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Full Name of Author — Nom complet de l'auteur

Brian James Gregg

Date of Birth — Date de naissance	Country of Birth — Lieu de naissance
May 19, 1958	Canada

Permanent Address — Résidence fixe

915 48th Ave S.W.
Calgary, Alberta
T2S-1E9

Title of Thesis — Titre de la thèse

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Date	Signature
October 7, 1983	Brian Gregg

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ALTERNATIVES IN WATER TRANSFER :
From the Clearwater to the Red Deer River

by

Brian James Gregg

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DEGREE FOR WHICH THESIS WAS PRESENTED MASTER OF SCIENCE

YEAR THIS DEGREE GRANTED FALL 1983

(SIGNED) Brian Gregg

PERMANENT ADDRESS:
915 48th Ave S.W.
Calgary, Alberta
T2S - 1E9

DATED October 7 1983

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled ALTERNATIVES IN WATER TRANSFER : From the Clearwater to the Red Deer River submitted by Brian James Gregg in partial fulfilment of the requirements for the degree of Master of Science.

Arleigh H. Rayrock

Supervisor

Date September 30, 1983

DEDICATION

This thesis is dedicated to my family and friends

without whom I would never have had the strength to complete this work which

has, ironically, taken me from them.

ABSTRACT

Major interbasin water transfers have been proposed in Alberta and hailed as the ultimate solution to growing irrigation water supply shortages just as they were in the Western United States. However, past large scale transfer proposals proved to be unworkable because of poor benefit-cost relationships, environmentalist opposition and political disfavour. In spite of this, the current activities of the Alberta Water Resources Commission are indicative of a continuing interest in our developing large interbasin transfers to support irrigation development in Southern Alberta. Alternative water management strategies for dealing with existing and future supply and demand conflicts do exist and are identified; however, the emphasis in this study is placed on water transfer. In Alberta, the exploration of alternative means of developing interbasin transfers from north to south has been vigorous and the opposition to existing proposals remains strong.

In response to the current situation, it is proposed that the viability of water transfer as a valid water development strategy can be improved through the application of a multi-means, multi-purpose approach to water transfer. A transfer from the Clearwater River in West-Central Alberta to the Red Deer River may lend itself to such development. In this study, the thesis that interbasin transfer from the Clearwater River to the Red Deer River may be developed in a number of ways with minimal damage and possible enhancement to the donor and receiving streams, is promulgated and investigated.

A discussion of the basic issues surrounding interbasin transfer in general, and its importance in Alberta water management in particular, is provided to place this study of Clearwater transfer alternatives in context. Existing conditions in the study area are discussed with particular emphasis upon physiographic features and their effect on streamflow, water-based resources and land use. Following a discussion of the development potential of a Clearwater transfer in terms of water volume and the irrigation development it could support, a broad range of transfer means is explored. Six transfer alternatives are selected and each is submitted to a preliminary evaluation based on the following criteria: the planning objectives supported, potential transfer volume, relative cost, potential environmental and socio-economic effects, and other general concerns regarding operation and future adaptability.

It is concluded that water transfer from the Clearwater River could be developed in such a way that a sequence of progressively larger transfer schemes may be used to alleviate water supply shortages in the South Saskatchewan basin. In addition, it is concluded that a Clearwater transfer could be conducted so that detrimental environmental and social impacts are kept to a minimum. Unavoidable detrimental impacts could be at least partially compensated for by operating the transfer so that certain stream environments in the area are actually enhanced. Such enhancement could improve the recreational potential of some of the receiving streams. In the light of these conclusions it is concluded that a multi-means multi-purpose Clearwater transfer study such as this could be used as a prototype or model for other studies of sequential transfer development in Alberta.

In Alberta, there is a need for consideration of a broader range of alternatives in water management planning in general and interbasin transfer specifically. In regard to future transfer development, it is recommended that: i) transfer development should take place slowly, in response to short term projections of actual consumptive use, ii) attempts be made to compensate areas detrimentally affected by transfer development, iii) possibilities be explored for developing transfers to serve a variety of purposes such as flood control and recreational development, and iv) public input be incorporated into the actual design and selection of alternatives. Further studies are recommended to determine the cost and feasibility of constructing Clearwater transfer systems and enhancing local stream environments.

ACKNOWLEDGEMENTS

Many thanks are due to my supervisor, Dr. Arleigh Laycock, for his careful direction, encouragement and constant inspiration throughout the course of this research. I have thoroughly enjoyed the time I have spent with him and his wife Audrey and members of his family. Dr. Ed Jackson of the Dept. of Geography and Dr. Guy Swinnerton of the Dept. of Recreation Administration made many valuable suggestions concerning the presentation of this research and I am grateful to them both.

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No amount of thanks can express the gratitude I owe to my parents for supporting me throughout my university career and instilling in me the confidence and curiosity required to explore and test the edges of my ability. I am indebted to all of the friends I have made in Edmonton, both in the Geography Department and Pembina Hall. I consider these friendships to be the most valuable and pleasurable result of my experiences in Edmonton over the past two years.

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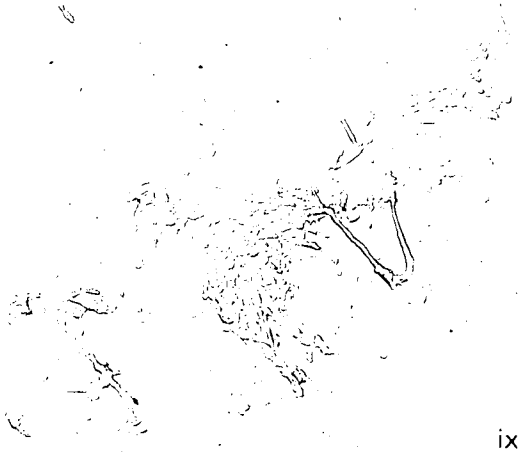

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I. INTRODUCTION

Alberta is blessed with an overall abundance of fresh water however, severe local and regional scarcities do exist and are of concern to Albertans. Considerable spatial variation exists in the water supply and water demand patterns within the province. Most of the streamflow (87%)[1] is in north-flowing tributaries of the Mackenzie River, while the majority of the population (89%)[2] and water demand is within southern basins. Southern basins include the Saskatchewan River basin, the Milk River basin (part of the Missouri drainage system) and the Beaver River basin (part of the Churchill drainage system). The Saskatchewan River basin accounts for 12% of the streamflow in the province, while the Milk and Beaver basins make up the remaining 1% of provincial streamflow. The "average" annual water supply for Southern Alberta fluctuates little with variations due primarily to variations in climate. In contrast to this, the water demand is steadily increasing and in future dry years, even with full management of available streamflow, the supply will not be adequate to meet projected demand (Laycock, 1979).

The prospect of increasing the water supply in the South Saskatchewan Basin by diversion of water from northern rivers such as the Peace, Athabasca and North Saskatchewan has been a prevalent one in Alberta water resource planning for many years. In the following chapter many of the proposals which have been made to develop large scale water diversion projects, both on a continental and a provincial scale, will be reviewed. Proposals for water diversion within Alberta will be emphasized, including those envisioned by William Pearce before World War I, the provincial government's Prairie Rivers Improvement, Management and Evaluation (PRIME) concept and the Saskatchewan – Nelson Basin Board Study (SNBB).

A major shift in government policy concerning future water transfers occurred in 1971 when the Alberta Social Credit government, which had been initiating water transfer studies throughout the sixties, was replaced by a Progressive Conservative government. This new government declared a moratorium on any further transfer studies and altered government water development policy so that it focused upon improved water use within basins. In recent years, especially after the drought of 1977, when at least one of the

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[1] Peter G. Melnychuk 1979. "Prairie Provinces Water Apportionment and Upstream Storage Options", *Canadian Water Resources Journal*, Vol. 4, No. 3, pp. 52–59.
[2] Statistics Canada 1982. *1981 Census of Canada: General Population, Housing, Household and Family Data: Alberta.*

irrigation districts in southern Alberta was unable to supply enough water to users, there has been renewed interest within the government in water diversion schemes. The projects which have been suggested, however, are essentially the same as those put forward in the PRIME and SNBB studies - they are large in scale and opposition to such development is strong.

There is great concern that most water development proposals, whether they involve interbasin transfer or not, fail to adequately review the physical, economic, social and environmental factors involved. Some opponents to such development may conclude that no development is better than the expensive and potentially detrimental large scale schemes proposed. Hence, while provincial water managers have effectively restricted themselves to only two options in relation to interbasin transfer - going ahead with proposed large scale development plans, or halting any further development, there are other options available. Alternatively; planners might concentrate on the "middle ground" between these options to determine whether planning can procede for smaller scale developments that will meet most of the better defined regional needs within the province.

The proposed research is partly an examination of this "middle ground"; it is a preliminary examination of the potential for developing a water transfer using a variety of alternative means in an effort to reduce the costs and impacts associated with water transfer. The argument for developing interbasin transfer to support further irrigation expansion is examined in chapter two. It is important to realize at this point that water transfer is only one of the means of relieving water deficiency problems in southern Alberta. Improvements in irrigation water use efficiency could alleviate the problem to some extent (Stanley/SLN Consulting, 1978) but other "non-technological" adjustments could prove to be just as important. For example, irrigators could apply less than the optimum amount of water and/or revert in part to dryland cropping during dry years when water supplies are limited. By doing so, agricultural productivity would be reduced during these years. But this may prove more economical than providing for optimum dry year irrigation demands through development of large capacity water supply projects.

It is likely that the growth in demand for water in the South Saskatchewan basin will initially be small and sporadic and that it may take many years to reach levels sufficient to justify the costs of implementing large interbasin transfer schemes. In the interim smaller,

low-cost, more flexible arrangements for increasing supplies in the South Saskatchewan basin could be implemented. Logically, one of the first transfers from the North Saskatchewan basin might be from the southernmost tributary - the Clearwater River. The volume of transfer could initially be small and be expanded as the need for water in the South Saskatchewan basin may dictate. Ultimately a sequence of transfers might be developed with subsequent transfer from the North Saskatchewan and if replacement supplies are needed in this basin, the transfers from northerly basins (ie. the Pembina, Macleod and perhaps in the very long term the Athabasca and Peace Rivers) could again be modest in the initial stages.

A variety of exceptional means could be employed to transfer water from the Clearwater River south of Rocky Mountain House to tributaries of the Red Deer River (Figs. 1 and 2). The possible methods of diverting the water are considered to be exceptional because, unlike most interbasin transfer schemes, a scheme designed to divert flow from the Clearwater River would not necessarily require the construction of large scale engineering structures. The unique physiographic and hydrologic conditions evident along a short section of the Clearwater River would make it possible to divert water into Stauffer Creek (a tributary stream in the Red Deer drainage system) with the construction of nothing more than a low weir and some short-distance ditching.

These unique possibilities for transferring water from the Clearwater River have been recognized for some time, as will become evident in the discussion in the following chapter; however, most of the alternative means of transfer have not yet been studied, even superficially. Studies are lacking in regard to social problems associated with water diversion, as well as prospects for environmental enhancement and multiple use of the donor and receiving streams. Many questions must be answered and alternative ways of solving problems must be reviewed. For example, the Raven River and Stauffer Creek are among the best trout streams in Alberta, largely because natural groundwater flow from the Clearwater contributes greatly to favourable regime and water quality in these receiving streams. It is not known whether water transfer would destroy these streams for fishing, although it is probable that transfer without provision for maintaining fish habitat would be damaging. Means of transferring water to the Red Deer which maintain the aquatic habitats and possibly improve them should be investigated. Preliminary studies

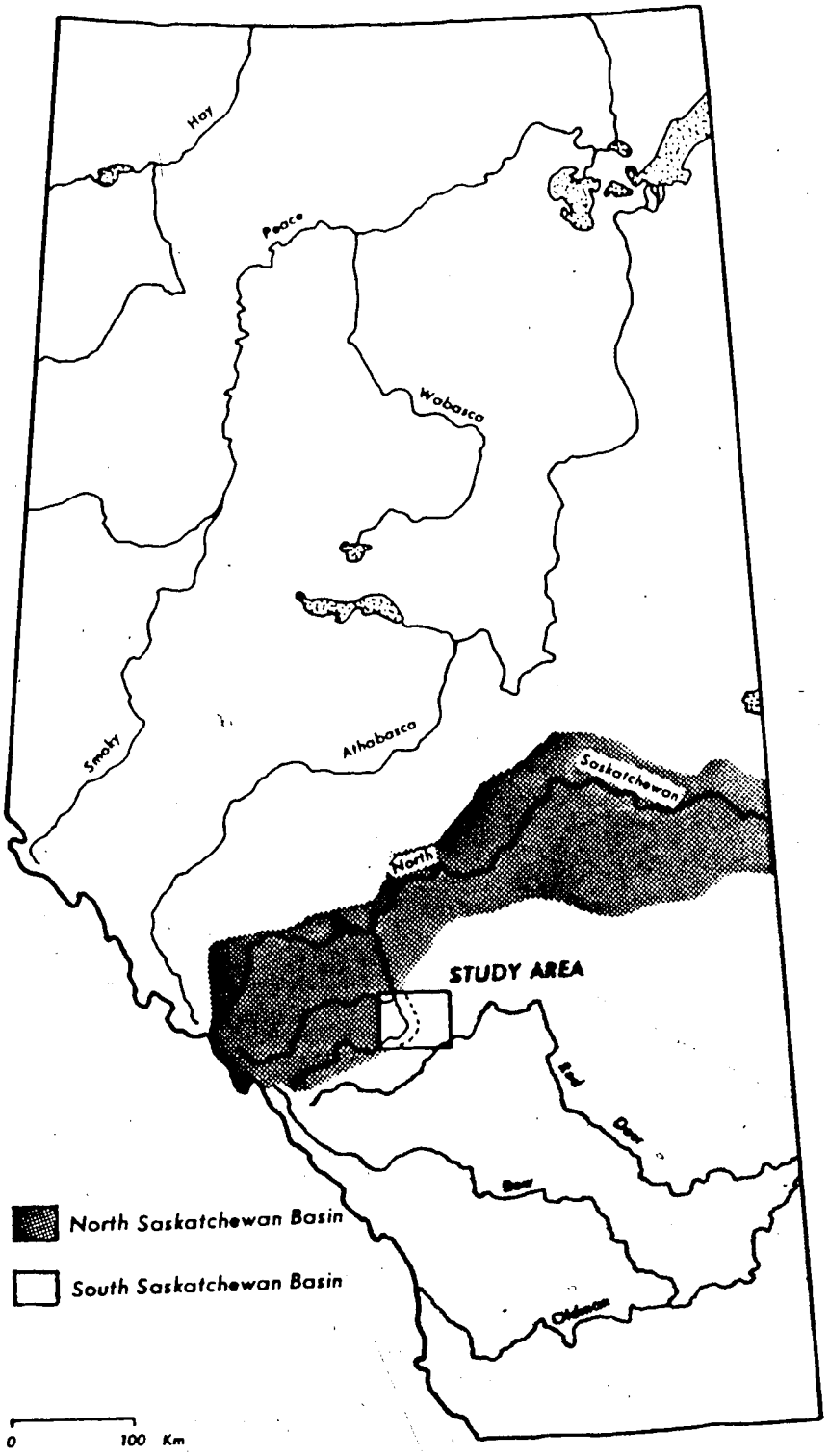


Fig. 1 Location of Study Area

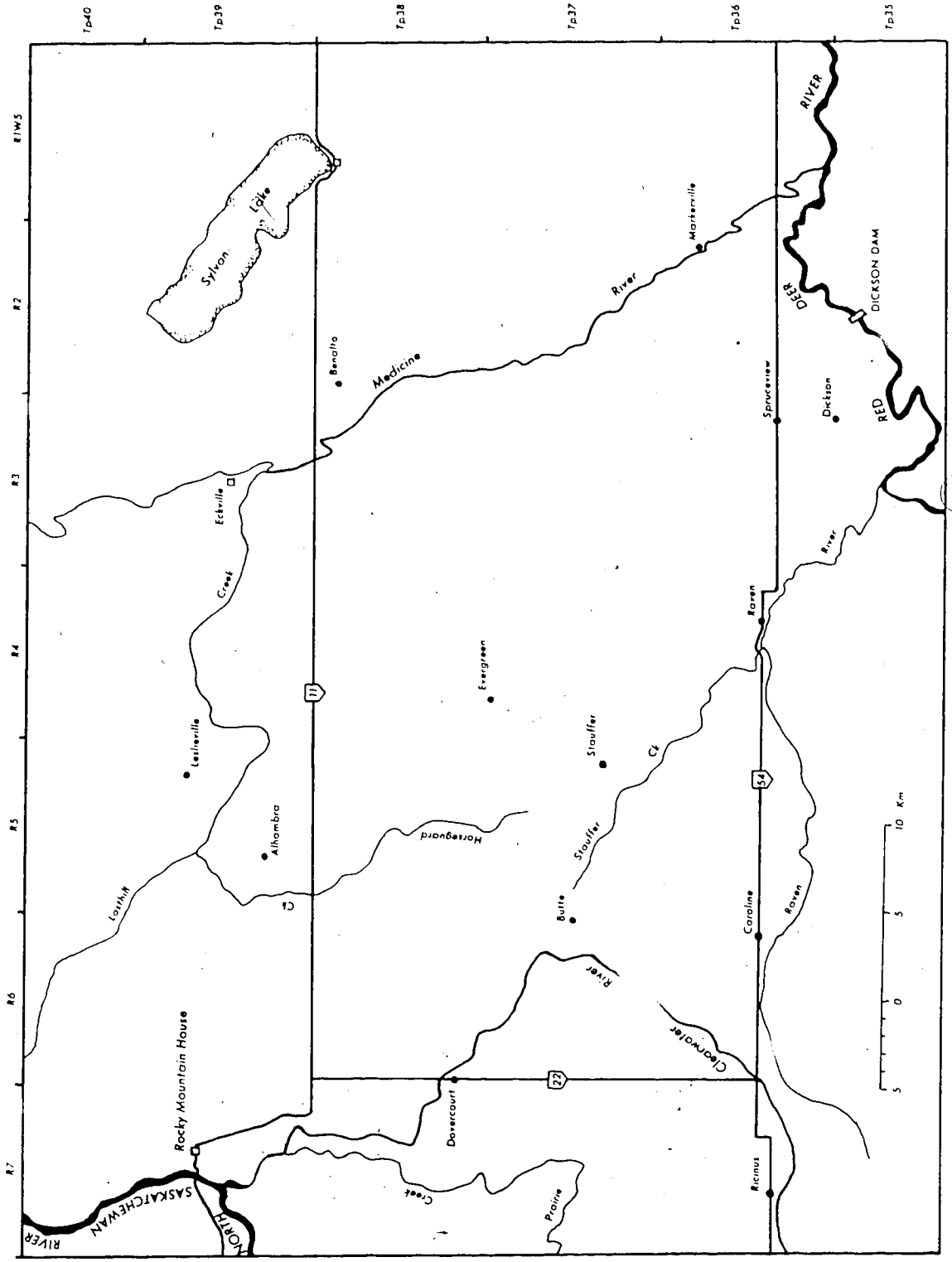


Fig.2 Study Area

hold promise; there may be several ways to carry out such a transfer. For instance,some of the ways are: water spreading to increase groundwater flow, transfer by several routes at various times and in various amounts, and perhaps pumping of surface and/or groundwater with transfer by pipeline.

It is proposed that this investigation into alternative means of transferring water can be treated as a prototype or model for future interbasin transfer studies for three reasons. First, the application of a multi-purpose and multi-means approach to water transfer is rare if not unique. Second, environmental and social concerns are seldom incorporated in the preliminary planning steps of water resource developments. Third, if water transfer development were to progress sequentially, then transfer from the Clearwater could be the initial step in such a sequence.

Research Problem and Objectives

Simply stated, the research problem is to investigate how water can be diverted into the Red Deer River from the Clearwater River while attempting to keep development costs and impacts to a minimum and provide for compensating environmental and/or social enhancement where possible. This involves exploring various physical means of actually transferring the water, as well as identifying the possible impacts of such transfers upon the ecosystems and human communities in the area.

The objectives in this research are threefold:

1. To investigate the possibility of transferring water from the Clearwater to the Red Deer River on a small scale as an initial step in a transfer development planning sequence.
2. To consider the potential for developing a transfer in such a way that a suitable compromise is reached between environmental protection and transfer objectives.
3. To examine a wide range of alternative diversion methods and combinations, and to evaluate a number of them in relation to several criteria, including: their ability to supply water to the Red Deer River, associated environmental and social impacts, relative cost, and other general concerns.

As part of the terms of reference it is assumed that there will be pressure for water diversion into the South Saskatchewan River basin; this is a study of how it may be done with minimal damage and with compensating enhancement. Alternative courses of action are identified and procedures studied that incorporate a balance of engineering, environmental, social and other concerns in water transfer development.

Because of the preliminary nature of the research, certain components of the water development planning process will receive greater emphasis than others. There is a strong emphasis in this research on describing the existing environmental and social conditions in the study area, as well as formulating water transfer alternatives and assessing their impact. Unlike most water planning studies, this research is not directed toward the discovery of a single "best alternative" method for fulfilling the proposed planning objectives. It is instead directed toward the sound application of a multi-purpose/multi-means water development planning strategy to an actual water resource problem.

In chapter two a discussion of interbasin water transfer and the problems involved with past transfer plans is presented. This includes a review of large continental scale diversion schemes, followed by a background concerning water transfer proposals in Alberta, the changes in government policy concerning them and the nature of the problems which have spawned them. This discussion is then used to place water transfer in general, and Clearwater transfer specifically, in context with other water management strategies designed to alleviate water supply shortages.

Existing conditions in the study area are discussed in chapter three with particular emphasis upon the physiographic features and their effect on land use in the area. The surficial and bedrock geology is outlined with an emphasis on the pattern of deglaciation which determined, to a large extent, the pattern of geomorphic and hydrologic features in the area. A review of the distribution and types of soils and vegetation, completes the description of the physical setting of the study area. A description of the cultural features of the area concerning community structure, agricultural practices, and population follows.

Chapter four is divided into two parts. The first part is a physical description of the water resources in the area; this includes a review of the local water balance based on monthly climatological records for Rocky Mountain House, as well as an analysis of local

streamflow for the streams in the study area. Groundwater contributions to streamflow are of great importance to several of the streams and therefore a considerable amount of detail is presented regarding groundwater flow in the area. In the second part of the chapter the existing and future use of streamflow is discussed. The potential for using transferred water in irrigation development in the South Saskatchewan basin is explored in addition to a discussion of the importance of instream usage of water within the study area for fish, wildlife and recreation. The potential for environmental damage and/or possible enhancement caused by water transfer in this area is discussed with emphasis on changes in fish and wildlife habitat and water-based recreational opportunities. The importance of establishing instream flow requirements is discussed in reference to both donor and receiving streams.

In chapter five, a set of potential planning objectives for the water diversion scheme are proposed and later used to formulate several plausible transfer alternatives. The potential volume of water which could be transferred from the Clearwater is estimated assuming various operational and physical constraints on removal from the Clearwater and transfer capacity of receiving streams. These volumes of water are then expressed in terms of the amount of irrigation development they could support. A range of physical transfer components is then described including location of water removal, methods of removal and transfer, and the route of transfer. Finally, six plausible transfer development alternatives are selected and subjected to a preliminary evaluation in terms of: i) the planning objectives they best support, ii) potential transfer volume, iii) relative cost, iv) significant environmental and socio-economic effects, and v) general concerns related to flexibility of operation and future adaptability of the alternative.

In chapter six the findings of each chapter are summarized and the principal conclusions are stated. Finally, recommendations are made in two areas: i) recommendations for future transfer development, and ii) recommendations for further study in regard to Clearwater transfer development.

II. WATER TRANSFER

Water transfer is a topic which has created a large amount of interest in North America over the past three decades. It is still the focus of many intense controversies today and will undoubtedly continue to be in the future. A huge body of literature has been generated on the topic including water transfer proposals and a plethora of publications concerning a wide range of political, economic, social, environmental, technical and legal aspects of water transfer. The most complete international bibliography compiled on this topic is the annotated bibliography of Whetstone(1970, Vols. 1 and 2).

In this chapter, a historical approach is used to present and discuss many of the issues related to interbasin transfer. The following discussion sheds light on several transfer issues associated with water transfer and demonstrates that the situation in Alberta in this regard is not unique. Analogous situations exist in the Western United States and there is much to be learned from these past experiences. Interbasin transfer is but one of the water management issues in Southern Alberta but it will likely continue to be seen as an ultimate solution to water shortages in the region.

The review of past transfer proposals reveals their weaknesses not only in the justification for transfer but also their poor exploration of alternatives and consideration of the environmental, socio-economic and political factors involved. It is suggested that a more complete exploration of alternative means, objectives and purposes in water development planning would improve the viability of future transfer proposals. In this regard, many of the unexplored development alternatives related to water transfer in Alberta (ie. matching scale of transfer to end-use need for water, multi-means/multi-purpose development, and incorporation of compensating environmental enhancement) could be beneficially applied in a transfer from the Clearwater River.

Water transfer may be defined as the artificial diversion of water from one drainage basin (the donor basin) to another (the receiving basin). Any movement of water across a drainage divide into a drainage basin other than the one it would otherwise naturally occur in, can be classified as an interbasin water transfer. Thus, not only are the more familiar methods of surface water transfer recognized (ie. ditches, canals and pipelines) but also less common methods, such as groundwater transfers induced by

pumping and atmospheric water transfers induced by cloud seeding.

Water transfer has often been hailed as the solution to water supply shortages; the impetus for long-distance water transfer has long been apparent in the American West. The immediate reaction to shortages of high quality fresh water has been to search for more water from elsewhere - the "extensive" approach to water management according to Quinn(1973). Typically, when the potential for exhaustion of local water supplies becomes apparent, decision-makers look progressively farther afield for supplementary ones. As early as 1965, there were 146 interbasin water transfers in the seventeen western states and one out of every four persons living in the region was served (at least in part) by a water supply system which imported water from 160 km or more away (Quinn, 1968).

This increasing imbalance between water availability and population in the dry Southwest and a reluctance to accommodate urban growth by reducing water allocations to agriculture, led to expectations of further water diversions. In the United States, the 17 western states alone account for about 84% (U.S. Water Resources Council, 1978) of the country's freshwater consumption (defined as the portion of water withdrawn for offstream use which is not returned to a surface or groundwater source). A similar situation exists in Canada, with Alberta alone accounting for almost 50% of the country's consumptive water use in drier years (Environment Canada, 1975 and 1982; Laycock, 1983). The majority of this water is consumed for agricultural purposes, primarily irrigation. In California, for example, 85% of the water consumed in the state, is consumed for agriculture (State of California DWR/SWRCB, 1982); irrigation in Alberta is responsible for 93% of the province's total consumptive use (Durrant, 1983).

According to Frederick and Hanson(1982), the Western U.S. is not running out of water. Rather, it is running out of "low-cost" water and irrigation is one of the most affected activities in response to rising water costs. Agriculture is not only the largest water consumer but also a marginal user of water. The prospect of sharply increasing water costs not only threatens expansion but also endangers the viability of many current agricultural areas. Attempts to maintain and expand agricultural production through irrigation, coupled with growing urban water demands, in many areas of the western U.S. and Alberta, have provided the impetus for most water transfer proposals in these

regions.

Water transfers in Alberta are, however, an exception to the overall Canadian pattern according to Quinn(1981). In Canada, hydropower development is the dominant consideration for the majority of existing water transfers. In fact, the volume of water transferred for this purpose in Canada is greater than the combined transfer totals for the next leading countries, the United States and the Soviet Union. Most Canadian projects have been developed by provincial corporations whose principal objective has been to maximize low-cost power generation and thus to move electric power, not water, to southern Canadian markets. Alberta's situation should therefore be considered as an exception to the Canadian water transfer pattern (even though hydropower development on the Slave River may change this) but closely resembling that of parts of the western U.S. (Laycock, 1979).

The rash of interregional and international water transfer proposals began soon after the U.S. Supreme Court ruling in June 1963, on the case of *Arizona vs. California*, which confirmed earlier allocation agreements on the division of water in the Colorado River Basin. California, which had exceeded its share, was forced to cutback and look elsewhere for new supplies. Many possibilities for augmenting California water supplies were investigated; those designed to exploit supplies within the state form part of the California Water Plan (California Dept. of Water Res., 1957). Similarly, with growing deficiencies in the Texas High Plains, Texans began to look for new water supplies both inside and outside their borders. The Texas Water Plan of 1968, narrowly defeated in a 1969 plebiscite, proposed transfer from East Texas, with the assumption that later replacement supplies could be obtained from the Mississippi, to supply the dry High Plains area of West Texas. Unfortunately for the proponents, both Lousiana and Arkansas indicated that they would oppose such replacement transfers. Thus, some interregional transfer schemes also involved transferring water into Texas by other routes in addition to those proposals to supply the Southwestern states.

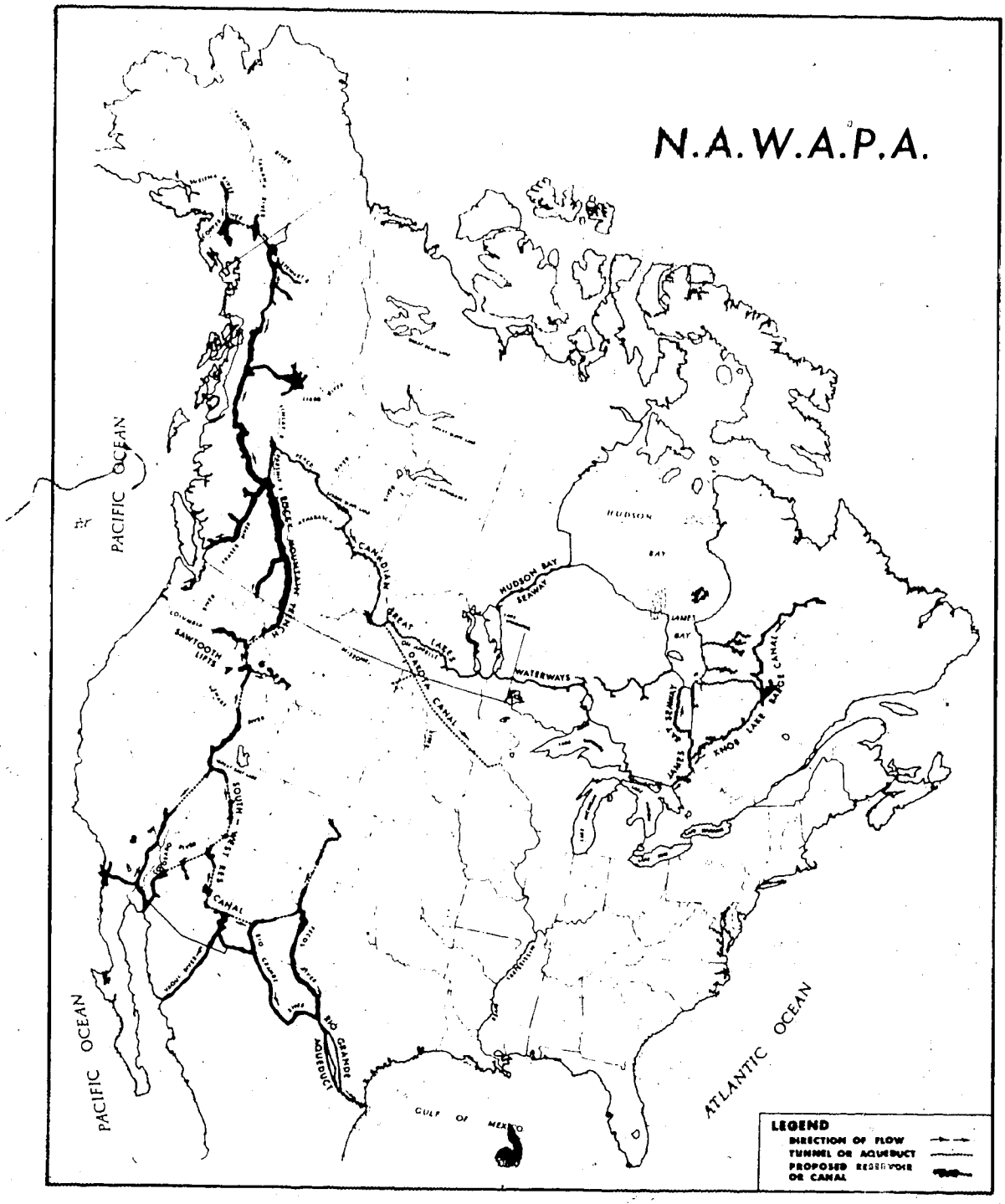
The realization that water supplies within California might not be adequate, much less accessible, spawned a number of interregional transfer proposals in the early sixties. These proposals involved transferring water from other "water rich" western states to the drier southwestern states. The Western States Water Council(1969) reviewed 12 of

these proposals including the Pacific Southwest Water Plan, the Sierra–Cascade Project, and the Snake–Colorado Project. Strong opposition to such plans was applied by the area–of–origin states (ie. Washington, Oregon and Idaho) and eventually, in 1967, Senator Henry Jackson of Washington suceeded in having a 10–year moratorium imposed on further federal government interbasin transfer studies involving transfer to the Colorado Basin. An amendment to the United States Water Resources Planning Act (U.S. Congress, 1965) forbids any study of water transfers between river basin areas organized under the Act by either the Water Resources Council or any commission responsible for a basin area. The moratorium was extended in 1977 for an indefinite period of time.

