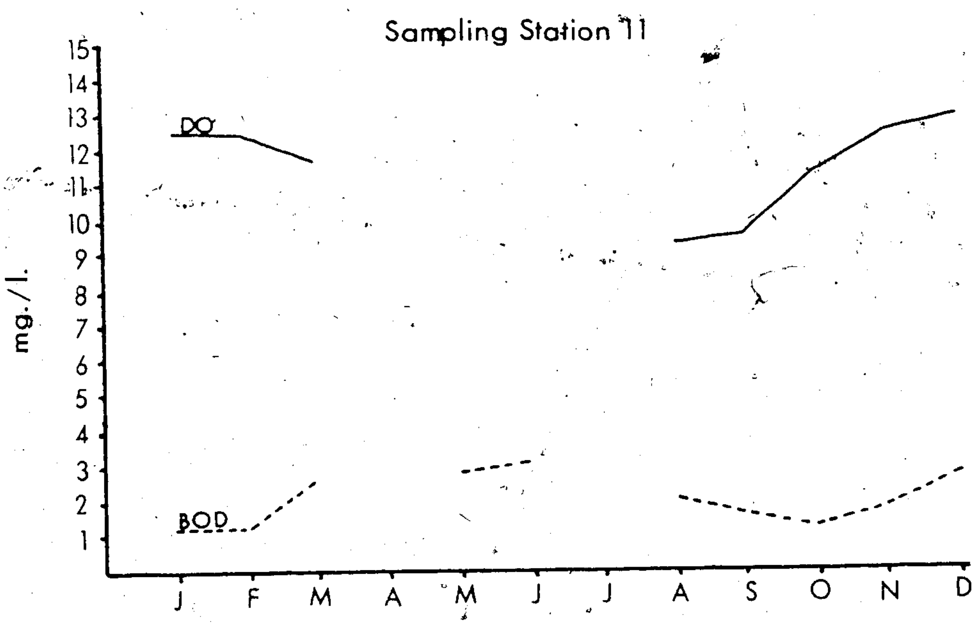
[21]Chinook induced melting may also be significant during the winter months in Calgary.

FIGURE 15 Dissolved Oxygen and Biochemical Oxygen Demand - Seasonal Variation

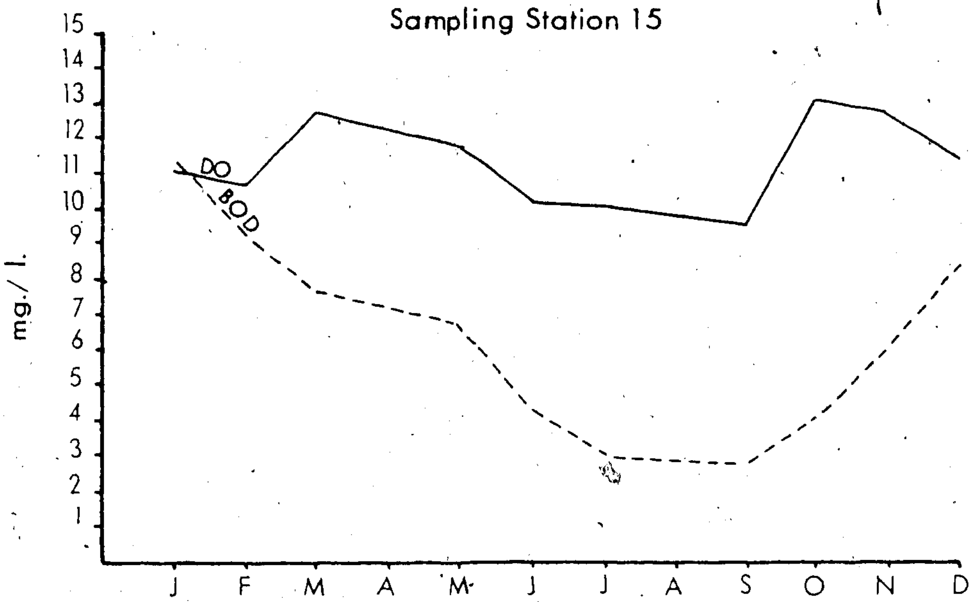




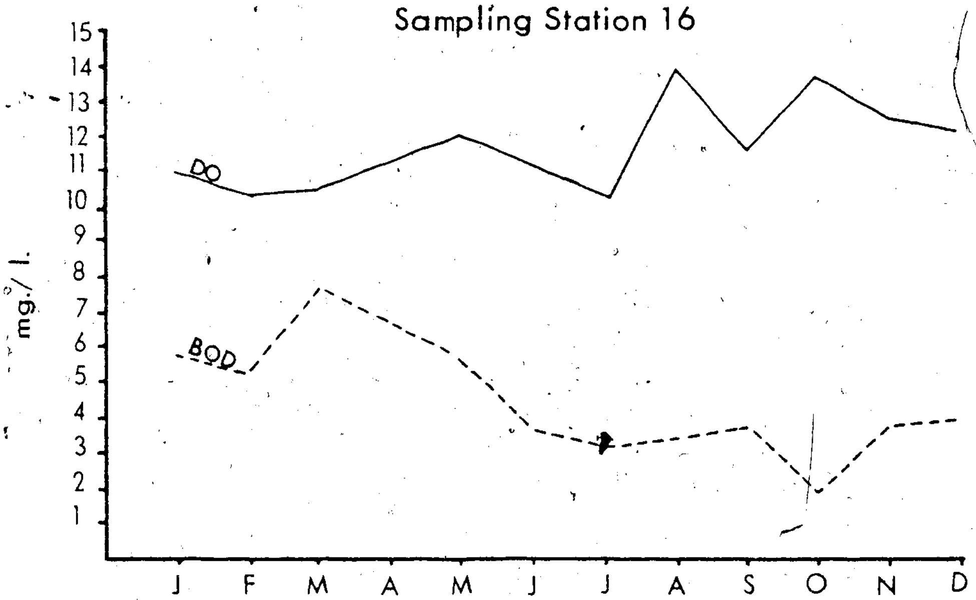
Source: Naquadat data supplied by Alberta Environment

FIGURE 16 Dissolved Oxygen and Biochemical Oxygen Demand - Seasonal Variation

Sampling Station 15



Sampling Station 16



Source: Naquadat data supplied by Alberta Environment

temperatures are highest in August). One would thus expect B.O.D. from decay to be at a peak in late summer and fall when the summer's growth dies and streamflow falls off to low levels. All four sampling locations do indeed have an increase in B.O.D. towards the end of the year and this is no doubt the reason.

Changes in temperature also directly affect D.O. concentrations and if this factor were the sole determinant of D.O. concentration one would expect levels to be lower in summer and start to rise in the autumn. There is some evidence to support this hypothesis (Figures 15 and 16, stations 8, 11 and 15) though the water of the Bow River does not become very warm except for short periods (see 4.2.1. Temperature).

Another important factor for D.O. concentration is turbulence. A rapidly flowing turbulent river has greater contact with the air and this allows oxygen to be taken up and dissolved in the water at a faster rate than would occur in a smooth flowing river. On this count one would expect, all other things being equal, that D.O.would be lowest under winter ice cover and highest in spring and summer when river flow is the most rapid and turbulent. While this hypothesis is supported by the data in Figure 15, it is not supported by the others, maybe because the decrease in temperature is enough to offset this affect. It is also possible that spring turbulence and increase in photosynthetic activity cancel each other out in their effects on dissolved oxygen levels.

In summary, there are marked seasonal variations in B.O.D. and D.O. levels but these are significantly different between sampling stations upstream of the main Calgary industrial areas and the sewage treatment plants than they are downstream . Upstream D.O. and B.O.D. levels indicate water of a good quality that is suitable for all types of recreational use. Downstream, however, although D.O. levels are well above the minimum considered necessary for the survival of fish they are depressed well below naturally occurring levels. This indicates that there is potential for for a problem of fish survival, if not for fish kills, at least for an increase in undesirable species at the expense of others with serious consequences for the quality of recreational fishing.

4.2.4 Turbidity

Turbidity is "capacity to scatter light" (Feth, 1973, p. 19). Thus it is a measure of the amount of suspended particles such as silt, clay, organic matter, plankton and microscopic organisms held in suspension which make water appear muddy. These particles may come from a variety of sources, such as natural erosion, runoff and algal blooms. In areas receiving winter precipitation in the form of snow turbidity usually increases in spring because of heavy runoff at snowmelt time. The concentration of these substances in water may be increased by man's activities. For example, land clearing may accelerate runoff and erosion, some agricultural practices increase the volume of sediment carried by runoff and the addition of nutrients encourage growth of algal blooms. An example of the first on a large scale is the increased turbidity and delta building in Lesser Slave Lake, Alberta as a result of the heavy sediment load carried by the Swan River from the Swan Hills where forest clearing has led to accelerated erosion. There are also many examples of the latter in Alberta where runoff from fertilized agricultural land has led to overfertilization of lakes and rivers.

These same processes are at work in the Bow River Basin though the ones which have the most dramatic effect are spring runoff and overfertilization of the Bow River by the addition of nutrients from city sanitary and storm sewage discharge. The high level of construction activity in Calgary may also contribute to turbid conditions in the rivers; directly when caused by bridge construction or indirectly by the draining of construction sites into storm sewers (Plate 9). Further, industrial effluents may sometimes exceed the licensed allowance for suspended solids (Alberta Environment, 1978 & 1979). However, these last two conditions are usually of limited duration and thus should not arouse undue concern with regard to long range planning for recreation in the river valleys.

Turbidity is measured by "comparing the optical interferences of suspended particles to the transmission of light in water in an instrument previously standardized with samples of standard turbidity units" (Environment Canada, 1979, p. 16). Natural turbidity levels may vary widely from non-detectable turbidity at 0 J.T.U. (Jackson Turbidity Units) to several hundred J.T.U.. Recommendations for turbidity levels in water used for recreation vary from 5 to 50 J.T.U.. Environment Canada (1972) suggests a maximum level of 50 but with an objective level of 5 for direct contact recreation.

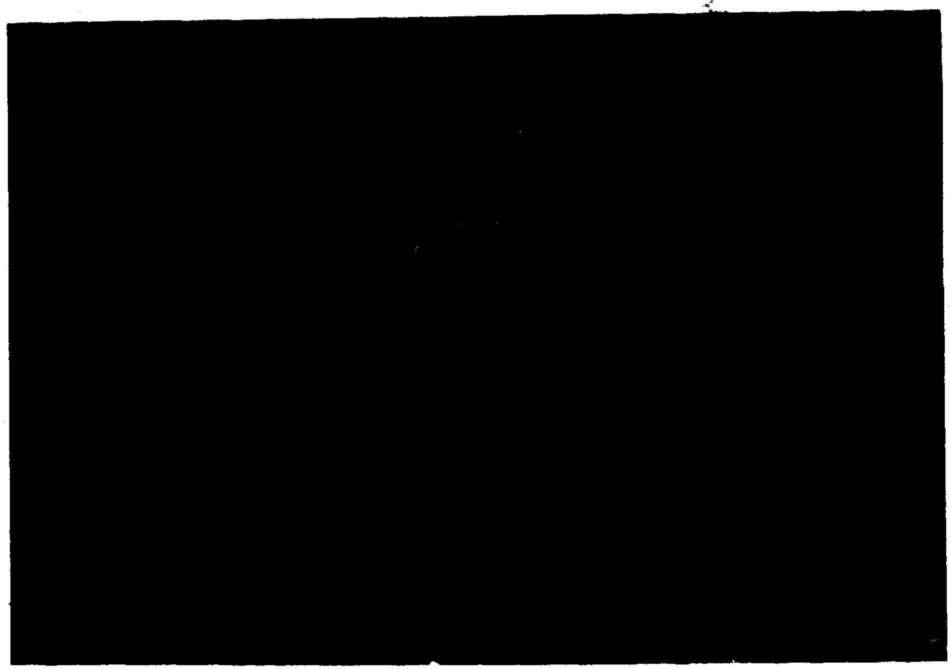


Plate 9 Turbidity in the Bow River caused by bridge construction

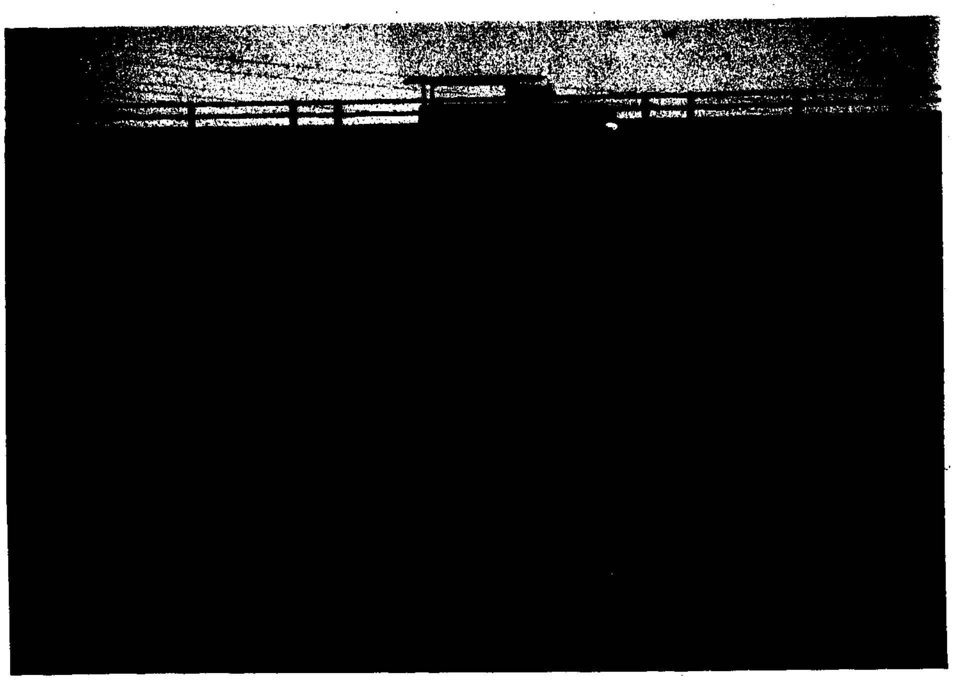


Plate 10 Weeds in the Bow River at Glenmore Trail, August 1980

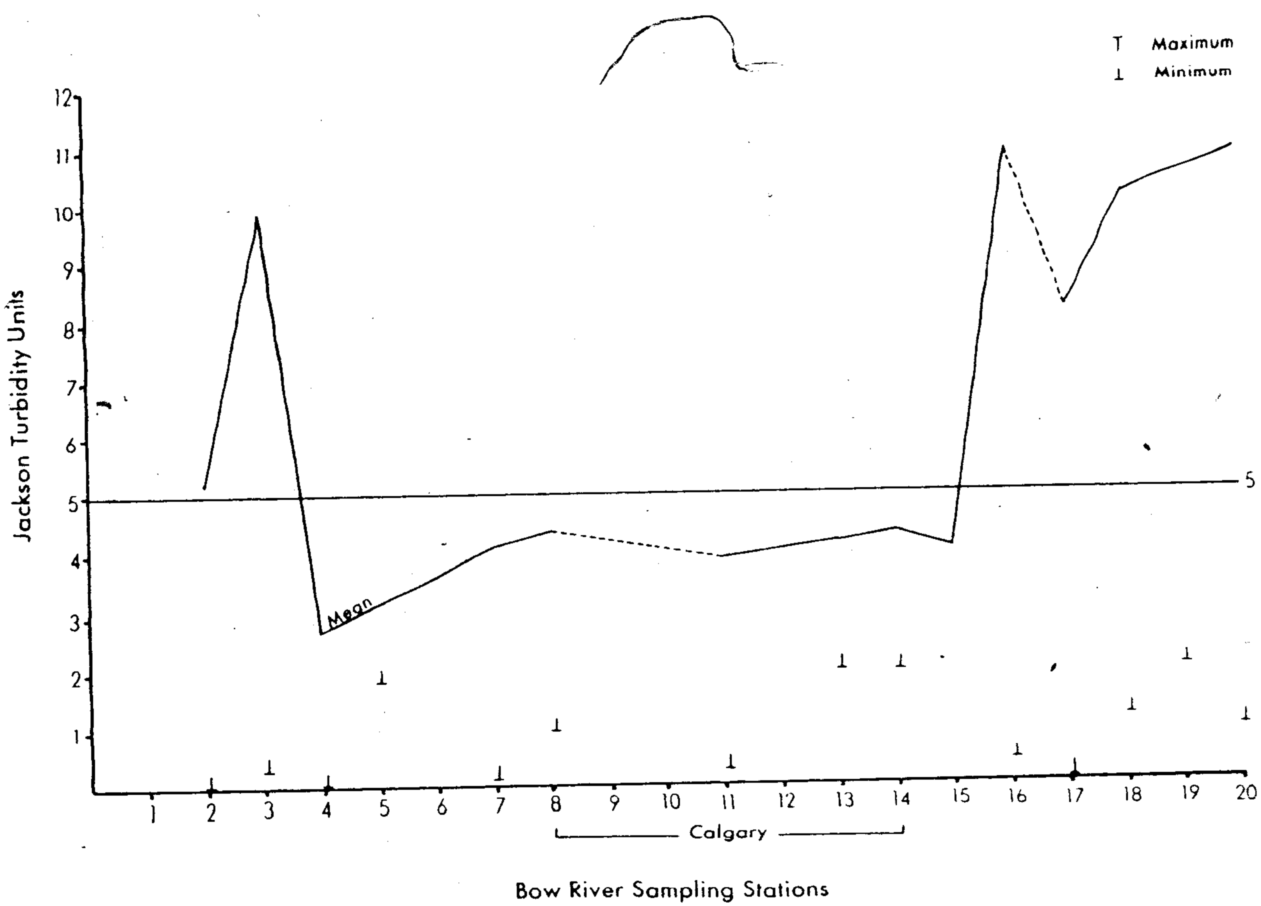
Alberta Surface Water Quality Objectives (1977) simply state that turbidity should not exceed natural conditions by more than 25 J.T.U., which therefore allows for significant increases due to man's activities. In contrast, Environment Canada (1979, p. 61) suggests that "discharges resulting from human activity should not alter ambient turbidity levels".