Technical and political difficulties with proposed water transfers in the Pacific Northwest led, in part, to prospecting further afield into Canada and Alaska. In order to provide a broader background from which Clearwater transfer proposals can be examined some of the major international and Alberta water transfer proposals will be reviewed. Such a background is needed to help place this study in context, both in terms of the Alberta water management situation and the broader continental situation. Many of the reasons for developing water transfers and for opposing such development can best be illustrated through discussion of the transfer proposals that initiated much of the controversy which surrounds the water transfer issue.

A. International Water Transfer Proposals

The North American Water and Power Alliance (NAWAPA) proposal of the Ralph M. Parsons Co., of Los Angeles, is probably the best known of the various international transfer proposals. The NAWAPA plan would involve diverting water from rivers in Alaska, the Yukon, British Columbia, and the Pacific Northwest of the U.S. to serve the needs of the western and southwestern parts of the United States, the Prairie provinces of Canada and the American midwest (see Fig. 1). This would be accomplished by the construction of a series of high dams in the headwaters of certain major rivers in order to divert their flows into a chain of reservoirs including the Tanana, the Yukon, the Peace, and the Rocky Mountain Trench. It would require the construction of 240 reservoirs, 112 irrigation systems and 17 navigation channels. The transfer of over 140 million dam^3 per year would result, with approximately 80% of this water going to the United States



Sources 1. Alberta Dept. of Agriculture 1968. "Water Diversion Proposals of North America" Water Res. Div. Development Planning Branch. Edmonton.
2. Ralph M. Parsons Inc. 1964. NAWAPA company brochure, Los Angeles.

Fig. 1 NAWAPA International Water Transfer Scheme

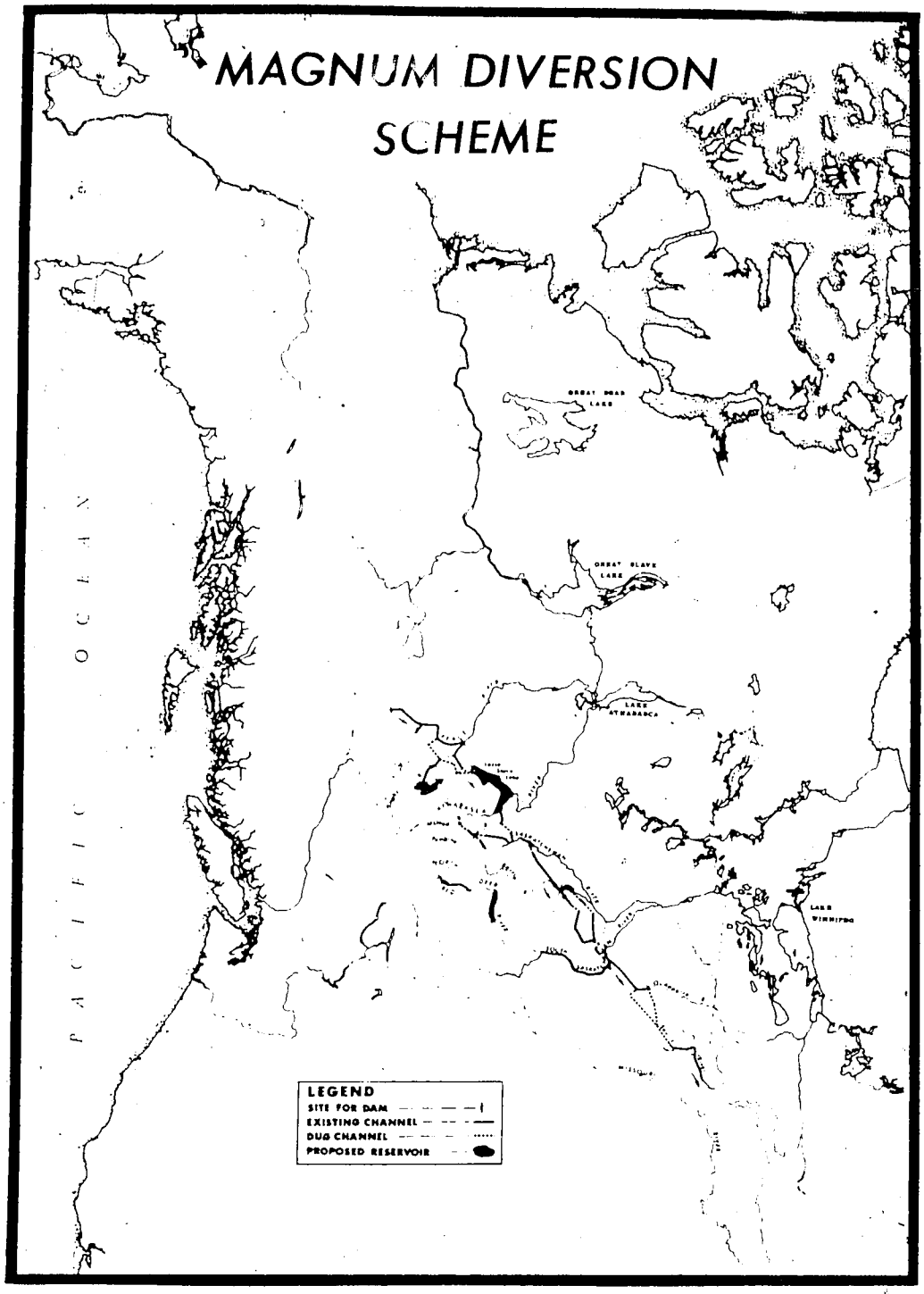
(Alberta Department of Agriculture, 1968; Ralph M. Parsons Co., 1964).

Other proposals for the transfer of Canadian water southward include the Western States Water Augmentation concept put forward by L.G. Smith(1969), Magnusson's(1967-1969) Magnum diversion scheme, the Kuiper(1966) diversion scheme, and the Central North American Water Project of Tinney(1967). Basically, these are all variations of or alternatives to the concept put forward by Parsons. They differ, however, in the extent and route of diversion from Canada, the administrative structure, and whether or not a price is put on the transferred water.

The Magnum diversion scheme (see Fig. 2) is one of the few continental water transfer proposals that would involve considerable alteration of streamflow within Alberta and is therefore of particular interest. According to this plan the Peace River would be the chief source of supply with additions coming from the Smoky, Athabasca, North Saskatchewan, Red Deer, and South Saskatchewan Rivers. From Alberta, the Magnum Canal would take this water southeastward across the Prairies into the Missouri Basin. Several of the transfer proposals were further developed in the Alberta government's PRIME concept and in the SNBB study which followed.

Obviously, the major incentive for such large scale interbasin transfers is to provide "water scarce" areas of Canada and the United States with a dependable water supply. Many feel that, if an abundant water supply is made available for all conceivable purposes, that many unfavourable trends will be countered: unemployment, rural decline, world food shortages, and so on. The list of benefits assigned to Canada in these large transfer proposals includes increased irrigation, marketable hydroelectric power, spinoffs from engineering development expenditures, expanded transportation networks, flood protection, and creation of new recreational areas.

Most of these benefits are illusory according to Laycock(1971,1972). The assumption that Canada will benefit from increased irrigation from schemes such as NAWAPA is unreasonable because more accessible and economical sources of water are available for irrigation development in Canada. The navigation benefits would be limited because the canals would be frozen much of the year. A large proportion of the "beneficial" hydropower would be required for pumping the water southward. Flood protection would be provided to some areas but at the expense of flooding out other



Sources: 1. Alberta Dept. of Agriculture 1968. "Water Diversion Proposals of North America". Water Res. Div., Development Planning Branch, Edmonton.
2. Magnusson, K. 1967-1969. Unpublished brochures, Ottawa.

Fig.2 Magnum International Water Transfer Scheme

valuable developed areas, principally in British Columbia. For Alberta, the adverse impacts which would result from such schemes outweigh any possible benefits they might create. Few of the proposals mention any form of compensation for environmental and social damages which would undoubtedly occur.

These large scale interbasin transfer proposals are essentially enthusiastic engineering reconnaissance studies; they have initiated a lot of discussion but have not progressed much beyond that stage. Poor benefit-cost relationships, environmentalist opposition and political disfavour, especially in basin-of-origin areas, are just some of the factors responsible for the shelving of most large scale inter-basin water transfer plans (Laycock, 1971; Quinn, 1973). The shortcomings of these international transfer schemes are, to a large extent, inherent in all interbasin transfer schemes and the proposals put forward for Alberta are no exception.

B. Interbasin Transfer in Alberta

It has long been recognized that much of Southern Alberta would require increased water supplies in order to support a dense population. Before the turn of the century, William Pearce, who was then the acting Superintendent of Mines for the Federal Department of the Interior, had recognized that the lack of adequate water supplies in much of the prairies would pose serious development problems in the region (Mitchner, 1971). Pearce fostered proposals for the construction of multi-purpose dams in the headwater regions of prairie rivers. Such dams would act as flood control devices, store spring runoff waters for use during the long dry growing season and even provide a means to electrify the CPR lines over the mountains to the Pacific.

Pearce was later to expand these ideas into a water resources scheme covering most of the arid regions of the present day provinces of Alberta and Saskatchewan. He also advocated the use of irrigation and his proposals concerning water rights were embodied in the Northwest Irrigation Act of 1894. One of the proposals he outlined was the North Saskatchewan Project or Red Deer River Diversion Project. This was a proposal to utilize the flow of the Red Deer, Clearwater and North Saskatchewan Rivers to distribute the available water supply by natural and artificial channels throughout a very extensive area north of the Red Deer and South Saskatchewan Rivers, primarily for the

development of the livestock industry (Russell, 1948).

Pearce continually pushed for greater federal participation in the development of Western Canada. Designed to aid the western economy, his recommendations foreshadowed the series of wide-ranging government programs such as the PFRA and the Agriculture and Rural Development Act (ARDA). He was particularly concerned over the semi-arid condition of the Canadian prairies and his ideas concerning the conservation of vital water resources instigated the large scale irrigation projects in Southern Alberta. Some of his ideas were included in comprehensive plans for the future development of waters flowing from the eastern watersheds of the Canadian Rockies including Alberta's PRIME concept.

The PFRA which was created in 1935, was designed to provide for the agricultural recovery of drought areas in the Prairie provinces. By allowing the Federal Department of Agriculture to promote systems of rural economy, arboriculture and irrigation, greater safeguards against droughts and greater economic security for agriculturists was provided. The basic concepts of conserving and storing water on the drought-prone prairies have been utilized in several PFRA undertakings collectively called the "Water Development Program" (PFRA, 1980). Included under this heading are individual farm and small community projects (ie. stock watering reservoirs, dugouts, water wells, and small water impoundments), irrigation developments, tree distribution programs and other associated activities. The PFRA can generally be classified as a resource development agency akin to the Bureau of Reclamation in the United States. It provides prairie agriculturalists and communities with expertise in the utilization of water reserves, crops and soils.

The PFRA has been involved in a major interbasin transfer project, a part of the South Saskatchewan River Project, which transfers water from the South Saskatchewan River at Lake Diefenbaker to the Qu'Appelle River basin. The project provides water for municipal use in Regina and MooseJaw, agricultural use for irrigation in the Qu'Appelle Valley and industrial use for potash mining in part of the Qu'Appel basin. PFRA was also involved in the SNBB study jointly commissioned in 1967 by Alberta, Saskatchewan, Manitoba and Canada to study the Saskatchewan-Nelson Drainage basin.

The SNBB study is the most detailed inventory of possible interbasin transfer schemes in the Prairie provinces. The terms of reference for the study were:

> The board shall carry out a study of the water resources of the Saskatchewan Nelson Basin including the potential additional supply by diversion or storage....In carrying out the study, the Board will consider the engineering feasibility and cost of the many combinations of storage and/or diversion works needed to provide a firm water supply of varying amount and with varying seasonal distributions, at various selected points along the river system. [3]

The historic files of both provincial and federal agencies were reviewed by the SNBB to ensure that all previous proposals were considered and numerous new studies were instituted. It was decided that a total of 55 dams and 23 diversions could feasibly be constructed, with enough water at each dam and/or diversion site to improve the downstream water supply. There was no attempt to decide which of the projects should be built at the time of the study or in the foreseeable future, nor was there any attempt to decide how, or where, the additional water supplies generated by each project might be used (Godwin, 1981).

The SNBB study does, however, serve as a future planning reference by identifying the physical means and approximate costs of providing large scale water storage and transfer facilities throughout the Saskatchewan-Nelson Basin and its potential donor basins. The study was strongly "structures" oriented, in that the only means of improving water supply considered were the construction of large dams and transfer structures. A minimum of effort was spent on investigating economic and environmental concerns. The findings of the study suggested that, with major expenditures, large supplies of water could be made available to the Prairies. Minimum stream flows could be increased by changing the operation of existing projects; some further increase could be obtained by adding new reservoirs; but diversion would be required to obtain large increases in water supply in the southern areas.

At the same time as the SNBB study was being carried out, the Alberta government was promoting the PRIME program that featured many of the water storage and diversion plans cataloged in the SNBB study. It was proposed that "... as water in southern rivers becomes fully utilized, surplus water from neighboring northern basins will be diverted to augment supply in over-allocated rivers. Thus basin by basin, a transfer of northern

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[3] pg. 3 Canada, Alberta, Saskatchewan and Manitoba 1972. "Water Supply for the Saskatchewan Nelson Basin", Main Report of the SNBB.

waters to the south will be achieved" (Bailey, 1969). To a large extent, the driving force behind such interbasin transfer proposals came from, and in the future will continue to come from, irrigation interests and contractor promoters in the southern part of the province.

With the change in provincial government from Social Credit to Conservative in 1971 and the induction of a new Minister of Environment (W.J. Yurko), the PRIME program was shelved and the emphasis was shifted away from interbasin transfer. Interbasin diversions could be studied and implemented where publicly desirable, but interbasin transfers of water would generally be discouraged and would have low priority (Alberta Environment, 1972). The Alberta government also placed a moratorium on the use of provincial funds for use in studies that involve the diversion of Alberta surface waters for export beyond the Canadian border (Yurko, 1972). The government's policy in water management since 1971 has been to concentrate on fully utilizing water supplies within basins before considering interbasin diversions (Alberta Environment, 1979). Senior water basin planners in the Alberta Department of Environment are not currently involved in any interbasin transfer studies (Barton, 1982 and Wuite, 1982: pers. comms.).

Even though the provincial government has officially denounced interbasin water transfer schemes it is evident that such schemes are still being promoted by some individuals in the government. In 1979 the Minister of Transport, Henry Kroeger, promoted renewed studies of potential irrigation expansion based on water diversion from northern rivers. The Water Advisory Committee, set up by Kroeger, was formed primarily to lobby members of the cabinet into increasing water supplies by transfer to southern Alberta. The committee has asked the cabinet to provide funding for a detailed physical survey of all apparently irrigable and potentially drainable crop lands in southern and northern Alberta respectively (Alberta Legislature, 1981).

Recent pedological studies in the South Saskatchewan River basin have identified large tracts of irrigable land (Canada West Foundation, 1982) but much of the identified land (particularly that in East Central Alberta) is of only marginal value for irrigation because of poor soil conditions and uneven topography. Pettapiece and Kjearsgaard(1981) suggest that north of the Red Deer River in East Central Alberta there are possibly 100,000 ha of land with a "fair" potential and another 200,000 ha which are marginal for

irrigation. A small irrigation project (ie. less than 50,000 ha) could perhaps be supplied with adequate volumes of water without the need for a large scale interbasin water transfer (this is discussed further in chapters four and five). Nevertheless, the report of the committee also recommends studies be undertaken to develop a "comprehensive plan for the interbasin transfer of water from Northern Alberta to the South Saskatchewan River Basin" (Alberta Legislature, 1981: pg 25). A cabinet decision in November 1981, leaves the impression that the government is deferring major water diversion, but remains interested in smaller diversion schemes (Byfield, 1982).

The Water Resources Committee has pointed to irrigation expansion within Alberta as a potential means of alleviating world food shortages (Alberta Legislature, 1981: pg. 10). Proceeding from the assumption that this is the best means available it has recommended that more studies be undertaken to determine the extent of irrigable land, as well as the potential for transferring water from northern basins to bring this land into production. Expansion of irrigation agriculture, as noted previously, has been used as a justification for most large scale interbasin water transfer schemes. Let us evaluate this argument for interbasin water transfer in Alberta.

First the threat of impending food shortage is of great concern, but it is far from obvious that the best way to deal with it is to raise more food in North America, especially through development of marginal croplands in Alberta. The heavy processing, transporting, and marketing costs involved in getting food to the needy would erase most if not all advantages that might be gained by producing it here; transfer of technological skills and direct technical assistance in the areas where the food is consumed would bring far greater returns (Crutchfield, 1967; Phillips, McMillan and Veeman, 1981).

Secondly, it is by no means certain that potentially irrigable land will be developed as anticipated simply because sufficient water is supplied to irrigate it. Several social and economic considerations must be addressed, such as the future potential market for the agricultural produce, ultimate size of the irrigation project(s), policy regarding the maximum individual land holding allowed within the project and effects the project will have on surrounding communities. For example, there is the possibility if land acquisition is unlimited, that large corporate interests would purchase large tracts of land within a project in order to produce cheap fodder for large cattle feed lot operations, as has

happened in southern California. It is unlikely that Albertans would massively subsidize development involving only 20 to 40 operators. Conversely, if land acquisition limitations were too stringent to allow a profitable farming operation, very little of the project land might be developed. This was what happened in the South Saskatchewan River Project in Saskatchewan where the maximum amount of land which could be acquired was considered to be too small to develop profitably by many of the farmers in the area (Laycock, 1981).

Thirdly, such a project would comprise a massive subsidy to a relatively small number of users. The Government of Alberta now pays the total capital and maintenance cost of irrigation headworks (this is where most of the expense of transfer would be incurred) and shares the capital and rehabilitation costs of the Irrigation Districts. The cost-sharing split for local distribution systems is 86% from the province and 14% from the Irrigation District; very few of the U.S. Bureau of Reclamation irrigation projects have as high a level of subsidy (Frederick and Hanson, 1982). The Alberta Government has provided funding for the rebuilding, rehabilitation and enlargement of the main irrigation canals and headworks systems which deliver water to the irrigation districts ($150 million from 1980 to 1995 carried totally by the province) and also for the water distribution systems within districts ($100 million from 1980 to 1985 with 14% payed by the districts) (Cookson and Schmidt, 1980). What is really involved, then, in the suggestion that the government intervene to prevent water scarcities in the South Saskatchewan basin, is a massive subsidy, borne by all Albertans, and designed to guarantee a rate of regional growth in southern Alberta independent of the cost of water. It is important to realize that irrigation projects do not pay for themselves and that they represent a marginal water use.

Fourthly, and most importantly, it is by no means clear that large scale interbasin water transfer is the best method of increasing the available water supply in order to meet expanding demands in the South Saskatchewan basin. Other water management alternatives do exist and although some of them have been identified, they have been given little emphasis in past development studies within the basin.

Several issues pertaining to the management of water supplies in southern Alberta have been alluded to, and it is important at this point to place water transfer in general, and this study in particular, in proper perspective. There are many facets to the controversy

over interbasin transfer in Alberta; the broad range of issues can be loosely grouped into three areas of concern: i) Provincial economic development policies and their relationship to water management, ii) the proper application of economic, social and environmental evaluation procedures to water development projects, and iii) water demand management and forecasting.

Perhaps the heart of the water supply and demand conflict revolves around the question of whether or not continued economic development in southern Alberta should be the primary objective for the management of Provincial water resources. According to the Alberta Government, the basic objective for the management of water resources in Alberta is to support the overall economic and social objectives of the Province:

> The Government's commitment to a program of balanced economic growth, the general welfare of Albertans, and the present and future quality of life are overriding considerations in water management. The supply of good quality water should not be a limiting factor in achieving these economic and social objectives.[4]

The development of water resources is apparently closely aligned with the government's overall regional development policy in which balanced economic development is an important ingredient. Balanced economic development has often been cited as an objective and used as a justification for further investment in large scale water resource development schemes in Alberta. This objective was cited in regard to both the Oldman River Basin Studies and the Red Deer River Flow Regulation Study which are briefly discussed in the following section on South Saskatchewan basin supply augmentation.

Given that balanced economic development is a valid objective for future water resource management, not only is it important that the precise economic development policies be clearly defined but also that water resource planning objectives and future development projects be in line with these policies. A review of economic and water resource development policy perspectives in Alberta is provided by Plain(1981), who concludes that the development of "operational" water resource and regional development policies is dependent upon the identification of specific regional development targets within each region of the Province.

The advancement of intermediate and long-range regional economic and water resource planning is, in turn, dependent upon two factors: i) accurate determination of

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[4]Alberta Environment 1979. *Water Resource Management Principles for Alberta*, p. 9.

existing quantitative and qualitative demands for water within various basins, and ii) the forecasting of future demands based on the pattern of urban and industrial growth and recreational use which is to be encouraged within each basin. Forecasted shortfalls in water supply, in the face of increasing demands in southern Alberta, have provided a major impetus for proposed large scale interbasin transfers. Those who argue against this form of "supply side" water management, suggest that a determination of the true "needs" rather than "demands" for water in the South Saskatchewan basin is required. It is felt that inefficient and wasteful water use obscures the measuring of need and thus focus is placed on meeting demand (Gysi, 1981). Reductions in domestic water use on a per capita basis would alleviate the situation somewhat; however, municipal and industrial water demands are small compared to those for irrigation (ie. equivalent to only 14% of the total net use in agriculture in 1978 for the Saskatchewan-Nelson basin).[5]

The primary reason for increasing available water supply in the South Saskatchewan basin is to allow for irrigation expansion in the region. Expansion of irrigated agriculture in both Southern and East-Central Alberta have been cited as potential regional development targets for the province (Alberta Legislature, 1981 and Horner, 1981). However, on strictly economic grounds there is some question as to the merit of expanding irrigation. Based on a review of the Oldman River Basin irrigation proposals, Phillips, McMillan and Veeman(1981) suggest that the development of internal basin supplies through a dam on the Oldman River cannot be economically justified and they suspect that the economic merits of water diversion from northern Alberta to supplement Oldman supplies are even less attractive. It is also suggested that the economics of water transfer to the scattered areas of non-solonetzic soils in East-Central Alberta are poorer still.

This conclusion does not mean that such development might not become economically attractive in the future with irrigated land being used more extensively for high value crops or with a rise in current crop market prices. Alternatively, other regional development objectives may override economic efficiency goals. Such objectives might include the impact on the provincial distribution of income, and the diversification of economic activity and population growth in the province.

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[5]Prairie Provinces Water Board 1982. *Water Demand Study: Historical and Current Water Uses in the Saskatchewan-Nelson Basin*, Main Report, Regina, p. 130.

In Fig. 3 the theoretical range of adjustments that may be employed by provincial water managers in response to growing shortages in the supply of water available for irrigation development are displayed. In Fig. 3 the various adjustments are separated into isolated categories. However, the overall adjustment to the water shortage should involve a combination of these individual adjustments as opposed to an isolated application of a single adjustment. For instance, a decision to support future irrigation expansion does not rule out the possibility of periodic adjustments to shortage during exceptionally dry years. Similarly, a decision to develop interbasin transfer does not mean that adjustments related to modifying the demand and supply within basins are ruled out. Indeed, the most effective adjustment to water supply shortages could very well involve the combined application of all the categories of adjustment shown in Fig. 3. Since the focus of this study is on water transfer, a detailed discussion of the entire range of adjustments to growing demands for water in the South Saskatchewan basin is beyond the scope of this research. Several of the means of modifying demand and adjusting to a shortage have been previously alluded to, they include: i) improving irrigation efficiencies, ii) limiting irrigation expansion, iii) changing agricultural practices in dry years, and iv) incorporating a water pricing scheme. Modifying water supply within the South Saskatchewan basin could involve such adjustments as: i) changing the downstream allocation arrangement within the basin in favour of particular sub-basins, ii) improving the runoff storage potential in the basin, and iii) managing the watershed to increase runoff.

In the following section some of the water management issues which have fostered proposals, to augment water supplies in the South Saskatchewan basin are reviewed. Following this review, interbasin transfer from the Clearwater River into the Red Deer basin is presented as a possible means of alleviating future water supply shortages in southern Alberta.

C. South Saskatchewan Basin Supply Augmentation

Agriculture, albeit the largest water use in the South Saskatchewan basin, is not the only one; other instream and withdrawal uses are also of concern. They range from federal-provincial and international contractual obligations (apportionment), through municipal and industrial water uses, to stream flow maintenance for recreational, fish and

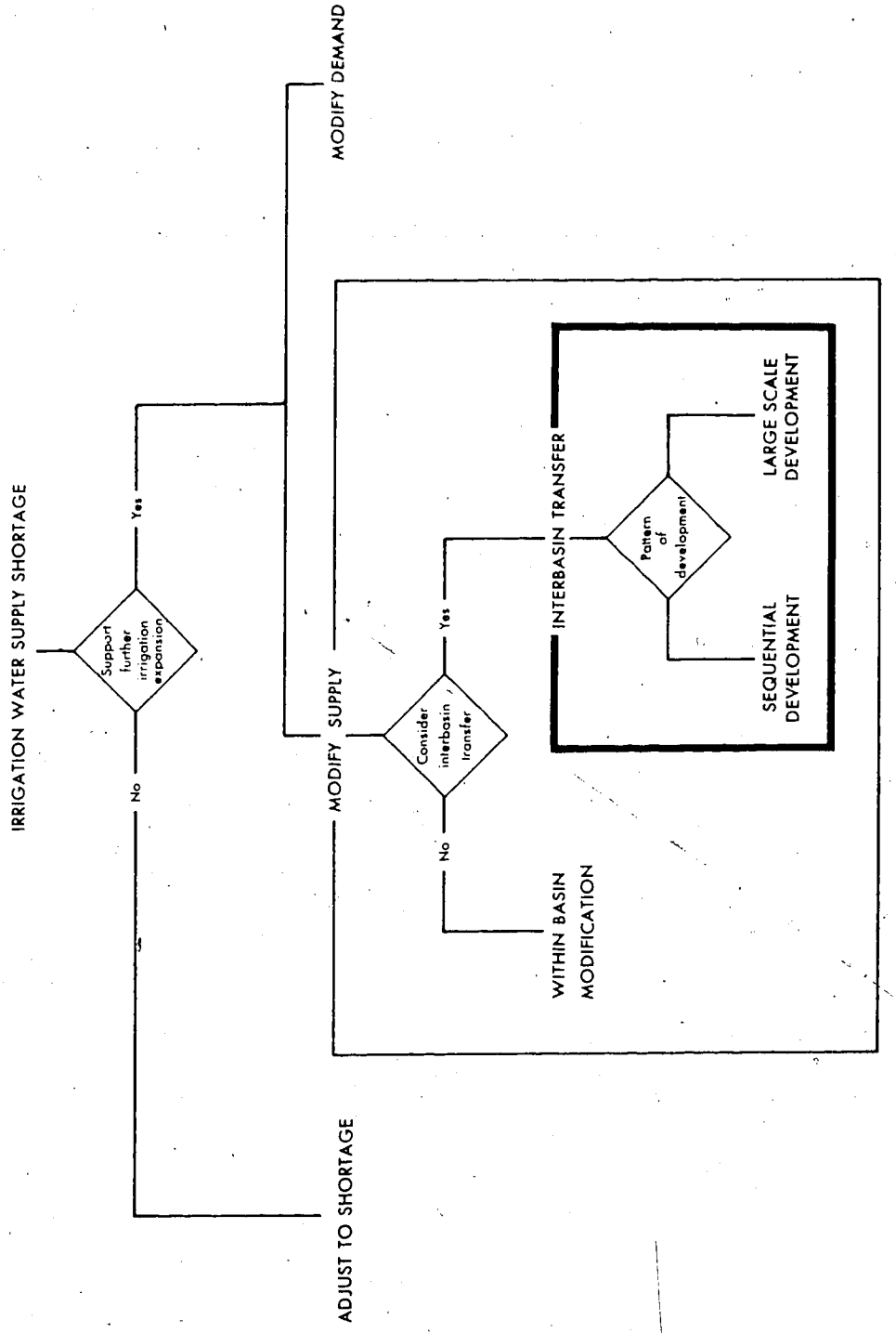


Fig.3 Theoretical Range of Adjustment to Irrigation Water Supply Shortage

wildlife uses.

The Oldman River Basin and Red Deer River Flow Regulation Planning Studies address the water supply and demand issues in these river basins. The ongoing South Saskatchewan River Basin Planning Study being carried out by the Alberta Environment Water Resource Planning Division is an attempt to first identify basin objectives for water management, to analyze management options which would meet those objectives and to recommend a management strategy for the basin. Several of the major water management issues for Alberta and much of the basic information concerning current water supplies and their uses are reviewed in reports by the Canada West Foundation(1982) and the Prairie Provinces Water Board(1982).

In 1974 the provincial government identified irrigation in southern Alberta as a high priority water use, with first priority being an examination of current and future water use requirements in the Oldman River Basin. The Phase I studies completed in 1976, supported the construction of an onstream storage dam at either the Brocket or Three Rivers site (Alberta Environment, 1976a). Several offstream storage reservoirs already existed within the basin but it was felt that a larger percentage of the spring runoff should be stored if irrigation and other needs were to be met in dry years.

Strong public reaction to this study caused the government to initiate the more comprehensive Phase II studies and carry out public hearings (administered by the Environment Council of Alberta) on the management of water resources in the Oldman basin. Following the completion of this study in 1978, it was recommended that rapid rehabilitation of the irrigation water delivery system, in order to improve water use efficiencies, should proceed and that construction of onstream storage dams be deferred for an indefinite period (Oldman River Study Management Committee, 1978; EQA, 1979).