While the occurrence of high turbidity levels does not present any direct danger to the health of participants in direct contact contact recreation activities it does often significantly reduce the aesthetic value of water bodies, thereby affecting both direct water users and those people using the riverbanks and adjacent land. Secondly turbidity reduces visibility within the water and may thereby increase the accident hazard at boating and swimming areas by obscuring submerged obstacles. Thirdly, high turbidity affects plant communities by reducing light penetration and therefore also the photosynthesis of submerged vegetation. This may upset the balance of the ecosystem and also reduce fish productivity thereby impairing the quality of recreational fishing. On the other hand, the settling out of suspended sediments which cause turbidity may enhance weed growth in areas of shallow, slow moving, water (Calgary Herald, August 1981).

Mean turbidity for the period of analysis at Bow River sampling stations is shown in Figure 17. The most striking feature of this graph is the extreme variation in mean values. While for most stations a large number of samples were available, at number 10 only thirteen have been recorded, considerably fewer than elsewhere, but, more important they were all recorded between May 2 and July 24 (eleven of the thirteen in May) of 1969. Thus the record here covers an extremely limited time period and indeed a time at which spring runoff is high. The data, therefore, are not valid for the purpose of comparing means though they do illustrate conditions in spring very well.

At no sampling station on the Bow River is the suggested maximum of 50 J.T.U. exceeded as a mean though at five it is exceeded as a maximum. However, these very high values are rare occaions and most occur in spring. This is to be expected for, even under completely natural conditions, it is unlikely that a fast flowing river such as the Bow River would be clear year round. Indeed, while some maximum levels may appear very high they are not outside the range within which natural turbidity may occur and since none of these locations is within the city of Calgary closer study will not be undertaken.

FIGURE 17 Turbidity - Bow River



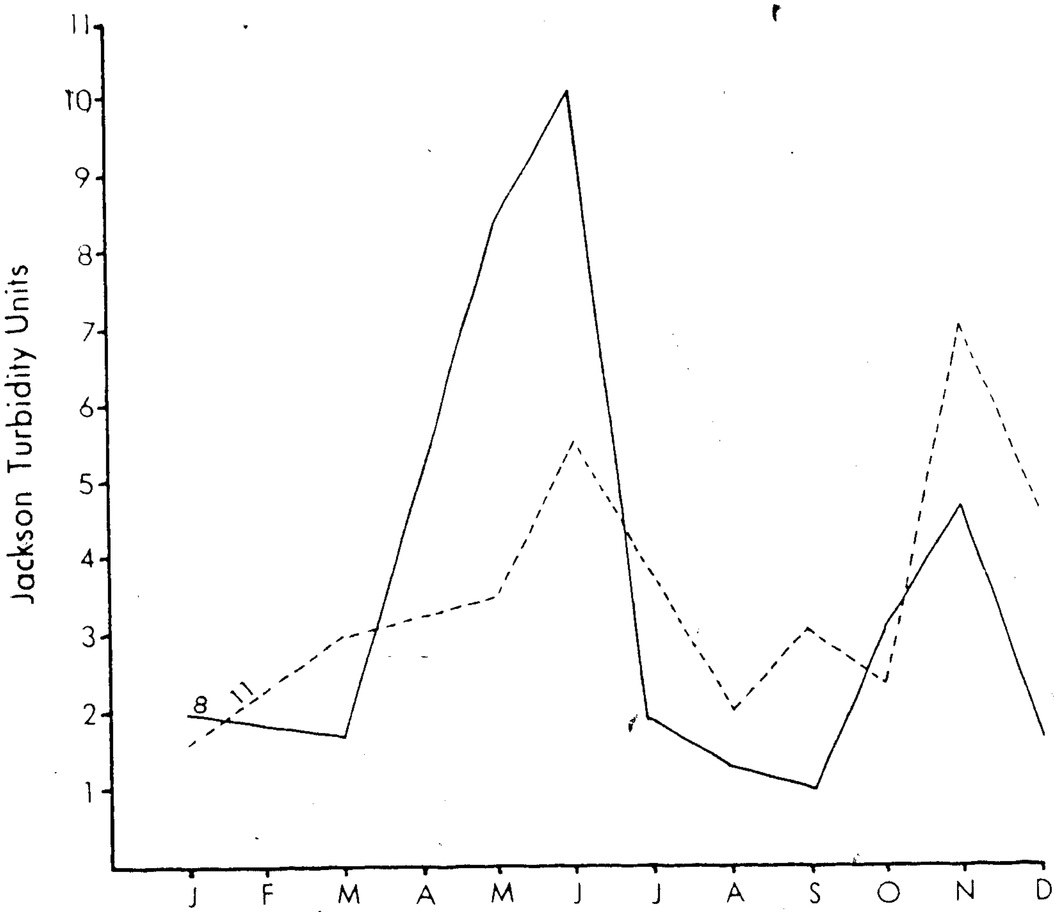
Source: Naquadat data supplied by Alberta Environment

Since variations in turbidity are hypothesised to be dependent on season some sampling stations have been analyses closely to test this (Figures 18 and 19). It is at once apparent that this supposition is true because the same basic seasonal pattern is evident for all four locations. That is, a peak in June with a secondary peak in November. The June peak corresponds, as expected, with peak discharge of the Bow River for June is the month of maximum snowmelt in the headwaters and also the month of maximum precipitation in Calgary. At this time erosion on land coupled with bank and bed scour by the river leads to high concentrations of mineral particles in water. The peak in November cannot however, be attributed to high discharge rates for streamflow is consistently low from October to March. However, at this time the summer's growth of algae and other aquatic plants has already been uprooted by the river's current and is decaying. In the process of decay pigments and organic particles are released causing high turbidity. While this process takes place under natural conditions the high levels of November in Calgary and downstream are no doubt directly attributable to overfertilization of the river by the addition of nutrients which stimulate algal growth. It is also worthy of note that, while stations 8 and 11 are within the drainage of a highly urbanized area (Calgary), stations 15 and 16 are located in agricultural areas and yet the seasonal patterns are the same. It must thus be concluded that either the pattern is controlled by natural causes as described above, or any urban effects are still present downstream.

In summary, therefore, while turbid conditions are common in the Bow River, within the city of Calgary mean values are all below the 5 J.T.U. level suggested as an objective for waters used for direct contact recreation. While this level is exceeded at times, it happens for the most part in the months of June and November. Turbidity caused by organic particles in the latter month is largely due to pollution of the river by the city of Calgary but occurs at a time when recreational use of the rivers and adjacent lands is at a minimum. In contrast, June is an intensive use month. It is thus at this time that impact of turbidity on recreation is of concern, however, since it is due to natural processes it is likely to be aesthetically less objectionable to recreationists; "people seem to adapt to and accept a wide range of water turbidities as long as changes in turbidity are part of natural processes" (United States Environmental Protection Agency, 1972, p. 16).

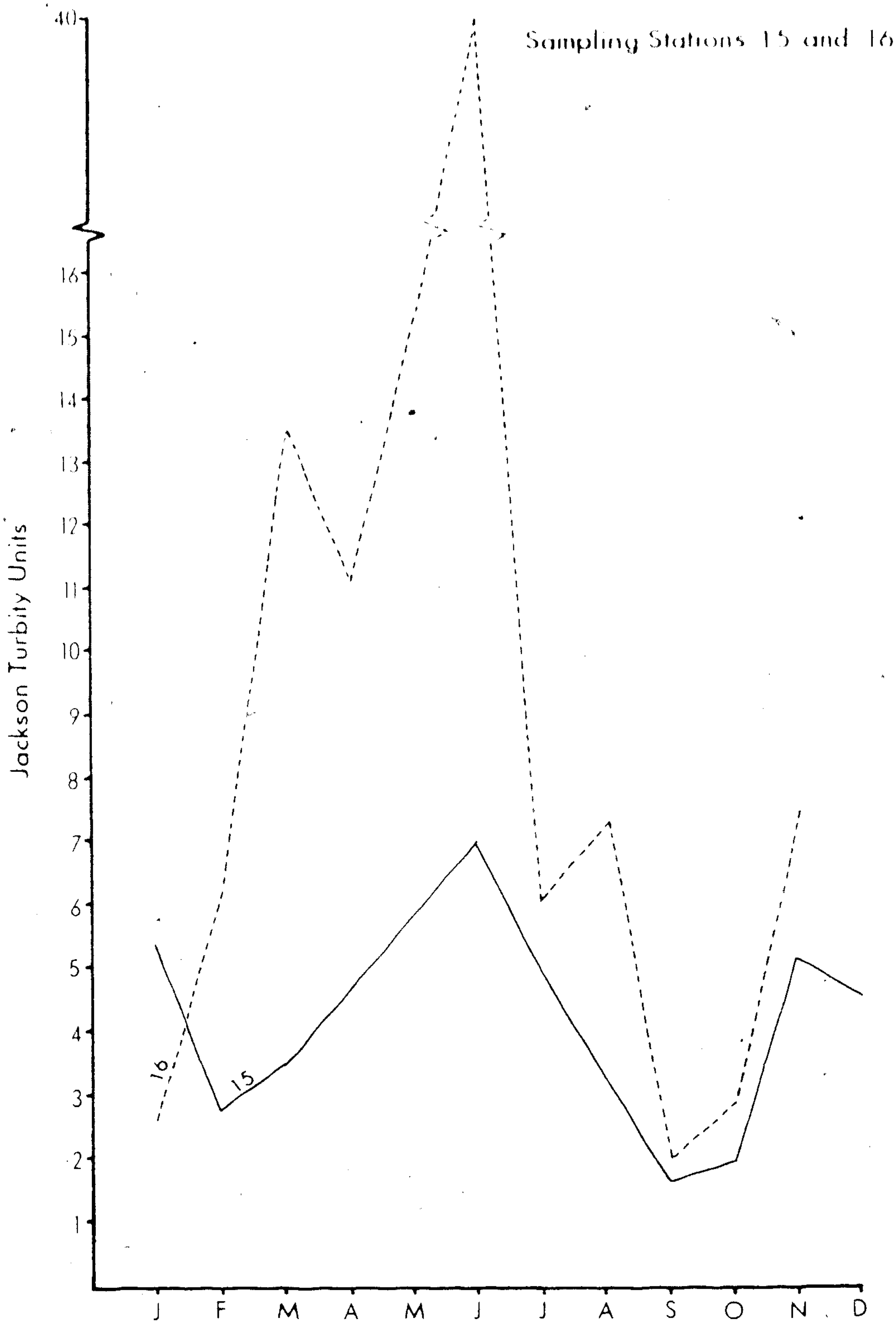
FIGURE 18 Turbidity - Seasonal Variation

Sampling Stations 8 and 11



Source: Naquadat data supplied by Alberta Environment

FIGURE 19 Turbidity Seasonal Variation



Source: Naquadat data supplied by Alberta Environment

4.2.5 Colour, Odour, Oil and Grease

The colour of water is a result of differential absorption of light frequencies by the particles in it. Many of these materials occur naturally in the environment; examples of inorganic materials are iron and manganese while common organic materials include algae, protozoa and phenolic products of decaying vegetation such as humic substances, tannin and lignin. Since the latter are both very common and also resistant to decay they are common sources of water colour. These same organic materials also are the most common sources of odour in water and they usually have as their source decomposing vegetation, municipal sewage and industrial wastes.

Until recently both the odour and colour of effluent from sanitary and storm ~~sewage and~~ industrial outfalls were usually objectionable in the Bow River. The conversion of the Bonnybrook Sewage Treatment Plant to secondary treatment in 1970 alleviated the problem somewhat and stricter pre-treatment requirements for industrial wastes[22], whether discharged directly to the river or processed at the municipal treatment plants, has also improved conditions in the receiving water. Colour is now only a relatively minor problem at outfall sites and in the case of storm sewage is very limited in duration. While the occurrence of colour and odour at unpleasant levels may well be a manifestation of water quality degradation, their main impact on recreation is purely aesthetic, for they reduce the enjoyment of recreational activities whether on or near water.

Oil and grease are hydrocarbon wastes which may enter the aquatic environment from a variety of sources. Biogenic hydrocarbons are ubiquitous in the environment but natural concentrations are negligible (Environment Canada, 1979). Therefore, elevated levels usually occur as a result of man's activities, though natural seepage does take place (usually at isolated points). The most common sources are petroleum products and wastes from petroleum refining, outboard motors, manufacturing industry effluents, urban runoff and municipal wastes. In the case of Calgary it is likely that at times of high runoff oil and grease discharged through storm sewers could lead to high levels in receiving waters. It also appears that oil has been infiltrating into the water table at the Gulf Asphalt Plant (the old BA refinery site) and at the old Imperial refinery site between

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[22]Wastewater effluent guidelines for Alberta fertilizer plants were issued by Alberta Environment in 1976 under the provisions of the Clean Water Act.

stations 11 and 12. An oily smell in groundwater near these sites has been noticed (personal communication, K. Exner and B. Mackintosh) and, since they are on the banks of the Bow, oil has probably seeped into the river.[23] It has certainly seeped into the Inglewood Bird Sanctuary lagoons on several occasions.

The impacts of oil and grease on recreation on or near water bodies are diverse. While ingestion is dangerous to health this is unlikely to occur, so unpleasant taste and odour are of greater concern, particularly since these may occur at oil and grease levels well below those that constitute a danger to health. This is thus primarily an aesthetic problem, as is the occurrence of visible oil slicks on water. However, oil and grease may also have detrimental impacts on the aquatic ecosystem. They reduce re-aeration, interfere with photosynthesis, prevent respiration of some insects, coat and destroy algae and plankton, contaminate spawning areas by coating river and lake bottoms, are both toxic to fish and interfere with their respiration by acting on their gills, taint fish flesh and interfere with waterfowl (Environment Canada, 1979).

Two measures of water colour are possible: 'true colour' which is a measure of the dissolved colouring compounds in water, and 'apparent colour' which is influenced by suspended materials. Since it is the latter which is perceived by recreationists, apparent colour is discussed here. Colour is measured by comparing samples with a series of standard chemical solutions according to the platinum-cobalt scale. Water colour which is less than 10 Pt-Co units passes unnoticed while water with a value of 100 resembles black tea (e.g. water draining peat deposits) and water from swamps and bogs may have values of 200 to 300 Pt-Co units. In Alberta Surface Water Quality Objectives it is stated that colour should not be raised by more than 30 units above natural values. Environment Canada has specific objectives for direct contact recreation: a maximum limit of 100 Pt-Co units with an objective that it should be less than 15.