It was suggested during the Oldman River Management Study that the useable supply of water in the Oldman River could be increased if commitments to downstream use could be reallocated to the other tributaries of the South Saskatchewan River. The Master Agreement on Apportionment was signed by each of the Prairie Provinces and Canada on October 30, 1969 (PPWB, 1969 and Alberta Environment, 1979). This agreement, which is administered by the Prairie Provinces Water Board, commits Alberta to deliver to Saskatchewan one-half of the natural discharge of streams which flow

eastward across the Alberta–Saskatchewan boundary. Alberta is entitled to a quantity of water equal to a net depletion of one–half the natural flow of the river. The total discharge is accounted for on a yearly basis. The discharge is a combination of the Red Deer and South Saskatchewan River discharges.

Although 50% of the natural flow of the South Saskatchewan is currently allocated to downstream use in Saskatchewan this could be reduced by increasing the allocation percentage of Red Deer River flow to greater than 50%. By increasing the volume of water allocated to Saskatchewan from the Red Deer an equivalent volume would become available for use in the South Saskatchewan River basin. Hence, South Saskatchewan basin users in Alberta would be able to use more than 50% of the natural flow in their basins.

Suggestions that flow commitments for the Red Deer River be increased from the original 50% to 75% of the natural flow of that river met with opposition. Richard White(1978) of the Red Deer Regional Planning Commission, maintained that this exploitation of the Red Deer basin for the benefit of the Oldman basin was not consistent with government policy providing for balanced economic growth through natural resource development. Augmenting the economic growth potential of one basin at the expense of another was seriously questioned even though it was felt that an allocation of 75% of the Red Deer flow would not cause any immediate hardship in the Red Deer basin unless consumptive demands in the basin increased substantially. There is much concern over how to apportion the flows of the Red Deer, Bow and Oldman Rivers. According to Primus(1981), this is the basic question now facing the Province in the South Saskatchewan basin. If some of the basins are allowed to consume more than 50% of natural streamflow, then the others will have to allocate more than 50% of their streamflow to meeting interprovincial commitments. The implications of such a decision are obvious; the basin with an extra allocation will grow at the expense of a basin whose supplies are restricted.

Alternatively, any scheme designed to increase flows in the Red Deer River could also produce excess deliveries to Saskatchewan which could then be applied against any deficiencies in delivery from the South Saskatchewan branch of the system. Proposals to increase flows in the Red Deer River hold promise for increasing useable supplies of water in the South Saskatchewan Basin without seriously jeopardizing future development

in the Red Deer Basin. Construction of onstream storage dams on the Red Deer River and interbasin transfer of water from the North Saskatchewan River Basin are two of the more thoroughly investigated alternatives for increasing Red Deer River flows.

The recent construction of Dickson Dam on the Red Deer River is another example of the relationship between regional development objectives and water resource development planning. Although this dam could be operated in a manner that would increase the average annual discharge of the Red Deer through storage from wet to dry years, this would conflict with the proposed manner of operation. The principal purpose of Dickson dam is to provide regulation of the Red Deer River in order to: i) increase low winter flows and thus make the central Alberta region more attractive for future industrial expansion, and ii) encourage decentralization of future industrial and population growth in central Alberta by providing an adequate water supply (Alberta Environment, 1975a). Secondary objectives such as flood protection, erosion control, creation of recreational potential on and around the reservoir and hydropower production were also suggested but not all can be realized given the single-purpose nature of proposed reservoir operation.

As with the Oldman River Basin Studies, a great deal of controversy surrounded proposals to construct Dickson Dam. Many of the concerns are discussed by Wycock(1977), who concluded that short term needs in the Red Deer basin could be met low cost, integrated, alternative means (notably transfer from the Clearwater and conjunctive use of groundwater).

D. Water Transfer From the Clearwater River

The Clearwater River in West-Central Alberta is the southernmost significant tributary of the North Saskatchewan River. Approximately 20 km up the Clearwater from its confluence with the North Saskatchewan, near the locality of Butte, the surface drainage divide between the Red Deer and North Saskatchewan River Basins is exceedingly low (ie. less than 2 m). The ease with which water could be diverted across this divide has been recognized for many years.

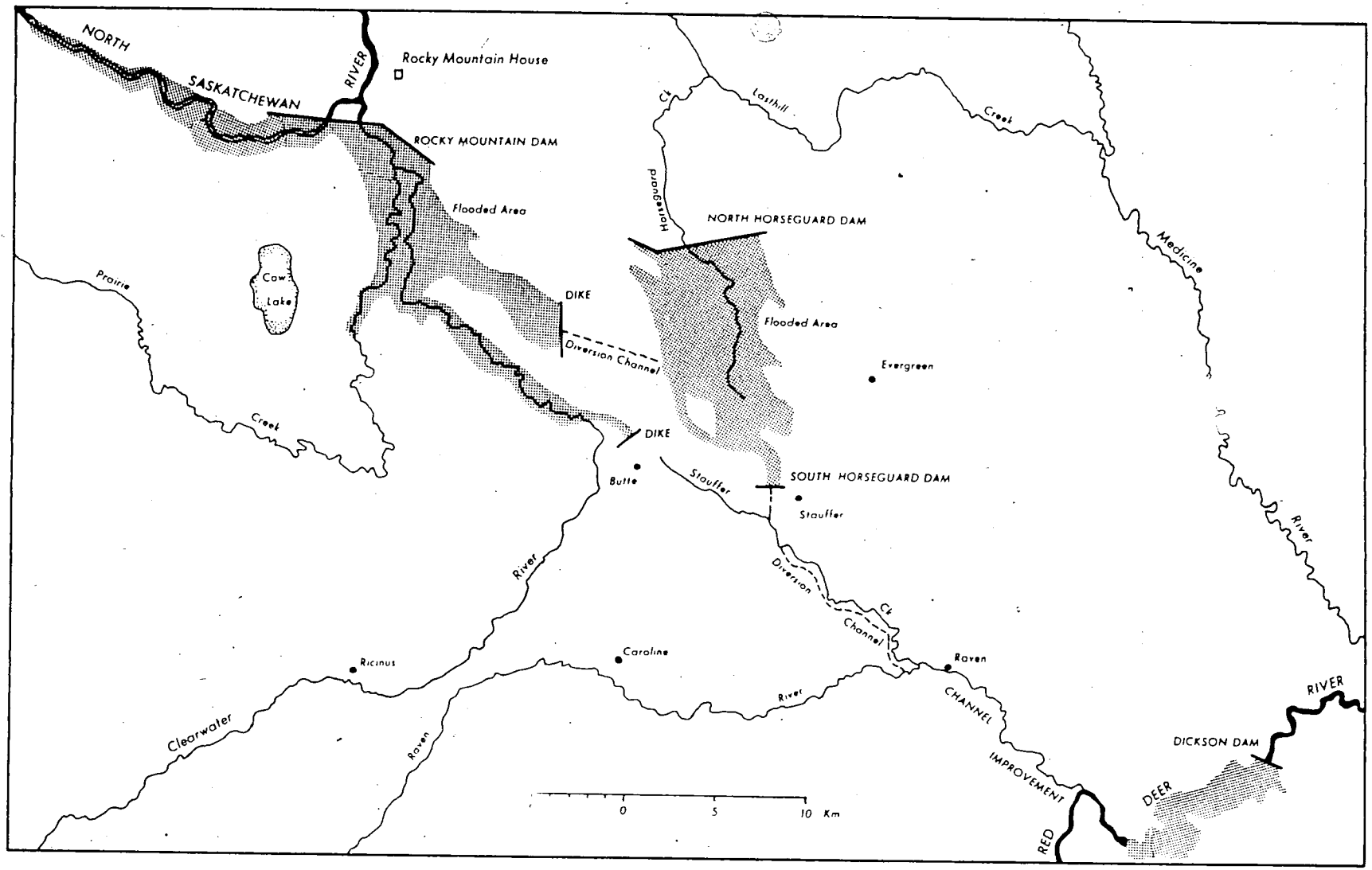
Although the information is unsubstantiated, Dean(1982: pers. comm.) suggested that as early as 1919 it was proposed that a small rock-fill dam be built in order to raise

the level of the Clearwater and divert water into the Red Deer Basin. It is not known who proposed this dam or for what purpose the water was to be used. William Pearce's plans also incorporated Clearwater diversion, as have most Alberta interbasin transfer proposals since then, including those of Russell(1948), Magnusson(1967-1969), PRIME and the SNBB. The most detailed and ambitious proposal for Clearwater diversion is that of the SNBB which includes plans for combined transfer from both the North Saskatchewan and Clearwater Rivers.

The SNBB scheme would consist of a dam across the North Saskatchewan and Clearwater Rivers which would raise the water level approximately 46 m to permit gravity diversion to Horseguard Reservoir (see Figure 4). The resulting reservoir would extend up the North Saskatchewan about 16 km, up Prairie Creek about 10 km and up the Clearwater as far as Butte. From this "Rocky Mountain Reservoir" a 5 km channel would be constructed to convey diverted water to the Horseguard Reservoir which would provide interim storage for the diverted water. The stored water would be released from the reservoir into a channel which would parallel Stauffer Creek and empty into the Raven River at the locality of Raven. Channel improvements along the Raven River would be required to convey diverted flows the rest of the way to the Red Deer River.

The detailed project data and cost estimates are listed in the SNBB Project Catalog for 4 different diversion capacities ranging from 28 cms to 113 cms. The total project would involve the flooding of approximately 14,200 to 16,700 ha of land, construction of 25 km of canal, 3 dams and 2 dikes, and cost between $128 and $135 million (in 1968 dollars).

Even though cheaper, potentially less detrimental, small scale diversion possibilities exist on the Clearwater the large scale dams and reservoirs have been the only possibilities studied. This research is aimed at investigating the more modest development alternatives which exist for water transfer from the Clearwater. As pointed out by Laycock(1981), there is currently no pressing need for large increases in water supply in the South Saskatchewan basin; transfer from the Clearwater could be considered as a small step in a larger interbasin transfer development planning sequence. This possibility is discussed in chapter five in relation to the utilization of various physical transfer components for transferring water from the Clearwater. Such development should be conjunctive with



Source Canada, Alberta Saskatchewan and Manitoba 1972 Water Supply for the Saskatchewan Nelson Basin SNBB Study. Appen 3. Project Catalogue

Fig 4 Proposed SNBB Water Transfer and Existing Dickson Dam Development

management of growing water demands and increased storage of water within the South Saskatchewan basin from wet to dry years. If and when larger amounts of water are required, diversion from the Clearwater could be increased by construction of an upstream storage dam; eventually the North Saskatchewan itself might be tapped. This idea of sequential development was proposed in Alberta's PRIME plan (Bailey, 1969) but the demand for water was greatly overestimated and as a result smaller, interim alternatives for augmenting supplies were ignored. The review of alternatives in the Red Deer River Flow Regulation Study (Alberta Environment, 1976b) is encouraging in this regard but it appears that small scale alternatives to the proposed dams are viewed as mere "stop-gap" solutions to a problem which ultimately only a dam can solve.

Summary

It was found that in both the Western United States and Alberta, attempts to maintain and expand agricultural production through irrigation have provided the incentive for most water transfer proposals. Past transfer proposals, both on a provincial and an international scale, were met with great opposition. The astronomical costs and unacceptable impacts associated with past interbasin transfer proposals have rendered them unworkable not only on economic and environmental bases but also on a political basis. It is instructive to realize that many of the problems associated with past water transfer proposals are related to both the scale of development and the general lack of consideration of environmental, social, political and economic factors involved. It has been suggested that current proposals for interbasin transfer on behalf of the Water Resources Committee exhibit many of the same weaknesses as past proposals and opposition to such development will remain strong. What is required in future water planning is a greater emphasis on exploring alternative solutions to management problems. Interbasin transfer is just one of several water management alternatives that could be implemented to alleviate water supply and demand conflicts in southern Alberta, other management alternatives were identified.

It was suggested that transfer from the Clearwater could be developed at relatively low cost with relatively little detrimental impact and perhaps even compensating environmental enhancement. In so doing, it could prove to be an acceptable compromise

between the the "no transfer development" and "large scale transfer development" positions. It is with these ideas in mind that alternatives are explored in chapter five for diversion of Clearwater flows.

III. STUDY AREA

The study area encompasses 3520 km² in West Central Alberta as shown in Fig. I.2. This area is part of the high western Alberta Plain, is greater than 50% cultivated, and is in a natural vegetation zone classified as an aspen ecotone to spruce. The topography ranges from level and undulating to gently rolling, with local relief generally decreasing from west to east. The boundaries of the study area were chosen with three concerns in mind: i) to include the Red Deer and Medicine Rivers which could receive water from a Clearwater transfer, ii) inclusion of the North Saskatchewan River, of which the Clearwater is a major tributary, and which has been considered as a future source of water for the South Saskatchewan Basin and, iii) to center the study area on the portion of the Clearwater River where an interbasin transfer of water to the Red Deer basin could most easily be effected.

The aim in this chapter is to provide a description of the type, quality and areal distribution of basic environmental and cultural resources in the study area. This information will be used in chapter five (in conjunction with the detailed water reource information discussed in chapter four) in both the design and assessment of Clearwater transfer alternatives. This knowledge of the resource base in the study area proved useful in the evaluation of environmental and socio-economic effects of water transfer development in the study area.

What follows is a brief discussion of the water courses within the study area and a more detailed review of the topography with particular reference to the surficial and bedrock geology. The sequence of deglaciation which partly determined the existing physiographic pattern will be discussed and a brief outline of the types and distribution of soils and vegetation in the study area will be presented. A review of the community structure is presented with reference to land use and population distribution.

A. Water Courses

The drainage divide between the North Saskatchewan and Red Deer River basins separates the study area into two drainage systems, the North Saskatchewan basin which incorporates 705 km² of the study area and the Red Deer basin which incorporates 2815 km². Three major physiographic regions are included in the drainage basins of streams of

the study area – the Cordilleran, Foothill and High Plains regions are all represented. The study area itself, with the exception of small foothills areas on the western boundary, lies almost entirely within the High Plains physiographic region.

In Table 1 some basic data for each of the streams metered by the Water Survey of Canada are shown. The location of the gauging stations is indicated in Fig. 1. It is apparent that for the streams in the study area, the size of the drainage basins as well as the mean discharge and runoff values vary considerably. The potential of the various streams shown in Table 1, in terms of annual water supply available, is striking. A detailed discussion of streamflow regime, drainage basin characteristics and related hydrologic factors is presented in chapter four.

In relation to the potential of the Clearwater River, the mean annual discharge of the Clearwater (above Prairie Creek) is equivalent to 30% of the annual Red Deer River discharge at Red Deer, but only 11% of the North Saskatchewan discharge at Rocky Mountain House. Hence, on a purely quantitative basis, the proportional increase in annual discharge on the Red Deer as a result of Clearwater transfer would be greater than the proportional decrease in the annual discharge of the North Saskatchewan. The high runoff for the North Saskatchewan (410 mm) in comparison with that of the Red Deer (130 mm) which has a similar basin area, is indicative of the larger proportion of high yield cordilleran and foothills areas in the North Saskatchewan basin as opposed to the lower yield plains areas in the Red Deer basin.

The higher yield of foothills streams is exemplified through comparison of the mean annual runoff for Prairie Creek (160 mm) and the Medicine River (which drains a plains area; 40 mm). The Raven River which drains an area on the boundary between the foothills and plains, has a basin area which is only a third of that for the Medicine River and yet it contributes approximately the same volume of water to the Red Deer River (ie. 4% of the mean annual discharge at Red Deer). Therefore it is apparent that the potential discharge of the particular basins is not so much a function of the actual drainage area as it is the character of that area. This point is discussed further in chapter four.

TABLE 1

General River Basin Data for Streams in the Study Area

	Drainage Area (km^2)	Mean Annual Discharge (dam^3)	Mean Monthly Discharge (cms)	Mean Annual Runoff (mm)
N. Sask. River at Rocky Mtn. Hs. (5DC001)	11,000	4,460,000	141.4	410
Red Deer River at Red Deer (5CC002)	11,600	1,550,000	49.1	130
Clearwater River at Dovercourt (5DB006)	2,230	473,000	15.0	210
Medicine River near Eckville (5CC007)	1,910	68,300	2.2	40
Raven River at Raven (5CB004)	655	67,200	2.1	100
Prairie Creek near Rocky Mtn. Hs. (5DB002)	860	135,200	4.3	160

Source: Historical Streamflow Summary, W.S.C. 1979.

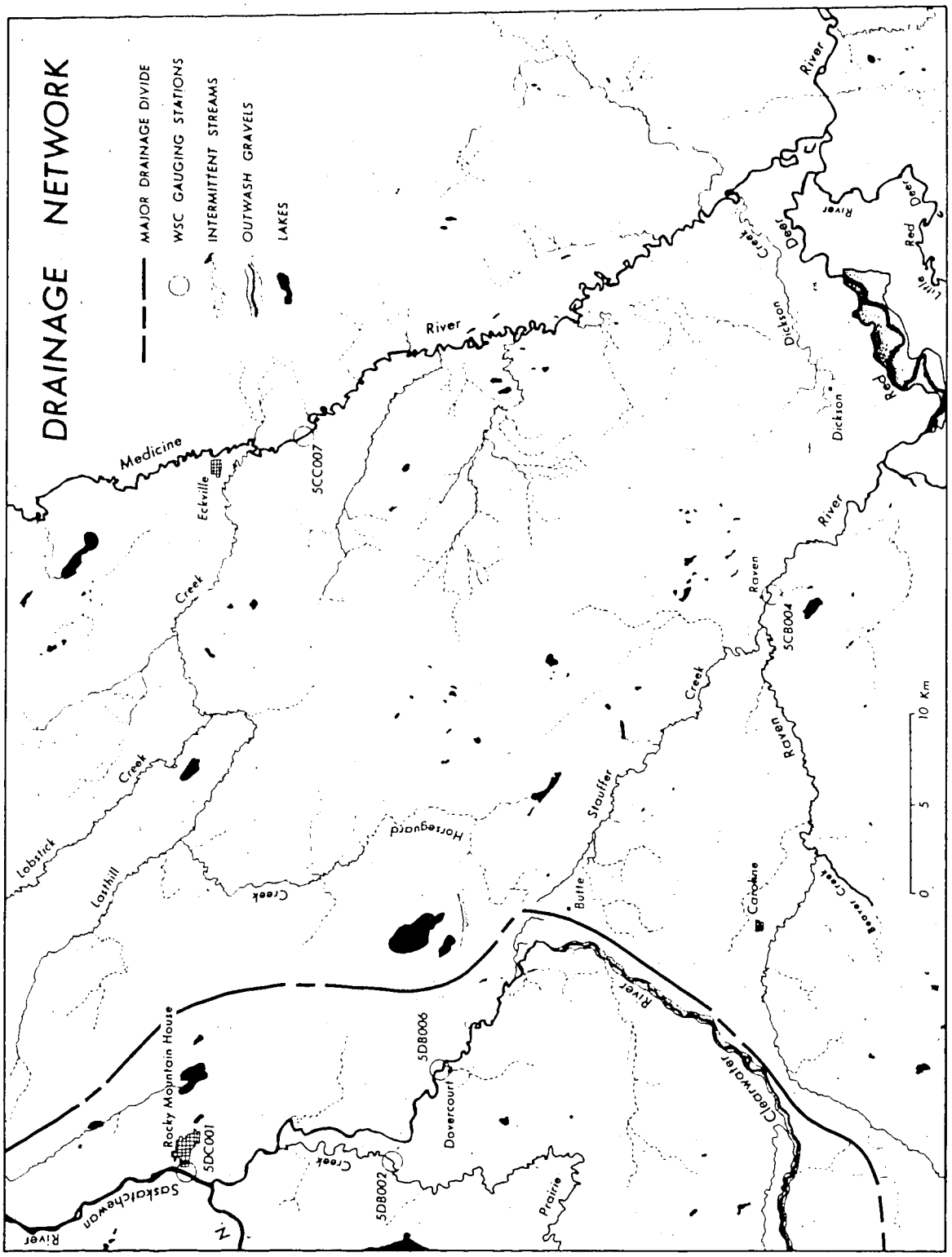


Fig 1 Drainage Network

North Saskatchewan Basin

Within the study area there are three streams in this basin – Prairie Creek, the Clearwater River and the North Saskatchewan River. Prairie Creek is tributary to the larger Clearwater River which is, in turn, tributary to the North Saskatchewan River. All three of these streams drain Eastern Slopes areas of varying size and hydrologic character. The differences in flow regime for the streams in the study area are discussed in the following chapter.

The North Saskatchewan River flows across the northwest corner of the study area; at this point it has drained an extensive mountainous region originating at the Saskatchewan Glacier on the Continental Divide and extending eastward through the Eastern Slopes and foothills regions of the Rockies. Bighorn Dam and Abraham Reservoir, 120 km upstream from Rocky Mountain House, alter the natural flow regime of the North Saskatchewan. They are operated principally to produce hydroelectric power, increasingly for peaking power production.

The "natural" flow regime of the North Saskatchewan is characterized by low base flows in the winter with sharp increases in April and May as snowmelt runoff begins to contribute to streamflow. Runoff from the higher elevation snowfields and glaciers maintains consistently high streamflows throughout the summer. This is exemplified by the high mean annual runoff shown in Table 1 (410 mm). Summer rain also contributes to increased flows and often leads to flooding. Operation of Bighorn Dam has increased the amount of flow in winter and reduced peak flows in the spring. Because the North Saskatchewan is the primary source of fresh water for many downstream communities, particularly the City of Edmonton, reduction in streamflow as a result of transfer from the Clearwater is of concern. However, it is believed that the scale of transfer envisioned for this study would generally have little effect on the future ability of the North Saskatchewan River to meet downstream demands. If large scale transfer from the North Saskatchewan does develop the Clearwater transfer might well be part of a larger program of sequential transfer in which water from the Athabasca basin might meet future needs in the North Saskatchewan basin.

The Clearwater River is the southernmost significant tributary of the North Saskatchewan. It originates near Mt. Willingdon in Banff National Park approximately 20 km from the Continental Divide and flows eastward draining an area of the Eastern Slopes south of the Ram River and north of the Red Deer and James Rivers. Within the study area the channel gradient changes from approximately 4.2 m/km, in a section from Ricinus to a point near Butte, to a gradient of 1.8 m/km from Butte to its confluence with the North Saskatchewan. A significant change in channel morphology accompanies this rapid change in slope. From Ricinus to Butte the Clearwater is highly braided with a wide gravel and sand valley outwash train. The existence of large unstable gravel bars is indicative of low channel stability and rapid rates of channel modification and migration across the outwash during high flow stages. This channel instability could cause problems with the installation of diversion structures (weirs, headgates, dikes, pumps, etc.) and channel stabilization may be required. For instance, where Highway No. 54 crosses the Clearwater, a large section of river bank has been stabilized with concrete gabions in order to prevent further bank erosion which might threaten the bridge footings. From Butte to the North Saskatchewan, the Clearwater becomes a single meandering channel of uniform width with relatively stable sand and gravel point bars.

Throughout the study area the Clearwater flows very close to the drainage divide in the southern section, the channels of the Raven and Clearwater come within 1.5 km of each other and the height of the divide is between 15 and 20 m. This would be the shortest transfer route from the Clearwater to a direct tributary of the Red Deer River (ie. Raven River). In the vicinity of Butte the height of the drainage divide drops to as little as 1.5 to 2.0 m. This would be the easiest location to divert water into the Red Deer basin from the Clearwater. Along this reach the Clearwater flows along the northwest edge of an ancient proglacial fan-delta deposit. In the past, the Clearwater River flowed along the southern flank of the delta and down what is now the Stauffer Creek Valley. This delta, which will henceforth be referred to as the "Clearwater delta", has been mentioned by Laycock(1977, 1981) and is described in more detail in following sections on surficial geology and groundwater.

The Clearwater delta area is a focal point for this study. Because of the unique hydrologic character of the delta area, a wide range of interbasin transfer methods are

plausible. For instance, it is apparent that riparian groundwater from the Clearwater River flows through the delta deposits into the Red Deer basin and appears as spring flow on the eastern edge of the delta in the headwaters of Stauffer Creek. In effect then, a considerable amount of interbasin water transfer is naturally occurring. Several alternative methods of increasing the rate of groundwater flow through the delta will be discussed in later sections. Another indicator of the prolific groundwater movement through the delta is the large spring which arises on the north edge of the delta 1.5 km north of the locality of Butte. This spring, henceforth referred to as "Butte Spring", forms a significant stream which flows northwest to the Clearwater River.

Prairie Creek is a tributary of the Clearwater which drains a small, timbered, foothills region to the west of the study area between the Ram River drainage basin and the Clearwater River. The creek flows 113 km out of the Clearwater Forest Reserve thro h a wide, shallow valley for much of its length. Even though Prairie Creek drains quite a small area its mean annual discharge is twice that of the Medicine River, which has twice the drainage area, and almost one third that of the Clearwater at Dovercourt. The large reduction in the runoff to precipitation ratio that occurs from foothills to high plains drainage basins was previously indicated by comparing the Prairie basin unit area yield with that of the Medicine River (see Table 1).

Red Deer Basin

There are two rivers which drain the Red Deer basin portion of the study area – the Medicine River and the Raven River. The hydrologic characteristics of these two drainage basins differ considerably. The Raven drains portions of both the foothills and high plains physiographic regions the Medicine drains only a high plains region.

The upper portion of the Raven drains a forested low foothills area similar to the middle section of the Prairie Creek basin; the lower portion drains an area of decreasing relief and increasing cultivation as it flows eastward to the Red Deer River. Stauffer Creek (also known as the North Raven River) is a tributary of the Raven which drains an area from its origin at the southeast edge of the Clearwater delta to its mouth about 20 km to the southeast, near the locality of Raven. A significant proportion of the discharge of the Raven (measured at WSC 5CB004) comes from Stauffer Creek. Thus, underflow

from the Clearwater River provides a significant proportion of Raven River discharge.

Beaver Creek is another small yet significant tributary of the Raven, like Stauffer Creek, the majority of its flow originates from a spring. The Beaver Creek spring supplies the water for the provincial spawning station located 5 km southwest of Caroline. Because of the consistency of flow and water temperature in the Raven River system, largely due to groundwater discharge, it supports perhaps the best trout fishing in Alberta. The nature of the exceptional fish habitat and populations found in these streams will be discussed in the following chapter together with the possible impacts (both positive and negative) that alteration of flow regime and channel morphology might have on them.

The Medicine River drainage basin is characterized by low gradient, highly sinuous and low discharge streams. The Medicine originates in Medicine Lake 30 km north of the study area; it flows southeastward draining a large area between the Blindman River and Sylvan Lake basins on the east and the North Saskatchewan River basin on the west. Within the study area many small, intermittent streams contribute to streamflow during the brief spring runoff period and after heavy precipitation events. Lasthill Creek is the only significant perennial tributary to the Medicine within the study area. Dickson Creek and Tindastoll Creeks, near the mouth of the Medicine, make minor contributions.

Lasthill Creek and one of its tributaries, Lobstick Creek, both flow in broad glacial spillway channels which extend to the southeast from very near the North Saskatchewan River all the way to the Red Deer River. They served as proglacial and early post-glacial channels of the North Saskatchewan River until the latter was captured to the north. Because of this they could be used as transfer routes from the North Saskatchewan. The flow in these streams is sluggish and the in-channel plant growth is excessive. Partly because of this, the potential fish and aquatic invertebrate habitat is extremely limited. The same conditions exist in Horseguard Creek which drains an area of interspersed muskeg and poorly drained pasture land originating 2 to 5 km northeast of the Clearwater delta. The possibility of actually creating sport fish habitat and hence new recreational opportunities by diverting water into the Medicine system via Horseguard and/or Lasthill Creeks is discussed in following chapters.

B. Surficial Geology

In the study area only one bedrock unit, the Paleocene Paskapoo Formation, is present at the surface. This formation consists of a succession of greyish, calcareous sandstones, siltstones and mudstones which dip slightly to the northeast. The surface expression, while generally subdued, is characterized by several low, southeast-trending bedrock ridges. See Figure 2 for general topography of the study area. Note the lack of a defined valley at the point where the Clearwater River turns northwestward, as mentioned previously the Stauffer Creek Valley (an old spillway channel) was once the route of Clearwater flow. The distinct outline of the Lasthill and Lobstick spillway channels is also evident on the northern edge of the study area.

The Paskapoo is underlain in the subsurface by the Upp etaceous Edmonton Group and the Belly River Formation. The strata of these formations within the High Plains region dip to the southwest at shallow angles, the angle of dip increases steadily in that direction (Tokarsky, 1971). The strong northwest-southeast topographic trend is a striking feature in Fig. 2, it is largely a result of past glacial activity in the area.

The surficial deposits are largely of glacial origin, with tills and glaciolacustrine sediments predominant. The North Saskatchewan, Clearwater and Red Deer River valleys have been infilled with postglacial gravels, and in these a number of terraces have been cut. Organic sediments occupy the courses of many former proglacial drainage channels. The surficial geology of the study area is displayed in Fig. 3 as interpreted by Boydell(1972). By reviewing the surficial geology of an area some insight into the recent depositional and erosional processes responsible for shaping the landscape can be obtained. In following sections the pattern of deglaciation and soil distribution are discussed in relation to the surficial deposits. The surficial deposits in the study area can be grouped into three categories according to their period of deposition: i) "Recent deposits" which include organic and alluvial depositional features, ii) "Pleistocene to recent deposits" which include only aeolian sands and, iii) "Pleistocene deposits" of glaciolacustrine, glaciofluvial and strictly glacial origin.

Recent alluvial deposits are present along most of the streams in the map area. Along the larger rivers, recent alluvium consisting of gravel and sand overlies Pleistocene alluvial outwash sediments consisting of boulders and coarse gravel and alluvial terraces.

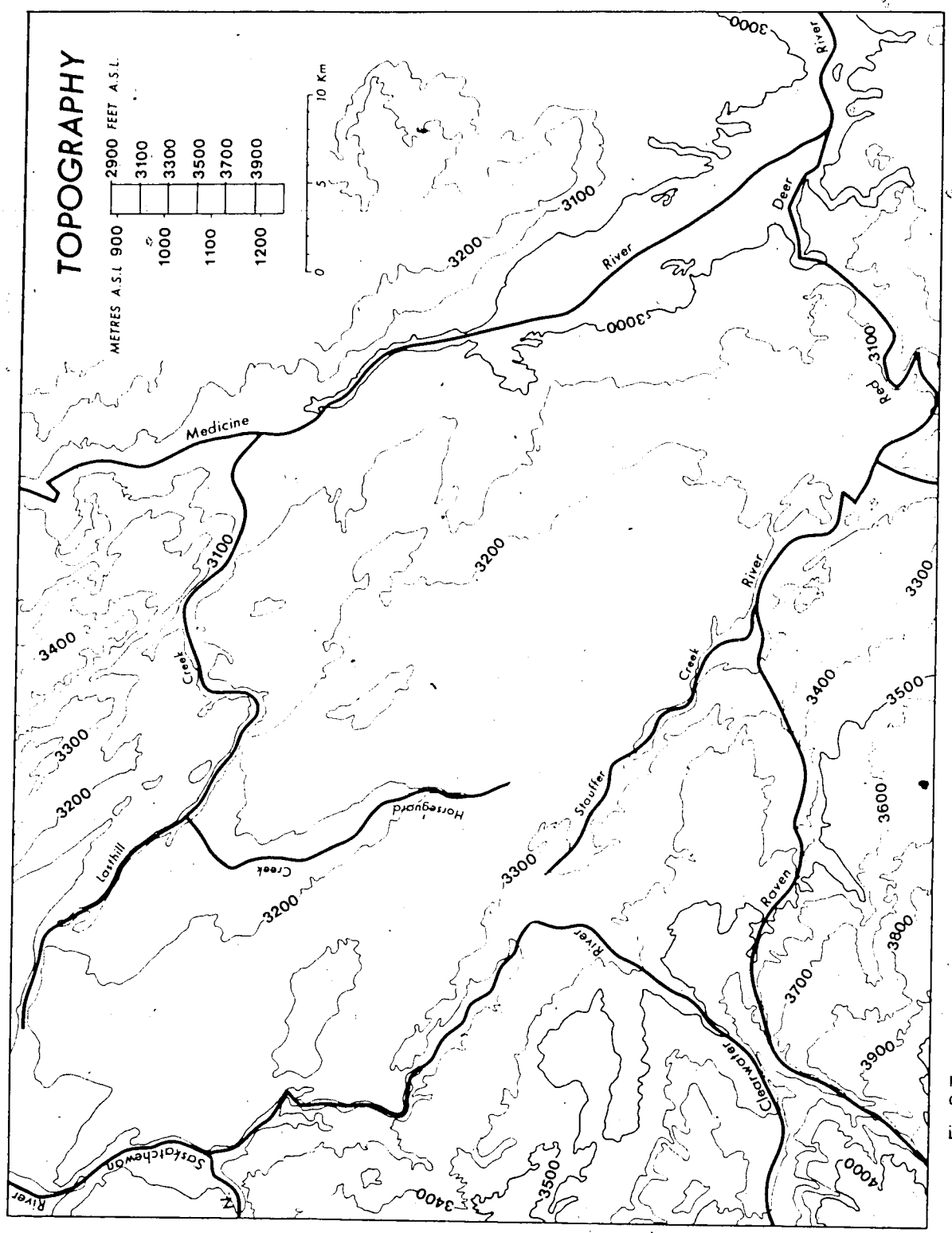


Fig.2 Topography

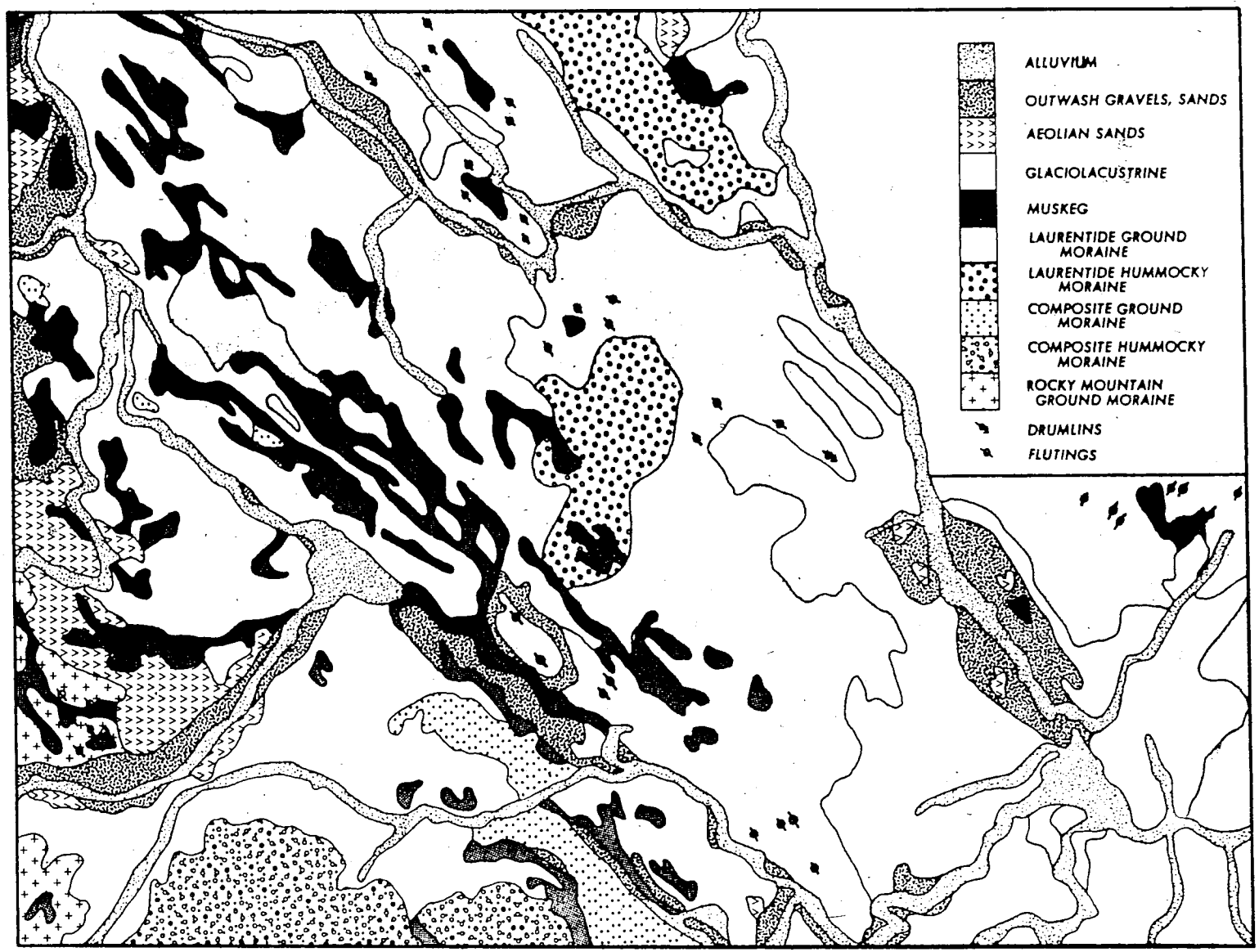


Fig.3 Surficial Geology

Source: Alberta Research Council 1974 Surficial Geology Rocky Mountain House NTS 83B. Edmonton

are also present. These deposits could be easily exploited for use as construction materials (ie. roads, rip-rap, canal lining, etc.). Alluvial deposits along smaller streams primarily consist of silt and sand. Postglacial accumulations of organic materials, better known as muskeg, cover a large portion of the study area having formed in poorly drained depressions between bedrock ridges and in glacial spillway channels. Most of the muskeg in the area is shallow but some may be as thick as 10 m. Some patterned or string bogs exist in the area and indicate slow flow of water within these bogs.

The aeolian deposits consist of fine- to medium-grained sand in sheets and dunes. The sand is derived from Pleistocene lacustrine and outwash deposits. No active dunes now exist as most of the areas are stabilized by covering vegetation. Several of the interdune areas are filled with muskeg.

Pleistocene glaciolacustrine deposits cover much of the study area indicating that proglacial lakes of considerable size existed in the area. In texture, the deposits range from clay through silt to sand, ice-rafted pebbles are also common. These materials may also prove useful for construction of dikes, weirs and canals. Generally the surface of the lacustrine plains is level, but north of Eckville and in the vicinity of Caroline the surface is hummocky. In these areas the lacustrine deposits were likely deposited over debris-rich stagnant ice which subsequently melted leaving the uneven surface.

The Pleistocene glaciofluvial deposits and landforms include outwash plains consisting of sand and gravel and valley train outwash deposits derived from mountain glaciers. Valley train deposits occur along the North Saskatchewan, Clearwater and Red Deer Rivers; they consist primarily of gravel, are generally thick and form broad terraces. Outwash plains of significant size are located on the Medicine River near Markerville, along Lasthill Creek and along Stauffer Creek. The outwash plains along Stauffer Creek are of particular interest and provide further support for the suggestion that the Clearwater at one time was part of the Red Deer drainage system. The areal extent and composition of the outwash deposits in the study area suggests that large volumes of water once flowed in these channels.

The remainder of the study area is covered by glacial till. Boydell has identified three types of till in the area based on differences in pebble lithology. The "Sylvan Lake" till which was deposited by the Laurentide ice sheet, the "Jackfish Creek" till deposited by a

Rocky Mountain ice sheet, and the "Athabasca" till, which has mixed pebble lithology, suggesting coalescence of the two ice masses. The Sylvan Lake till is located in the eastern portion of the study area, its morphology is often subdued with extensive areas of hummocky dead-ice moraine occurring on and around areas of higher bedrock topography. These hummocky moraine areas are located to the northwest of Eckville and to the northeast of Stauffer. The Jackfish Creek till occurs on the westernmost edge of the study area, just north of Ricinus. The existence of drumlins in this area indicates the direction of ice movement was towards the southeast. Athabasca till occurs in a broad zone between the two other tills; it is present in the southwest corner of the study area where much of it has been overlain by glaciolacustrine silts and clays.

Deglaciation

The bedrock surface topography (Carlson, 1970) indicates that the major drainage before glaciation was to the southeast. It appears likely that the present channel of the North Saskatchewan River downstream from Rocky Mountain House developed as a result of glacially induced river diversions during Pleistocene time. A number of the preglacial valleys are now buried, and contain sands and gravels, parts of which may be preglacial in age.

According to Carlson's interpretation of the bedrock topography in the area, the "preglacial" Clearwater River was actually part of the Red Deer drainage basin. It flowed southeastward from a point near Butte along what is now the Stauffer Creek valley and emptied into the Red Deer River. At some point during the Pleistocene or soon after the retreat of the Laurentide ice sheet from the area, the Clearwater River drainage was captured by the North Saskatchewan drainage basin. However, as mentioned before, along the Clearwater delta the surface drainage divide between the two basins is poorly defined and the phreatic or groundwater divide is apparently nonexistent with transfer taking place.

The Rocky Mountain House area was affected by at least four Pleistocene ice sheets (Boydell, 1972 and 1978) which originated either in the Rocky Mountains or on the Canadian Shield. The limits of the most recent ice sheets are marked by a zone in which surficial deposits contain materials derived from both the Shield and the mountains. This

zone of mixed continental and cordilleran source glacial deposits (ie. Athabasca or composite till) occurs only in the southwest corner of the study area. East of this zone only continental glacial drift is found and to the west only drift derived from cordilleran sources is found.

The likely sequence in which glacial advances and retreats took place as well as, the probable extent of each in the area has been investigated by Boydell. The correlation of apparent glacial events in the Rocky Mountain House area with the findings of Roed(1968) in the Edson-Hinton area and McPherson(1970) in the upper North Saskatchewan River Valley lends support to Boydell's conclusions regarding the glacial history of the study area. Boydell suggests that the Rocky Mountain House area was subjected to four glacial advances during the Pleistocene, three of Rocky Mountain origin and one of continental origin.

The first advance into the area occurred in the Early Wisconsin as a Rocky Mountain ice mass advanced over the Brazeau Range and east to the edge of the foothills. It does not appear that this advance extended far enough east to enter the study area; the till deposited during this advance has largely been overlain by subsequent advances but small surface exposures are present to the west of the study area on top of plateau-like ridges of the outer foothills. It is likely that outwash sediments associated with this advance were deposited in the study area although differentiation between these deposits and those associated with subsequent Rocky Mountain advances is difficult.

The second and third advances occurred in the Late Wisconsin as a Rocky Mountain ice mass moved eastward along the North Saskatchewan River Valley. This ice mass was deflected to the southeast by the advancing Laurentide ice sheet. A series of temporary proglacial lakes were formed as meltwaters were impounded by opposing ice fronts. During this time, the margin of the Laurentide ice sheet was to the west of the study area, leaving the whole area under the ice sheet. Near the margin, Rocky Mountain ice slowly began to retreat and the piedmont valley spillways and North Prairie Creek channel to the west of the study area were cut by meltwater streams.

The fourth and final glacial advance, referred to as the "Jackfish Creek" advance by Boydell, also occurred in the Late Wisconsin as Rocky Mountain ice moved eastward and coalesced with the Laurentide ice which had remained in the area. Much of the contact

zone was obliterated by a series of spillway channels developed between the two ice masses. These northwest-southeast trending spillway channels are dominant features in the study area and also exist to the north and west. The orientation of glacial features such as drumlins and flutings suggests that the primary axis of glacier movement in the study area was northwest to southeast. A small grouping of flutings to the east of the Medicine River indicate the perpendicular flow direction of the main body of Laurentide ice. The Jackfish Creek ice began retreating before the Laurentide ice. Retreat of the Laurentide ice to the northwest was slow and recession was marked by in situ stagnation of large ice masses, usually on areas of higher ground, surrounded at lower elevations by glacial lakes.

The largest of these proglacial lakes was Glacial Lake Caroline; the areal extent of glaciolacustrine deposits in the study area is indicative of the area which this lake covered. The coarse gravel and boulder outwash sediments carried by the Clearwater River were deposited in glacial Lake Caroline forming the Clearwater delta. Glacial Lake Caroline covered an extensive area and was drained by a succession of spillway channels which formed as the Laurentide ice front continued to retreat. According to Boydell, five spillway channels formed during the draining of this glacial lake: Crammond I was the first, located south of Caroline, followed by Crammond II, Kevisville, Stauffer and finally Lasthill each progressively lower and farther east than the last. This represents the last stages of Laurentide ice retreat in the study area, although its disintegration may be traced progressively farther to the east and northeast. It is believed that deglaciation probably began between 13,500 and 12,500 years BP, and the Rocky Mountain House area was probably ice-free soon after 9600 years BP (Boydell, 1978: p.33).

C. Soil Type and Distribution

Soil is the product of climate, vegetation, and topography acting on the parent material over a period of time. The degree and variability of any or all factors and their interaction is reflected in the numerous kinds of soils that exist in any given area. Climatic influences include precipitation and temperature, as well as wind and water erosion. Furthermore, climate determines the type of vegetative cover and degree of biological activity. With topography it governs drainage and moisture conditions thus producing

microclimatic variations which in turn produce variability in vegetative cover. A major influence, however, is exerted by the parent material itself, with its variability in texture and mineralogy.

The study area is roughly bisected by the boundary between a predominantly black or Chernozemic soil zone to the east and a Grey Wooded or Podzolic soil zone to the west. Peters and Bowser(1958) identified six soil "Orders" in the area, namely Chernozemic, Podzolic, Solonetzic, Gleisolic, Organic, and Regosolic. Maps of soil capability for agriculture, completed as part of the Canada Land Inventory, also exist for the study area (ARDA, 1968). In the soil classification system used, soils are grouped into seven classes according to their potentialities and limitations for agricultural use. The first three classes are capable of sustained production of common cultivated crops, the fourth class is considered marginal, the fifth is capable of use for only permanent pasture and hay, the sixth is capable of use for native grazing, and the seventh class has no capability for agricultural use. No class 1 soils are present in the study area and the only significant areas of class 2 and 3 soils are located in the southeastern portion.

The strong relationship between parent material and soil type in the study area becomes apparent upon comparison of Boydell's surficial geology map and the aforementioned soil survey maps. Each soil type can be related to a particular surficial deposit as mapped in Fig. 3.

Regosolic Soils are young, immature soils found mainly in large river valleys and are developed on gravel and coarse sand alluviam. Recently deposited outwash gravels along the Clearwater, Red Deer and North Saskatchewan Rivers contain very little fine textured material and plant nutrients. These regosols are Class 7 soils which have little or no agricultural value. Alluvium is periodically deposited by rivers during flood stages. The overbank deposits in the study area have developed into sandy and silty loams capable of providing fair pasture and small amounts of good arable land. These sandy and silty loams are found along Prairie, Lasthill and Lobstick Creeks, the Medicine and Raven Rivers, and along the lower portion of the Clearwater River below Dovercourt. Most of these soils fall into Class 5 with very severe limitations (primarily uneven topography and dense brush cover). The flood plains of streams in the area are small and well defined, thus the areal extent and actual agricultural significance of these regosolic areas is limited.

Organic Soils are found in poorly drained, level to depressional areas (ie. bogs or muskeg). As previously mentioned, these muskeg areas are a striking feature of the landscape and are of importance in relation to groundwater storage, controlling runoff and providing wildlife habitat. They are characterized by an organic surface layer which consists of a semi-decomposed mat of sedges and grasses greater than 30cm thick, this is underlain by a grey colored subsoil. Organic soils are not placed in C.L.I. soil capability classes but according to Peters and Bowser(p. 35) the sedge peats when well drained provide fair arable land however moss peats are unsuitable for agriculture.

Gleisolic Soils are poorly drained soils that have developed in the presence of a high or fluctuating water table and often have a somewhat peaty surface with a sticky clay subsoil. The Raven Silty Clay Loam is the only Gleisolic soil mapped in the study area. It is a meadow soil formed on lacustrine material and is found adjacent to muskeg or on slightly elevated areas within muskeg areas. The largest area of Gleisolic soil is located just west of Lasthill Creek, other small occurences appear adjacent to muskeg areas south of Raven. The proximity of the water table to the surface, the depressional topography and the fine texture tend to create a "cold soil" more suited to the production of coarse grains and especially hay crops. These soils have been placed in Classes 4 and 5 with severe to very severe limitations on their agricultural capability.

Solonetzic Soils develop on saline parent material such as lacustrine silts and clays. Solonetzic soils are located only in the eastern part of the study area corresponding to the glaciolacustrine deposits along the Medicine River. The combination of a hard, compact B horizon and somewhat saline subsoil can restrict the agricultural capability of these soils. Nevertheless, these soils are identified as Class 2 and 3 with moderate to moderately severe limitations for use. The native vegetation cover was likely aspen poplar but much of the area has been cleared and is fairly productive under cultivation.

Podzolic Soils are formed under relatively humid conditions and under a forest vegetation. Grey Wooded soils are the only group of Podzolic soils found in the study area; they cover an extensive portion of the study area to the west of the major soil zone boundary. The cooler wetter western areas were and largely still are under a cover of conifers and mixed forest. To the east of this, Chernozemic soils developed primarily under grass cover are predominant. The Grey Wooded soils are low in fertility because

the leaching process by which they were formed has removed much of the soluble mineral plant nutrients from the upper horizons. All of the Grey Wooded soils are identified as Class 4 or 5 and Peters and Bowser(p. 23) suggest that "...wheat grown on these soils is usually low in protein content and hence of poor quality...(but) good malting barley and legumes for hay and seed have proven quite successful". These soils have developed on a few types of parent material including glacial till, glaciolacustrine silts and aeolian sands.

The slightly warmer and drier eastern areas were under a parkland vegetation cover where chernozemic Soils developed under a grassland vegetation in moderately- to well-drained locations. Chernozems have developed on glacial till, glaciolacustrine silts and clays, glaciofluvial gravels and, aeolian sands. Those developed on glacial till are rated as Class 2 or 3 and vegetative growth is usually quite luxuriant. Those on lacustrine material are subject to wind erosion but if adequately protected provide very good arable land (ie. Class 2 and 3). Chernozems developed on glaciofluvial gravels are found along the Clearwater River and covering the Clearwater delta. These soils are excessively drained, subject to drought and the fertility reserve is low. They are identified as Class 3 soils and are primarily used for pasture and hay crops. Along the Medicine River, near Markerville, finer textured chernozems have developed on glaciofluvial sands; these soils retain moisture effectively but still have a low natural fertility and are identified as Class 3 and 4 soils.

Along the Stauffer and Horseguard Creek valleys (the two areas most likely to be directly affected by Clearwater diversion) the agricultural potential of the soils is limited (ie. Classes 3, 4 and 5). Organic and Grey Wooded soils are predominant and agricultural land use is restricted to pasture and scattered hay fields. The Clearwater delta, however, does support wheat and barley crops given adequate soil moisture availability during the short growing season.

D. Native Plant Communities

Across the study area the native vegetation changes from a "parkland" type in the east to a "boreal forest" type in the west. The parkland phytogeographic region has been described by Moss(1955) as a mosaic of prairie patches and aspen groves, with prairie occupying the drier areas and aspen the more moist and sheltered places. Trembling

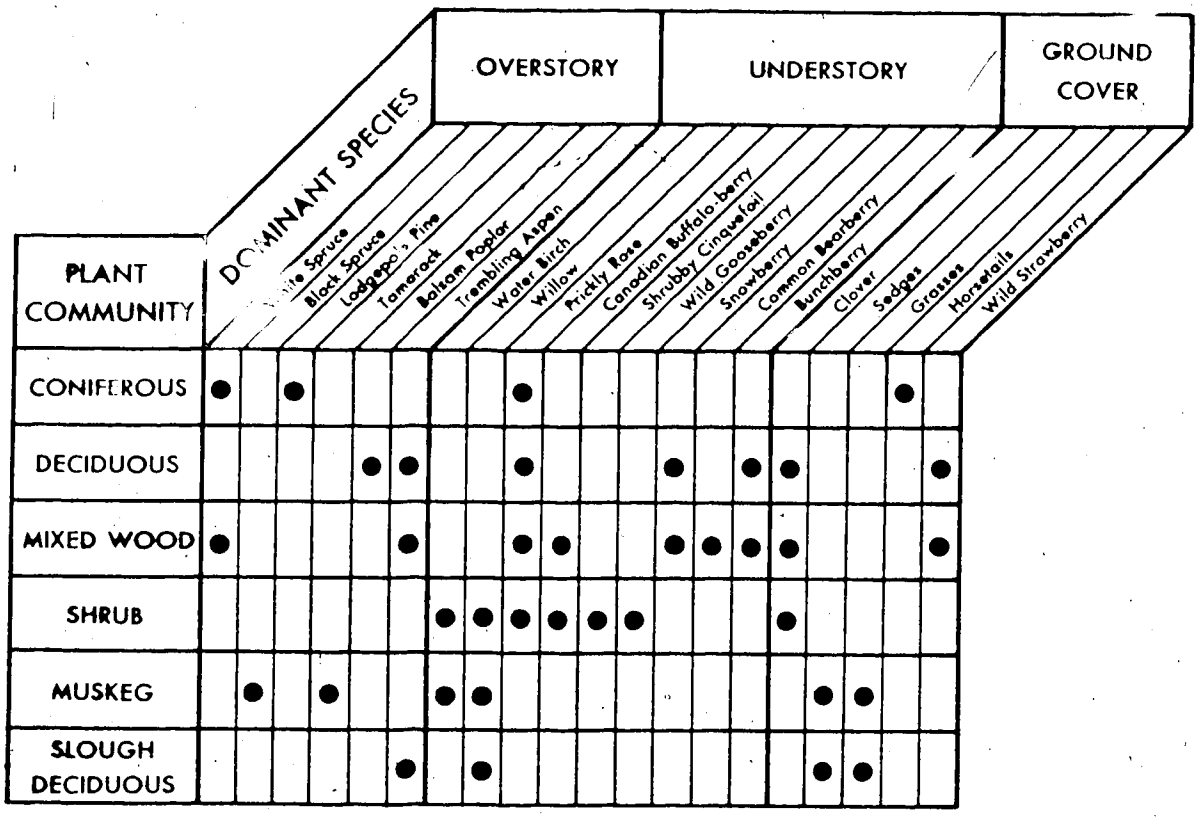
aspen is the main tree species and it occurs over a wide range of edaphic conditions, including dry knolls, moist river flats, and soil textures ranging from clay to sand. The balsam poplar is more restricted in its occurrence, reaching its best development in the moist situations suc as river flats.

Several identifiable plant communities exist in the study area; certain "dominant" plant species characteristic of each community are used to distinguish between these various plant communities. Six generalized communities were described for the area in the Environmental Assessment section of the Red Deer River Flow Regulation Planning Studies(Alberta Environment, 1975b). The combination of dominant plant species which characterize these six communities is laid out in Fig. 4.

In the eastern half of the study area native vegetation exists only in small patches interspersed between cleared crop and pasture lands. Deciduous and mixed wood communities are most common with larger slough deciduous and muskeg areas occurring in hummocky and poorly drained depressional locations. The oldest and most extensive areas of native vegetation in the parkland region occur in the major river valleys. The flood plain of the Red Deer River supports well established deciduous and mixed wood communities on the infrequently flooded portions and a slough deciduous community on the frequently flooded portions. Small stands of coniferous forest are present on some of the river escarpments.

Small stream courses throughout the eastern portion of the study area support dense phreatophyte shrub and "stunted" slough deciduous plant communities. The importance of these narrow vegetation strips to aquatic and terrestrial wildlife is briefly discussed in chapter four. In all but the most difficult locations (ie. oxbow lakes, steep banks), the vegetation along the Medicine River has been removed and land is cultivated and/or grazed right to the stream banks. Along Lasthill Creek the riparian vegetation gradually changes from a dense slough deciduous community in the lower reaches to muskeg in the upper portions.

In the western half of the study area, with a shift from Chernozemic to lower capability Podzolic soils and extensive areas of muskeg, the proportion of the total land area that is cleared and cultivated is noticeably reduced. This part of the study area is part of the Boreal–Cordilleran transition zone (Moss, 1955). The dominant tree species is



Source Alberta Environment 1975 "Red Deer River Flow Regulation Planning Studies" Vol 5. Environmental Assessment (Part 1)

Fig.4 Composition of Plant Communities in the Area

white pine but lodgepole pine, trembling aspen and balsam poplar have assumed a dominant position in areas which have been burned over. In a large area north of the Raven River and east of the Clearwater River the mixed wood community is most common in the better drained locations while muskeg occupies the moist, abandoned spillway channels. In the higher elevation areas to the south of the Raven and west of the Clearwater the mixed wood community gives way to the coniferous community. Along the Clearwater and North Saskatchewan Rivers the inactive flood plain areas and escarpments support both mixed wood and coniferous communities; the more active areas support a phreatophyte shrub community.

E. Population and Community

The eastern portion of the study area was settled around the turn of the century with settlement radiating out from the Edmonton – Calgary railway line. The building of the Alberta Central Railway line from Red Deer to Nordegg (completed about 1914) gave impetus to the settlement of areas further west (Rocky Mountain House Reunion Historical Society, 1977). The present rural population (including hamlets with less than 50 residents) of the actual study area is difficult to determine because it overlaps a number of census subdivisions. However, a rough approximation of the present rural population of the study area is between 5000 and 7000 (Statistics Canada, 1982).

Rocky Mountain House is the largest town in the area (population 4698). The first trading post was established here in 1799 and a post remained in operation in the area until about 1875. Currently, the town acts as an agricultural service centre, supports oil and gas exploration activity in the area, plus a small lumber industry, and provides services for tourists. Sylvan Lake (population 3779) is a resort town as well as an agricultural service center. Other significant villages in the area that provide services to the agricultural community are Eckville (population 870) and Caroline (population 436). The total population in the study area is estimated at 15,000 to 17,000, 10,000 of whom are living in towns or villages of 50 or more people.

The soil conditions and length of the growing season restrict most of the area to production of hay and grain crops. But mixed farming operations including ranching, dairy farming and raising poultry are also evident. This is part of a marginal agricultural fringe

area, where marginal arable land gives way to pasture land and ranching along the margins of the foothills. According to the economic survey completed for the Red Deer River Flow Regulation Study, which covers a comparable region, 43% of the labour force is occupied in farming, horticulture and/or animal husbandry. The next largest occupational group, comprising services of all types, makes up 36% of the labour force (Alberta Environment, 1975c). It is assumed that with any additional resource development activity in the area that the service sector would expand accordingly.

The infrastructure of the area is fairly well developed with an extensive network of all-weather gravel service roads and several main highways (notably Highways 54, 11 and 22). Oil and gas exploration and periodic clearing of previously forested land has expanded the road network in the region. All of the towns, villages, hamlets, and most of the established farmsteads are supplied with natural gas, electricity and telephone service.

The potential for new development in the area appears limited with the local labour market offering few opportunities for youths. The initiation of a water development project in the area may provide temporary employment for a number of local people. The creation of new recreation opportunities around the reservoir formed by Dickson dam coupled with an increased demand for recreation from Red Deer residents may cause a population increase and gradual landuse change in the area. Further discussion of water-based recreational resources appears at the end of chapter four. Some of the more important conclusions and recommendations made in the Red Deer River Flow Regulation studies that apply here also, are: i) population growth will most likely take place in the cities and larger towns; ii) those families required to move should be compensated on an individual basis; and iii) compensation to families should take into account facts other than the market value of their property. Because the population of the area is so small and scattered and the value of the land use throughout the area is relatively low, it is not anticipated that social disruption associated with a Cearwater transfer will be large. However, the effects of development on the existing recreational resources in the area need to be assessed.

IV. STREAMFLOW AND RELATED RESOURCES

A. Water Balance

In order to gain a thorough understanding of water supply patterns, and ultimately streamflow in a particular area, a number of variables need to be considered, such as climate, topography, vegetation, soils, and so on. By using the concept of "water balance" it is possible to analyze variations in temperature and precipitation in such a way that changes in moisture availability can be predicted. Accurate interpretation and understanding of moisture availability depend upon an analysis that includes all critical elements in the hydrologic cycle: precipitation, evaporation, transpiration, and surface and subsurface movement of water. See Appendix 1 for a definition of the basic variables included in the water balance equation.

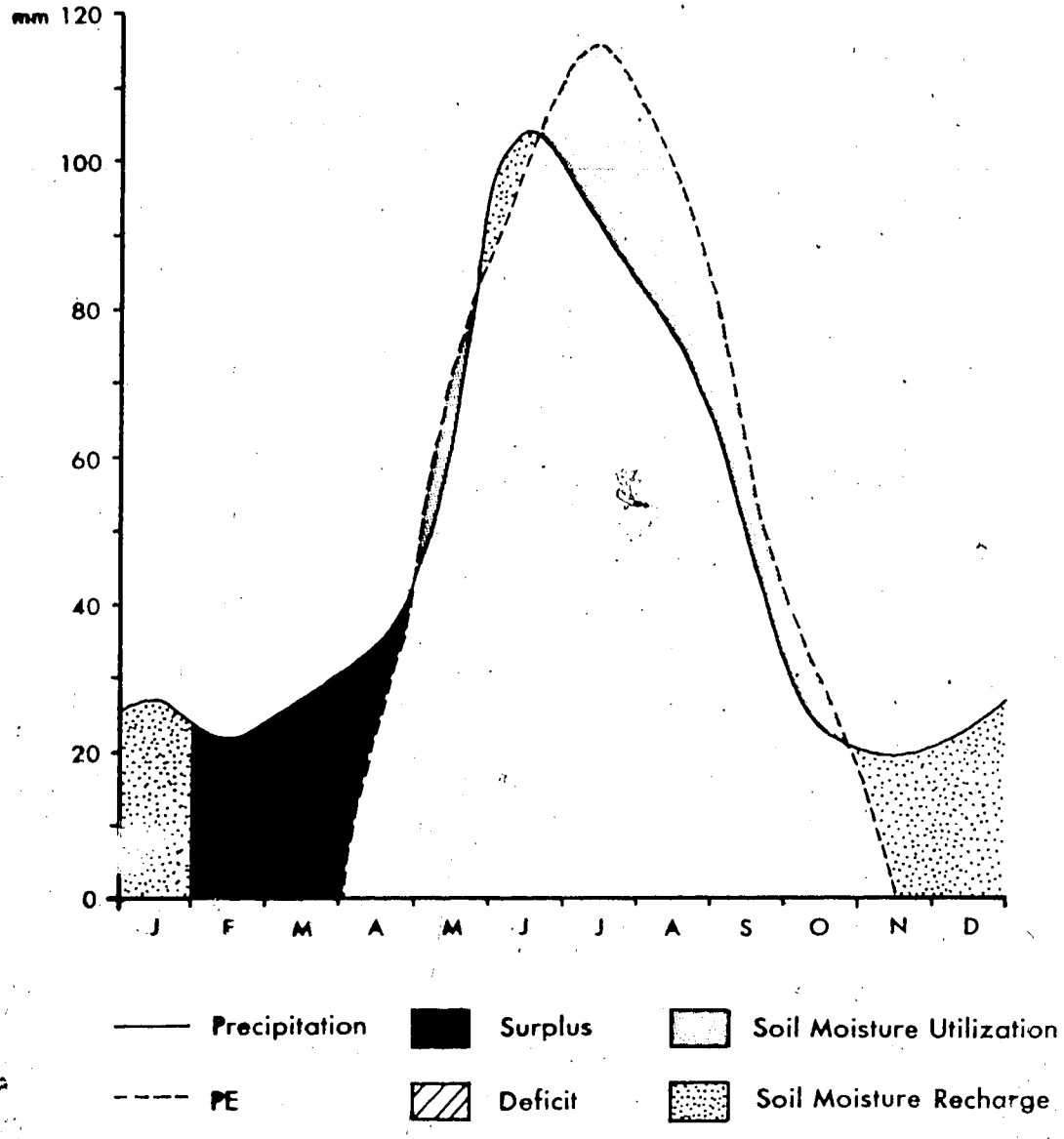
The procedures described by Thornthwaite(1948, 1957 and 1958) for calculating the water balance are perhaps the most useful for illustrating the effects of precipitation and evapotranspiration upon regional water surplus patterns. This procedure has been successfully applied in Alberta to describe water surplus and deficit patterns on both a regional and local scale; Laycock(1967) used it to describe patterns in the prairie region and MacIver(1964) used it to describe patterns in a small drainage basin. Some approximations to the various inputs and outputs of the water balance can be made by processing commonly recorded climatic data (ie. temperature and precipitation) according to Thornthwaite's procedures to derive potential and actual evapotranspiration, surplus, and deficit patterns for various soil moisture storage values. Soil moisture storage values reflect basin characteristics such as plant cover, soil texture, root depth, and land use. The amount of water a soil can hold depends on the type and structure of the soil as well as the depth. It can vary from just a few millimeters on bare rock, paved roads and shallow sands to well over 400 mm on a deep silt loam with a natural forest cover. It is expected that soil moisture storage capacities for soils in the study area vary greatly. They range from the poorly developed regosolic soils which retain little moisture (some less than 12 mm storage capacity) to the finer textured chernozemic and podzolic soils with a deep rooted crop or forest cover which may have a 250 mm storage capacity. For discussion purposes it is assumed that a soil moisture storage capacity of 150 mm is the

most representative single value for the soils and land uses of the study area.