Alberta provincial government water quality sampling has included very few measures of colour but extensive monitoring at some stations has been done by the federal government. Conversely, while the former has monitored odour, oil and grease, the latter has not. For this reason there is a total lack of data at some stations but enough are available for others for useful comparisons. In Figure 20 mean and maximum values

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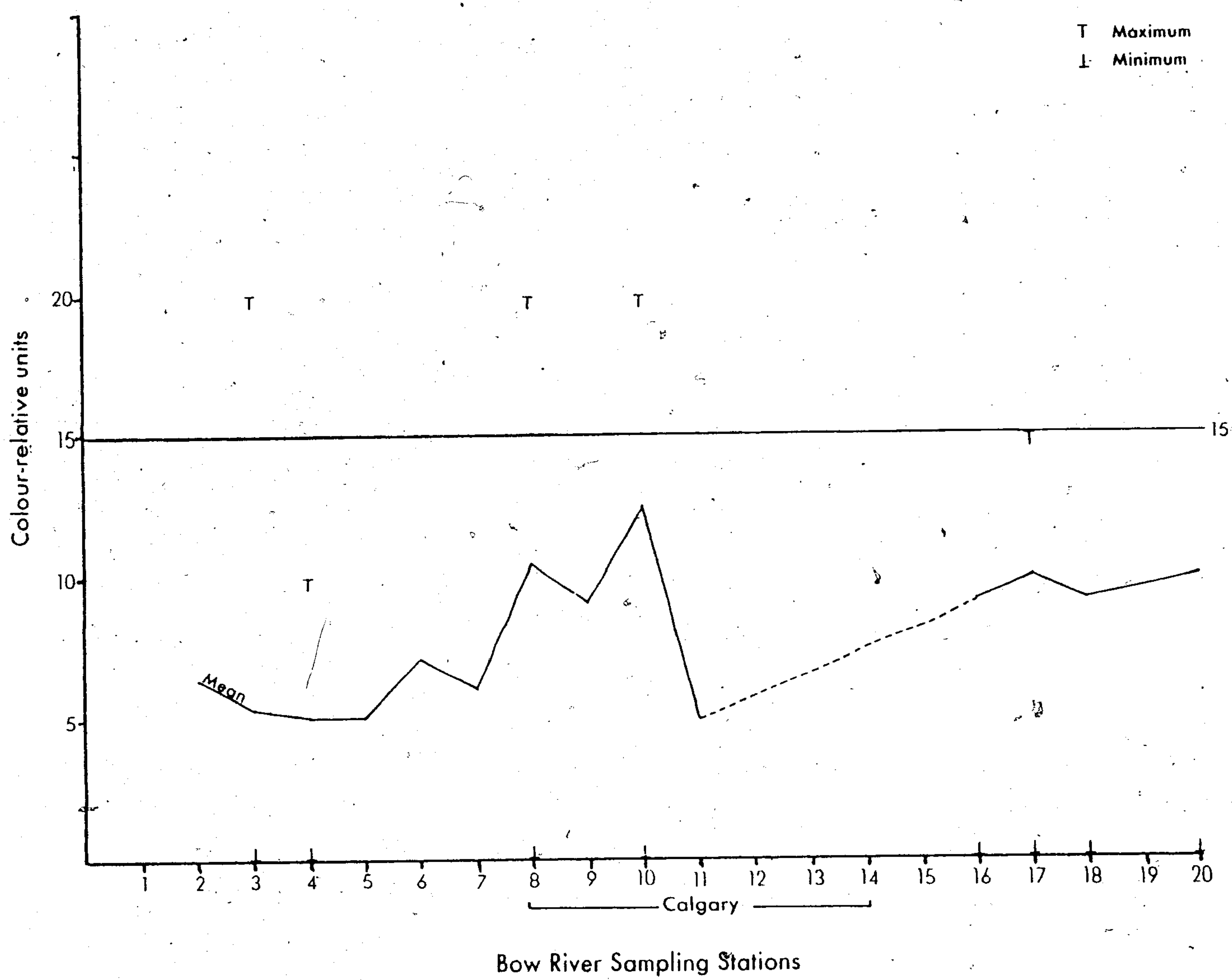
[23] Bouthillier reported that seepage from refinery sites had been noted during field studies (Alberta Dept. of Public Health, 1965).

FIGURE 20 Colour - Bow River



Source: Naquadat data supplied by Alberta Environment

for colour in the Bow River are shown (all minimums are less then 5 Pt–Co units). From this it can be seen that colour is not a serious problem to recreation on the Bow for all mean values are well below 15 Pt–Co units. Although maximum values are often greater, they represent a small percentage of the samples and from station 10 upstream all but one of the values which are greater than or equal to 15 occur in May and June,[24] that is the months of high streamflow and turbidity (section 4.2.4). At stations 16 to 20 many of the high values occur in May and June but also in March and April, no doubt due to earlier snowmelt runoff in this area.

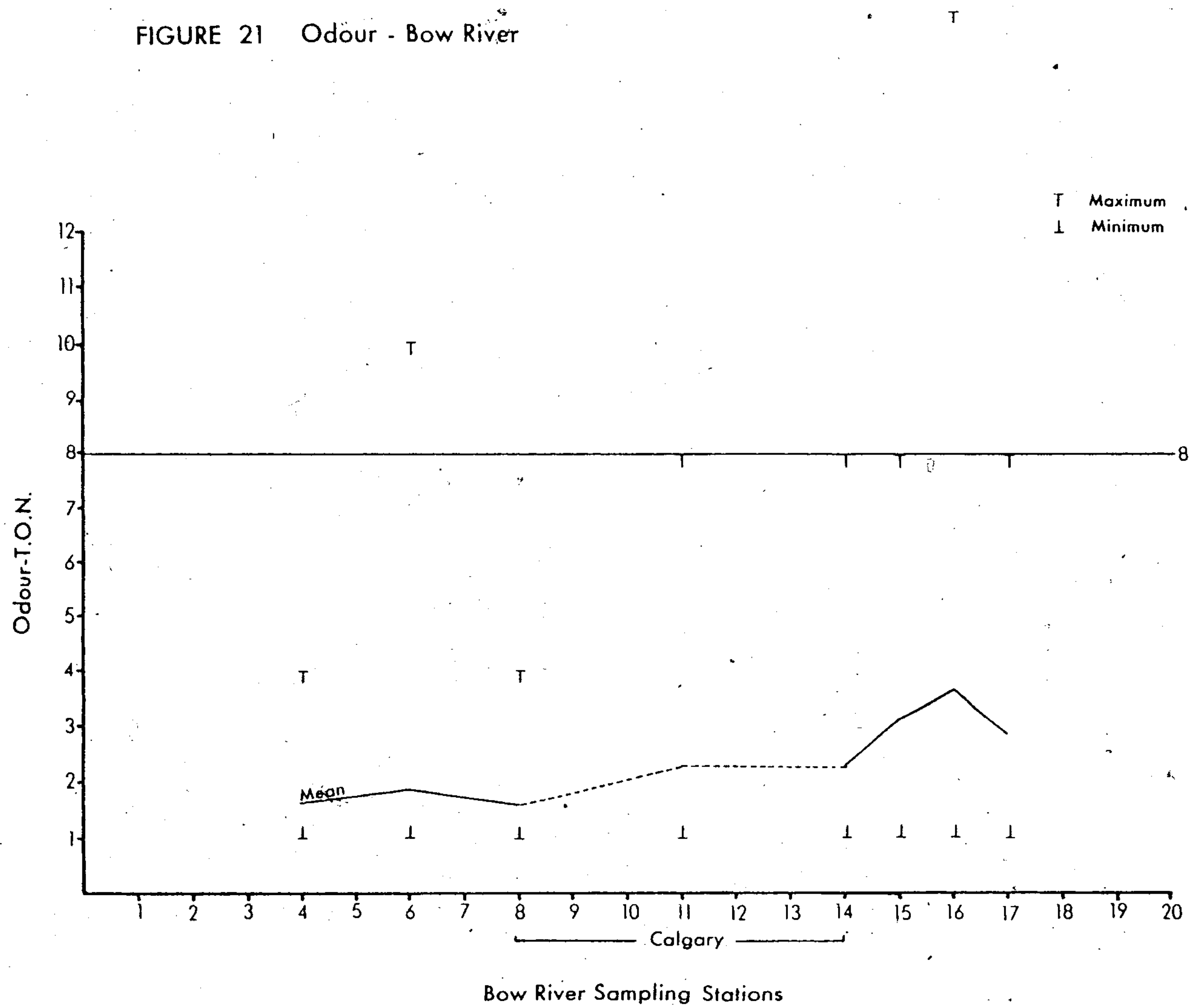
Unfortunately, stations 8 and 10 are the only ones within the city of Calgary with data on colour. However, these samples were taken in the months when colour values are likely to be highest, so one may surmise from the results that this is not a serious problem for recreational use of the river valleys, because the mean values are still less than 15. Data for colour in the tributaries are available only for T1, Elbow River at Bragg Creek, and T2, Elbow River below Glenmore Dam. At these stations colour conditions and seasonal changes are as described for the Bow River.

The best indicator of water odour, though highly subjective, is the human sense of smell and thus odour is reported as the 'threshold odour number'. This is reached by diluting an odiferous sample with odour free water until the odour is only just detectable. The T.O.N. is then the ratio of the volume of dilution water to the original volume and is not, therefore, a precise value. It may range from 'no odour detected' to 200.

Environment Canada guidelines for odour are that the maximum permissible level be 16 T.O.N. but with an objective that it should be inoffensive. The Alberta objective, however, is for a maximum of 8 T.O.N.. In Figure 21 it is shown that mean T.O.N. is less than 4 at all Bow River sampling stations, but that at six out of eight stations the Alberta objective level of 8 is exceeded at least once and the Canadian federal maximum of 16 was equalled on one occasion at station 16. At sampling stations 8, 11 and 14, which are within the city of Calgary, the maximum recorded values do not exceed the Alberta objective but mean T.O.N. values do increase downstream from the city. There are not enough values which equal or exceed 8 T.O.N. to draw conclusions from the data when distributed by month though it may be worth noting that more of these high values fall in

[24]Mean values for stations 8 and 10 are probably artificially high because all samples were taken in early summer.

FIGURE 21 Odour - Bow River



Source: Naquadat data supplied by Alberta Environment

September than in any other month and that this is a month when weed and algal decay are at a height.

Krishnaswami and Kupchanko (1969), reporting on the latest of a series of tests carried out since 1952, found that there was a definite relationship between T.O.N. of pertoleum refinery wastes and oily taste in rainbow trout and that it was possible to prevent this simply by reducing the odour of the wastes to a very low level (less than 0.25 T.O.N.). Their findings, however, draw attention to two important points: that the source of odour (or of any form of degradation of water quality) is important when assessing suitability for a particular use and that, in some cases, critical levels may be well below those prescribed by authorities. An earlier report by Bouthillier for the Alberta Department of Public Health (1965), while coming to the same general conclusions did, however, point out that 'musty odours' were caused by sewage effluent (then receiving only primary treatment) and that there appeared to be oily wastes in the effluent from the Ogden Sewage Treatment Plant (now closed). The fact that the problem of odour and oily taste in fish improved markedly after the institution of secondary treatment at the Bonnybrook plant (1970), despite the fact that the refineries were still operating, has led to the commonly held belief that the main source of this problem was in fact the sewage effluent, not refinery effluent (personal communication, K. Exner).

As with colour a very small number of samples have been measured for odour on the tributaries but, of those available, no value exceeds 4 T.O.N. and all mean values are less than 2. Though the data are insufficient to enable one to draw firm conclusions, when taken together with the data from the Bow River, it appears that water odour is not a serious problem in Calgary, and though it does rise to levels which may be detectable to those in close proximity to the water it is not usually objectionable to most people.

Oil and grease levels in milligrams per litre for Bow River sampling stations are shown in Figure 22. In both provincial and federal documents on water quality objectives it is stated that oil and grease should not be visible and should be virtually absent from water and Environment Canada adds a maximum allowable level of 5 mg./l.. While mean values are all well below this level,[25] at three stations it is exceeded as a maximum, though in each case on one occasion only. Though only a very limited amount of data is available

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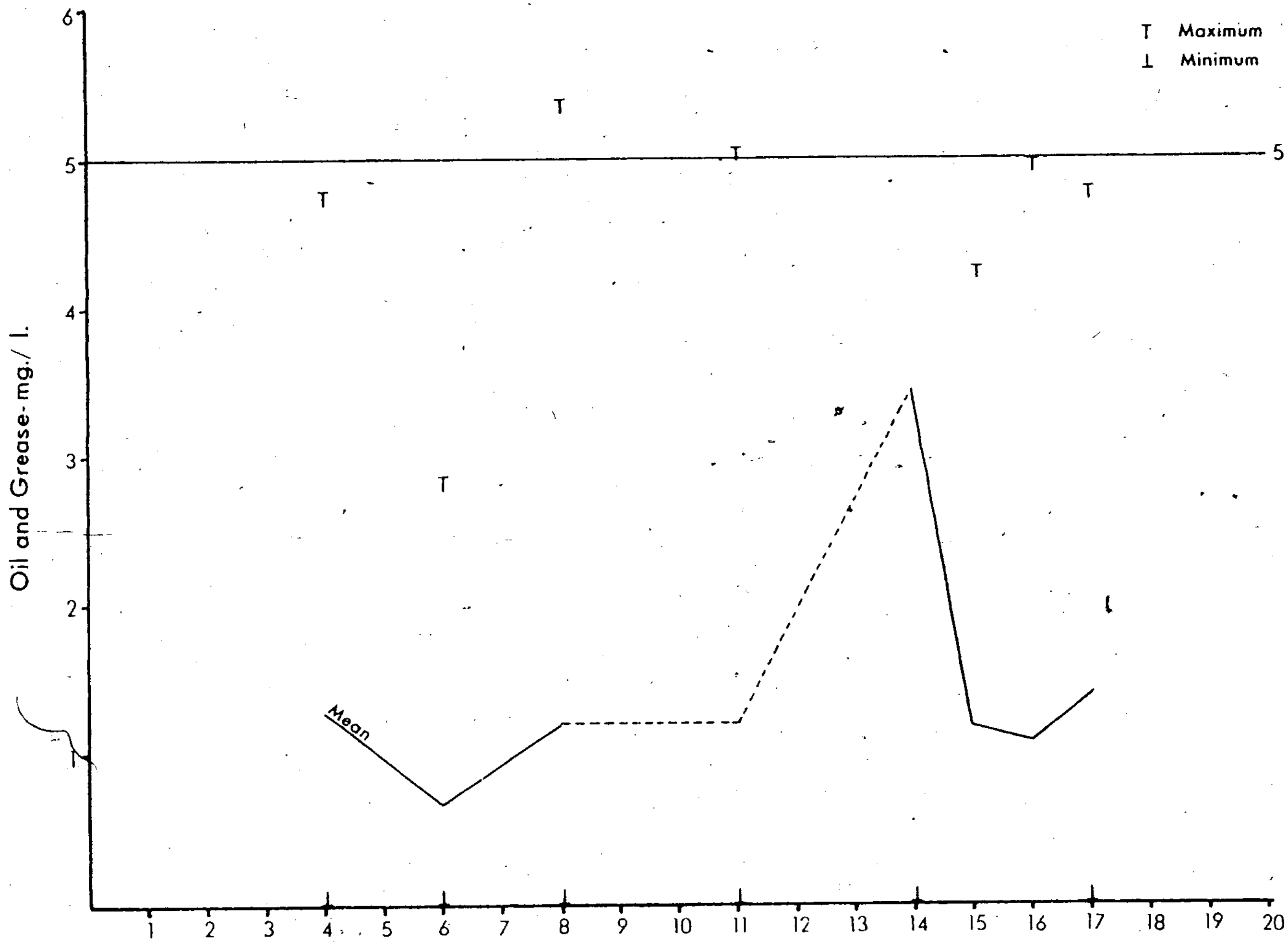
[25]The higher mean at station 14 ia a result of one very high value, but also the sample is smaller than for other stations.

FIGURE 22 Oil and Grease - Bow River



Bow River Sampling Stations

Source: Naquadat data supplied by Alberta Environment

for the tributaries, of the samples taken only one exceeded the maximum limit (5.1 mg./l. in Fish Creek) and all mean values are less than 2 mg./l..

Water quality degradation by the addition of oil and grease does not, therefore, appear to be serious in the Bow River, either in Calgary or elsewhere, though sporadic discharge by storm sewers may go undetected. However, when it is considered that the maximum desirable level in drinking water is 0.2 mg./l. and levels of 0.25 mg./l. may taint fish flesh it would seem to be possible for oil and grease to be detectable at times in the Bow River by those engaged in direct contact water activities, though it may not reach nuisance levels. However, since recreational fishing is an important use of the Bow River it is of concern to many people that oil and grease and odour levels should not cause tainting of fish flesh, which has been a problem in the past. The conversion of the Fish Creek Sewage Treatment Plant to secondary treatment in April 1980 and the forthcoming introduction of tertiary treatment at Bonnybrook (and possibly also Fish Creek) should very significantly reduce the risk of colour, odour or oil and grease levels being deterrents to recreational use of the rivers and their shorelands in the future.

4.2.6 Bacteriological Data

The importance of bacteriological measures of water quality to recreational use of water resources and the problems of their application have been discussed at some length in Chapter 2 and will not be repeated in detail here. Coliform bacteria are monitored because their presence in large numbers indicates anthropogenic contamination of water. The presence of faecal coliforms in particular is a reliable indicator of contamination by faecal wastes. Ease of detection and analysis has made the coliform count the most widely used measure of water quality for health purposes for, if large numbers of coliforms are found it may be reasonably assumed that pathogenic organisms less easily detected by analytical methods will also be present. While faecal stretococci are a more reliable measure of health hazard they are not routinely monitored so are available for a few sampling stations only, none of which is within the city of Calgary. For this reason the discussion will be based upon coliform bacteria counts only.

In Alberta Surface Water Quality Objectives (1977) it is stated that

> "in water used for outdoor recreation *other than direct contact*, at least 90 percent of the samples should have a total coliform density of less than 5000 per 100 ml. and a faecal coliform density of less than 1000 per 100 ml.."