The water balance for Rocky Mountain House was calculated for the 30-year period 1951-1980. The summary tables in Appendix 2 contain annual totals for precipitation, potential and actual evapotranspiration, water surplus and deficit, and change in soil moisture storage for each of five different soil moisture storage capacities. These annual totals are useful for general discussion of climate in the study area but they mask short term fluctuations. For instance, the mean annual precipitation was 550 mm and the mean annual PE was 502 mm; mean annual deficits ranged from 8 to 128 mm while surpluses ranged from 54 to 17[illegible] mm for soil moisture storage capacities of 250 to 12 mm respectively. By constructing an "average" annual water balance for a soil moisture storage capacity of 150 mm several features of the water balance become evident (see Fig. 1).

Since precipitation and evapotranspiration are due to different meteorological causes, they are not often the same either in amount or in distribution through the year. The interplay between the two determines the pattern of moisture availability throughout the year. At Rocky Mountain House, on average, the first three and last two months of the year are characterized by below zero temperatures and relatively low amounts of precipitation (ie. less than 30 mm/month). Because PE levels are effectively zero, all of the precipitation which falls as snow during these months accumulates and is available for replenishing depleted soil moisture supplies come spring melt in late March and April. Any precipitation in excess of that required for recharge raises groundwater levels and produces surface and subsurface runoff; on average, the greatest proportion of the annual surplus occurs in spring. Naturally, the higher the storage capacity of the soil, the smaller the proportion of precipitation that runs off.

During the summer months PE levels are highest, with the maximum typically occurring in July or August and reaching a level of approximately 115 mm/month. Precipitation levels are also the highest during the late spring and summer but they fluctuate greatly from year to year. Because the amount of precipitation varies so much through the summer months discussion of an "average" condition can be misleading. Even though on average there is no surplus during the summer, in many years significant surpluses do occur as a result of short duration, high intensity rainfall events. Actually,



Source Environment Canada 1951-1980 Monthly Record. Meteorological Observations in Canada AES. Downsview, Ont.

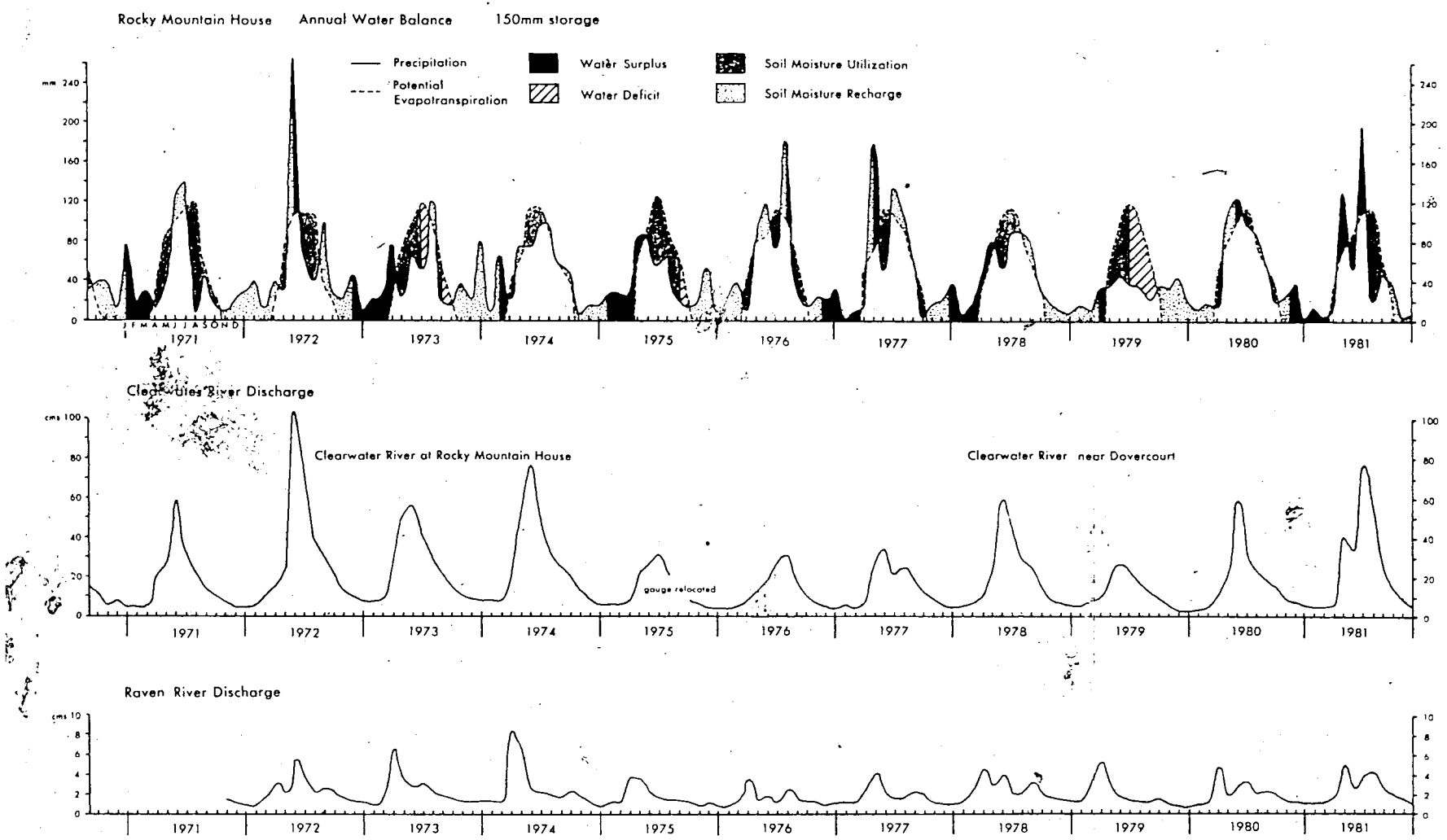
based on mean monthly temperature and precipitation 1951-1980

Fig.1 Rocky Mountain House Water Balance (150 mm storage)

there have been both deficiencies and surpluses during the summer months although they are not revealed by averaged data. When average monthly precipitation and temperature data are used to calculate the water balance the extremely wet and dry years which produce surplus and deficit situations are averaged out. Therefore, in Fig. 1 the average surpluses and deficits (based on mean annual water balance shown in Appendix 2) are underestimated. In fact, no deficit is shown even though the average deficit for this period was 22 mm. For the most part, however, the summer months are a time of soil moisture utilization with minor deficits occurring in August and September. Over the 30-year period the mean annual deficit ranged from 128 mm (12 mm storage) to as little as 8 mm (250 mm storage). In the autumn precipitation levels once again exceed PE and soil moisture recharge resumes.

The historical monthly averages for elements of the water balance used in compiling Fig. 1 and, even more so, the annual averages in Appendix 2 mask yearly fluctuations. For this reason some description of the past fluctuation of these values over a sequence of years is needed for a more complete interpretation of water balance conditions at Rocky Mountain House. A comparison of the course of precipitation and evapotranspiration on a year-to-year basis, as opposed to an average annual basis, reveals significant changes in the amount and timing of surplus and deficit conditions. A diagrammatic representation of the water balance for the eleven year period 1971-1981 for a 150 mm storage capacity can be seen in Fig. 2

While the curves of potential evapotranspiration do not change greatly from year-to-year, the precipitation varies greatly both in annual amount and seasonal distribution. The eleven year period contains a range of climatic conditions from decidedly "dry" years such as 1979 (ie. lowest annual precipitation in 30-year study period) to moderately "wet" years such as 1981. The wide fluctuation in the amount and timing of the water balance components is well illustrated by the six year period 1976 through 1981. The annual total precipitation in 1976 was above average (634 mm) but because the soil moisture storage had been totally depleted during the dry autumn of 1975, all of the winter and spring precipitation was taken up by soil moisture recharge and no spring surplus occurred. During August, which was a high rainfall month, recharge was complete and a small 20 mm surplus occurred. Moderate levels of soil moisture utilization in



Sources 1. Environment Canada 1971-1981 Monthly Record Meteorological Observations in Canada AES, Downsview, Ont
2. Environment Canada 1971-1981 Surface Water Data, Alberta Inland Waters Dir., Water Res Branch, WSC, Ottawa

Fig.2 Water Balance and Related Streamflow

September and October left soil moisture levels high enough that even small amounts of precipitation during the winter produced a surplus of 43 mm for the first three months of 1977. This surplus became available from snow detention storage when spring temperatures were high enough for snowmelt.

Precipitation peaked twice in 1977, once in May producing a large surplus when PE levels were moderate, and again in July but this time without any surplus. A small amount of soil moisture utilization in October was more than compensated for by snowmelt recharge in the spring, leaving soil moisture levels near capacity. A surplus situation existed well into May of 1978 but by the end of the year soil moisture storage was below capacity and the scant precipitation in the winter was totally consumed by recharge the following spring allowing only a small surplus in April. The summer of 1979 was the driest of the 30-year study period; the total annual precipitation was only 357 mm in contrast to a mean annual total of 587 mm. Soil moisture was exhausted by July and the total deficit reached 119 mm as compared to a mean annual deficit of 22 mm. Moderate amounts of precipitation throughout the autumn and winter, plus consistently high amounts during the spring and summer of 1980, replenished the soil moisture levels and produced a very minor surplus in June.

From July through October precipitation kept pace with PE levels with only minor amounts of soil moisture utilization; soil moisture capacity was reached in November. The winter precipitation combined with a large precipitation event in May 1981 to produce a 40 mm surplus. July was another high precipitation month and a 52 mm surplus occurred; in August and September precipitation was low and soil moisture storage levels dropped well below capacity and did not return to capacity by the end of the year.

Although the concept of water balance is useful for describing the seasonal variations in local moisture availability, the relationship between water balance and streamflow clearly involves other variables. Because the precipitation regimes are different for the upper basin areas of the Clearwater and North Saskatchewan than those in the study area, correlation between streamflow and water balance could be greatly improved through the use of upper basin climatic data. Laycock(1957) provides an explanation of precipitation and streamflow in the mountain and foothill region of the Saskatchewan River basin. However, several significant features of the streamflow

hydrographs for the Clearwater and Raven Rivers can be explained by comparing them with the water balance for Rocky Mountain House. The snowmelt runoff peak occurs in May or June on the Clearwater and a month earlier on the Raven. Low flow or baseflow conditions on both the rivers naturally coincide with the winter period when precipitation is being stored as snow. The effect of spring and summer precipitation events is also evident, particularly the peak flows during June 1972 and the dual peaks in 1981.

It is difficult to see any strong correlation between high streamflow years and years containing significant water surpluses. For example, 1974 was a relatively high flow year for both streams and yet the annual surplus was below average (ie. 57 mm with the mean being 68 mm). Similarly, the streamflow for 1977 was only average at best, while the surplus at Rocky Mountain House was 110 mm. Perhaps the strongest correlation between streamflow peaks and water surplus is that of 1981 where the large surpluses in May and July correspond to the two peaks in streamflow on both the Clearwater and Raven Rivers. In order to discuss the relationship between water balance and streamflow, in anything but very generalized terms, meteorological data representative of conditions in the upstream portion of the drainage basins is required. Streamflow characteristics could be better correlated with water balance conditions for a station which is more representative of headwater areas in the basin such as Lake Louise. Climatic features of the mountain parks area are described by Janz and Storr(1977). The climate in the headwater areas is Marine West Coast rather than Interior Continental as in the study area. Therefore, the precipitation maximum occurs in winter in the headwater areas as opposed to a summer precipitation maximum in the lower Clearwater basin as exemplified by data for Rocky Mountain House.

B. Streamflow Regime

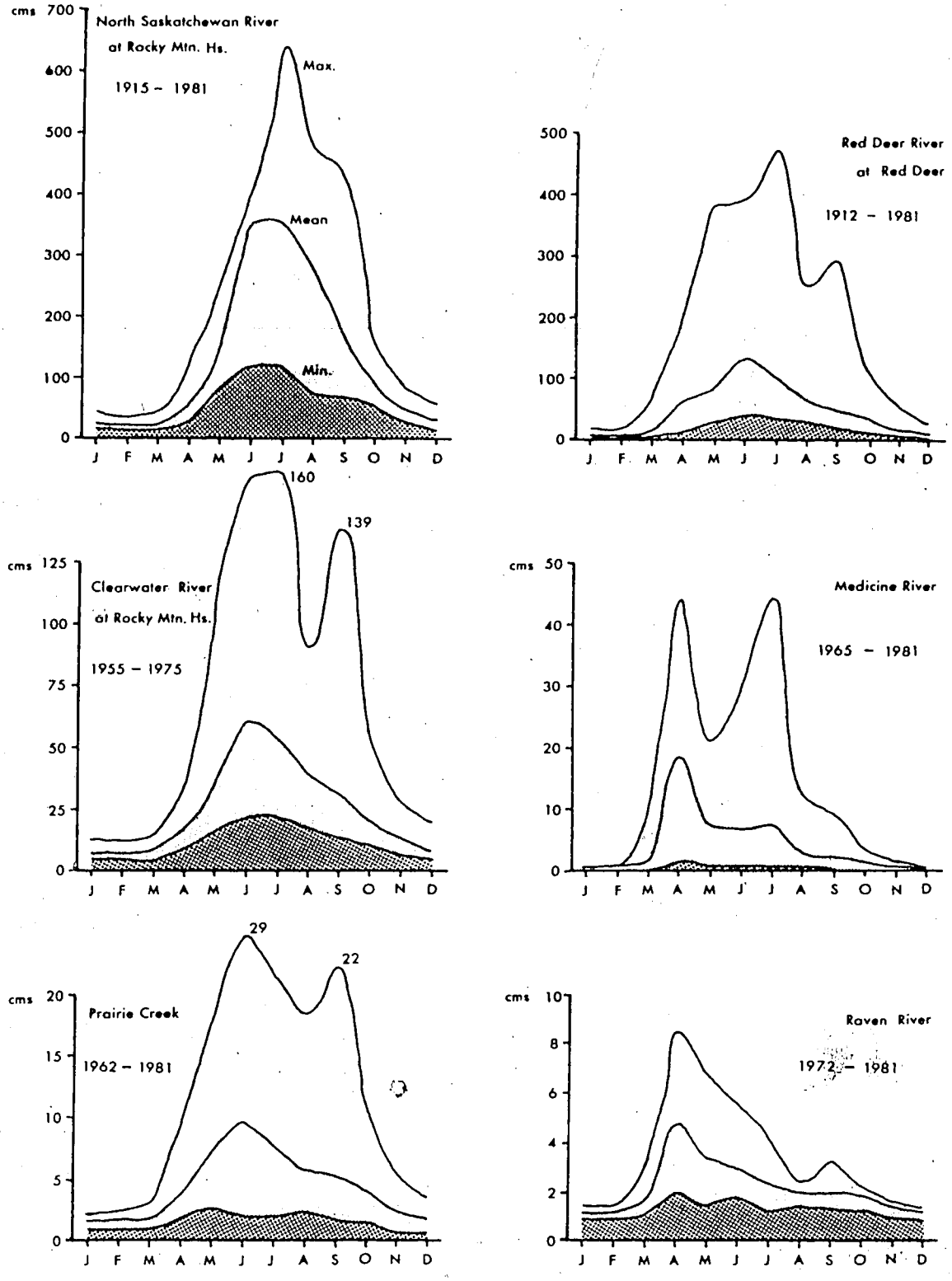
By reviewing the historical streamflow records for the streams in the study area we gain a better understanding of the timing and quantity of surface water availability. Upon making a decision to augment water supply in one stream, through transfer from another, it is crucial that streamflow variations over both time (ie. on a daily, monthly and/or annual basis) and space (ie. within and between the donor and receiving basins) be considered. In order to avoid accentuating any undesirable periods of extremely high

and/or low streamflow, a sound knowledge of the natural streamflow regime of the streams involved is required. Streamflow "regime" is here defined as the seasonal distribution of stream discharge characterized by a regular pattern. The regularity of the annual pattern of discharge for the Clearwater River (particularly for the years 1971-1974) is a good example of the steady state or consistency of pattern implied in the concept of regime. The importance of large fluctuations in discharge is masked in hydrographs of mean monthly discharge but becomes apparent upon analysis of mean daily discharge hydrographs.

The mean, maximum and minimum monthly discharge hydrographs for six of the streams in the study area are presented in Fig. 3. The streamflow regime for the various streams is compared and contrasted through discussion of a number of features of these hydrographs, including: the highest flow month, the low flow period, the shape of the mean discharge hydrograph, and sheer differences in magnitude between streams of the two major drainage basins. The major streams of the North Saskatchewan basin are on the left side of Fig. 3 while those of the Red Deer basin are on the right side.

High Flow Month

For the streams in the Upper North Saskatchewan basin, the highest flows typically occur in June although for the North Saskatchewan River itself, July flows are equally high. The high summer flows on the North Saskatchewan are a result of the combination of later more consistent yields from high level snowfields and glaciers in addition to the longer basin lag time in a basin of this size. Historical maxima also tend to come in June but large precipitation events occurring as late as September do cause secondary peaks in discharge; these secondary peaks are particularly evident for the Clearwater River and Prairie Creek. The streams draining lower elevation areas in the Red Deer basin tend to reach peak discharge earlier in the year. The highest flow month for both the Medicine and Raven Rivers is April when local snowmelt runoff contributions are largest. The highest flow month on the Red Deer River occurs in June just like on North Saskatchewan streams; snowmelt runoff contributions from high elevation, headwater areas are responsible for this delayed peak. Historical maxima for the Red Deer and Medicine appear to be related to summer precipitation events which may occur anywhere from June through September. The Raven, on the otherhand, invariably experiences the highest



Source: Environment Canada 1979. Historical Streamflow Summary, Alberta. Inland Waters Dir., Water Res. Branch, WSC, Ottawa.

Fig.3 Streamflow Regime for Rivers in the Study Area

flows in April with little evidence of summer discharge peaks due to precipitation. The absence of a distinctive summer discharge maxima on the Raven is likely a function of the short period of record in which no large summer precipitation events occurred rather than y significant difference in basin characteristics.

Low Flow Period

The lowest flows occur during the winter period for all of the streams in the study area. The low flow period is slightly longer for those streams in the North Saskatchewan basin than for those in the Red Deer basin. Streamflow begins to increase in March in the Red Deer, Medicine and Raven Rivers while the North Saskatchewan and Clearwater Rivers plus Prairie Creek remain at low baseflow levels until April. Low flow conditions return in the fall for all of the streams as stream discharges slowly decrease to the lowest levels in December. Baseflow is that portion of streamflow which is derived from groundwater inflow to the stream from: i) transient bank storage, ii) transient groundwater storage caused by rapid water table rise following infiltration of precipitation, and iii) long-term groundwater storage where water movement is largely controlled by the general water table configuration in the basin (Newbury, Cherry and Cox, 1969). When there is no surface runoff from rainfall or melting snow, the streamflow is wholly derived from groundwater. This results in a steady lowering of the water table and a constantly diminishing streamflow until a precipitation event or snowmelt period occurs of sufficient magnitude to produce either surface runoff or groundwater accretion. Typically, the period from October through March is characterized by baseflow conditions for the streams in the study area, but at different levels depending in part upon how wet the fall was. In recent years storage in Lake Abraham has increased the flow of the North Saskatchewan in the fall.

Shape of the Mean Discharge Hydrograph

The mean discharge hydrographs for the streams in the North Saskatchewan basin have a distinct shape. A highly variable precipitation runoff component is consistently reinforced by a dependable snowmelt runoff component in order to produce the consistently high streamflows starting in April and peaking in June. The influence of the snowmelt component is most evident for the minimum monthly discharge hydrographs which likely reflect conditions of low precipitation runoff and yet retain the same shape as

the mean discharge hydrograph.

The shape of the mean discharge hydrographs for the Red Deer basin streams differ markedly from each other as well as from those of the North Saskatchewan basin. Both the Medicine and Raven River hydrographs are skewed towards the earlier part of the year, when rapid local snowmelt runoff occurs, while the remainder of the spring and summer streamflow is derived from rainfall and groundwater discharge. The presence of a consistent snowmelt runoff component is not apparent for either the Medicine or Raven which drain primarily lower elevation plains areas. Characteristics of streams draining both higher elevation Eastern slopes areas and high plains areas are apparent in the mean discharge hydrograph for the Red Deer River. The earlier rise in discharge due to snowmelt runoff in the high plains region appears as a slight plateau on the ascending limb of the hydrograph but the overall shape is consistent with those of the North Saskatchewan basin streams indicating the considerable contribution of higher elevation areas.

Magnitude of Discharge

The larger differences in the magnitude of discharge for the streams in Fig. 3 are obvious but some of the more subtle differences deserve mention. For instance, the mean annual discharge of the Raven River is 75% of that for the Medicine and yet it drains an area only 34% the size of the Medicine basin. The mean discharge of the Raven exceeds that of the Medicine for seven months of the year (ie. September through March) and accounts for as much as 15% of the flow of the Red Deer during the four month period from November through February, and even more in the drier years. Prairie Creek is another example of the higher yield basins to the west of the study area. The Prairie Creek basin is only slightly larger than that of the Raven (ie. 860 km^2 vs. 655 km^2) but the mean annual runoff is twice that of the Raven. Increased annual precipitation in the foothills caused by orographic lifting along the foothills rise explains the higher water yield in the Prairie Creek basin; reduced evapotranspiration and lower infiltration with increases in elevation and proportion of bare rock surface are also important.

Representative Streamflow Conditions

The streams which would undergo the greatest change in flow regime as a result of an interbasin transfer from the Clearwater are the Clearwater River, Stauffer Creek –

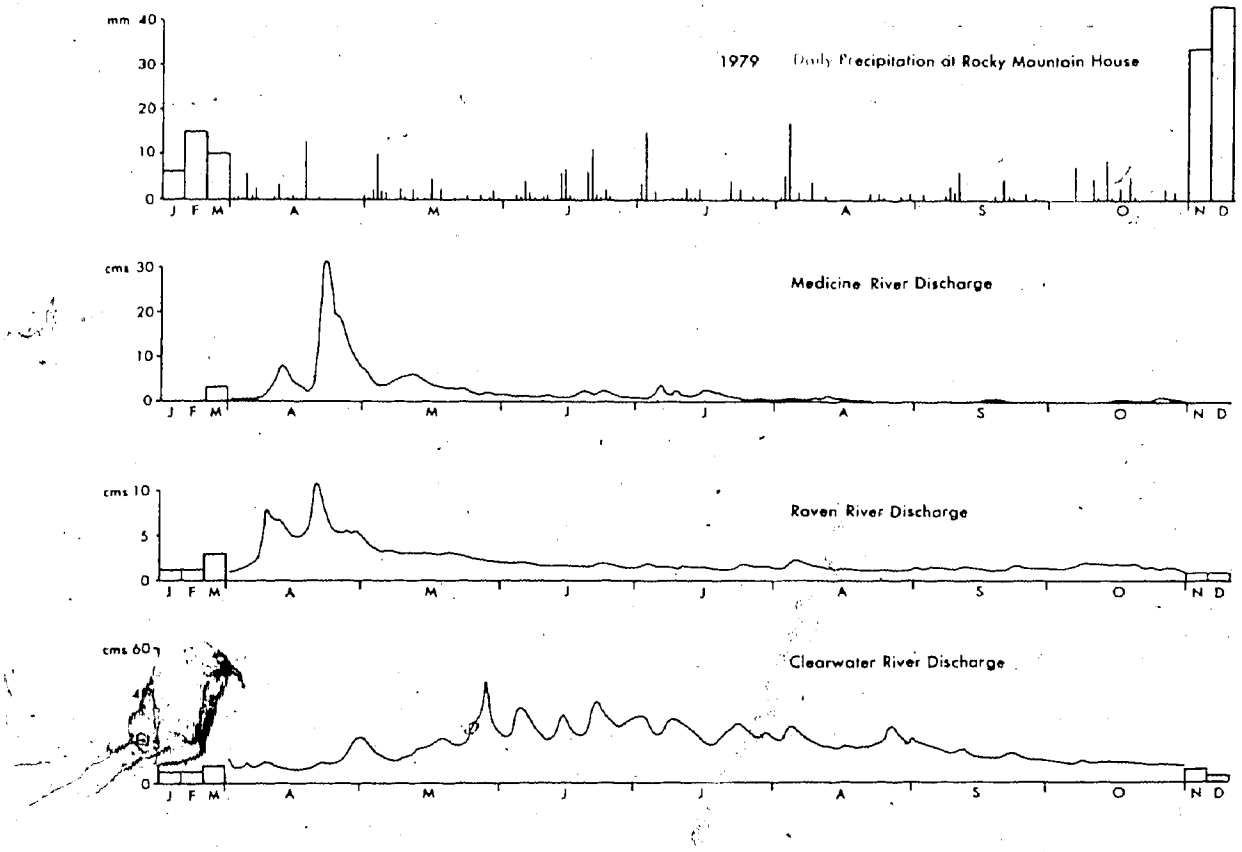
Raven River, and Horseguard Creek - Medicine River. Streamflow records are available only for the Clearwater, Medicine and Raven Rivers although individual discharge measurements exist for several locations on Stauffer Creek. Because important fluctuations in streamflow are masked by monthly mean flow data, discussion of an "average" flow year can be misleading. Thus, actual discharge for years representative of high and low discharge conditions will be used to illustrate the effects that various water transfer alternatives might have on streamflow in both donor and receiving streams. By considering the range of historical streamflow conditions a significant portion of the natural discharge spectrum for these streams is encompassed in discussion of transfer alternatives.

The representative "high flow" year selected is 1981; over the period of record (which varies from stream to stream - the Raven having the shortest record starting in 1972) this is the highest discharge year on the Medicine River and the second highest on the Raven. It is important to consider the high flow years on these potential receiving streams in order to determine what volume of water could be added to natural channels throughout the year without causing extensive flooding. The representative "low flow" year selected is 1979; this is the lowest discharge year on the Clearwater since the relocation of the gauging station at Dovercourt. It is important to consider the low flow years on the potential donor stream in order to determine what volume of water could be withdrawn during these years while maintaining an acceptable level of flow within the donor stream.

The mean daily discharge hydrographs of the Clearwater, Medicine and Raven Rivers are presented in Figs. 4 and 5 for 1979 and 1981 respectively. The corresponding daily precipitation at Rocky Mountain House appears at the top of the figures.

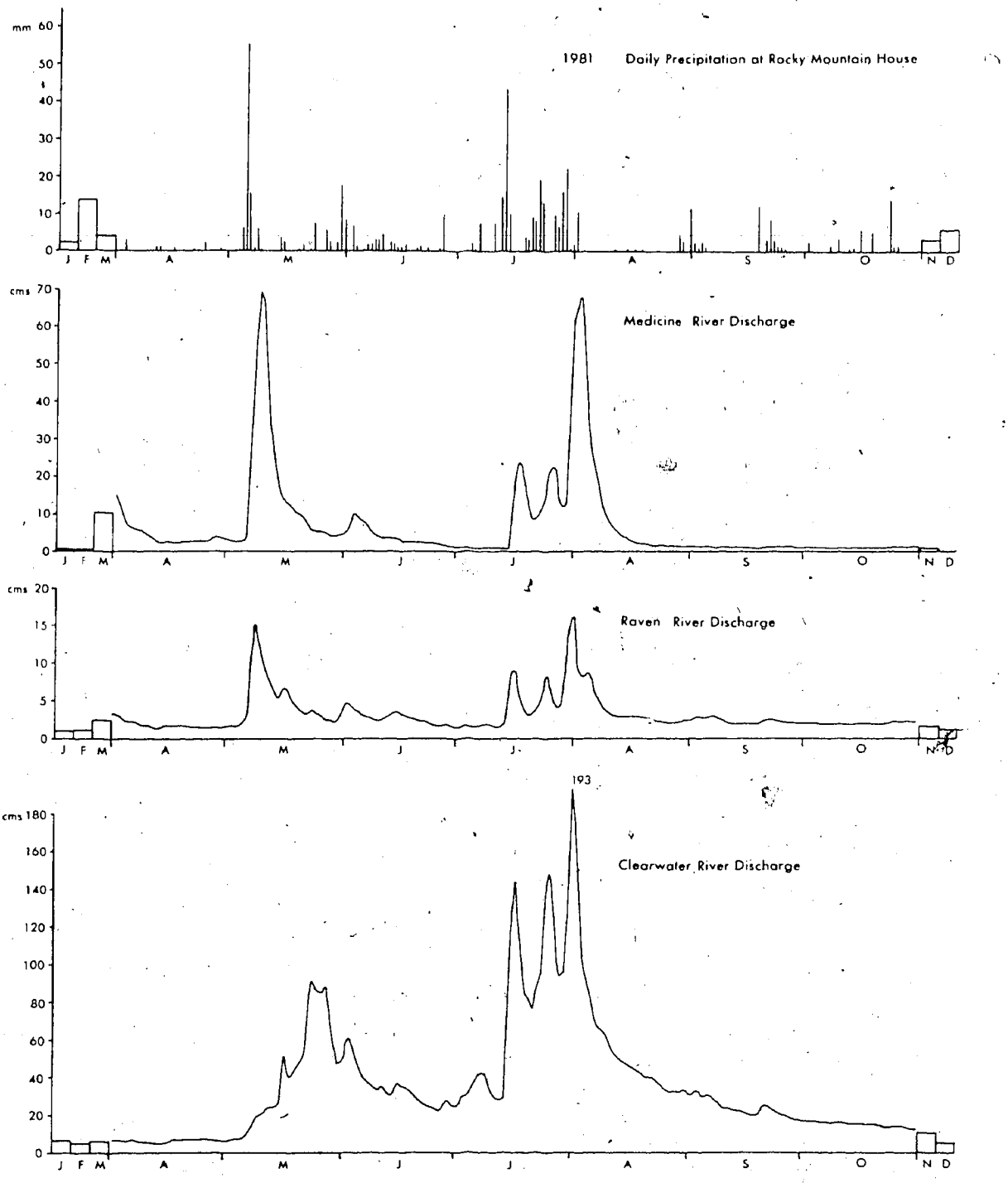
1979 - Low Flow Year

As discussed before, 1979 was a year of below average precipitation and streamflow in the study area. The discharge for the Medicine and Raven Rivers peaked in April as snowmelt runoff combined with small amounts of spring precipitation. Medicine River discharge declined rapidly from 31.5 cms on April 22nd to 3.5 cms only 12 days later on May 4th. For the rest of the year Medicine River discharges seldom exceeded 1 cms except when runoff from small precipitation events boosted it to 3 or 4 cms; after



Sources: 1. Environment Canada 1979 Monthly Record: Meteorological Observations in Canada. AES, Downsview, Ont.
2. Environment Canada 1979 Surface Water Data, Alberta Inland Waters Dir. Water Res. Branch, WSC, Ottawa.