It is also stated that

> "For water used for *direct contact* recreation the geometric mean should not exceed 1000 per 100 ml. total coliforms, nor 200 per 100 ml. faecal coliforms, nor exceed these numbers in more than 20 percent of the samples examined during any month, nor exceed 2,400 per 100 ml. on any day."(Alberta Environment, 1977, p. 5.)

Environment Canada recommendations for bathing water are that

> "the geometric mean of the number of faecal coliforms should not exceed 200 per 100 ml. nor should more than 10 percent of the total samples taken during any 30 day period exceed 400 per 100 ml."

and that total coliform bacteria ahould be less than 500 per 100 ml.. Thus, federal recommendations for total coliforms are significantly more restrictive than the provincial objective. Furthermore, Environment Canada has also recommended that levels of less than 100 total coliforms per 100 ml. should be the objective of water quality programmes.

The data available on coliform bacteria will be discussed with reference to the above objectives but it should be noted that the geometric means should be based on at least 5 samples for any 30 day period. With the exception of one set of data, enough samples are not available to make this possible. Thus, the geometric mean of all samples at each station will be discussed as an indication of average conditions. However, there is the possibility that one high value during a 30 day period when none others are available might reflect high coliform counts throughout that particular time period, though when this figure is combined with others which are lower for that month in other years, this fact may be obscured.

First, maximum recorded values were examined (Table 2) and the available data were examined with regard to the Alberta indirect contact recreation objectives. It was found that at sampling station number 15, just outside the city of Calgary, at least 17 percent, possibly[26] as many as 48 percent, of samples exceed 5000 total coliforms, and it is possible that this standard is also exceeded at stations 14 and 16. With regard to faecal coliforms, more than 10 percent of values at the same three stations definitely exceed 1000 per 100 ml..

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[26]In many cases the result is recorded as 'greater than' another value which is less than 5000 total coliforms or 1000 faecal coliforms.

TABLE 2

Maximum Recorded Levels of Total and Faecal Coliform Bacteria, Bow River

Sampling Station	Total Coliforms	Faecal Coliforms
1	-	-
2	-	-
3	240	>120
4	240	500
5	-	-
6	2,400	140
7	-	-
8	2,400	220
9	-	-
10	-	-
11	540	12
12	(>16)	(>16)
13	>16	>16
14	>2,400	>2,400
15	180,000	>2,400
16	>2,400	>2,400
17	>2,400	540
18	-	-
19	(23)	(5)
20	15,100	350

Source: Naquadat data supplied by Alberta Environment.

Note: Values for stations with three or less samples are given in brackets.

When the same method is used to compare values to direct contact recreation objectives it is found that stations 14, 15, 16, 17 and 20 (maybe also 13) have values exceeding 2400 total coliforms per 100 ml. (these are all the stations from south-east Calgary downstream for which data are available). Furthermore, at stations 14 to 17 well over 20 percent of samples had values above 1000 total coliforms per 100 ml.. With regard to faecal coliforms, at least 20 percent of samples at stations 14, 15 and 16 had more than 200 per 100 ml..

Having established that at sampling stations from south-east Calgary downstream both direct and indirect contact recreation standards are exceeded for coliform bacteria, the geometric mean of samples will now be examined to obtain further information.[27] In Figure 23 it is shown that mean values of total coliform organisms in the Bow River are well below the Canadian federal direct contact objective of 100 ml. as far as Calgary. However, they then rapidly rise in south-east Calgary to exceed not only this objective but also the objective of 500. Levels then fall off but still remain well above those found upstream of the city of Calgary. The same pattern is apparent for faecal coliform bacteria though in this case no geometric mean meets the Canadian objective for direct contact recreation of less than 20 organisms per 100 ml.. Of particular interest is the proportion of coliforms which are faecal in origin. As far as station 14 the proportion is low, however, at this point (south-east Calgary) a very large proportion (more than 50 percent) are of faecal orogin, then further downstream from the city once again the proportion declines.

These observations indicate that without doubt a large number of coliform organisms are added to the Bow River in the city and that most of these are faecal in origin. Therefore, it is clear that the major source is the effluent from the sewage treatment plants. Indeed, the contrast in water quality of the Bow River between the north-west part of the city and the south-east is extreme. While at station 8 the number of coliform organisms falls well within all objectives but the federal one of 20 faecal coliforms, at station 14, in Fish Creek Provincial Park, all objectives for direct contact recreation are exceeded by a considerable margin. Thus, the Bow River in the latter area

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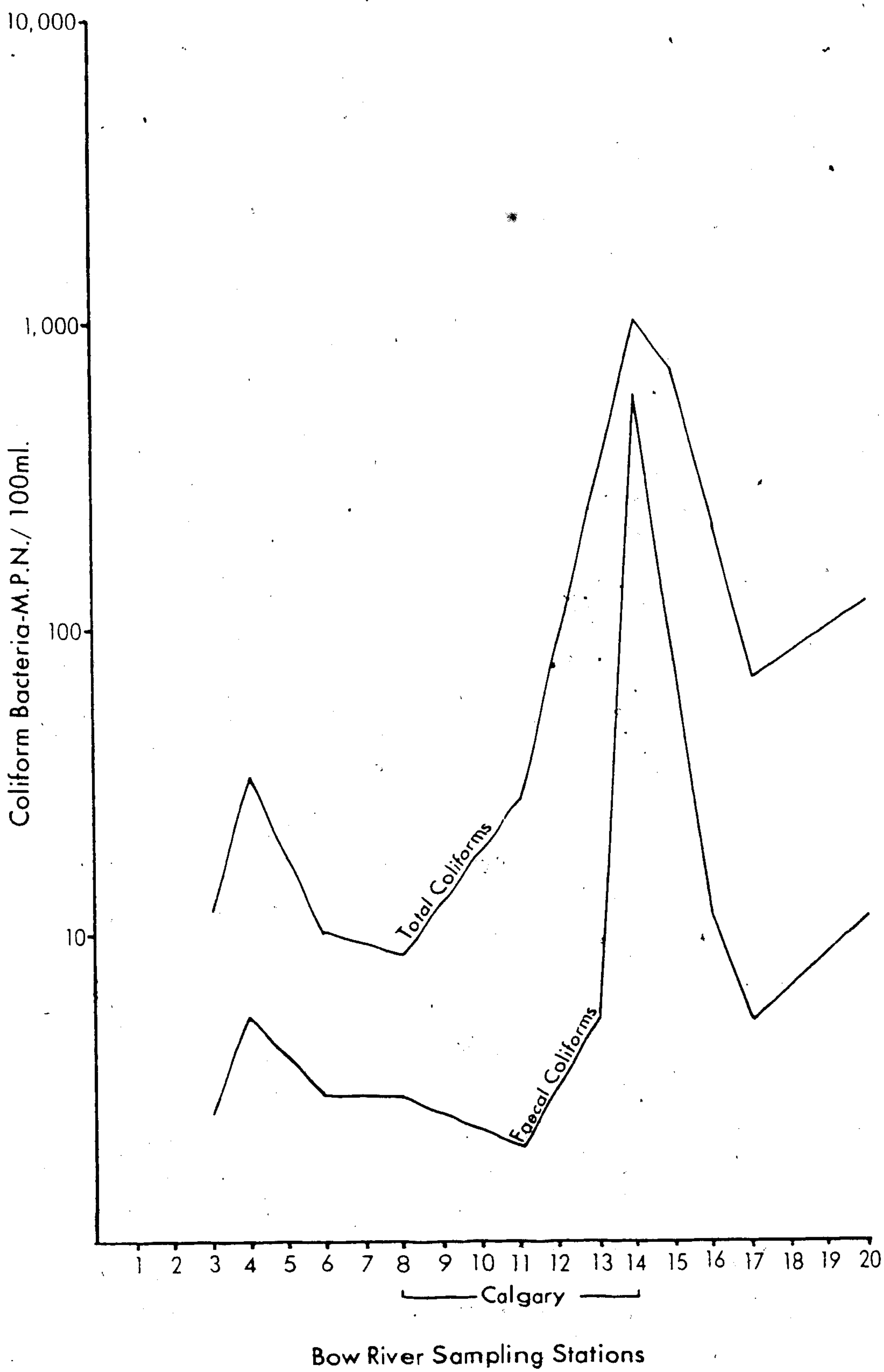
[27]The geometric mean is preferred in analysing coliform data because, with the very great range of values found, an arithmetic mean would be unrepresentative since it may be strongly weighted by just one extreme value.

FIGURE 23 Coliform Bacteria - Bow River



Source: Naquadat data supplied by Alberta Environment

is certainly not suitable for direct contact recreation activities, by whichever standards suitability is judged. While the generalized geometric means do indicate that water is suitable for indirect contact recreation by Alberta provincial standards, the previous analysis of the proportion of samples exceeding the maximums suggested shows that, in fact, this is not so.

The importance of using two methods of testing suitability is thus demonstrated and, furthermore, it suggests that the geometric means used may result in an underestimate of coliform levels (with the data limitations described). Having said that, it should be reiterated that coliforms are used as an indicator species and their presence in large numbers does not always mean that the incidence of pathogenic organisms is high, but simply that the likelihood of their being present is high.

In the summer of 1979 Alberta Environment carried out an intensive sampling survey of the Bow River at Calgary, taking samples from seven sites, left and right banks, on ten days from June 20 to July 24. The results of this survey are summarized in Table 3 and the suitability of the river for recreational use, judged on these results, is shown in Table 4, using both provincial and federal objectives. The conclusions are clear, the river is only suitable for direct contact recreation in the north-west corner of the city and ceases to be suitable for even indirect contact recreation somewhere between Centre Street and south-east Calgary. Thus, a very large part of the Bow River in Calgary is unsuited to both forms of recreation. Deterioration in bacteriological water quality begins in the city of Calgary, no doubt as a result of input from the many storm sewer outfalls,[28] and is particularly bad from the vicinity of the Bonnybrook Sewage Treatment Plant downstream. The effluent from the latter is discharged into the river only a short distance downstream from the Ogden Road bridge, so this source might well account also for the high coliform counts at that location.

Unfortunately, very few bacteriological measures of water quality have been done on the tributary streams, however, due to the great importance of these parameters to recreation, those data which are available are presented here (Figure 24). Since the sample sizes are very small mean values may be misleading. The range of values, in

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[28]Analysis of stormwater outfalls serving both residential and industrial areas, conducted by Alberta Environment for The Calgary Stormwater Monitoring Programme 1979, revealed extremely high coliform levels.

TABLE 3

Total and Faecal Coliform Counts,*
Bow River, June-July 1979

Location	Left Bank		Right Bank	
	Total	Faecal	Total	Faecal
85 Street	48	10	63	13
Centre Street	441	182	337	71
Ogden Road	1,053	484	657	229
Input of Bonnybrook Sewage Treatment Plant Effluent				
Glenmore Trail	699	87	2,305	1,576
Conmac Site	1,906	535	2,305	1,101
Highway 22	1,732	833	2,400	1,985
Stiers Ranch	-	-	2,400	2,304

Source: Data supplied by Alberta Environment.

* Geometric menas of sample counts.

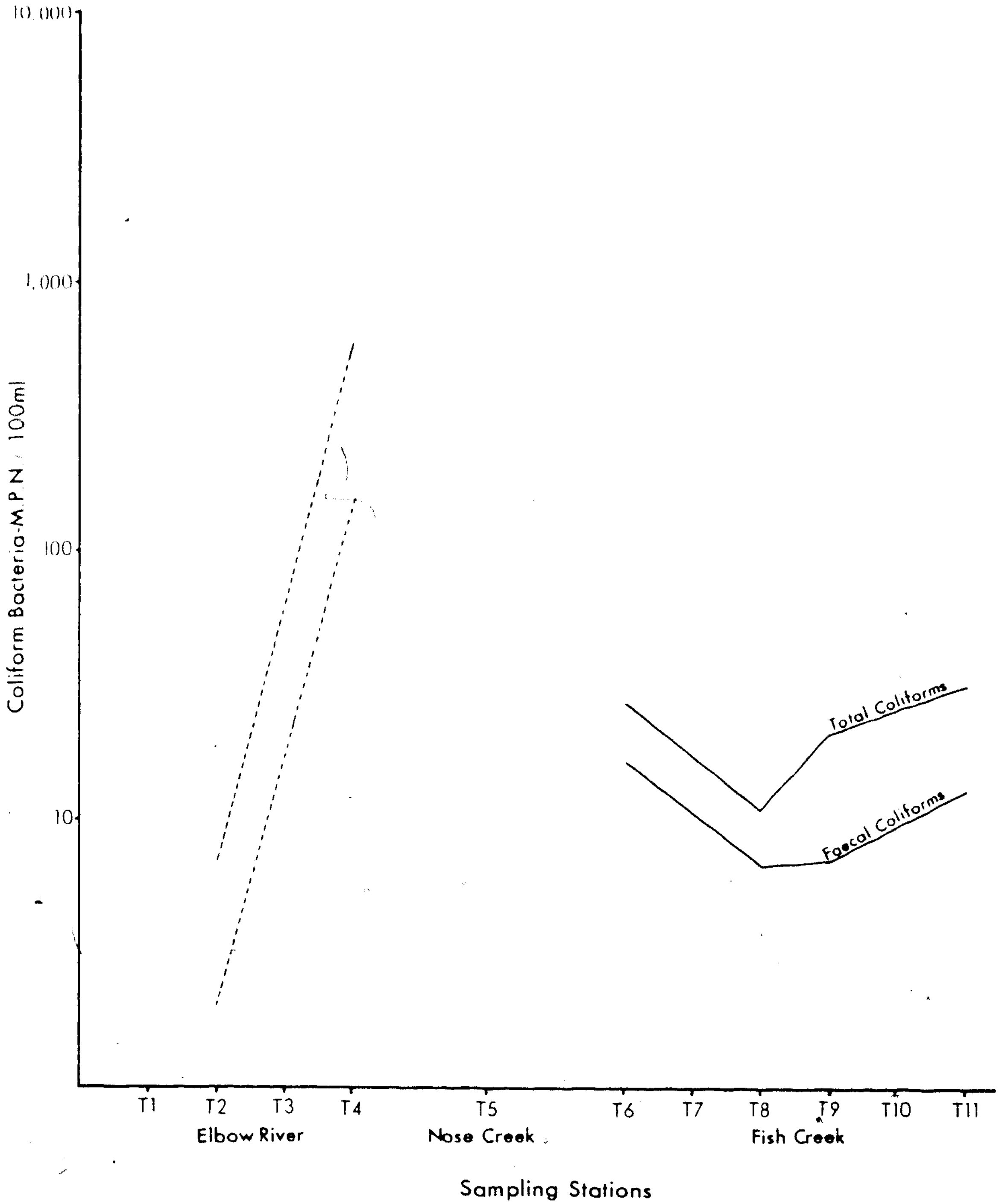
TABLE 4

Recreational Suitability, Bow River, June-July 1979

Location	Direct Contact Suitability	Indirect Contact Suitability
85 Street	Yes	Yes
Centre Street	No	Yes
Ogden Road	No	No
B.S.T.P. Outfall		
Glenmore Trail	No	No
Conmac Site	No	No
Highway 22	No	No
Stiers Ranch	No	No

Source: Derived from data supplied by Alberta Environment.

FIGURE 24 Coliform Bacteria Tributaries



Source: Naquadat data supplied by Alberta Environment

particular the maximum value, is of greater use as an indicator of prevailing conditions. This information is shown in Table 5. The Elbow River near the mouth is neither suitable for direct contact recreational use nor even for indirect contact use because of the intermittent occurrence of high concentrations of coliforms, both total and faecal. However, due to the difference in land use between this lowest part of the river valley and that of the upper parts within the city (Chapter 3) conditions here cannot be assumed to be typical of the whole river. Conditions in Fish Creek, however, appear from the limited data available to be suited to all categories of recreation. Although at sampling stations T7 and T10 total coliform counts would indicate that the water is not suited to either type of use, faecal coliform counts give no cause for concern. Since the latter are a more reliable indicator of health hazards, it has to be concluded that the water is suitable with the rider that quality conditions here might warrant close examination in order to determine the source of the coliforms present. The suitability of Fish Creek and the lower Elbow River for recreation is summarised in Table 6.

The volume of data is not sufficient for any sound analysis of seasonal variations in coliform concentrations: the samples, when separated by month, give a very small sample size for each station and the number of samples taken in summer months is significantly less than in winter. Nevertheless this was done to see if any pattern emerged. Though it cannot be verified with the available data, it does appear that at stations 11 and 15 total coliform levels are high in winter with a secondary peak in July. At station 8, near where the Bow flows into the city, faecal coliform concentrations are always low and at stations 11 and 15 there is a July peak in faecal coliform concentrations. The most concentrated source of coliforms is the effluent from the sewage treatment plants and the only seasonal variation in this flow is an increase in late winter. This is due to the fact that ice cover on the river at this time causes a rise in the water table with the result that groundwater infiltrates into sewer trunklines which pass near the river and through the downtown area. However, since this increase is in the form of river water rather than sewage, it cannot be reasonably concluded that it might account for a winter increase in coliform counts. Rather, such an increase in winter is more likely to be a result of low streamflows, that is less dilution of sanitary wastes. While this same factor would seem to militate against a july peak in coliforms it is likely

TABLE 5

Maximum Recorded Levels of Total and Faecal Coliform Bacteria, Tributaries

Sampling Station	Total Coliforms	Faecal Coliforms
Elbow River		
T4	>2,400	>2,400
Fish Creek		
T6	540	240
T7	>2,400	79
T8	>920	170
T9	540	350
T10	>2,400	95
T11	540	170

Source: Naquadat data supplied by Alberta Environment.

TABLE 6

Recreational Suitability, Elbow River and Fish Creek[1]

Station		Direct Contact Suitability		Indirect Contact Suitability	
		Total Coliforms	Faecal Coliforms	Total Coliforms	Faecal Coliforms
Elbow River	T4	No	No	-[2]	No
Fish Creek	T6	Yes	Yes	Yes	Yes
	T7	No	Yes	No	Yes
	T8	Yes	Yes	Yes	Yes
	T9	Yes	Yes	Yes	Yes
	T10	No	Yes	No	Yes
	T11	Yes	Yes	Yes	Yes

Source: Derived from Naquadat data supplied by Alberta Environment.

Notes: 1 No data is available for stations T1, T2, T3 on the Elbow River and station T5 on Nose Creek

2 Detection limit is below the provincial objective.

that the large volume of surface runoff at this time adds a great many coliforms to the system through the stormwater outfalls.

4.2.7 Phosphorus

Phosphorus is toxic to neither man nor fish and is not usually included in a discussion of water quality suitability for recreation, but is included here because of its importance to the Bow River. Phosphorus is an essential element for the growth of algae and aquatic plants, thus high concentrations may stimulate such growth to reach nuisance levels. This is a severe problem in the Bow River where excessive algal and weed growth has lowered the aesthetic quality of the water and shoreline thus reducing the recreational value of the river and, in particular interfering with sport fishing. This has occurred in the reach of the river in south-east Calgary and downstream (Plate 10). Here the problem is especially acute for the growths interfere with the operation of irrigation equipment[29] and cause treatment problems for towns such as Bassano, Brooks and Medicine Hat which rely on the Bow River for water supply.

Phosphorus is rarely found in high concentrations in surface waters because, even where large loadings are added from anthropogenic sources, most of it is taken up by plants. Thus, while high phosphorus levels may be found near a point of input, these will then usually decline rapidly. When the concentration is less than 0.05 mg./l. nuisance aquatic plant growths are usually restricted (Environment Canada, 1979; Pitcairn and Hawkes, 1973), however, when levels in flowing water exceed 0.1 mg./l. algal and weed growths usually reach nuisance levels and difficulties with water treatment occur. Although both nitrogen and phosphorus are essential to plant growth it has been shown that phosphorus is more often the limiting factor, there being a significant correlation between phosphorus levels and the volume of algae produced each year (Pitcairn and Hawkes, 1973). Furthermore, since the main source is so concentrated and removal technology is better developed than for nitrogen it is more useful to study phosphorus in this context. Alberta Environment is currently studying this problem in the South Saskatchewan River Basin and the results of their preliminary findings will be included

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[29]"...during the particularly bad year of 1976...direct costs and lost agricultural production due to downstream drifting of filamentous algae totalled approximately one million dollars." (Alberta Environment, 1979, p. 1)

here.

Natural sources of phosphorus include mineral salts from rocks which are carried by rivers in or on sediment particles and decomposing organic matter (Allan, 1979; Environment Canada, 1979). However, problems of excessive loading often occur as a result of human activities. The main anthropogenic sources are domestic sewage, urban runoff, industrial effluents and drainage from fertilized land. In the case of the Bow River it has been shown (Alberta Environment, 1979) that storm and sanitary sewer discharges at Calgary account for 70 percent (17 and 53 percent respectively) of total phosphorus loading, upstream sources just 4 percent, industry 0.4 percent, irrigation 5 percent and input from the tributaries 21 percent.[30] While the sewage treatment plants contribute most of the phosphorus to the Bow River, concentrations in the effluent have been and are being gradually improved. In 1970 the Bonnybrook plant went over to secondary treatment and in the same year the federal government introduced regulations to control the amount of phosphorus in laundry detergents, which had been a major source (Environment Canada, 1980). The amount of phosphorus allowed in detergents was further decreased in 1973, thus reducing the concentration by 80 percent from pre-1970 levels and resulting in a significaant reduction in loads to the sewage treatment plants. The installation of secondary treatment facilities at the Fish Creek Plant in 1980 should also have a marked improving effect on the quality of river water through Fish Creek Park and downstream in the lower Bow basin. It is planned to put tertiary treatment for phosphorus removal, possibly at both Calgary plants, on line in 1983 and this will drastically reduce the river loading.

The second largest source of phosphorus is storm runoff and since the city of Calgary is growing rapidly so also is the proportion of the watersheds which is impervious. Therefore, the volume of storm runoff reaching the rivers is increasing all the time (Chapter 2) and nutrient loading from this source can be expected to become more significant as time goes by. For example, a total phosphorus concentration of 0.67 mg./l. was recorded in Nose Creek after a storm (Alberta Environment, summer of 1980) and this creek receives no sanitary sewage at all but is the recipient of storm runoff from residential and light industrial districts.

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[30] This input from the tributaries thus includes both natural sources and stormwater discharges. Maybe therefore, the proportion from urban runoff is underestimated.

While industrial sources represent only 0.4 percent of the total phosphorus loading, just a few individual sources may account for most of this. Effluent discharge from fertilizer plants is regulated under the Clean Water Act (Albert Statute 216/73, discussed in Chapter 2). However, while effluent standards specified in the individual licenses are usually met, it has been found that other components, not specified because they are not part of the manufacturing process, may reach high levels. For example, the Cominco fertilizer plant in south-east Calgary is not required to monitor their effluent for phosphorus because the company does not manufacture phosphorus based fertilizers. However, in both 1978 and 1979 the phosphorus allowance under the 'Wastewater Effluent Guidelines for Albert Fertilizer Plants (Albert Environment, Standards and Approvals Division, 1976) was exceeded by 30 percent.[31]

Total phosphorus for Bow River sampling stations is shown in Figure 25. While the concentration is very low in the upper part of the basin, at Calgary there is a sharp increase, with a sample mean of 1.21 mg./l. at station 14 in south-east Calgary which is downstream of both the sewage treatment plants. Further downstream there is a decline because of uptake by aquatic plants[32] and towards the confluence with the South Saskatchewan River the concentration is quite low again, though still higher than in the upper basin. Many complaints have been voiced by officials of the towns of Bassano, Brooks and Medicine Hat who have experienced difficulty with water treatment (they draw municipal supplies from the Bow River) and have been forced to spend large sums of money on more effective treatment processes to eliminate the odour caused by algae (Calgary Herald, 16/1/79 and 17/9/79). In fact, the problem at these downstream sites is attributable to conditions within the city in two ways. First, phosphorus added to the Bow at Calgary stimulates aquatic growth downstream, and secondly, aquatic growths in the river at Calgary are uprooted by the river current in late summer and autumn, float downstream and clog water intakes as well as causing odour problems.

The total amount of phosphorus is not biologically available so it is more useful to examine that portion which is when nuisance growths are the point of interest. Thus,

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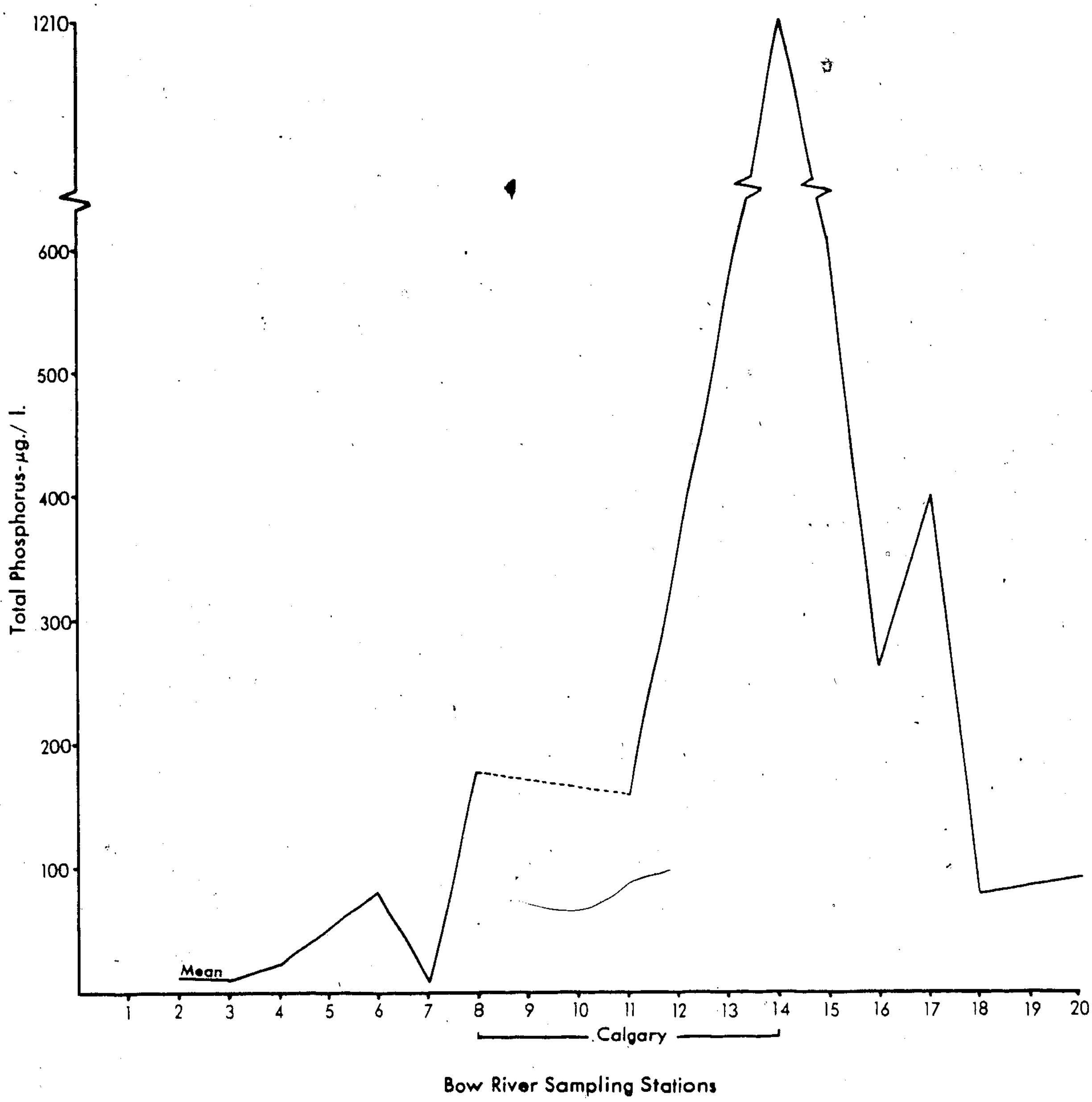
[31] This is discussed in *Wastewater Survey, Cominco Ltd, Calgary, Alberta, 1978* and *Effluent Water Quality Compliance Report, Cominco Ltd, June 1979* of Albert Environment.

[32] The decline is made to appear very rapid because of the compaction of distance in the horizontal scale of the graph.

FIGURE 25 Total Phosphorus - Bow River



Source: Naquadat data supplied by Alberta Environment

dissolved orthophosphate phosphorus which forms the greater part of the soluble reactive phosphorus available to plants is more relevant to nutrient studies than particulate phosphorus which has little fertilizing effect on rivers (Allan, 1979; Alberta Environment, 1979). Unfortunately, data are lacking on levels of orthophosphate phosphorus at several of the Calgary sampling stations but the magnitude of loading at Calgary is clearly shown by the difference between concentrations in the north-west and central parts of the city (stations 8 and 10) and at Carseland (station 16) as illustrated in Figure 26. Furthermore, since this form of phosphorus is rapidly taken up by plants it can be expected that concentrations at stations 12 to 15, for which information is not available, might be even higher than at 16.

The proportion of phosphorus which is orthophosphate phosphorus was calculated from the data, revealing that this is much greater downstream from Calgary than upstream (Table 7). This finding is supported by the Alberta Environment sampling programme carried out in the spring, summer and early autumn 1979 as part of the 'South Saskatchewan Basin Eutrophication Control Study' which showed that phosphate concentration in the Bow River increases dramatically at Calgary and that more than half the increase is in the form of soluble reactive phosphorus which then declines while the proportion that is particulate phosphorus remains relatively stable (Alberta Environment, 1979 and Figure 27). This is very significant because it is thus apparent that a large part of the phosphorus added to the Bow at Calgary is in this form and thus biologicaaly available for algal and plant growth. They also determined 'algal growth potential' (AGP) and found a very strong correlation with soluble reactive phosphorus, while the portion of total phosphorus which was not SRP was was poorly correlated with AGP. This emphasises the importance of soluble reactive phosphorus to plant growth.

Station 16 at Carseland was chosen for a seasonal analysis of data because it had large sample sizes and is just 26 miles downstream from Calgary. Mean monthly levels of both total and orthosphosphate phosphorus were calculated and are shown in Figure 28. While the concentrations of total phosphorus rise and fall from month to month,[33] there is, nevertheless a seasonal trend for levels to be lowest in September to October with peaks in November and March. However, it can be seen that when levels are high in the

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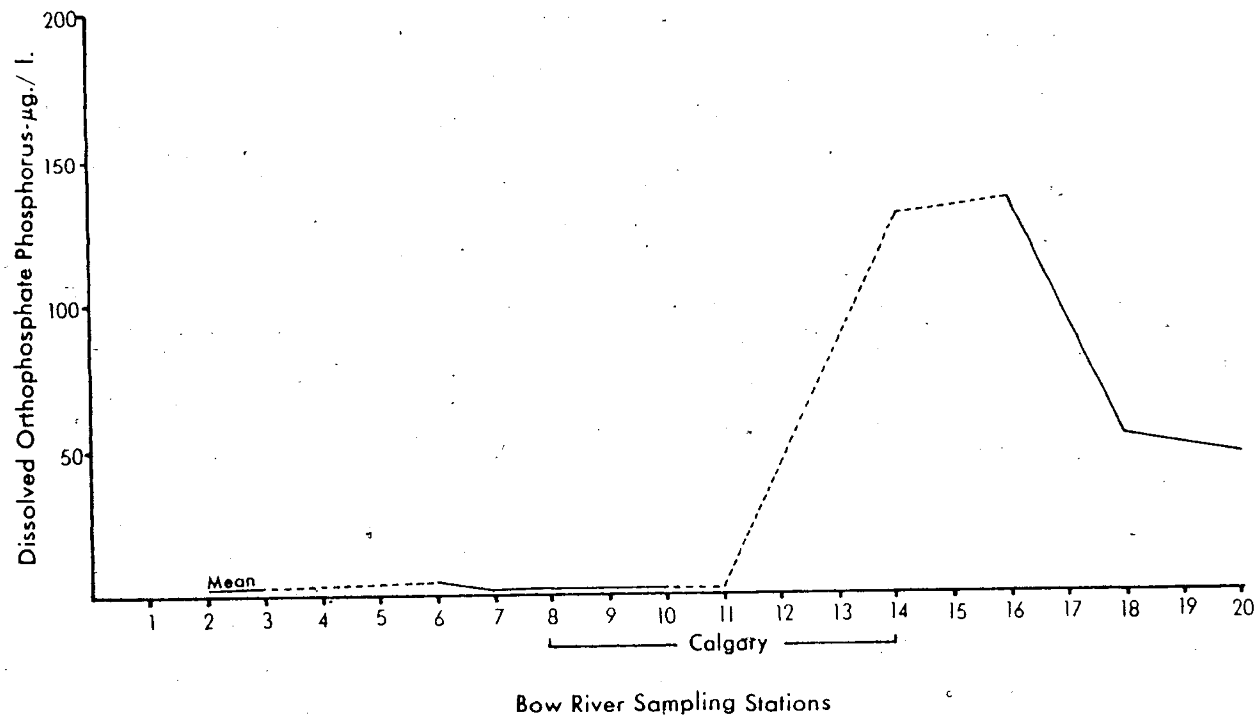
[33]Alberta Environment (1979) found that the range in total phgosphorus for each station was much greater than that for SRP.