Fig 4 1979 Precipitation and Streamflow: Representative Low Flow Year



Sources: 1. Environment Canada 1981. Monthly Record. Meteorological Observations in Canada AES, Downsview, Ont.
2. Environment Canada 1981. Surface Water Data, Alberta Inland Waters Dir. Water Res Branch, WSC, Ottawa.

Fig.5 1981 Precipitation and Streamflow: Representative High Flow Year

approximately mid-August discharge remained at or below 0.5 cms. Considering the size of this drainage basin the contribution of groundwater to streamflow is very small; baseflow levels are extremely low and decline is rapid following spring snowmelt runoff. The rapid decline rate following spring runoff indicates a lack of active storage within the Medicine River drainage basin. Even though a significant amount of the basin is poorly drained muskeg, these areas appear to contribute little to streamflow during dry periods. In dry years much of the local flow is into these depressions and evapotranspiration would exceed inflow thus net outflow for these parts of the Medicine basin would be below that representative of local runoff for the rest of the basin.

The fluctuation in discharge on the Raven River is much less dramatic. After the spring runoff peak of 11cms on April 20th the discharge dropped rapidly to 5.5 cms five days later, and from then on the decline in discharge was very slow and interupted only by minor oscillations resulting from precipitation runoff. Baseflow levels for the Raven are extremely consistent, remaining between 1 and 2 cms throughout the last half of 1979. For eight months of the year (ie. August through March) the difference between the historical maximum and minimum monthly discharge is less than 0.75 cms. This indicates the significance of groundwater discharge to the streamflow regime of the Raven.

During 1979, Clearwater River discharge fluctuated markedly throughout the summer but a general overall increase, likely due to delayed snowmelt from mountain areas of the basin, was evident. Although the highest discharge occurred in May, the actual seasonal decline in discharge did not begin until July and continued slowly through the summer and fall reaching baseflow levels between 5 and 10 cms in October.

1981 - High Flow Year

Many of the features noted for the 1979 discharge hydrographs such as decline rates, comparitive baseflow levels, and snowmelt contributions apply to those for 1981 also. The intense precipitation event of May 5th (55 mm) resulted in a large peak in discharge on the Medicine and Raven Rivers; the snowmelt runoff occurred in March. On the Clearwater the effect of this precipitation event was not apparent, the snowmelt runoff peak occurred late in May and discharge declined throughout June. Lesser rainfalls in late May and June caused several oscillations in an otherwise declining discharge curve for all three of the streams. By mid-July both the Medicine and Raven had reached

baseflow discharge levels.

In July, three large precipitation events occurred. The areal extent of these rain storms must have been large since all three of the streams experienced corresponding peaks in discharge. Although the first event brought the most precipitation (75 mm), the third event (67 mm) yielded by far the highest runoff. A much greater proportion of the precipitation was utilized for soil moisture recharge during the first event than in subsequent events after soil moisture capacities had been reached. The base flow levels were slightly higher for the streams in 1981 than in 1979, this is likely a result of increasing water table levels consequent with higher precipitation.

C. Groundwater

A part of the precipitation on basins percolates down through the soil and, upon reaching the water table, becomes groundwater. Some groundwater is discharged to streams as groundwater runoff and some is discharged into the atmosphere by the processes of evapotranspiration. Evapotranspiration is important where groundwater tables are shallow and within easy reach of plant roots. Evapotranspiration and soil moisture requirements have first priority on precipitation. Rainfall percolates to the water table to recharge the groundwater reservoir during periods when precipitation is in excess of both evapotranspiration and soil moisture requirements and the ground is not frozen. In the study area, groundwater recharge is greatest in the spring when snowmelt runoff occurs and PE levels are low. In the summer, little precipitation reaches the water table except during periods of excessive rainfall.

By monitoring water levels in wells over an extended period of time the behaviour of a groundwater reservoir in response to precipitation, streamflow and other local sources of recharge and discharge can be investigated. No intensive studies of this nature have been carried out in the study area but some monitoring of groundwater levels in relation to spring flow south of Caroline has been done by the Alberta Research Council (Borneuf, 1983: pers. comm.). An evaluation of groundwater potential in the Rocky Mountain House area was carried out by Tokarsky(1971) in an effort to determine the expected quantity of well yield and quality of groundwaters. Much of the information on which the hydrogeological mapping is based was obtained from reports submitted by well

drillers. The recorded information includes depth to water measured during drilling, extent of the water bearing interval, initial test rate, and general lithological description.

Estimates of probable well yield, information concerning groundwater chemistry, and the location of major springs are displayed on the hydrogeological map constructed by Tokarsky. Well yields to be expected within the study area range between 100 and 500 l/min as a regional average. The main aquifers are bedrock sandstones of the Paskapoo Formation. Yields above the regional average (ie. 500 to 2500 l/min) can be obtained from alluvial or buried sands and gravels, from confined aquifers in topographically low areas, and from aquifers receiving water by induced infiltration from surface waters. Yields below the regional average occur in areas where the permeability of the Paskapoo Formation is low (due to increased shale content) as is the case in the southeastern corner of the study area where wells may yield only 25 to 100 l/min. All of the communities within the area (except Rocky Mountain House) and the majority of the farms use groundwater for their domestic water supply.

The zones of high groundwater discharge which contribute to local streamflow are of particular interest in this study because the potential exists for an interbasin water transfer via enhancement of groundwater discharge into the streams of the Red Deer basin. Several large capacity springs occur on the Clearwater delta (see Fig. 6), some of which drain into the Clearwater River and some which constitute the origin of Stauffer Creek. The continuous discharge of a number of these streams was measured for a 20 month period from May 1971 through December 1972 (Borneuf, 1983). Two of the three springs on the northwest edge of the delta which flow into the Clearwater and have been previously referred to as Butte Spring have been monitored. The combined discharge of these two springs ranged from 0.38 cms in September 1971 to 4.76 cms during a flood in June 1972. The stream which is formed by Butte Spring was monitored at a road culvert approximately one kilometer from the easternmost spring (see Plate IV.2).

As can be seen in the cross-section in Fig. 6, the Clearwater River is at a higher elevation and is hydraulically connected to the springs through the alluvial delta deposits. The extensive gravel deposits are evident in the gravel pits on the delta (see Plate IV.3). This gravel pit is located in the southwest quarter of section 7-37-5W5 and does not appear on the air photo. Several of the features discussed in earlier sections regarding

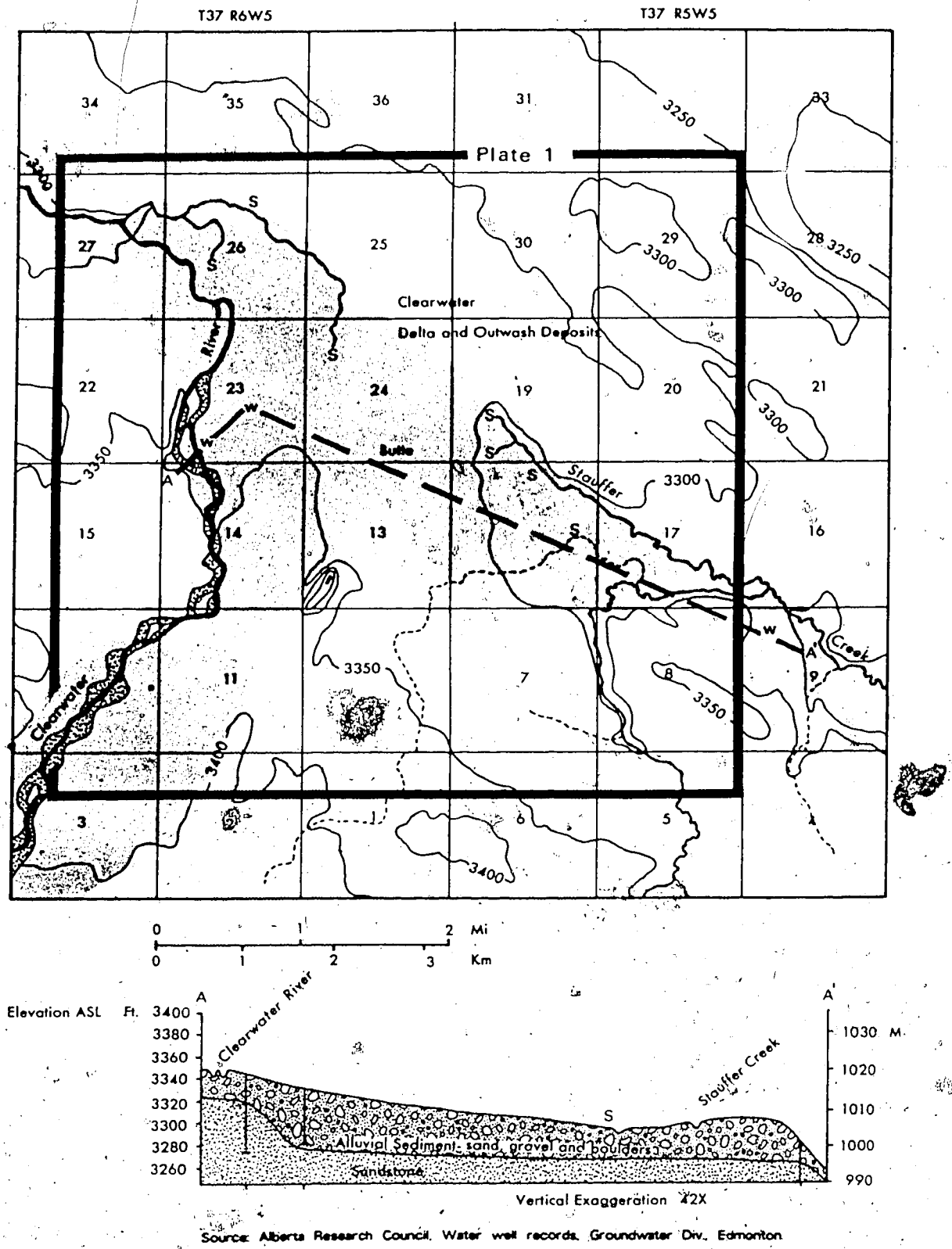


Fig.6 Location of Major Springs on the Clearwater Delta

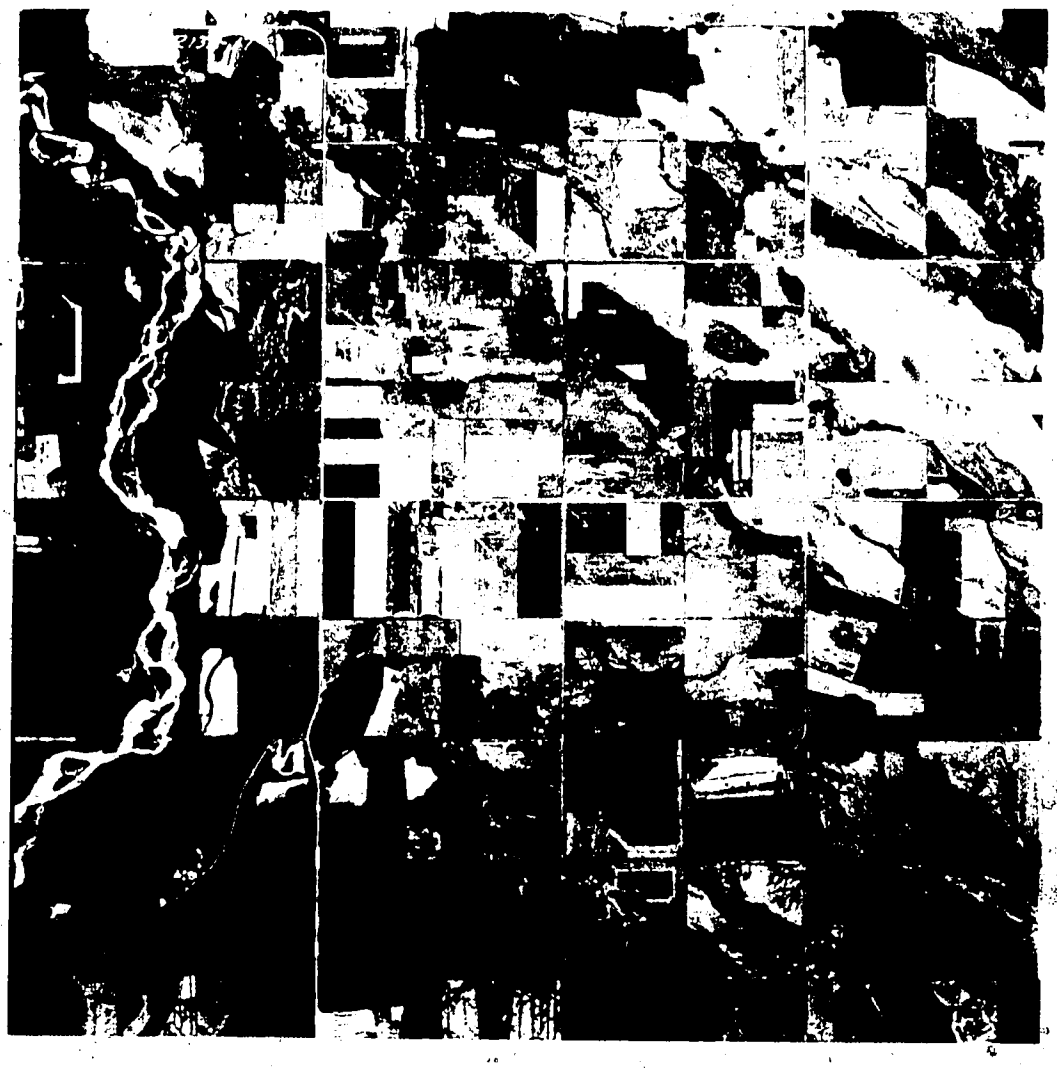


Plate IV.1 Air photo of Clearwater delta area – Summer 1966(scale 1:46,080).

Plate IV.2 Butte spring flow in Sept. 1982, upstream view 1 km from origin.

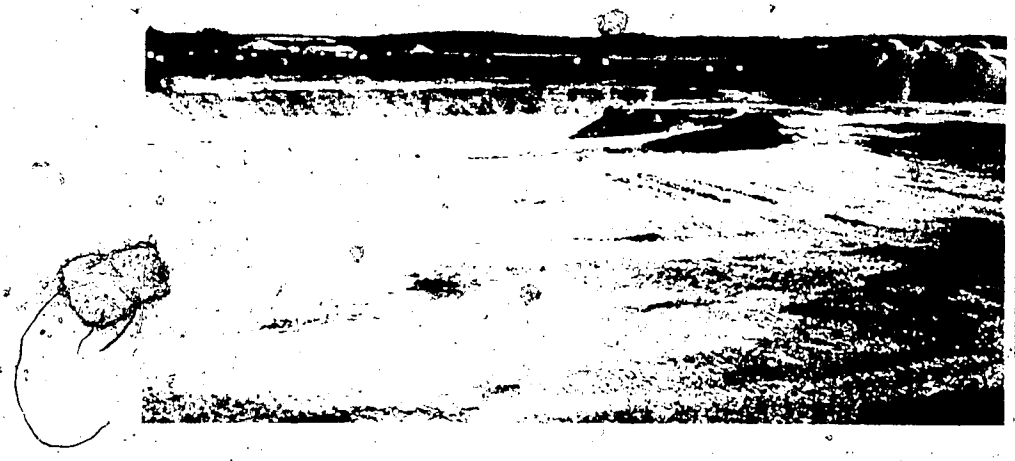


Plate IV.3 Gravel pit on Clearwater Delta.

the land use on the delta and the highly braided Clearwater channel are readily apparent on Plate IV.1. Although a small amount of brush clearing has taken place along Butte Spring and to the south of the delta, the area still looks very much as it did in 1966. The origin of the Butte and Stauffer springs are clearly visible, and the size of Butte Spring is apparent in Plate IV.2. The depth of excavation in the gravel pit is approximately 7 meters (see Plate IV.3) but water well drilling records indicate a total alluvial deposit as thick as 18 meters.

The fluctuations that were observed in discharge in these delta springs were attributed to three factors: i) a daily drop in discharge due to the influence of evapotranspiration; ii) sharp increases resulting from precipitation and snow melt runoff; and iii) increases related to high water stages of the Clearwater River. The high discharge in June 1972 does not reflect the true spring discharge because the Clearwater overflowed into the spring channel during this flood period (Borneuf, 1983; p.36).

As a result of several large precipitation events in June 1972, the Clearwater River reached flood stages (ie. max. daily discharge at Rocky Mountain House of 442 cms on June 26th) and overland flow across the Clearwater delta into Stauffer Creek was reported by Tokarsky(1983:pers. comm. and Geoscience, 1975) and Shirvell(1972). Tokarsky witnessed overland flow into the Butte Spring channel and from there along the northern edge of the delta down into Stauffer Creek; Shirvell reported overland flow across the southern edge of the delta into intermittent stream channels of Stauffer Creek. It is evident that the surface drainage divide is poorly defined on the delta and that a groundwater divide is not present. Although it is not known whether or not the Clearwater River is aggrading along the delta reach, there is a considerable potential for a natural shift of the channel to the east and perhaps recapture by the Red Deer basin. If aggradation is occurring then management might be introduced in order to limit the damage associated with such a channel shifting.

In the southeastern portion of the delta four distinct springs have been identified, these are but a few of a multitude of small groundwater discharge points that supply the northernmost branch of Stauffer Creek. In July of 1972 Shirvell(1972) measured discharge at ten locations along Stauffer Creek; at a point near the confluence of the north and south branches the discharge was 0.57 cms on the north branch and 0.59 cms below the confluence. The south branch drains a slightly higher area to the south of the delta and

obviously contributes significantly less flow to Stauffer than the north branch. The discharge at the mouth of Stauffer Creek was 1.30 cms, thus at least half of the streamflow was derived from the riparian groundwater springs on the Clearwater delta.

Over the same 20 month period that Butte Spring was monitored, the Stauffer Creek discharge (near the two springs in section 19-37-7W5) varied from about 0.19 cms in January 1972 to 0.38 cms in June 1972. Just as with Butte Spring, fluctuations in discharge are related to precipitation events and Clearwater River stages. Contrasts between the streamflow hydrograph for Prairie Creek and that for Stauffer Creek over a 16 month period in 1978 - 79 indicate differences in the hydrologic character of the two streams (see Fig. 7). It must be kept in mind that the gauging location on Stauffer is so close to the origin springs that the surface drainage area above the gauge is extremely small compared to that of the Prairie Creek gauge. Thus, the influence of surface runoff on fluctuations in discharge is more pronounced on Prairie Creek. Aside from small distinct peaks following summer precipitation events, the Stauffer discharge hydrograph is very stable and marked by a gradual yet consistent increase in summer and decrease in the fall. The lag time between the highest stages on the Clearwater (ie. May and June) and those on Stauffer (ie. August and September) during 1978 and 1979 is about three months. The delta acts as a groundwater reservoir which is slowly depleted during the fall and winter and recharged again in spring and summer when stages are high on the Clearwater River. The Stauffer Creek hydrograph is indicative of this regulation of discharge provided by the delta groundwater reservoir.

Water temperature measurements taken by Tokarsky (Geoscience, 1975) in 1971 and 1972 indicated that the spring water was warmer during the winter than in the summer. This would suggest that it may take several months for warmed Clearwater River water of the previous summer to move through the delta to the Stauffer springs. By comparing water temperatures of the Clearwater and Stauffer the average velocity of the groundwater flow through the delta was estimated at 5.3 m/day; based on other estimates (ie. permeability of alluviam, hydraulic gradient across the delta, and saturated thickness of the aquifer) the average transmissivity of the delta was calculated to be 2609 m^3/day/m (Borneuf, 1983).

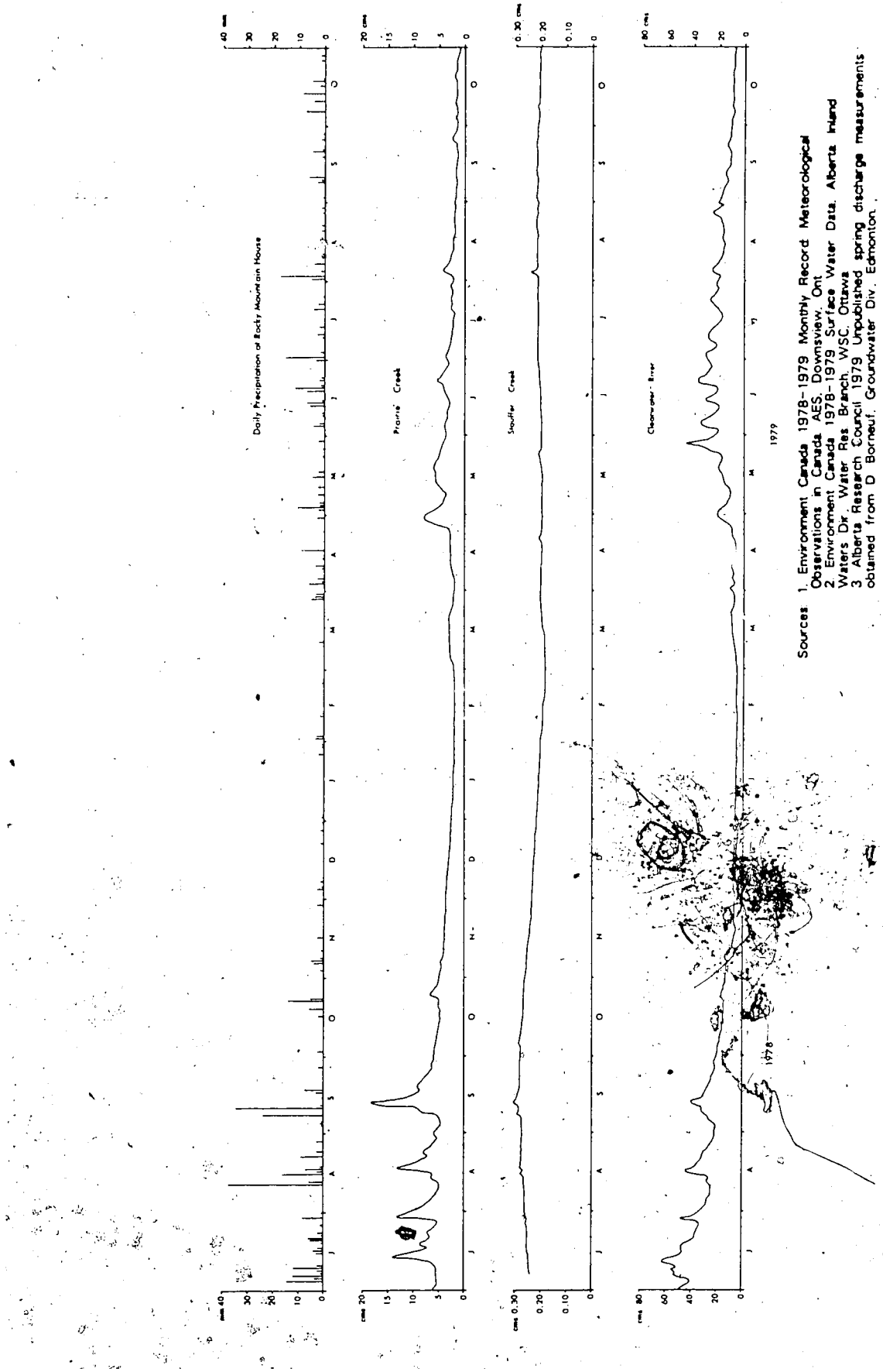


Fig.7 Contrasts in Stream Discharge-Stauffer and Prairie Creeks

Any means which could be used to increase the hydraulic gradient across the delta would increase the volume of spring discharge into the Red Deer basin. In chapter five some rough quantitative estimates of the effect that raising the level of the Clearwater River might have are discussed. Another alternative would be to increase the elevation of the water table in the delta by means of artificial groundwater recharge using Clearwater River water in some sort of water spreading scheme.

Artificial Recharge

Artificial recharge may be defined as the practice of increasing, by artificial means, the amount of water that enters a groundwater reservoir. An artificial recharge installation may serve more than one purpose. In the Clearwater delta area artificial recharge could be practiced to: i) conserve and divert a greater percentage of local runoff and flood waters from the Clearwater, ii) supplement the quantity of groundwater available in the delta reservoir, and iii) increase the water level in the delta reservoir.

Recharge directly from precipitation and by infiltration of surface water involves the downward movement of groundwater under the influence of vertical head differentials. Thus, recharge involves vertical leakage of water through deposits. The quantity of vertical leakage is controlled by the permeability and thickness of the deposits through which leakage occurs, the head differential between sources of water and the aquifer, and the area through which leakage occurs. Spreading methods may be classified as flooding, basin ditch or furrow, natural channel, and irrigation. With the relatively flat topography on the Clearwater delta, water could be diverted from the Clearwater and spread over a large area. Compared with other spreading methods, flood spreading costs the least for land preparation (Walton, 1970).

The creation of one large, or a number of smaller ponds on the delta could be used to artificially recharge large portions of the permeable delta deposits. This would raise the water table in the underlying reservoir and in turn cause an increased groundwater discharge into Stauffer Creek. These ponds may also create a small amount of additional recreational potential in the area. This is one alternative interbasin transfer method which is considered in the following chapter but many other combinations of artificial recharge and groundwater extraction could also be used. For instance, by operating a network of water production wells on the delta the pumped water could be run into Stauffer Creek;

any drawdown in the groundwater reservoir would likely be offset by an increase in the amount of recharge from the Clearwater River.

A better understanding of the actual hydraulic system involved in the delta would be required before any further development of the existing system of groundwater underflow could proceed. Accurate information concerning the aquifer thickness and lateral extent, in addition to lithological variations would be required to model flow through the delta. Borneuf(1983:pers. comm.) suggested that oxygen isotope ratio comparisons between groundwater samples taken throughout the delta and Clearwater River samples could be used to accurately determine the velocity of flow through the aquifer. An accurate simulation model of the aquifer could help in optimizing the operation of an interbasin transfer scheme based on increasing groundwater discharge. Numerical models of groundwater basins do, however, have limitations (Boonstra and de Ridder, 1981).

The Raven River, like Stauffer Creek, has a very stable streamflow regime indicative of a strong groundwater baseflow component. A large spring flowing at between 200 and 300 l/s emerges from sandstone underlying thick gravels near the Raven River, southeast of Caroline (Borneuf, 1983: p. 76). This spring provides water for a provincial fish spawning station. Borneuf(1983:pers. comm.) suggests that, based on monitoring of groundwater observation wells in the catchment area to the south of this spring, the local recharge in the catchment is sufficient to supply a spring of this magnitude. However local water balance calculations do not support such a claim. The largest mean annual surplus for the study area is 177 mm (ie. 12 mm storage capacity). Assuming the drainage area supporting this spring is roughly equivalent to that of the Beaver Creek basin (ie. 5 sections or 13 km^2), the maximum discharge for the basin (both groundwater flow and surface runoff) would only be 73 l/s. This discrepancy plus the fact that this spring flows relatively consistently in both wet and dry years suggests that some additional source of groundwater recharge is supplying the spring. It is possible that the Clearwater River is that source; it would be interesting to further investigate the possibility of a groundwater connection.

Carlson's(1970) work could be used to support the existence of a buried preglacial or inter-glacial valley connecting the present Clearwater and Raven valleys west of Caroline. Further analysis of existing well logs and cores in addition to a seismic survey would make

it possible to determine if such a depositional connection between the basins exists. If so, in an effort to determine whether or not a hydraulic connection exists, a network of piezometers and observation wells could be used to monitor water table variations and compare them with variations in stage on the Clearwater. In addition, chemical comparison of groundwater and streamflow samples could be useful; such comparison was used successfully by Newbury, Cherry and Cox(1969) to identify groundwater discharge derived from in-basin and out-of-basin sources in a small drainage basin in Manitoba.

D. Existing and Future Use of Streamflow

Fundamentally, water resource development entails the modification of a natural hydrologic system to meet man's needs. Regardless of the modifications made to certain parts of the system, the equilibrium of the system is changed and other components or elements are affected. Consequently, one of the main concerns raised in connection with any water development scheme is the effect it will have on the existing stream system's use. The usage of streamflow can be divided into two categories: i) "instream use" which encompasses any and all uses of water in a stream channel (ie. navigation, hydropower, recreation, fish and wildlife, riparian vegetation, aesthetics), and ii) "out-of-stream use" which includes any of the uses for which water is withdrawn from a stream (ie. agricultural, industrial, municipal, recreational, mining and thermal power).

As noted in Chapter two, the primary justification for developing interbasin transfers of water to southern Alberta is to increase the supply of water available for out-of-stream use in irrigation. Although much controversy exists over whether such water developments can be justified on these grounds, it is generally accepted that the ultimate end-use of transferred water would be for irrigation. Putting aside the question of whether or not expansion of irrigation agriculture is sufficient justification for interbasin transfer, the potential expansion of irrigation water usage in the province will be briefly reviewed.

Water Use in Irrigation

It was suggested earlier that water transferred from the Clearwater along with improved use of existing South Saskatchewan supplies could support reasonable levels of irrigation expansion in lieu of large interbasin transfers from the North Saskatchewan. The amount of water used for irrigation is influenced by a large number of interrelated factors; in very generalized terms, the volume of water used for irrigation can be estimated by applying an average "irrigation duty" to a given area of irrigated land. The actual usage of water is influenced by such factors as:

- Amount of precipitation during the growing season.
- Irrigation efficiency defined as the percentage of water diverted for irrigation that is actually made available to plants.
- Water requirement and efficiency of water use by various crops.
- Farm management decisions concerning the area of land to be irrigated plus the timing and amount of water application.

For southern Alberta, the Prairie Provinces Water Board uses an irrigation duty estimate of 4.57 dam^3/ha (PPWB, 1982). This is the amount of water that is needed in a dry year to irrigate most crops in southern Alberta. In 1977, considered to be an extremely dry year (ie. May to September precipitation was 60% of normal), the average net consumptive use for all of the irrigation districts was 4.8 dam^3/ha (PFRA, 1982).

In Chapter five this irrigation duty estimate is applied to various Clearwater transfer volumes to determine the amount of irrigation it is capable of supporting. By providing further estimates concerning the average annual increases in land area irrigated, a rough estimate of the number of years of average irrigation expansion Clearwater transfer could support is also obtained. Although the total area of land actually irrigated fluctuates greatly from wet to dry years, the general trend (based on dry year values) over the 1965 - 1979 period was an increase in the total irrigated area of 10,000 ha per year. Hence, combining these two rough estimates yields an average annual increase in irrigation water usage of 45,700 dam^3; this value is also used in discussion of potential Clearwater transfer volume in Chapter five.

Assuming these estimates are realistic, a transfer of 1 cms for the period May through September could provide enough water to irrigate approximately 2900 ha of land.

This would be enough to support some of the smaller irrigation districts (ie. Mountain View, Leavitt, Aetna, or McGrath) but it would be of little significance in expanding irrigation, providing only one sixteenth of that required to support a year of future expansion. However if the rate of transfer was increased to 5 cms. and the transfer operated year round, enough water would be transferred to irrigate 34,500 ha of land. This would be enough water to supply the Taber Irrigation District or support almost 3.5 years of irrigation expansion. If the entire Clearwater Riv[illegible]s diverted enough water would be transferred to support 8 to 17 years of fu[illegible] expansion. A water transfer that could provide volumes of water at this sc[illegible]f great use (at least in the short term) in dry years for alleviating conflicts betw[illegible]ream and out-of-stream uses in the Oldman basin. By increasing discharge in the Red Deer River, water users in the South Saskatchewan basin in Alberta could utilize greater than 50% of the streamflow in that basin; this means of effecting a transfer was discussed in chapter two.