FIGURE 26 Dissolved Orthophosphate Phosphorus - Bow River



Source: Naquadat data supplied by Alberta Environment

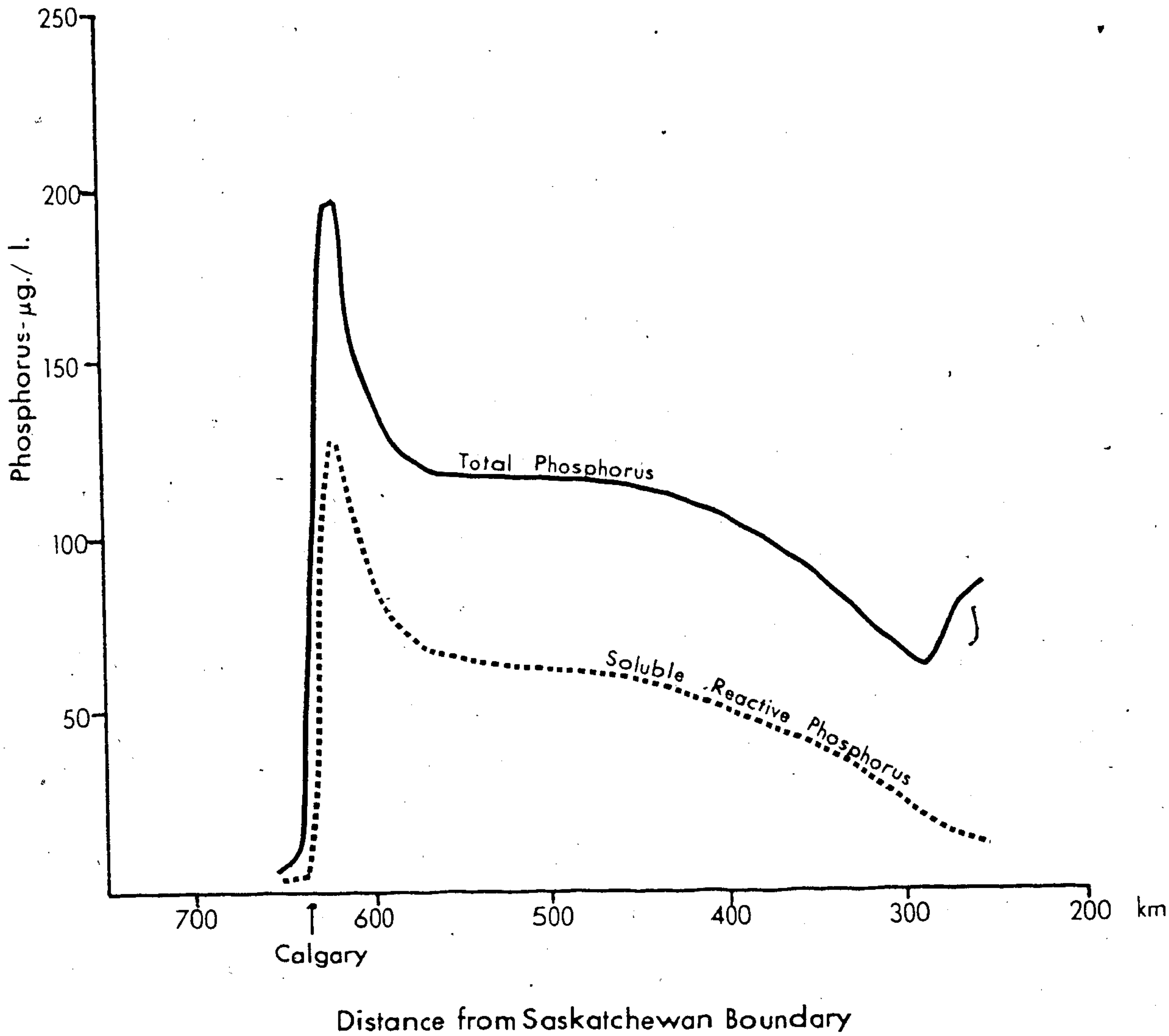
TABLE 7

Dissolved Orthophosphate Phosphorus as Percentage of Total Phosphorus, Bow River

Station No.	Location	Percentage
2	Banff	13.3
3	Spray confluence	21.4
6	Cochrane	6.2
7	Bearspaw Dam	22.2
8	85 Street bridge	1.1
Input of Bonnybrook Sewage Treatment Plant Effluent		
16	Carseland	50.9
18	Bassano Dam	66.2
20	At the mouth	50.0

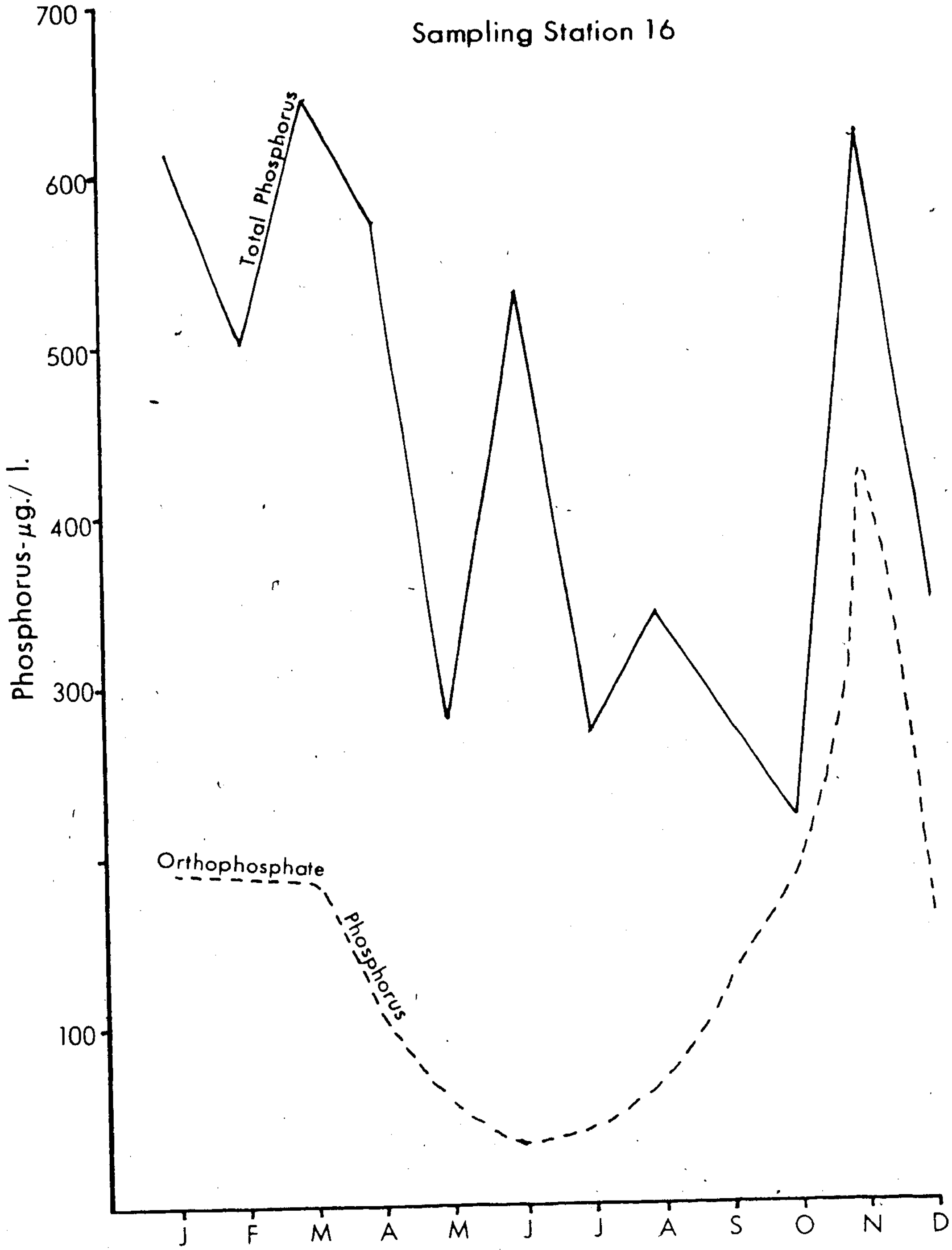
Source: Derived from Naquadat data supplied by Alberta Environment.

FIGURE 27 Mean Phosphorus Concentration - Bow River



Source: Alberta Environment, South Saskatchewan Eutrophication Control Study, 1979, p. 11.

FIGURE 28 Mean Phosphorus - Seasonal Variation



Source: Naquadat data supplied by Alberta Environment

early part of the year only about one third of the total phosphorus is orthophosphate. That is, at snowmelt and peak runoff time most of the phosphorus is particulate whereas in November when total phosphorus levels reach another peak, a very large part of this is orthophosphate.

While total phosphorus levels decline gradually to low levels in September and October, orthophosphate phosphorus rapidly declines to very low concentrations in the summer months; being lowest in June. In fact, it is in the month of June that orthophosphate phosphorus forms the smallest proportion of the total phosphorus present, which is in fact still high. It is likely, therefore, that at this time much of the phosphorus present is apatite phosphorus, derived from soil and bank erosion during spring runoff, which is not available for aquatic growth (Allan, 1979; Alberta Environment, 1979). Orthophosphate phosphorus then rises, at first gradually then rapidly, to reach a peak concentration for the year in November. This is the month in which turbidity levels also reach a secondary peak (section 4.2.4) as a result of the large quantity of suspended organic solids in the river following decay of algal blooms. At this time, therefore, phosphorus is released into the water. However, this peak is short-lived and the concentration drops off to winter levels, which are nevertheless still high, though total phosphorus is particularly high in winter.

While the summer decrease in concentration of biologically available, phosphorus is due to uptake by aquatic plants, the winter increase can be due to one or a combination of four factors. First, of course, plants die off and no longer use up the phosphorus added to the water; second, streamflow is very low and the dilution factor is greatly diminished from summer levels, thus increasing the concentration of phosphorus; third, phosphorus is released from decaying aquatic vegetation; and fourth, sometimes phosphorus may be released from bottom sediments under anaerobic conditions of ice cover (Allan and Roy, 1980). While the last is a possibility, the first two undoubtedly exert the greatest influence on seasonal variations in phosphorus levels for the main source of the phosphorus is sanitary sewage effluent which is discharged constantly throughout the year.

Insufficient data are available for comparison of the proportion of dissolved orthophosphate phosphorus to total phosphorus for the tributary streams. However, the data for total phosphorus, though based on very small samples, indicate that this rises to undesirable levels in the Elbow River at the 9 Avenue bridge (T4) near the confluence with the Bow River and in the lower part of Fish Creek (T9 and T11). Thus, the tributaries undoubtedly contribute to total phosphorus levels in the Bow River, though in what form cannot be ascertained from this data. However, according to Alberta Environment (1979) it is for the most part in the particulate form and would thus have little influence on algal and plant growth.

From this information it is clear that phosphorus levels in the Bow River at Calgary are very high and that while 70 percent is added by Calgary storm and sanitary sewer discharges, the 53 percent from the latter accounts for an even larger proportion of that phosphorus which is biologically available for aquatic plant growth. The concentrations occurring are sufficient to stimulate nuisance algal growths in large volume. However, while phosphorus levels in the Bow River downstream from Calgary are always sufficient to support nuisance algal growths, the magnitude of growth in any particular year will depend on physical factors such as precipitation, volume of sediment, hours of sunlight and temperature (Exner, 1977). For example, precipitation and runoff influence suspended sediment load and a low concentration of sediment allows greater light penetration into the water. If this is coupled with greater than average temperatures and hours of sunlight then conditions for algal growth will be optimal. Analysis of these parameters showed that they were critical in bringing about the nuisance blooms of 1973 and 1976 (Exner, op.cit.).

Although this is not a problem on the tributaries, the growth of large mats of weeds on the Bow is unsightly and particularly inappropriate for park areas . However, this is not only an aesthetic problem. Dense growths also interfere with fishing by making it difficult to reach desirable fishing spots. The value of the Bow River for recreation is thus seriously impaired by the addition of large quantities of phosphorus to its water and it is to be hoped that measures underway to reduce the phosphorus input will bring about a significant improvement.

4.3 Summary

From the preceding discussion it is clear that there are water quality problems in the Bow River and its tributaries (but less serious in the latter) and this is evident in the data on a variety of quality parameters. While in some cases, for example the parameters of temperature, pH and turbidity this may largely be the result of natural conditions, in others it is a result of degradation by the addition of man's waste products. This degradation may be brought about either directly and continuously as in the form of discharge of effluent from sewage treatment plants or indirectly and discontinuously, as in the form of storm runoff.

From the data analysed it seems that in some respects the water quality is good; for example, dissolved oxygen and colour. However, other aspects of quality are potentially limiting factors on the recreational use of the rivers because they are not always at the most desirable levels: for example, pH, biochemical oxygen demand and odour. Yet others, that is, water temperature and the occurrence of coliform bacteria are clear-cut restraints on the use of the rivers for direct contact recreation activities in most parts of the city and at most times.

However, there are both seasonal and spatial variations in water quality within Calgary. Thus, while in the south-east part of the city bacteria levels and algal growths stimulated by high phosphorus concentrations make the Bow River unsuitable for recreation from both health and aesthetic viewpoints, in the north-west the use and enjoyment of the river for recreation is limited only by naturally occurring temperatures and turbidity levels. Likewise, the algal growths in the south-east segment of the Bow become a nuisance in late summer and autumn, while turbidity is not conducive to recreation from an aesthetic viewpoint in all the rivers during peak runoff in spring and early summer. It is clear, therefore, that these water quality conditions must have an impact on recreational use of the rivers and their valleys, but that the type and degree of impact varies through the city and through the year.

5. RELATIONSHIPS BETWEEN WATER QUALITY AND RECREATION

5.1 Discussion of River Valley Segments

In this chapter the information on present uses of the river valleys and demand for recreational opportunities (Chapter 3) will be considered together with that obtained from the analysis of water quality (Chapter 4). This will be supplemented by the opinions of those involved in water-based sport clubs, in order to correlate observed conditions and theoretical implications with the perceptions of those who actually use the rivers on a regular basis.[34] An assessment will thus be made of the impact of river water quality on outdoor recreation activities in the valleys and any implications for proposed or possible developments will be discussed. In thus assessing the type and extent of resource use conflict in the Calgary river valleys it should be possible to come to some conclusions on ways in which conflict might be reduced. Suggestions can then be made on steps which might be taken to do so by improving water quality, and on ways in which such improvements might enhance, extend, or open the way for further development of recreational use of the river valleys.

This discussion will be organized on the basis of valley 'segments' for the key factors to be considered all vary spatially. There are very distinct spatial contrasts of the prime factor, water quality, and also of land use in or adjacent to the river valleys, and to a lesser extent of demand for outdoor recreation opportunities.[35] For this reason, the impact of water quality on recreation can be expected to vary spatially and thus, also, the implications of that impact for planning recreational use of the river valleys.

5.1.1 Bow River

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[34]Prominent members of local recreation groups were contacted on an informal basis and questioned about the ways in which (if any) water quality affected their activities.
[35] While large parks do serve a city-wide population, there are areas such as the north-east, where lack of open space means that there is a large demand unmet and residents have to travel relatively long distances to find open space for outdoor recreation pursuits, particularly water-based ones.

5.1.1.1 North-west Area

In Chapter 4 it was shown that the water of the Bow River flowing into Calgary in the north-west is of good quality, the only problems with regard to recreational use being of a physical nature. That is, the water is cold throughout the summer months and the swift current makes activities such as swimming or paddling hazardous. The aesthetic quality, however, is very high and existing land use in adjacent areas poses very few direct conflicts with recreational use. This section is, therefore, suitable for canoeing and kayaking and non-contact activities such as walking and park uses along the banks. The only significant conflict is the existence of a gravel washing facility on the east side of the 85 Street bridge, however this is to be phased out and the area reclaimed as Bowmont Park.[36] There has been a proposal that local kayakers be allowed to use the lagoons and channels in the disused gravel pit for their activities. In the light of water quality conditions this would seem a most appropriate use and could be enhanced by reclamation of the site.

Water quality in this segment is such that enclosed channels or lagoons receiving water from the river could be built (or extended in the case of Bowness Park) for canoeing and swimming. The main (or only) obstacle to such development is financial. The cost of developing swimming facilities has been estimated at $3.4 million for Bowness Park and $3.6 million for Lowery Gardens (CH2M Hill, 1980). The latter site has no such development at present and its situation on a glacio-fluvial terrace at the foot of a wooded escarpment is very suitable. The only land use conflict would be with the C.P.R. tracks which use the same terrace. The only existing outdoor swimming facility of this kind in Calgary is in the extreme south, so a man-made lake in the north-west would be well used.