Water transferred to the Red Deer River from the Clearwater could also be used to directly off-set that withdrawn for irrigation in East Central Alberta if such a irrigation scheme was ever to develop. Irrigation in this area would basically involve supplementary watering of crops already grown in the area such as cereal grains and forage crops. These crops [illegible]erally harvested by mid-August, thus water transferred from the Clearwater [illegible]llocated to the Oldman basin to supplement dwindling supplies late in the irrigation sea[illegible].

In the following chapter, the development potential of several selected transfer alternatives will be asessed. One of the more tangible measures of this potential is the amount of irrigation a particular transfer is capable of supporting. In the following section important instream uses of water in the study area are explored in regard to the potential effects brought about by Clearwater transfer.

Instream Use of Water

The claim is often made that "surplus" water can be removed for out-of-stream uses without dramatically affecting the aquatic system. This raises questions in regard to determining what amount of stream flow can be [illegible]dered to be surplus, and what amount can be considered to be excessive when flows are augmented. It is important to

determine how much water should remain for the maintenance of viable aquatic ecosystems (water quality, fish and wildlife) as well as the s for aesthetics and recreational use by man.

The interrelationships among elements of the hydrologic system, though varied and complex, are relatively simple in comparison with the social, legal, economic, political, and institutional interdependencies involved. Not only is it hard to balance trade-offs between instream and out-of-stream uses of water but it is difficult to ascertain what a desirable instream flow requirement might be, given conflicting requirements among the various instream uses. A general overview of the existing instream uses of water in the study area and a review of several approaches used to establish instream flow requirements for each of these uses is presented. A range of flow requirements will be defined for the donor and receiving streams and applied in quantitative volumetric estimates of water transfer for a number of alternative transfer methods outlined in chapter five.

There are a number of questions which should be borne in mind when considering the establishment of instream flow requirements. The following questions are particularly pertinent and are but a few of those addressed by the Pacific N.W. River Basin Commission(1972) during an instream flow requirement workshop focusing on fishery and recreational water quality needs:

- Should the objectives in establishing instream flows be i) the maintenance of existing quality and usage, ii) the return of the stream to some natural condition, assuming such return is an improvement, and iii) the enhancement of the stream to its optimal condition?
- How should one attempt to integrate various instream flow requirements?
- How does one compare the cost of different ways of maintaining instream flow levels when natural flows are inadequate (ie. storage, transfer, reduction of withdrawls) with the benefits from flow regulation?
- How does one evaluate instream flow requirement in relation to benefits foregone?

In general, water resources planning is a technique of public investment decision making. Consequently, there has been an upsurge of interest and concern in water allocation and instream requirements for maintaining the integrity of the aquatic-riparian

ecosystem. This would unquestionably be the concern in regard to a water transfer using the Stauffer–Raven system which is recognized as a high value aquatic habitat and recreational resource worthy of protection. Instream requirements for the Clearwater must also be considered since in this case a portion of the stream might have to be sacrificed altogether in order to obtain significant quantities of water. For the Horseguard–Medicine system, which has little if any value as a recreational resource, the possibility exists for improving the stream habitat and perhaps creating a viable trout stream; this possibility warrants further investigation.

Fish and Wildlife

The emphasis in this review is on the sport fish in the study area, in Stauffer Creek particularly, because they represent a unique and obviously highly valued resource in the area. They also stand to be greatly affected by any water transfer from the Clearwater which utilizes the Stauffer Creek channel to convey the diverted water. The long term effect of such a development on wildlife, with the possible exception of aquatic wildlife such as beaver and muskrat, is thought to be negligible. However, if major channel improvement was undertaken along any of the receiving streams the removal of riparian vegetation could bring about a significant change in wildlife habitat.

Formal methodologies for determining instream flow requirements for wildlife purposes do not exist (Kadlec, 1976) but some methods that have been used to assess the effects of other water resource developments (ie. dams, reservoirs, land drainage) on wildlife, might be modified for this purpose. It is felt however that the disturbance created during the construction phase would be the greatest source of impact on resident wildlife populations and that during the operational phase the impact would be negligible.

The two most sought after sport fish groupings in Alberta are trout which are primarily native to cold–water eastern slopes areas and walleye native to northern areas. The resources available within the development unit of Alberta's Fisheries Branch of the Fish and Wildlife Division are focused on the resolution of sport fish resource shortfalls through habitat improvement particularly as it concerns trout (Crutchfield and Paetkau, 1982).

The objective of habitat management on trout streams is to provide ideal living conditions for trout. Ideal trout streams provide the following characteristics in adequate and optimum amounts: cover, living space, spawning areas, food, temperature and streamflow (White and Brynildson, 1967). Streamflow is perhaps the most important because it fluctuates so do the other characteristics of the stream. Most limiting factors are reduced in the presence of a stable flow. The difference in flow regime between Stauffer and Prairie Creek is likely the major reason for their differences in gamefish productivity (Fitch, 1981). A productive trout stream has well defined banks of firm sod supporting abundant grass and shrub cover. A near equal ratio of pools to riffles and a clean gravel bottom for trout food production and spawning are also characteristic. Cover and shade provided by overhanging vegetation is important for maintaining cool water temperatures (Hunt, 1966 and Hooper, 1973).

Fish population surveys on Stauffer Creek carried out by Cunningham in 1961 and again in 1964 indicated that the amount of productive trout habitat had decreased substantially. By 1972, when Shirvell(1972) conducted a more detailed fisheries study, it was evident that watershed deterioration caused by increased siltation was the major cause of the decline in the resident trout population. The purpose of Shirvell's study was to provide needed fluvial and biological baseline data, as well as to develop a plan by which further habitat deterioration could be halted, deteriorated habitat improved, and existing habitat protected along Stauffer Creek.

Stauffer Creek is inhabited by nine species of fish. The most abundant species are eastern brook trout and brown trout which occur commonly in the areas of faster flowing, cool water. Northern pike and white suckers occur in low velocity, warm water areas where abundant aquatic vegetation and silt substrate is present. Longnose suckers, two species of dace and brook stickleback are also present. The two species of trout separate their distribution in the creek according to water temperature. The upper 1.5 km (summer max. of 10° - 11° C) on the north branch of Stauffer Creek supports predominantly brook trout. Between 1.5 and 5.0 km downstream (11° - 19° C) equal numbers of brook and brown trout are present, while predominantly brown trout occur from 5.0 to 10 km (19° - 21° C) downstream. The remaining 10 km downstream section of the creek has a very low trout density (ie. less than 90 fish/km of channel) compared to

the upper 10 km of Stauffer (ie. averaging 560 fish/km) and is therefore assumed to have limited potential trout habitat principally becuase of higher water temperatures and limited spawning area. Perhaps the trout habitat in the lower half of Stauffer could be improved if water diverted from the Clearwater was introduced at a point half way down the creek, or if groundwater discharge into Stauffer Creek was increased.

Shirvell(1972; p. 67) came to the conclusion that it is the physical characteristics, especially high amounts of sediment (covering spawning and food producing gravel areas) that are the major limiting factors to the trout population in Stauffer Creek. The brook trout population in the upper reaches of the stream is limited by food production and space. The downstream distribution of brook trout appears to be limited by higher water temperatures during the summer. By removing beaver dams in these sections of the stream the water temperatures could likely be reduced thereby expanding the brook trout's downstream range. Brown trout were generally found farther downstream than the brook trout, near undercut banks or other cover; the lack of cover in the upper sections could be the reason for their limited abundance there. Inadequate spawning areas limit the number of brown trout in the lower sections of Stauffer Creek; silting over of spawning gravels has reduced the amount of favorable spawning area.

The provincial government has since taken action to preserve and restore the upper half of Stauffer Creek based on recommendations made in Shirvell's study and its policy of acquiring and/or preserving valuable sports fisheries habitat. In 1972 a habitat management unit was organized within the Fish and Wildlife Division. This marked a new direction and expansion towards fish and wildlife management not concerned solely with the harvest of resources. The "Buck For Wildlife" program was part of this reorganization. It involves the acquisition of revenue from the sale of fishing and hunting licences. Current annual revenues are approximately $650,000 (Crutchfield and Paetkau, 1982). The objectives of the Buck For Wildlife program will be discussed in more detail in the following section on water-based recreational resources.

Along Stauffer Creek it was felt that a protection effort on public and private land was necessary and Buck For Wildlife became actively involved in the protection of significant trout habitat (see Plate IV.4). This has primarily involved the fencing of disturbed streambanks in order to isolate important habitats from adverse agricultural

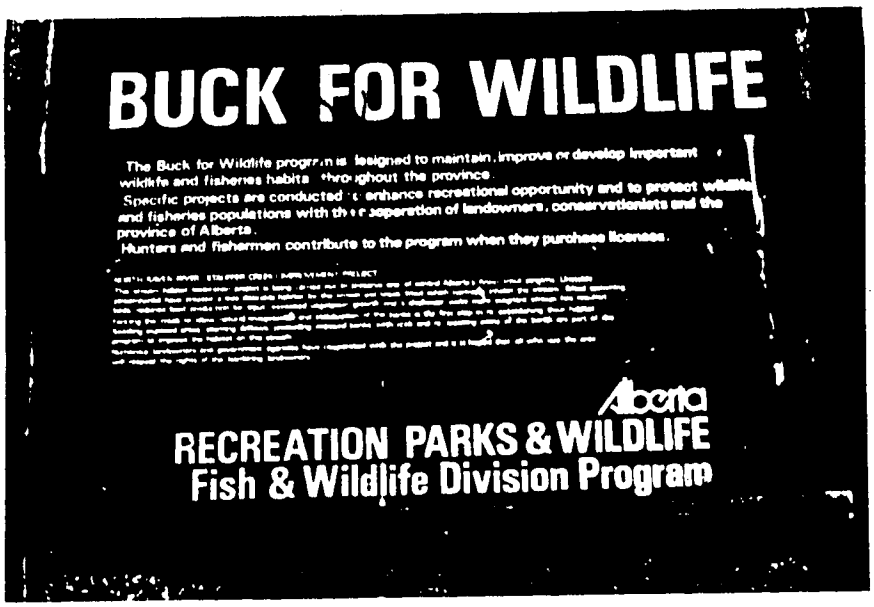


Plate IV.4 Sign posted along Stauffer Creek

Plate IV.5 Upstream view of Stauffer Ck.: note meter tape and gabion baskets

activities. Much of the effort has been directed to stream areas bordered by private land and undergoing heavy encroachment from cattle grazing and watering, land clearing and vehicle crossing sites. Fencing off the stream (which began in 1974) has allowed riparian vegetation to reestablish and stabilize stream banks, to date, it appears to have been effective in reversing the processes responsible for degradation of trout habitat.

In addition to fencing, some stream channel improvements were undertaken. The primary objectives were to develop suitable pools and scour fine sediment from the stream bed to expose a more suitable gravel substrate. The channel improvement work involved a two kilometer section of creek. It entailed the narrowing of the channel width with wooden and steel basket gabion groins to induce bank development and the development of new banks with gabion baskets (see Plate IV.5). Although the objectives of this project appear to have been met the impact on the trout population is not known, no post-project fisheries studies have been conducted. According to Kraft(1983: pers. comm.), the habitat improvement program will result in the alteration of the trout population profile, especially for brown trout. He expects that there is a higher proportion of older, larger fish but that the total population may have dropped, partly due to increased angler use of Stauffer Creek.

It has been suggested previously that a habitat improvement or more precisely a habitat creation program could be undertaken on Horseguard Creek in conjunction with water transfer from the Clearwater. Kraft(1983: pers. comm.) felt that there was definite potential for creating habitat based on work done in Wisconsin by White and Brynildson(1967) but the cost may be prohibitive. A large amount of clearing and snagging of aquatic and riparian vegetation and creation of adequate spawning areas would be required and perhaps straightening of the channel to bring about a needed increase in channel slope. As it presently exists, the Medicine River system has little if any suitable trout habitat, water temperatures are too high, flow is sluggish and the substrate is unsuitable. Iron concentration in the stream might also be of concern since the creek drains organic-rich muskeg areas which yield high amounts of soluble iron (Hynes, 1971). According to Fitch(1981) good trout streams have iron concentrations less than 0.7 ppm and fish die at concentrations between 1.0 and 2.0 ppm. Stauffer and Prairie Creeks have iron concentrations ranging from 0.1 – 0.2 ppm and 0.1 – 1.0 ppm respectively. Chemical

analysis of the Horseguard water would be required, and if found inadequate, the effectiveness of using Clearwater water to improve the quality would need to be investigated.

The excessive amount of aquatic and riparian vegetation along the upper reaches of the Horseguard is evident in Plate IV.6. The actual channel capacity of the creek is quite substantial (See, Plate IV.7) but because of the extremely low gradient and excessive in-channel obstructions it drains very slowly. In fact, in August of 1982 (a low flow period for other High Plains streams) the Horseguard was very close to bankfull condition in the upper reaches but the actual discharge was insignificant. Hence, the ability of the system to handle an increased level of flow would need to be improved in order to avoid widespread flooding caused by interbasin augmentation.

Instream Flow Requirement

Most instream uses have an 'extinction point', a minimum volume of water below which that use cannot exist. Similarly, most in-place water uses have a 'flood point' where excess flows, or levels, effectively extinguish that water use. Somewhere between those two points lies an optimum, being that flow or level at which a water use is maximized (Trihull and Loomis, 1973). On Stauffer Creek the situation is somewhat unique in that a determination of the maximum recommended streamflow is required in contrast to determination of minimum flow requirement which is the focus of most of the research in this field.

High levels of discharge can cause extreme damage to trout populations even if flows occur for only a short period of time (Shirvell, 1972). During floods, large amounts of silt and debris are washed off the watershed, which includes cultivated land, into Stauffer Creek. Fish eggs or individuals of any size can be destroyed by unusually high silt laden water. The reduction in fish survival resulting from the 1972 flooding on Prairie Creek is discussed by Fitch(1981). Although it is obvious that the volume of transfer into Stauffer Creek should be below that which would cause flooding, it is not so obvious how much below the flood level it should be. Maintaining high discharge levels for long periods of time could cause increased bank erosion and bottom scouring (ie. increased sediment loads) in addition to eliminating valuable trout habitat through the disturbance of the existing pool and riffle sequence. Higher flow levels maintained for short periods of time

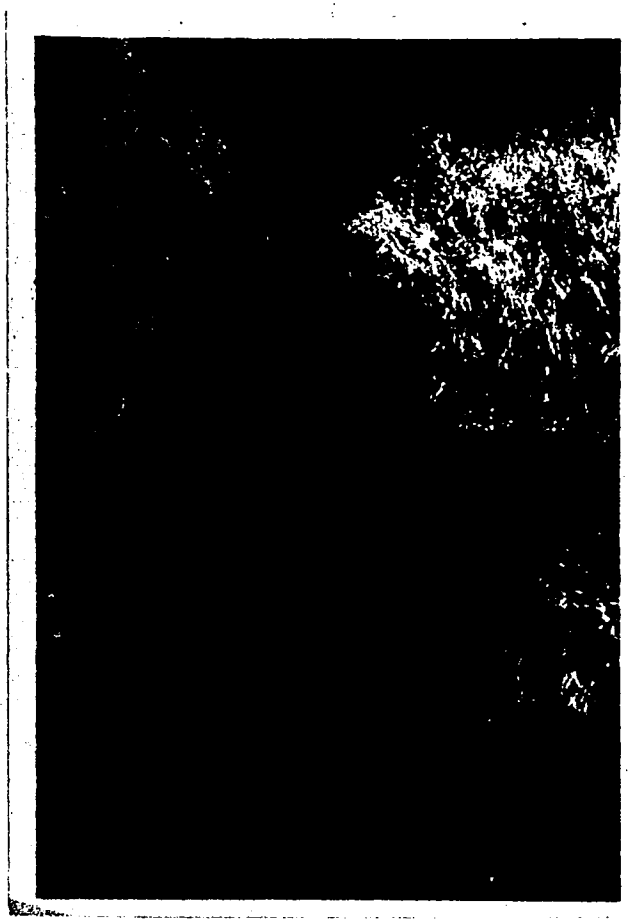


Plate IV.6 Vegetation choked channel of Horseguard Creek, Aug. 1982

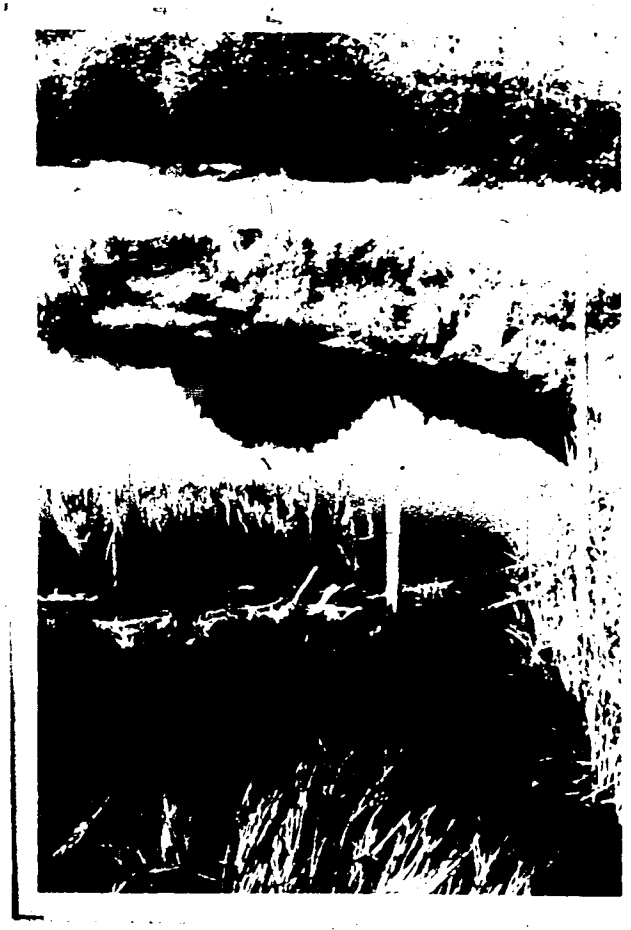


Plate IV.7 Evidence of high flow stages on Horseguard Ck., estimated bankfull discharge of 6 cms

may however be beneficial and help maintain a more desirable habitat for trout. Determining the consequences, that varying the timing and amount of flow in Stauffer Creek would have on the aquatic habitat, is beyond the scope of this research but it is important to consider the possibility of actually operating a water transfer and at the same time improving aquatic habitat for selected species in the receiving stream.

Methods for assessing uninhabitable (high velocity) portions of stream environments have received little attention primarily because most instream flow assessment has been directed toward flow reduction rather than flow augmentation. This situation is slowly changing and several references which could prove useful for further research are listed by Stalnaker and Arnette(1976). Due to the preliminary nature of this study and the lack of detailed stage vs. discharge relationships for various section of Stauffer Creek a number of "best-guess" estimates of bankfull discharge will be used to base calculations of the volume of water transfer.

Actual and bankfull discharge estimates were made based on rudimentary channel cross-section and velocity measurements taken at two locations on Stauffer Creek in August 1982. One of the cross-sections was located immediately downstream of the two headwater springs. An upstream view of the section is presented in Plate IV.8, note the meter tape at the bottom of the photo and the gravel substrate. Using flattened stream bank vegetation and general channel morphology indicators the cross-sectional area was determined for a bankfull condition. The actual cross-sectional flow area measured 1.00 m^2 and the estimated bankfull area measured 1.84 m^2. Assuming that the average flow velocity at bankfull stage would be one and a half to two times that actually measured; the bankfull discharge at this location would be in the order of 1 to 2 cms.

The second cross-section was located approximately 5 km downstream of the first (see Plate IV.5). Here the channel is considerably larger and the discharge was estimated at roughly twice that of the first section at the time of measurement. A bankfull discharge of 3 to 5 cms is postulated for Stauffer Creek at this location. Obviously an accurate determination of stage vs. discharge at a number of locations along the creek would be required to make any definite decision regarding maximum modified flow recommendations for water transfer alternatives.

Plate IV.8 Stauffer Creek immediately downstream of the origin springs

The maximum modified flow recommended for the purposes of this study is 2 cms for the upper half of Stauffer Creek and 5 cms for the lower half. Assuming that the flow measured in 1978 and 1979 by the ARC (see Fig. .7) is indicative of average conditions on Stauffer Creek, the average discharge at the first metering section is between 0.25 and 0.35 cms. Again, assuming that for average conditions, discharge is roughly twice as high at the second metering section, the average discharge would be between 0.5 and 0.7 cms. By subtracting the natural discharge estimates from the recommended modified flow maximum we obtain a maximum transfer flow of 1.7 cms for the upper half of Stauffer Creek and 4.4 cms for the lower half.

There is virtually no streamflow data available for Horseguard Creek, except for the crude flood discharge estimate (ie. 6 cms) made based on visual evidence for a location near the head of the creek (LSD 14-20-38-5W5. see Plate IV.7). It is however, assumed that with considerable channel modification and vegetation removal that the Horseguard could convey up to 4 cms of transferred water without causing major flooding.

Since withdrawal of Clearwater River water would be involved in any interbasin transfer scheme it is important to address two questions: i) what minimum flow requirement for fish, wildlife and recreation in the Clearwater River should be? and ii) what compromise can be made between water withdrawal and Clearwater instream flow needs during dry years when Clearwater discharge is too low to meet both needs?

In reference to the first question, three different methodologies utilizing average flow records are applied to determine a flow regime which would be satisfactory for maintanence of the various instream flow needs. The three methodologies that are applied are all based on historic streamflow records. Based upon flow studies and numerous observations, Tennant(1976) suggested semi-annual discharge regimen based on mean annual flow percentages. The U.S. Fish and Wildlife Service (Anonymous, 1974) developed a flow recommendation scheme for application to streams in the Northern Great Plains area. This procedure is based on individual monthly flow duration curves and recommends instream flows that are exceeded 90% of the time (referred to as the 10 - percentile flow). This technique results in a series of monthly flow estimates. The third technique, developed by the United States Forest Service and described by Stalnaker and Arnette(1976; p. 92), specifies preservation streamflows based on discharge percentile

levels also but is based on studies carried out on Rocky Mountain trout streams. The recommended flows for the Clearwater River, calculated utilizing these three methodologies, are displayed in Appendix 3.

Methodologies utilizing average flow records are primarily of value for reconnaissance or limited field studies for recommending instream flows early in the planning stages. For an appraisal of an extensive area, this type of method provides a relatively quick, inexpensive base for flow recommendations. Tennant's 30/60 percentage average annual flow and the monthly 10 percentile figure of the USFWS are usually satisfactory preservation flows.

Flow record analysis, developed in a particular region and based on a local hydrologic cycle, may be limited in its usefulness in other regions. The division of flow criteria into seasonal regimes should be adjusted to the climatic conditions of the region in question. Furthermore, flow regimes can also be modified to satisfy specific life cycle requirements of a given species, such as satisfactory flows for fall spawning brown trout. Before deciding on a flow recommendation these considerations would have to be more fully assessed. More detailed instream flow methodologies are available. These methodologies require varying amounts of intensive on-site field work and therefore larger time and funding commitments. They relate changes in hydraulic parameters gathered at one or several stream cross-sections at different flow stages to changes in habitat features such as pool and riffles, substrate, wetted perimeter, stream bank vegetative cover, turbidity, etc. These methodologies are attempts to assess instream flow needs in such a way that the effect of "with" and "without" development plans on the various instream needs can be more accurately quantified. The U.S. Bureau of Land Management(1977) has evaluated several instream flow methodologies and Stalnaker and Arnette(1976) have provided an excellent review of the entire range of methodologies for determining instream flows for fish and other aquatic life.

In reference to the second question regarding restrictions on withdrawal during dry years, a real trade-off between local environmental objectives and irrigation (assuming it is the end use of the transferred water) will have to be made. The importance of the Clearwater reach between the diversion point and the North Saskatchewan River should be assessed. The significance of this reach to fish populations, recreationalists, bordering

farmers and the region in general are of concern. Initially transfer would be small enough that provision for off-stream storage could eliminate the need for withdrawal from the Clearwater during occassional summer low flow periods thereby preserving recommended instream flow levels and reasonable transfer rates. However as demand for transferred water increases other alternatives would have to be explored including upstream storage, supplementary transfer from the North Saskatchewan or sacrificing this section of the Clearwater. A discussion of physical availability of water plus receiving and donor stream limitations is provided in chapter five where potential transfer volumes are calculated.

Recreation

It is common practice to include recreational development as an overall benefit arising from major water development projects. Modification of an environment can result in the creation of new recreational resources as well as the loss of existing ones. Opportunities for recreational enhancement exist in conjunction with a Clearwater transfer project. By incorporating features in the project design that provide for enhancement of existing resources and creation of new ones, some degree of compensation for any detrimental effects associated with development could be offered. However, several questions need to be answered to fully assess the "value" of such benefits to the community, the region and indeed the province.

Although it is beyond the scope of this study to discuss the issues and conflicts involved in outdoor recreation and water resources planning, some of the more relevant issues that would need to be considered in relation to Clearwater transfer development are stated they are:

- *Recreational use of agricultural land*: i) conflict over access, trespass, compensation, and the question of liability; ii) harassment of livestock and the physical damage to farm property and crops; iii) disruption of private enjoyment of a person's own property; iv) landuse change accompanying intensive recreation development (eg. agriculture to country residential or public reserve); v) public acquisition of land for recreational development, and vi) multiple landuse management approaches. Many of these issues are

discussed by Glasgow(1982) and Swinnerton(1982) in relation to use of agricultural land in Alberta for recreation.

- *Development trade-offs in water resource and recreation planning*: i) sacrificing operating efficiency (ie. diversion rate or reservoir level) for maintenance of recreational resources (ie. fishing, boating, viewing); ii) higher capital and operating costs with development of new recreational opportunities. The economics of including recreation as an objective of water resource projects is dealt with by Knetsch(1974).
- *Outdoor recreation development planning in general*: i) assessing both the supply and demand for recreation; ii) distribution of benefits and costs of such development; iii) ability of facilities to meet demand; iv) conflicts between various types of recreational activities.

The prime water-based recreational activity in the study area is sportfishing. Unfortunately detailed information is not available on the number of fishermen using the area and their preferences concerning when, where and why they choose to fish in the area. However, it is suggested that fishing in upper Stauffer Creek, the Raven River and parts of the Clearwater is generally excellent (Hilburn, 1980; Scammell, 1980). In fact, Stauffer Creek is recognized as one of Alberta's finest trout streams. In terms of productivity, Stauffer Creek was found to produce six times the average gamefish standing crop of Prairie Creek which is considered to be a good fishing stream in its own right (Fitch, 1981; p. 33). Both Cunningham(1964) and Kraft(1983: pers. comm.) noted that fishermen from many parts of the province use the area and that the upper portion of Stauffer Creek is fished year round.

Stauffer Creek has the characteristics of a "specialized recreation stream" as defined by Morris(1974) in his classification of rivers according to their recreational use. It offers a special recreational attraction such as high quality fishing. The participants travel to the site from the local area as well as from relatively long distance. The relative assessibility of the river to population centers is not a distinguishing factor and they normally take care to plan their visit to the site at a time when the conditions are suitable for their activity.

The larger streams in the study area are not as specialized toward one type of recreation use. The North Saskatchewan, Red Deer and Clearwater Rivers are used for instream recreation including fishing and boating as well as recreation adjacent to the stream (ie. picnicking, camping, hiking, driving, and viewing). The Red Deer and North Saskatchewan Rivers are much better suited for boating than the Clearwater (which can become very shallow) and as a result are used to a much greater degree. Trout fishing on the Clearwater is generally better in the areas upstream of the study area (Scammell, 1980) and therefore actual recreational activity on the Clearwater in the study area is low relative to other sections of the river.

Streams in the Medicine River system offer very little recreational opportunity principally because of their poor aesthetic and water quality. The appearance of these streams could be greatly improved with flow augmentation and through extensive clearing of bank and instream vegetation; such improvements would provide new opportunities for recreation adjacent to these streams. If water quality and flow regime could be improved enough to create viable sportfish habitat, new instream recreation opportunities could result and this would supplement the existing recreational resources in the area.

The provincial government has taken action to preserve the biological and recreational fish resource in the area through the Buck for Wildlife (BFW) program as mentioned previously. The large amount of money expended on fisheries research, aquatic habitat maintenance and preservation, and stream channel improvements on Stauffer Creek indicates the value placed on this stream not only by the sportsmen and local landowners (who continue to contribute to the preservation of this resource) but also by the provincial government. The BFW improvements carried out on this stream have set a strong precedent for the ongoing management of this stream, this should be given due consideration during the design of possible water transfer alternatives. Another consideration is the fact that many people may derive satisfaction from knowing that work is being done to preserve and enhance environmental quality whether they engage in fishing or not, and whether they visit the site or not. Thus, environmental enhancement could prove to be a valuable addition to water transfer development and serve to dispell many of the negative attitudes towards interbasin transfer in general. Additional recreational opportunities such as waterfowl hunting, fishing, boating, swimming, and

cottage development might be created by developing storage reservoirs and transfer canals with this purpose in mind.

Some of the objectives of BFW could easily be incorporated in Clearwater diversion plans to improve and perhaps create recreational opportunities in the area. Two of the primary objectives of BFW (Crutchfield and Paetkau, 1982) are:

1. To design and manage habitat on public or private land to intensify the production of significant wildlife species through habitat development, manipulation and management to: i) increase the quantity of habitat, ii) alter it in favour of one or more species, and iii) maintain habitat at a desirable level.
2. To promote change in the existing philosophies of land and water use toward that based on sound ecological principles.

There are two basic environmental modifications associated with water transfer that would have significant effect on the existing bio-physical recreational resources in the area. The first is altered streamflow regime. Depending on the rate of transfer, the receiving streams could experience either improvement or loss of valuable aquatic habitat and associated sportfishing potential. Secondly, instream structures on the Clearwater River would detrimentally affect boating on that river.

Measuring the impact of changing streamflow on these recreational activities would be difficult because approaches for specifically assessing recreation/streamflow relationships have not been developed. The study of stream-related recreation in the area could be important to the development of a water transfer for a number of reasons. If the transfer is to be developed for multiple purposes, one of which is environmental enhancement for recreation, planners will need to know the attributes of streams that users consider important. They can gather this information by observing, measuring and quantifying the existing recreational patterns for the area. Comprehensive data are also required on actual and potential resource conditions, ecological and social constraints, attitudes, and user interests. Andrews et al(1976) reviewed several of the methodologies that are applicable to measuring the effects of streamflow on recreation behaviour in order to reach conclusions concerning the availability of recreational opportunities in an area, the economic benefits associated with different "mixes" of recreation activities, and the existing and potential future demand for a variety of recreational resources. Other

methods used to assess the recreational potential of rivers, in general, are reviewed by Hooper(1977).

V. CLEARWATER TRANSFER ALTERNATIVES

A. Potential Transfer Volumes

In order to gain a perspective on the actual scale of water transfer possible from the Clearwater River, the potential volume of water that could be diverted is estimated. The combination of three distinct variables controls the maximum amount of water which can potentially be transferred: i) the Clearwater discharge at the point of diversion, ii) the maximum capacity of the transfer system utilized, and iii) the desired Clearwater discharge below the point of diversion. A range of potential transfer volumes can be calculated by changing the value of one variable while holding the other two constant.