The only forseeable future problem with water quality is likely to arise as a result of storm water runoff. Residential development of land in the north-west of the city is proceeding at a rapid rate and large quantities of storm runoff discharged to the Bow can be a significant factor in water quality degradation (Chapter 4). However, in view of the large volume of flow in the Bow River and its high quality at present, such additions in this segment are more likely to cause a brief lowering of quality below optimal levels

[36]A master plan was prepared by the Lombard North Group (1979) for the City of Calgary Parks and Recreation Department but has not yet been implemented.

rather than any serious degradation. Temporary problems are likely to be manifested in turbidity and oil and grease levels, while the volume of runoff is unlikely to be enough to result in odours from either that source or the decomposition of aquatic growths which might be stimulated by the addition of nutrients. The possibility of using storm water detention ponds in the north-west has been aired and this would certainly help to alleviate the problem, in which eventuality chemical water quality in the north-west segment of the Bow River is not likely to be a problem for recreation in the forseeable future.[37]

5.1.1.2 Central Area

The data analysed in Chapter 4 showed that the water quality of the Bow River deteriorates in this part of the city, though not to such an extent as to be a serious problem. The same physical limitations apply as for the previous segment and, likewise, the input of nutrients from storm runoff is not sufficient to elevate levels in the receiving water to such an extent that nuisance aquatic growths occur. Water quality does not, therefore, detract from the aesthetic value of the river valley. However, since a very large number of storm sewers serving the city centre, residential and commercial areas, enter the river in this segment, this storm sewage probably accounts for the rather high coliform levels recorded here (Chapter 4). The number of organisms recorded in the summer of 1979 survey shows that while mean values fall within the objectives set (Alberta Environment, 1977; Environment Canada, 1972.), both total and faecal coliform levels do exceed maximum permissible values at times. Thus, the water here is theoretically unsuitable for direct contact recreation activities during the crucial summer season (particularly following storms), though it is safe for indirect contact activities, such as canoeing. In view of the physical limitations discussed in the previous section, elevated coliform levels should not result in any further limits on direct contact recreational use of the river. Nevertheless, there are some areas where recreationists (in particular fishermen and young children) do come into direct contact with the water. For example, at Princes Island Park there is a lagoon with paddle boats in the shallower part of which children are liable to play; on St George's Island and at the Pearce Estate Park

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[37]Any addition of pollutants here,though relatively small, would however add to the already serious problem downstream.

there are some side channels and pools which are very inviting on hot summer's days; also, people sometimes wade into the river at a number of points along the banks.

Since there is no discharge of sanitary sewage into this reach of the Bow River, or that above it, any pollution loading must come from either upstream sources (eg. Lake Louise, Banff, Cochrane), direct dumping into the river, or from storm sewer discharges. Since the latter appears to be the source in this case, in order to raise the water quality to such an extent that it would be suitable for direct contact use at all times, discharge of bacteria through the storm sewer system would have to be controlled. Water quality problems after storms or rapid snowmelt are likely to be the same as for the north-west valley segment but, although still short-term, they would be more intense due to the greater volume of runoff from densely developed and industrial areas. Although there are no proposals to construct lagoons for swimming, in order to protect both present and future use of the parks and shoreline pathway system in this segment for informal direct contact use, the aim should be to protect water quality and improve it to a suitable level.

5.1.1.3 South-East Segment

From the Cushing Bridge, the Bow River flows southward through the industrial part of Calgary (Chapter 3, Figure 3) down to Fish Creek Provincial Park at the city limit. It is into this reach of the Bow that all the effluent from Calgary's sewage treatment plants is discharged: the Bonnybrook plant discharges into the northern end and the Fish Creek plant into the southern end. Furthermore, since the south-east is the industrial part of the city, the river also receives effluent directly from large industrial plants - notably the fertilizer plants of Cominco and Western Co-operative Fertilizers. Such industrial effluents may be a significant factor in river pollution (Chapter 4). Also, storm runoff and groundwater seepage from industrial areas may include high levels of, for example, oil and grease. When these factors are coupled with the discharge from the sewage treatment plants, which serve a population of more than half a million people plus industries, it is to be expected that pollution will occur unless the most stringent standards and treatment technologies are applied.

Water quality, as indicated by a number of parameters discussed in Chapter 4 (eg. coliform bacteria, B.O.D., dissolved oxygen and phosphorus) is unsuitable for recreation throughout this valley segment. In particular, the results of the 1979 Alberta Environment survey of coliform bacteria preclude the advisability of using this part of the Bow River for either direct of indirect contact activities. Furthermore, high nutrient levels, having as their principal source the sewage treatment plants' effluent, make it aesthetically displeasing in late summer and autumn by stimulating excessive weed and algal growth. The upgrading of sewage treatment will alleviate this problem in future. At present, since public access to the central (and longest) part of this reach is very limited, if not impossible, the impact of poor water quality is felt by shorebound recreationists only in the north and south.

A recently completed (1980) addition to the Bow River pathway now links the system through from the central area to Beaverdam Flats Park (Figure 2) in the south-east, thus opening up a little more of this segment of river valley to pedestrians and cyclists. In summer and autumn weed growth starts a few hundred yards below the Bonnybrook outfall and is clearly visible from this pathway. However, it is even more abundant further downstream. Just above Fish Creek Park effluent is added from the second sewage treatment plant and the problem aggravated further. Algae and weeds are abundant in the river and washed up on the shore in Fish Creek Park (Plate 11) and the presence of both these nuisance growths and very large numbers of bacteria is particularly serious here since this is a provincial park and thus designated for single use as a recreational area and is heavily used in both summer and winter. Nevertheless, for a large part of the year these growths are not in evidence and some people are not deterred from even direct water contact, such as paddling, even when they are (Plate 12). This backs up Barker's findings (Barker, 1971) that when good quality water resources for recreation are in short supply or distance is a barrier to seeking them out, then people will use recognisably poor quality water.

For those recreationists who are not shorebound but travel on the river, that is canoeists and kayakers, the quality of water throughout this segment of the valley is of great importance. The nuisance growth of weeds together with unpleasant odours from industrial and sewage outfalls makes a trip on the river unpleasant. For this reason, many canoeists launch their craft at Fish Creek Park and paddle downstream (Personal communication, H. Benthin, Association of Alberta Canoe Clubs) where weed growth is still bad but there are no sewer outfalls and the river passes into a rural setting.

Plate 11 Weeds on the bank of the Bow River, Fish Creek Park

Plate 12 Paddling in weeds in the Bow River, Fish Creek Park.
Sampling Station 14

Nevertheless, others (Bow Waters Canoe Club) who have their headquarters a long way upstream find it inconvenient to carry their craft that far by road. They launch the canoes near the Ogden Bridge and paddle through this reach simply in order to reach the other end. While it has been reported from these sources that odours at outfalls have been greatly reduced in recent years and that the excessive weed growth resulting from high phosphorus levels is now the main problem, many canoeists still find the odours present offensive. Furthermore, many canoeists are also fishermen and fishing is a major objective of their river trips. The weed growth in this segment of the Bow together with the 'oily' taste that some people still profess to detect in the fish flesh (Chapter 4) means that they do not fish in this area but paddle further downstream, out of the city.

The potential of the river for fishing is very great for the Bow River below Calgary is said to be the best trout stream in North America (L.H. Perkins, 1979). However, there is a direct correlation between good quality water and good quality fishing grounds.[38] In order to protect indigenous fish populations that are highly prized by fishermen it is necessary to maintain water quality at suitable levels. In addition, excessive weed and algal growth detracts from the aesthetic satisfaction of fishing which is a vital component of the sport (Jennings, 1979; O'Riordan, 1970) and may even prevent fishermen from reaching desirable sites (Exner, 1977, p.5; Jennings, 1979, p. 9). There is a good deal of local concern about the quality of fishing in the Bow River and fishermen have presented their views to a select committee of the legislature in an effort to preserve the Bow River as a trout fishing stream of the highest quality.

It is, thus, in this reach of the Bow that water quality has had the greatest impact on recreational use and, therefore, it is here also that improvement in that quality has the greatest potential to both improve and extend water-based recreational opportunities. The City of Calgary is going ahead with an expansion and upgrading of the Bonnybrook Sewage Treatment Plant to tertiary treatment which will include removal of phosphorus and is likely to add this equipment at the Fish Creek plant also. The equipment for phosphorus removal is expected to add about $14 million to the cost of expansion and will remove about 97 percent of phosphorus in the sewage. When this new process

[38] To some extent cultural eutrophication leads to increases in fish populations, however, at some point first quality and later quantity of fish decline. It is also desirable to protect indigenous fish species for whom the changed water quality may be sub-optimal (Chapter 4).

comes on stream in 1983 it should lead to a great reduction in algal and weed growth. This should then reduce the problem of high oxygen demand by weeds at night which, it has been shown, may reduce the dissolved oxygen content of the water to levels dangerous to fish. Furthermore, while the Bonnybrook Plant is now licensed to discharge effluent with 20 p.p.m. B.O.D. it is expected that the level will be reduced to 15 p.p.m.. This also will alleviate the depression of dissolved oxygen levels in the river at Calgary (Chapter 4) and help make this segment much more attractive to recreationists.

However, while improvement in water quality will enhance the quality of the environment, in order to extend opportunities for water-based recreation in this segment, public access must also be provided and the shores reserved for public open space. Thus these two sets of action must go hand in hand if the optimum use is to be made of the river valley for recreation.

5.1.2 Elbow River

5.1.2.1 Glenmore Reservoir

Glenmore Reservoir (Chapter 3) is the principal water supply for the city of Calgary and there is a by-law prohibiting certain recreational uses of it, for example use by motor boats, swimming and windsurfing. However, it is the focus for the very large area of parkland which borders onto it and is very well used for sailing (Plate 4)[39] and canoeing, which are not considered to present a hazard to the water supply function. The Calgary Sailing Club and the Canoe Club have their headquarters on the reservoir, there is a public launching and mooring area at Heritage Park, a canoe rental facility on the Glenmore Park shore and a pleasure boat plies the reservoir from Heritage Park.

While the quality of water in the reservoir is, of necessity, good, conditions have deteriorated and given rise to considerable concern. The water treatment plant is experiencing difficulty in removing offensive taste and odour from the water. Since the quality of water flowing into the reservoir from the Elbow River is generally good (Chapter 4) the cause of these problems has to be the only other input, that is storm sewage. In fact, the reservoir is the recipient of storm runoff through 26 outfalls, all of which serve parks, golf courses and low density residential areas. In Chapter 2 it was

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[39]Calgary has the largest inland sailing club in Canada.

shown that such areas may contribute very significant pollution loads, especially in the first flush after a storm. Of particular concern in such cases is the addition of nutrients from chemicals used as lawn ferrilizers. It is thought to be these additions which have stimulated the growth of planktonic algae and thereby given rise to the taste and odour problem in drinking water supplies.[40] However, the quality standards for drinking water are the most stringent and this problem has not yet become serioius enough to have an impact on recreational use; in fact, the water is of very good quality for both recreation and aesthetic appreciation. Any problems associated with the water concern fluctuating levels in the reservoir. This makes it necessary to use floating docks for boat launching and at certain times of the year a large expanse of shore is exposed and unattractive.

A most important point to make here is that, of all water bodies in the river valleys, this is the one most likely to be affected by the impact of recreation on water quality. Whether or not recreation on domestic water supply reservoirs is in fact detrimental to water quality, or to what extent, is a subject of some controversy.[41] However, since a city by-law prohibits those uses most likely to have an effect on water quality, recreational use is not a subject of concern at the Glenmore Water Treatment Plant at the present time. However, it has been suggested (CH2M Hill, 1980) that a part of the reservoir could be sealed off for swimming. Under this proposal the water would be circulated and treated and overflow would not be returned to the main body of the reservoir. The costs of providing such a facility are high: the estimated capital cost is $4.5 million. Nevertheless, in view of the lack of outdoor swimming facilities in 'natural' conditions in the Calgary area this might warrant further consideration at some time in the future.

In summary therefore, in so far as the Glenmore Reservoir is concerned, it is not a case of poor water quality limiting, or degrading the quality of water-based recreation, but rather of the protection of water quality for domestic use imposing restrictions on the types of activities allowed.

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[40]Nevertheless, Calgary's drinking water, as judged by a panel of experts is considered one of the best.

[41]See, for example, the policy of the American Water Works Association, A.W.W.A. Journal, v.63, p.540, 1971; H.J.Ongerth, A.W.W.A. Journal, v.56, p.149, 1963; R.D.Barbaro et al, Water Pollution Control Federation Journal, 1969, v.41, p.1330.

5.1.2.2 Lower Elbow River

From the Glenmore Dam the Elbow River flows first through a district of parkland and low density residences then, further downstream, it is flanked on one side by Stampede Park, a very large part of which is covered by an impermeable surface, and on both sides by associated stable facilities. To the north of the Stampede grounds lie extensive railway yards, then the river flows into the Bow at the site of Fort Calgary.

Problems of water quality in the lower Elbow, therefore, are likely to stem from storm sewers draining park and residential areas (thus including street runoff and lawn applications), draining Stampede Park, the stables and the rail yards. Water quality in the upstream section is quite good and the river is used extensively in summer for paddling, wading, floating rubber tires and dinghies and for canoeing. However, it does appear that the first flush of storm drainage into the river (there are 77 outfalls between the dam and the confluence with the Bow) is a problem for body contact activities after rainfall. This is especially the case in view of the fact that the majority of those who participate in this type of activity are children and that good quality at other times makes people unaware of the possibility of contamination during these short time periods. This problem is likely aggravated by reduced flows in the spring when water is stored in the Glenmore Reservoir.

In the lowest segment of the valley both water quality and adjacent land uses conflict with recreation by degrading the environment. It is in this section that water quality deteriorates significantly (Chapter 4) and that dumping in the river becomes a problem. A pathway along the river bank uses the narrow strip of land available and is used by pedestrians and cyclists as a link between the Bow and Elbow pathway systems. The aesthetic quality of the water is thus important here but dumping in the river, together with smells emanating from the stables, detract considerablly from the quality of the river environment and thus also from the quality of the recreational experience. The latter odours are particularly distasteful because they suggest the possibility of faecal contamination of runoff entering the river through the storm drainage system. Indeed, the finding of the analysis in Chapter 4 that gives rise to particular concern here is that bacterial pollution[42], while not as severe as in the south-east segment of the Bow River, nevertheless makes the water unsuitable for direct contact recreation activities, such as those practised further upstream. Were it not for these factors, the adjacent land uses might well be viewed as interesting points en route rather than part of an area that must be passed in order to reach the pleasant section upstream.

Any future 'clean-up' of this valley segment would, therefore, significantly improve the aesthetic quality of the environment for those using the pathway and would be likely to lead to both increased use levels and a reduced health risk to those who might then use the river itself for their activities. Since in the upper part of this segment water quality is already suitable for recreation, improvement of water quality alone would do little to improve aesthetic quality or increase use levels, though control of storm runoff would certainly increase the 'safety' of direct contact activities at those critical times. Rather, since the main constraint on use is the very low water level in late summer and autumn,[43] greater opportunities for recreational use of the Elbow River could be provided by the construction of swimming lagoons, a deepened central channel to make it possible to use canoes and kayaks at times of low water, or by stocking it with trout.[44]

5.1.3 Nose Creek

Unlike the Bow and Elbow valleys discussed above, the Nose Creek Valley is as yet totally undeveloped for recreational use though some informal use, for example the use of trail motorcycles on the escarpment, does occur. While water quality is very poor (Chapter 4) a conclusive argument cannot be put forward that the valley is underused for recreation for that reason. Since the valley is a busy transportation corridor (Chapter 3) it is more likely to have conflicting or non-complementary land use (Figure 3) in the valley. Poor public access to certain parts also deters potential recreationists. This effect occurs despite the extreme shortage of open space in north-east Calgary. Development of a linear regional park in this valley thus clearly will depend on a very comprehensive programme of planning and implementation. However, since we are concerned here with

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[42] As measured by both total and faecal coliform counts.
[43] It is, however, the small size of the river and low flows that make it both popular with and suitable for young children.
[44] In 1968 a trial of trout stocking was done for 'put and take' fishing and this indicated that it could be successful. Hamill, 1969, Part 1, pp.98-99.

the relationship between water quality and recreation, other aspects will be dealt with only briefly. Also, since it is assumed that the present situation of non-use is not due to poor water quality in the creek, the discussion will deal with the question of what problems water quality may present to the planning of an extensive park system as has been proposed (Walker, Newby & Associates, 1976; Professional Environmental Recreation Consultants, 1980) and how the type of recreational opportunities provided might be influenced by those problems, rather than with present impacts.

It was noted in the previous chapter that, in the past, water pollution in Nose Creek had its origins in agricultural operations upstream and the meat packing plants in the lower part of the valley.[45] Since the closing down of the latter activities the pollution loading from runoff from industrial and, in particular, residential areas which are being developed at a rapid rate to the north has emerged as the problem of central concern. The magnitude of this problem is demonstrated by the results of Alberta Environment's 1980 stormwater study (Chapter 4). This is aggravated further by the small volume of water flowing in the creek[46] even in years of average precipitation and the consequently low assimilative capacity of this small creek with a large drainage basin.

In the Nose Creek Valley Provisional Master Plan (presented to the City of Calgary Department of Parks and Recreation in January 1980 by P.E.R.C.) the problems of conflicting land use, noise and air pollution are discussed and suggestions made as to ways in which they might be alleviated. The assessment of water quality in relation to this plan is being done by Alberta Environment. As yet no conclusions have been published by Parks and Recreation or Alberta Environment on ways of dealing with this. However, the Nose Creek master plan does suggest that a recreational lake be constructed by the creek (near 16 Avenue North) and that it be supplied with creek water. This would be used for skating in winter and canoeing, swimming or model boating in summer. In view of both the low flows in the creek and poor quality of water (likely to decline with increased development of the watershed) the feasibility of such a project is doubtful, even with a massive capital outlay. However, there are also plans afloat to construct stormwater detention ponds on Beddington Creek (also known as West Nose Creek) and

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[45]It is interesting to note that, in Hamill's 1969 report, Tough concluded that these uses precluded the possibility of any significant recreational use (Hamill, 1969, Part II, p. 27).
[46]No figures are available for the flow of Nose Creek but it might well be as low as 1 c.f.s. much of the time.

the main stem of Nose Creek just inside the city limits (Figure 3). While the quality of water in such impoundments is not sufficient for bodily contact activities they could make a significant contribution to the recreational resources of the area. They can be used for canoeing and model boating while there is too little water in the creek itself to make these activities feasible. The advantages of such impoundments are that they serve a practical purpose in reducing the pollution load of storm runoff, while at the same time being a recreational asset.

While the P.E.R.C. report recognizes the necessity that "a program to clean up the creek and its banks be conducted concurrent with development of the trail system",[47] it is optimistic on the potential of advances in technology to change such limiting factors with time.[48] However, the fact that the most significant pollution loading to Nose Creek has a non-point source and originates in the land use type which is expanding more than any other in the watershed, should lead one to be most cautious when planning for water-based recreational opportunity development. While efforts should be made to enhance the environmental quality of the valley, and the valley should be developed as a linear parkway, it seems reasonable to conclude that the creek itself will be a visual and geographic focus for the system rather than a base, in its[illegible] for recreational activity.

5.1.4 Fish Creek

There are certain similarities between Fish Creek and Nose Creek: both are small creeks with low water levels much of the time and the watersheds of both are undergoing rapid development as residential areas. However, in the case of Fish Creek this started relatively recently, while in the case of Nose Creek it is an onward expansion. As far as other land uses of the valleys are concerned the two are entirely different. While most of Nose Creek valley is a transport corridor with a certain amount of industry and vacant land, the Fish Creek valley is a Provincial Park. Despite these differences, the main source of effluent input to the creeks is the same, that is storm sewage from predominantly residential areas. The data analysed in Chapter 4 showed that Fish Creek water quality is, for the most part, good, though on occasion total coliform counts at

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[47]P.E.R.C., 1980, p. v)

[48]"Conditions and limiting factors which exist today will change in time as technology changes.We will find ways to deal with air, water and noise pollution (P.E.R.C., Nose Creek Valley, January 1980, p. vi).

two locations have been recorded at levels above those recommended as the limits for both direct and indirect contact recreation. However, in view of the fact that faecal coliform counts are low this has no serious consequences for recreational use of the creek (Chapter 2) but does alert one to the fact that there might be potential for a problem in the future, possibly originating with storm runoff.

The water level in the creek is too low most of the year to make fishing, canoeing or swimming viable. However, it is used for cross-country skiing in winter and in summer many children play in it, especially near the picnic areas (Plate 6). The small size of the creek precludes its use for most water-based activities, but it does provide a raison d'etre for the Provincial Park. The impact of water quality should thus be considered with regard to the aesthetic value of the creek and the public health aspects of informal use by young children. Eutrophication has not become an aesthetic problem in Fish Creek and turbidity is mostly of a seasonal nature. However, the creek needs to be protected from degradation by dumping and large inflows of storm sewage, both of which are likely to increase with the rapid expansion of residential areas on all sides and the concomitant increase in use of the park.

5.1.5 Others

In this section water resources which have potential for recreational use within the river valley system but are not actual rivers or creeks will be discussed. Although water quality was only analysed for the actual rivers and creeks, these resources will also be dealt with here, though briefly, because they are an integral part of the system.

5.1.5.1 Lake Sikome

The lack of facilities for outdoor swimming opportunities in Calgary, together with the great popularity of the sport, has created a greater unmet demand for this water-based activity than for any other. In view of the physical limitations of the rivers and creeks themselves (aside from any water quality problems), the building of artificial lakes or creation of lagoons is the only viable way of providing attractive outdoor swimming opportunities in the city and is, thus, a matter of some interest.

Lake Sikome is an artificially constructed recreational lake of 4 hectares (10 acres) using water from Fish Creek (circulated and treated) and discharging overflow to the Bow River. It was opened to the public in 1979 and is the only swimming lake in or near Calgary. Since similar impoundments have been suggested for the Nose Creek, Elbow River and Bow River valleys it deserves particular attention.

Problems of water quality in such impoundments can be seen in two ways. First, the impact of intensive body contact use on water quality must be considered. Since the water is treated and bacteriological monitoring by the City of Calgary Public Health Department has revealed no cause for concern (personal communication), it can be said that, at present levels of use, there is no such impact. Second, the quality of water supplied to the lake affects the type of treatment needed and, therefore, also affects costs. It has been shown that water quality in Fish Creek is quite good (Chapter 4 and 5.2.4.) so this is not a problem either in this case. However, while the quality of water in the north-west segment of the Bow River and in the Elbow is also suitable for this type of development, that of Nose Creek is probably not. The popularity of Lake Sikome suggests, therefore, that the development of similar facilities in the Bow and Elbow valleys would be very worthwhile projects to increase outdoor swimming opportunities in Calgary.

5.1.5.2 Storm water detention ponds

Since there are several storm water detention ponds in Calgary (Chapter 3), and proposals to build more in valley settings, they also deserve some consideration. At present such ponds are located on Confederation Park golf course and in Queen's Park (outside the valleys discussed in this thesis), at the southern end of the airport (McCall Lake) and at 68 Street East. The latter two are relatively new and there are proposals to develop McCall Lake (20 hectares, 49 acres) as a recreational resource in conjunction with the Nose Creek Valley park. While it is already used to irrigate the golf course, it could also be used for skating in winter and model boating or canoeing in summer plus serve as the focus for a picnic area connected to an extensive pathway system (P.E.R.C., 1980). The 68 Street pond (21 hectares, 52 acres) lies well outside the river valleys but has been mentioned as a possible site for canoeing or model boating (CH2M Hill, 1980). Of particular interest in the context of this thesis is the proposal to put storm water detention ponds on Beddington and Nose Creeks (5.2.3.). Since it is also proposed to develop the Nose Creek valley as a regional park, steps should be taken at the planning stage to ensure that they could be used as recreational resources, even if this only amounts to landscaping to improve their aesthetic appeal.

5.1.5.3 Western Irrigation District Canal

The irrigation canal leads off the Bow River and follows the Bow valley for a short distance. It is thus connected to the Bow River pedestrian and bicycle pathway system. The canal is used for recreation to some extent, but it has a lot of undeveloped potential (Chapter 3). While water quality has not been analysed for the canal, it is not used (nor is likely to be) for direct contact recreational use. It is reported to be of suitable quality for the only indirect contact use, that is, canoeing (personal communication,Bow Waters Canoe Club). The main constraint on use by the canoe club who use the canal is the limited time during which water is let in from the Bow River. Once the headgates are closed in late summer they cannot use it so the fact that at this time the remaining water is very turbid and clogged with weeds (personal observation) is not of concern to them. However, since the pathway has been extended along the northern end of the canal, this is now of concern to non-contact users i.e. cyclists and pedestrians. The canal draws water off the central reach of the river, so inputs of nutrients from the Bow are probably quite low at most times. However, the loading from storm runoff of streets, residential and industrial areas may be significant for there are 27 storm sewer outfalls into the canal within the city. Also, the shallowness of the canal coupled with exposure of the water to sunlight and warmth are, no doubt, major factors in its water quality and are largely immutable. Any improvement of the aesthetic quality of the canal water will thus probably depend on control of storm water input.

5.2 SUMMARY OF RELATIONSHIPS BETWEEN WATER QUALITY AND RECREATION

From the foregoing discussion it is clear that there is a relationship between prevailing water quality and recreational uses of the river valleys. Since the quality of the water is largely a function of the land uses of the watersheds, any impact of the former on recreation is a symptom of conflict between those uses and recreational uses. This conflict arises because, while a river and its environment are a social resource to recreationists, they are an economic resource to, for example, industry and municipal sewage treatment plants which use it for waste assimilation. Thus, while much of the river shorelands may be used for parks and open space, the river water itself is used both by the recreationists in those parks and by other users occupying land further back in the watershed.

This type of conflict does not, however, exist uniformly throughout the valley system. It arises where the river is used for waste disposal (whether industrial or municipal effluent or storm runoff) and the natural processes of purification are not able to assimilate the volume of waste. Elsewhere, land use conflicts are not manifested in water quality problems but in, for example, lack of public access to the rivers. This problem arises despite provincial ownership of the rivers and their banks because, where no public right-of-way is established, landowners may be reluctant to give easements for public footpaths.[49]

In the north-west segment of the Bow River valley, for example, the chemical and bacteriological quality of the water has not been degraded to such a degree as to impose restrictions on recreational use. The only limitation with regard to the water itself is its physical characteristics; that is, it is too cold and the current too swift to make swimming, or even paddling, safe. The only conflict here is that of public access, discussed above, and this is being improved as the city acquires more land (e.g. Bowmont Flats).

In the case of Nose Creek, on the other hand, water quality imposes definite limitations on recreational development. This small stream is unable to accommodate the biochemical oxygen demand or assimilate the nutrient inputs which are imposed on it by the inflow of storm runoff. This makes the water unsuitable for any sort of recreational use involving contact. Here also plans for recreational development must contend with the presence of conflicting land uses which greatly impair any aesthetic value the valley and creek might otherwise have.

Water quality itself, however, has the greatest impact on recreational use (both actual and potential) where the scope for that use is very great and might be realized were it not for the conflict with other uses. This is the case in the south-east industrial area of the City of Calgary. The use of the Bow River for waste disposal in this reach has

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[49] For example, this was a problem in constructing the Elbow River pathway.

seriously degraded its value for recreation, though, again, the fact that much of this valley segment is not used at all for recreation is partly a result of poor accessibility, another symptom of the same conflict. However, while in the past there was little residential development near the river in the south-east part of the city, this situation has changed. The area near the confluence of Fish Creek and the Bow River has been rapidly developed for residential use and large areas to the east of the Bow are now being developed. This development represents a large influx of people to the area and so pressure for accessibility to the river shorelands is bound to increase.

There is no doubt, therefore, that further improvement and protection of water quality could enhance, and therefore also extend, recreational opportunities in the river valleys of Calgary. However, conflicts with other land uses must be resolved in order to make the best possible use of this natural resource. Water quality improvement should be but one part of a broad based programme to do this.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Analysis of the water quality data clearly showed that urban land use causes a marked degradation in the quality of water in the rivers and creeks in the city of Calgary and that the quality varies both spatially and temporally. This variation in quality is caused by the large volumes of sanitary sewage and industrial effluent discharged into the Bow River and by the storm runoff which drains into all the streams. The rapid growth of the city means that, while the quality of sanitary and industrial effluents is gradually being improved, the absolute volume is increasing, and very significant improvements in effluent quality are needed to offset this increase. Furthermore, the rapid urbanization of the watersheds of the Bow and Elbow Rivers and Nose and Fish Creeks has increased peak runoff very significantly in the small streams. The debris of urban areas which is washed off the surface by storm runoff has contributed to the degradation of the quality of all the streams.

From the analysis undertaken, the very high concentrations of bacteria and the heavy nutrient loading imposed on the river emerge as the problems of primary concern to recreational users. There is no doubt that these water quality conditions have a negative impact on recreation and that improvement would not only enhance the satisfaction gained by present users of the river valleys, but also would lead to recreational use by a greater number of people and over a wider area.

Some forms of water quality degradation have improved in recent years, such as odours from sewage plant effluent since secondary treatment was started at the Bonnybrook Plant in 1970. However, the increase in demand for water-based recreation opportunities, coupled with economic growth and urbanization which have diminished the supply of water resources effectively available to the public for recreation, has heightened the impact of poor quality on this use. That is, conflict has arisen over the use of rivers and associated shorelands in the city. For this reason, care is needed in planning the use of the river valleys and allocation of use of the water resources between competing uses in order to ensure that the greatest benefit is derived for the widest possible public. Although to a very large degree both water and associated land use is pre-determined by existent uses, planning is essential to ensure that the public is not forced to accept degradation of the rivers and shoreland environment by such uses and that public access is assured. Long-term planning is especially important because decisions made now may narrow the range of choice in resource use in the future. While allowing for multiple use of the river valleys, since non-recreational uses (transportation and industry) are already well established, planning should minimize conflict and ensure that appropriate potential uses of the river valleys are not usurped by the activities of present users.

6.2 Recommendations

Given that it is City of Calgary policy to develop the river valleys as a focal point for recreation it is necessary to take certain steps to ensure that this use is enhanced and not degraded by the water quality of the rivers. This entails control of the three major pollutant sources responsible for degradation: sewage treatment plant effluent, stormwater runoff and industrial effluent. Tertiary treatment of sanitary sewage is already planned and will reduce water quality degradation significantly. However, as this source of pollution is brought under control it becomes increasingly important to control storm runoff as this too may seriously degrade water quality. Since urbanization of the watersheds is increasing at such a rapid rate in Calgary, the quality of runoff to streams is being decreased rapidly. Thus, control of storm runoff should be given high priority in water quality management.

For the two major pollutants identified, bacteria and phosphorus, sanitary and storm sewage are the principal sources, thus reduction in the quantities discharged to the rivers will depend on control at these sources. Although sanitary sewage undergoes secondary treatment, the concentration of both these pollutants in sewage plant effluent is still very high. Extremely high concentrations of both total and faecal coliform bacteria have been found in storm runoff from residential areas of Calgary, and yet only a small portion of the city's runoff is controlled in any way other than sceening of large pieces of debris at the outfalls. It is thus recommended that more efforts be made to control the quality of stormwater. For example, stormwater can be detained to allow die-off of pathogenic organisms before the water enters the rivers.

The other major cause of water quality degradation in the Calgary rivers, phosphorus, is derived from all three major pollution sources. It is estimated that 53 percent of the phosphorus added to the Bow River above the confluence with the Oldman River comes from the Calgary sewage treatment plants. Phosphorus removal at the treatment plants, planned to commence in 1983, will drastically reduce the loading from this source. However, it is estimated that another 17 percent of the phosphorus is derived from storm runoff to the Bow River and an unspecified amount of the 21 percent of the phosphorus contributed to the Bow by the tributaries is also derived from runoff. While industry accounts for only 0.4 percent, most of this is derived from a few major sources and is thus spatially very concentrated. Levels in industrial effluent have been shown to exceed provincial standards. It is thus recommended that steps be taken to ensure better control of industrial sources and to reduce concentrations in storm runoff before it enters the rivers. Again, this can be accomplished by the use of detention basins. If storm runoff is detained in ponds where wetland vegetation is established, nutrients such as phosphorus will be taken up by the plants.

While high levels of treatment of industrial and sanitary sewage and detention of storm runoff are the major methods of pollution control, there are a number of other methods which may supplement these to increase effectiveness and reduce treatment costs. For example, both these above problems could also be alleviated somewhat by augmenting flows in the rivers at critical times in order to increase dilution and bed scour. While it is not recommended that dilution be seen as an alternative to control at source, in view of the damming of the Bow and Elbow Rivers it is recommended that the possibility of timed releases to alleviate water quality conditions downstream be investigated as a supplementary measure for water quality improvement. For example, while much of the flow is detained in reservoirs in the spring, bigger releases at this time would increase the flushing effect of high spring flows for removal of aquatic debris with high phosphorus contents.

In addition, the accumulations of debris on city streets that contribute to pollution of urban runoff can be disposed of by other means, for example, a more intensive programme of street sweeping. Measures could also be taken to reduce the amount of fertilizer applied to public parks and private lawns, which is often excessive, and thereby to reduce the amounts of phosphorus washed off the surface with runoff. These methods of pollution control are very low cost compared to the construction of high technology treatment facilities and their use may lessen, though probably not eliminate, the necessity for the expenditure of very large sums of money on those facilities.

It is thus clear that the water quality of the rivers in Calgary can be significantly improved and that any such improvements would both enhance and extend the recreational resources of the city. However, in order to make the best use of this valuable resource, water quality improvement must go hand in hand with careful land use planning for the river valleys, with improved access to river shorelands and with provision of water-based recreation facilities (e.g. canoe launching sites).

While the importance of the provision of recreational opportunities within the city has been stressed, experience with Fish Creek Provincial Park has shown that extra-urban resources can, and should, have a major role to play. The burgeoning population of the city of Calgary will inevitably lead to the necessity for provincial agencies to plan for recreational use of under-utilized resources close to the city, with the express purpose of serving the urban population. For example, Bearspaw Reservoir, situated at the north-west city limits close to rapidly expanding residential areas, has a great potential for water-based recreation use which has hitherto been neglected. Utilization of extra-urban potential of this kind would effectively be an addition to the opportunities for water-based recreation available to residents of the city of Calgary.

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