Although the actual Clearwater discharge fluctuates greatly on an annual, seasonal and daily basis (as discussed in Chapter four), investigation is limited to a representative low flow year (1979) and a high flow year (1981), thereby encompassing a range of flow conditions. The second variable, maximum transfer capacity, is varied from 1 to greater than 30 cms. The maximum transfer capacities for various potential receiving streams are listed in Appendix 4. Whereas the first two variables can be described as physical constraints on transfer, the third variable is best described as an operational constraint. Two operational alternatives are considered: i) the restricted withdrawal of Clearwater River water based on Instream Flow Recommendations (IFR) established using the Montana method (see Appendix 3), and ii) unrestricted withdrawal with diversion of water taking place at receiving stream capacity.

In Figs. 1 and 2 the range of potential annual transfer volumes available is shown for a low flow and high flow year, respectively. The potential transfer volumes are also expressed as a percentage of the total annual discharge of the Clearwater River for the respective years. This percentage is used as a crude measure of "transfer efficiency". In order to justify beginning a sequential interbasin transfer at a lesser level such as this, Clearwater transfer alternatives should ultimately be capable of achieving transfer efficiencies of at least 30% in low flow years. This level of efficiency might not be reached until later stages of development when water from the North Saskatchewan River is also being provided. If constraints on transfer were such that less than 30% of the Clearwater discharge would be all that is available when it is most needed in dry years,

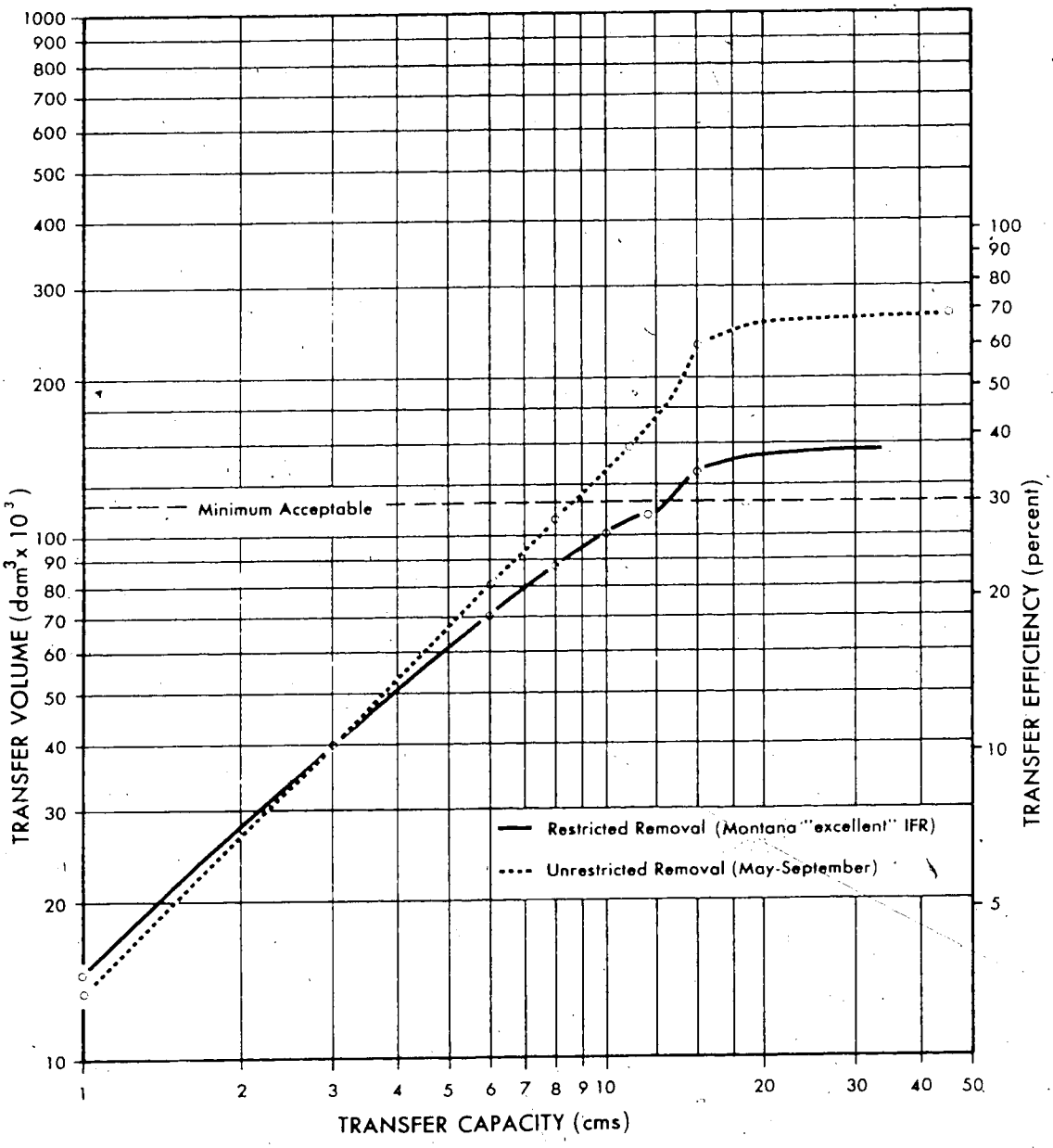


Fig.1 Potential Low Flow Year Transfer Volume – 1979

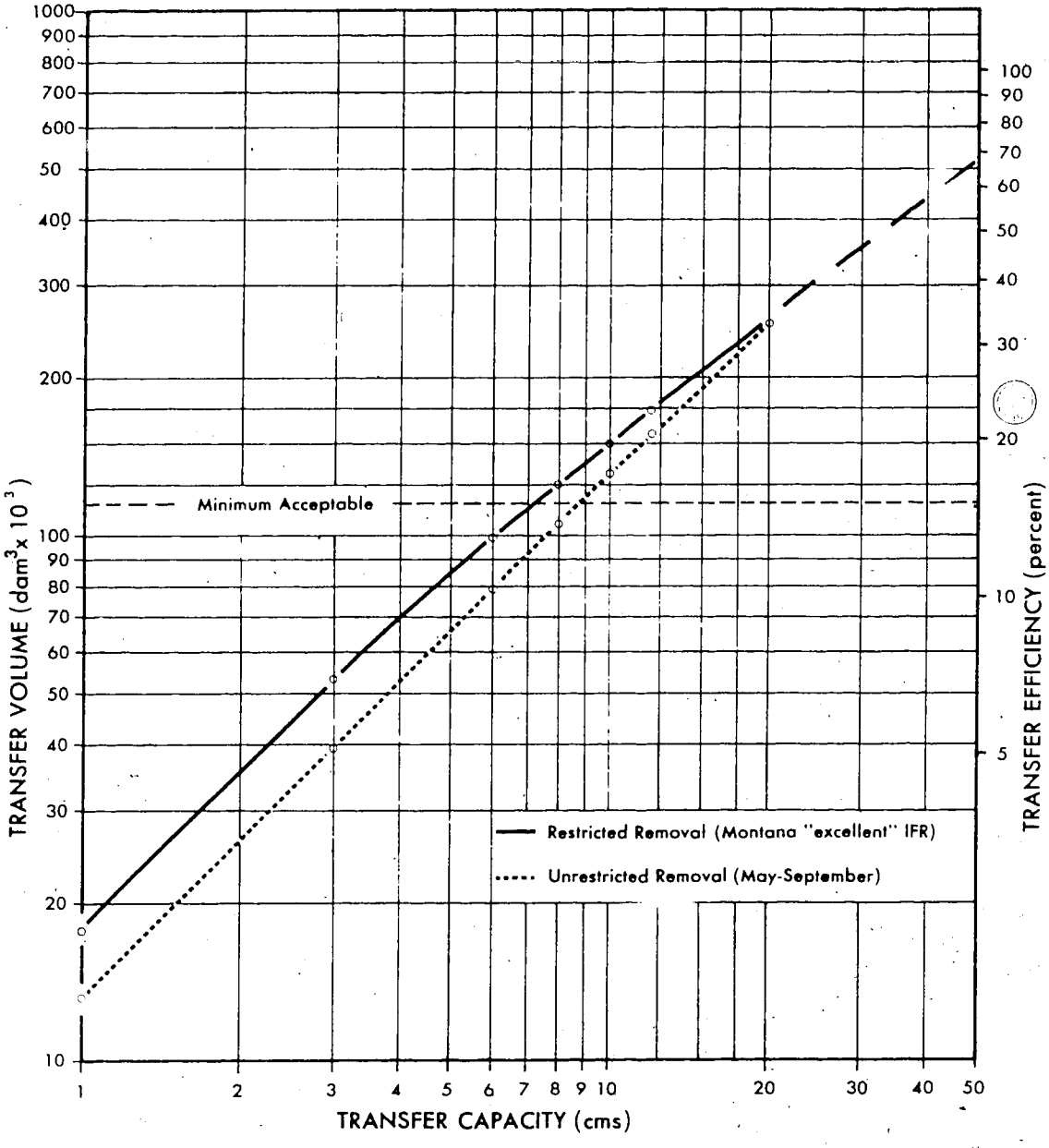


Fig.2 Potential High Flow Year Transfer Volume – 1981

planners might look elsewhere for a more feasible source of water. If such levels cannot be achieved by a combination of various transfer alternatives on the Clearwater, then perhaps the potential for a large scale transfer from the Clearwater or supplemental transfer from the North Saskatchewan River should be considered.

Upon close examination of Fig. 1 it is apparent that the maximum volume of water that could be transferred, regardless of removal restrictions (assuming diversion during May through September period only) and transfer capacity restrictions, is 264,000 dam^3. This volume represents a 68% transfer efficiency. Although a transfer capacity of 45 cms (35 cms with restriction on removal) would be required to secure the maximum volume of transfer, it is apparent that increasing transfer capacity past about 15 cms would increase transfer efficiency by less than 10% in a low flow year. With restriction on removal from the Clearwater a maximum of 145,000 dam^3 is obtainable (38% transfer efficiency).

The Montana method IFR for "excellent" flow regime was applied in calculating the plotted values (ie. 6.8 cms Oct. - Mar. and 10.2 cms Apr. - Sept.). Application of the "satisfactory" flow regime IFR would place a curve between the two shown. Applying more stringent instream flow methodologies (ie. USFS or USFWS) would greatly reduce the transfer efficiency no matter what the capacity. For instance, application of the USFWS methodology (see Appendix 3) in 1979, would allow a maximum transfer of only 36,000 dam^3 which is less than a 10% transfer efficiency.

Assuming that a minimum acceptable level of transfer efficiency is 30%, the minimum required transfer capacity without restriction on removal is 8.6 cms; with removal restrictions applied the requisite minimum transfer capacity becomes 13.0 cms. Therefore, transfer alternatives should have a minimum transfer capacity of about 8 or 9 cms in order to be capable of providing significant transfer volumes in low flow years. Capacities of a least 13 cms would however be preferable, in order to maintain suitable instream flow levels in the Clearwater.

The difference between the y-intercept values of the two curves in Fig. 1 represents the small volume of water which could be transferred early in the spring (before May 1) and in the fall (after September 30) assuming application of the Montana method IFR. Application of any of the instream flow methodologies reviewed, effectively restricts withdrawal to the open-water season with only minor diversion allowed before

May and after September. It is obvious that at transfer capacities below about 8 cms the application of an IFR on the Clearwater has little impact on transfer efficiency (ie. discrepancy of less than 5%). As transfer capacity increases however, so does the discrepancy between the transfer efficiencies for the two operational alternatives; the maximum discrepancy is equivalent to 30% of the annual discharge.

The greatest potential for Clearwater transfer is naturally associated with high flow years such as 1981 (see Fig. 2). The total volume of water required to meet Clearwater instream flow recommendations amounts to only 34% of the total annual 1981 discharge. In comparison with low flow years like 1979 where the Clearwater IFR is equivalent to 70% of the annual discharge, application of removal restrictions has little effect on transfer efficiency during high flow years. As an example, using a 10 cms capacity and restriction on removal, 50,000 dam^3 more water could be transferred in a year like 1981 than in a year like 1979. Thus, as expected, the problem of reaching a compromise between water diversion and maintenance of Clearwater instream flows would be most acute during low flow years.

The maximum potential transfer volume that could be obtained in the May to September period, assuming no restriction on removal, would be 621,000 dam^3. However, a transfer capacity of almost 200 cms would be required to handle peak Clearwater discharges. With the addition of upstream storage and subsequent Clearwater flow regulation the transfer capacity required to obtain such large volumes of water would be significantly reduced. At a smaller transfer capacity of 15 cms, about 200,000 dam^3 of water would still be obtainable in high flow years.

Although the efficiency of transfer is less important in high flow years, it is interesting to note that a transfer capacity of at least 18 cms would be required to capture just 30% of the total annual 1981 discharge. Also of interest is the greater transfer volume available with restriction on removal than without restriction (ie. at transfer capacities below 20 cms). This is a result of the relatively high Clearwater discharge in the fall of 1981, discharge did not reach base flow level until December (see Fig. IV. 5), thus allowing considerable diversion when flows exceeded the IFR.

Although it is difficult to estimate the exact amount, it is apparent that transfer efficiencies could be improved with flow regulation on the Clearwater River involving

controlled release of a large proportion of the upper basin summer snowmelt runoff and some storage from wet to dry years. This process of storage is occurring naturally in the study area (albeit at a small scale) with storage of Clearwater River water in porous delta sediments during high flow periods. As discussed in a preceding section on groundwater, this stored water is also moving slowly eastward through the delta aquifer, ultimately appearing as spring discharge in Stauffer Creek and Butte spring. Various assumptions must be made in order to estimate the actual volume of transfer that is naturally occurring through the delta and to determine the potential for artificially increasing the rate of transfer. Assuming that the Clearwater delta is acting as a large groundwater reservoir, it is possible to estimate the volume of water that could be withdrawn from storage for transfer into Stauffer Creek. This could be accomplished by either increasing the rate of groundwater discharge in springs along Stauffer Creek or by actively withdrawing water from the reservoir via pumping of water wells.

In the first instance, it is assumed that the rate of groundwater flow from the Clearwater River to the springs along Stauffer Creek can be increased by raising the water surface elevation of the Clearwater River or by raising water table elevation in the delta by means of artificial recharge. The increased discharge is estimated using a modified form of the Darcy equation (Johnson Div. UOP, 1972: p. 41):

$$Q = T\,I\,W$$

where Q is the rate of discharge (m^3/day), T is the coefficient of transmissibility (m^3/day/m), I is the hydraulic gradient (m/m) and W is the width of vertical section through which flow occurs (m).

The transmissibility value for the delta aquifer was determined by Borneuf(1983: p. 40) to be 2609 m^3/day/m. The drop in elevation from the Clearwater to Stauffer Creek is estimated at 21 m over a distance of 4 km, yielding a hydraulic gradient of 0.0052 m/m. An aquifer width of approximately 3.8 km corresponds to the distance that the Clearwater River actually flows across the western edge of the delta (see Fig. IV. 6).

Based on these estimates a discharge of 51,500 m^3/day or 0.60 cms can be expected from this aquifer. This value closely corresponds to the discharge measured by Shirvell(1972) just below the delta on the north branch of Stauffer Creek (ie. 0.57 cms). The corresponding increase in discharge is estimated by adjusting the hydraulic gradient.

Elevating the Clearwater stage or lowering the spring discharge point by 1 to 4 meters results in a discharge increase of 0.06 to 0.15 cms. Over a period of a year this translates into an increase in discharge volume of 1900 to 4700 dam^3 respectively.

In the second instance, it is assumed that the Clearwater delta acts as a homogeneous groundwater reservoir. The volume of water that could be obtained from such a reservoir by drawing it down a set amount is estimated using the following equation:

$$V = A\ d\ p$$

where V is the volume of water withdrawn (m^3), A is the reservoir area (m^2), d is the depth of drawdown (m), and p is the average reservoir porosity. The area of the reservoir is taken as the area of the delta itself as delineated by the extent of alluvial deposits and is approximately 1000 ha (ie. 1.0×10^7 m^2). The porosity of the reservoir was estimated at 35% which is representative of sand and gravel deposits. Hence, for each meter of drawdown over this area a volume of 3500 dam^3 could be withdrawn.

These increases in groundwater discharge would be too small to provide any significant volume of water transfer, but they could be significant in extending the transfer season in a dry year and/or in providing environmental enhancement in Stauffer Creek. For instance, a direct withdrawal of water from the aquifer equivalent to only a 10% transfer efficiency would require drawdowns in the order of 11 meters throughout the delta. A drawdown of this magnitude would undoubtedly lower the water table below the spring discharge points, effectively removing the water supply to Stauffer Creek and Butte spring. Even though the enhancement of groundwater discharge cannot provide significant quantities of water on its own, at relatively low cost it could be effectively combined with other alternatives to provide additional transfer volume, offstream storage, extend the transfer season, and improve operational flexibility. These considerations are discussed further in reference to specific transfer development alternatives in following sections.

Irrigation Development Potential

Now that the range of potential transfer volumes has been estimated, the values are related to various future end-use requirements and existing water withdrawal uses in

southern Alberta. Because irrigation comprises by far the largest consumptive water use in the province, it is useful to measure the potential utility of Clearwater transfer in terms of the amount of irrigation it could support. Therefore, in Fig. 3 a comparison is made between transfer volume and various measures of irrigation development.

Transfer volume is plotted against the equivalent irrigation expansion it could support in terms of both time and area. An average irrigation expansion rate of 10,000 ha per year (PFRA, 1982) and a dry year irrigation duty of 4.57 dam^3/ha (PPWB, 1982) are assumed (refer to section on irrigation in Chapter four). Thus a volume of 45,700 dam^3 is assumed sufficient to supply one year of average irrigation expansion in Alberta. Two additional scales are also shown, one relating transfer volume to the 1979 Clearwater transfer efficiency and the other relating transfer volume to the percentage of the total irrigated area in Alberta (ie. actual area irrigated in 1979 – a dry year) it could support.

The range of transfer volumes under consideration is bounded by the minimum acceptable volume of 115,000 dam^3 (ie. low flow year transfer efficiency of 30%) and the maximum obtainable volume of 768,000 dam^3 (ie. total 1981 Clearwater discharge). This range is drastically reduced by applying various combinations of the three controlling variables previously discussed (ie. Clearwater discharge, transfer capacity and instream flow recommendations). There are five notable points identified along the line plotted in Fig. 3. The first two points *Clearwater Discharge Totals* are indicative of the maximum transfer potential of the Clearwater River. Clearwater discharge in a high flow year could irrigate 170,000 ha – representing almost half of that irrigated in Alberta in 1979 and enough for 17 years of future irrigation expansion. In a low flow year 84,000 ha could be irrigated – representing 23% of that actually irrigated in 1979 and enough for 8.5 years of future expansion. It is this larger scale potential which the SNBB proposals sought to develop and, indeed, to capture and divert such volumes would require large storage facilities and high capacity transfer methods.

The third point *Maximum transfer without removal restriction* represents that volume which could be obtained if all flow during the May through September period was diverted during 1979. This volume could irrigate about 57,000 ha (16% of that actually irrigated in that year), which is equivalent to 5.7 years of irrigation expansion. However, either a combination of Clearwater flow regulation and an intermediate level of transfer

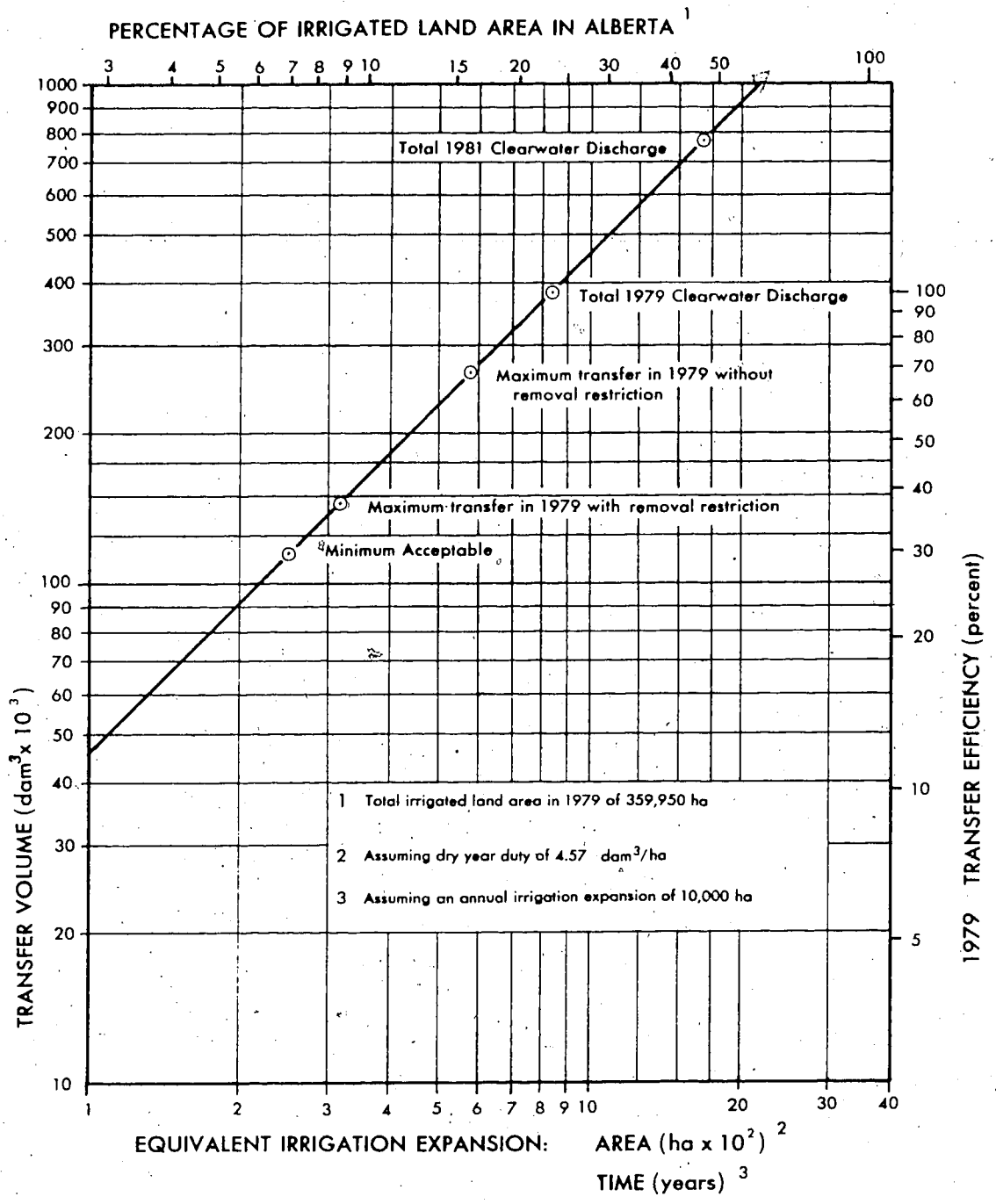


Fig.3 Comparison of Transfer Volume and Irrigation Development Potential

capacity or large scale transfer capacity would be required to attain this level of transfer efficiency (ie. 70%).

The fourth point *Maximum transfer with removal restriction* represents the obtainable volume in a low flow year assuming diversion of all flow in excess of the Clearwater IFR. This volume could irrigate 31,800 ha (9% of actual 1979 total) which is equivalent to 3.2 years of irrigation expansion. Hence, unless wet to dry year storage was provided, this is the maximum volume of water that could be transferred without jeopardizing conditions on the Clearwater below the diversion point. Transfer systems which do not incorporate storage would require a large transfer capacity (ie. at least 35 cms) to reach a maximum transfer efficiency of 38%.

The fifth point *Minimum acceptable transfer* represents the volume of water equivalent to a 30% transfer efficiency in a dry year as discussed earlier. This volume could irrigate 25,000 ha (7% of 1979 total) which is equivalent to 2.5 years of future irrigation expansion.

In summary, a wide range of water volumes are potentially available depending on the physical and operating constraints which are built into a transfer alternative. Based on the preceding discussion of Clearwater transfer potential, a number of concerns and recommendations arise in regard to the design of alternative transfer methods:

- Transfer alternatives should be capable of transferring water at a rate of 8 cms or greater.
- In dry years alternatives with transfer capacities less than 13 cms would initially risk lowering Clearwater flow below a level satisfactory for recreational use, and ultimately, below a level satisfactory for survival of fish and other aquatic wildlife.
- For low flow years, increasing transfer capacities beyond 15 cms results in little increase in transfer efficiency.
- The enforcement of instream flow recommendations on the Clearwater significantly influences transfer volume only in low flow years for transfer capacities above 6 cms.
- Clearwater River flow regulation would increase transfer efficiency in dry years.

With these points in mind the possible range of physical options for Clearwater transfer alternatives is explored.

B. Physical Transfer Components

Water transfer development alternatives are characterized by both the structural means they incorporate and the operational procedures laid out for their use. A range of physical transfer alternatives are presented for Clearwater interbasin diversions. The associated operational alternatives suggested in the previous section are discussed where appropriate.

A wide variety of physical transfer alternatives are plausible, consisting of several combinations of structures, diversion routes and storage options. Even though a number of alternatives will be discussed, the list presented is by no means exhaustive. The scale or capacity of transfer and storage options, although not indicated, is equally important in defining the entire range of physical transfer alternatives. Manipulation of strictly operational variables, such as the timing and volume of water transfer, further complicates the picture.

In an effort to clearly, yet succinctly, describe the numerous physical transfer alternatives, each is broken down into five discrete components: i) water source, ii) water removal location, iii) removal method, iv) transfer method, and v) transfer route. The range of physical transfer alternatives as described according to these components is presented in Fig. 4. The options presented within each component are not necessarily mutually exclusive; for instance, more than one removal method may be incorporated with optional storage and transfer methods to deliver water to as many as three different receiving streams. Sequential development options involving upstream storage on the Clearwater and transfer from the North Saskatchewan are not shown on the diagram. These have been alluded to in chapter one and two and are further discussed in following sections. Other alternatives such as water spreading schemes do not appear as distinct alternatives but rather as options within alternatives and are indicated with footnotes.

Although the ultimate source of the water to be transferred is the Clearwater River, a distinction is made between direct removal from the river and indirect withdrawal from groundwater sources. Based on this distinction there are two withdrawal locations

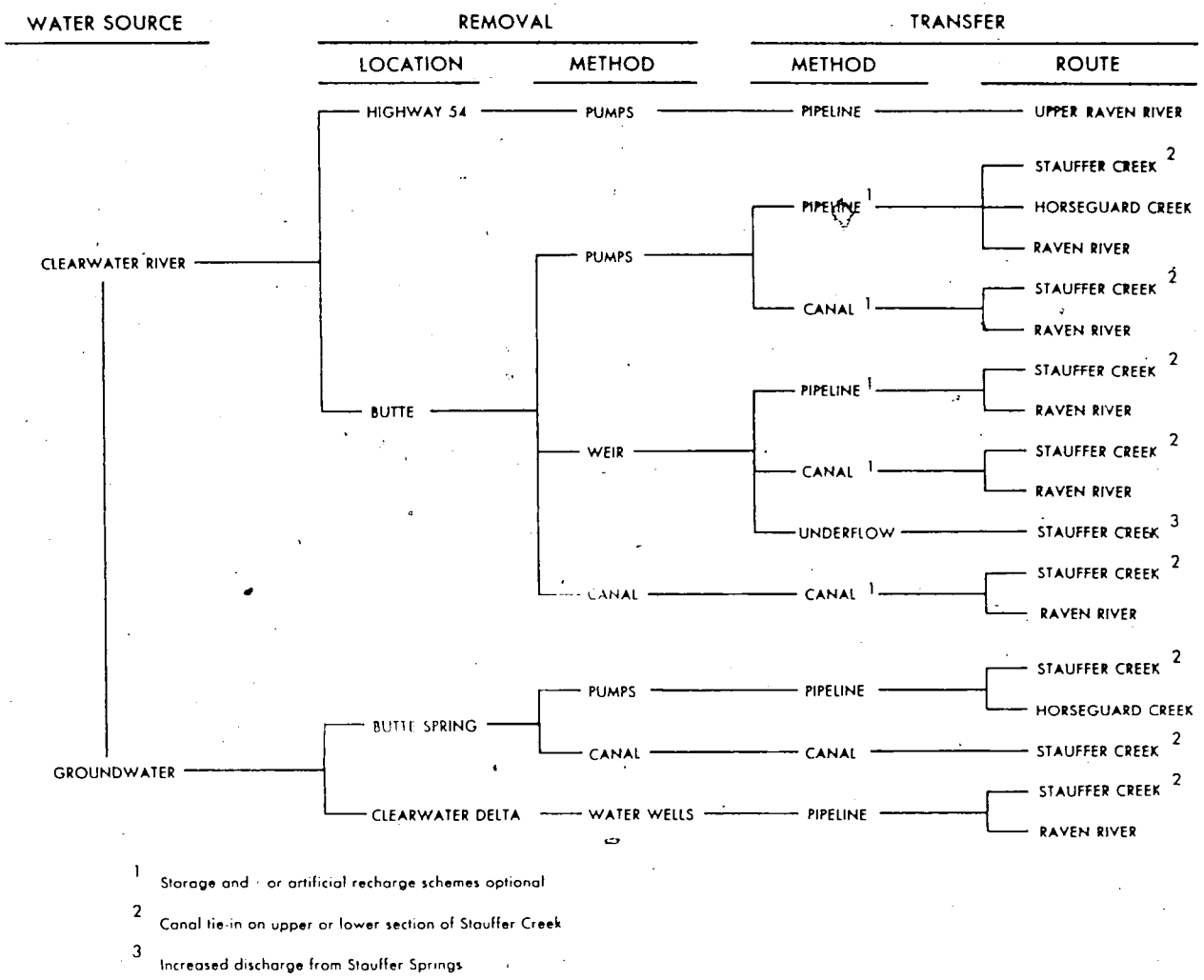


Fig.4 Physical Range of Clearwater Transfer Alternatives

considered for surface transfer and two others for groundwater removal. The two stream diversion locations are chosen for different reasons; the location near Butte is chosen because it corresponds to a point where the drainage divide between the Clearwater and Red Deer basins is the lowest. The Highway 54 location is chosen because it represents the minimum distance between the Clearwater channel and a major tributary channel in the Red Deer basin (ie. the Raven River). For groundwater sources, identification of the removal location is understandably less specific except in the case of Butte Spring which has a readily identifiable point source.

Removal Methods

Three basic methods of water removal are considered: i) the direct removal of river water by means of gravity diversion, ii) removal by pumping, and iii) indirect groundwater withdrawal from the Clearwater delta through the use of a network of water wells or directly from Butte Spring. The construction of a weir on the Clearwater could raise stream stage enough to allow overland transfer of water across the delta with a relatively small amount of requisite ditching or canal construction. The weir would need to raise stream stage by only 2 meters or less to divert flow out of the Clearwater channel and over the drainage divide. The construction of a canal alone, from the Clearwater to Stauffer Creek, would require a relatively small amount of excavation to allow gravity diversion. Although withdrawal by canal would have little impact on Clearwater streamflow, compared to that of a weir, problems caused by natural channel shifting and bank erosion would have to be dealt with.

A detailed topographic survey of this section of the Clearwater and the delta (1.0 to 2.0 m contour interval) would provide the information needed to locate gravity diversion structures so that weir height and/or canal excavation could be minimized. Based on field observations and review of existing topographic maps, it appears that the best location for gravity diversion is somewhere along the Clearwater reach immediately west of Butte (ie. within section 14 or 23-37-6W5). A likely location for such a diversion is shown in Plates V.1 and V.2. The lowest effective weir height should be specified in order to minimize the "backwater" effects of the weir (ie. increased channel width, depth and rates of sediment deposition upstream of the weir) and reduce the chances of

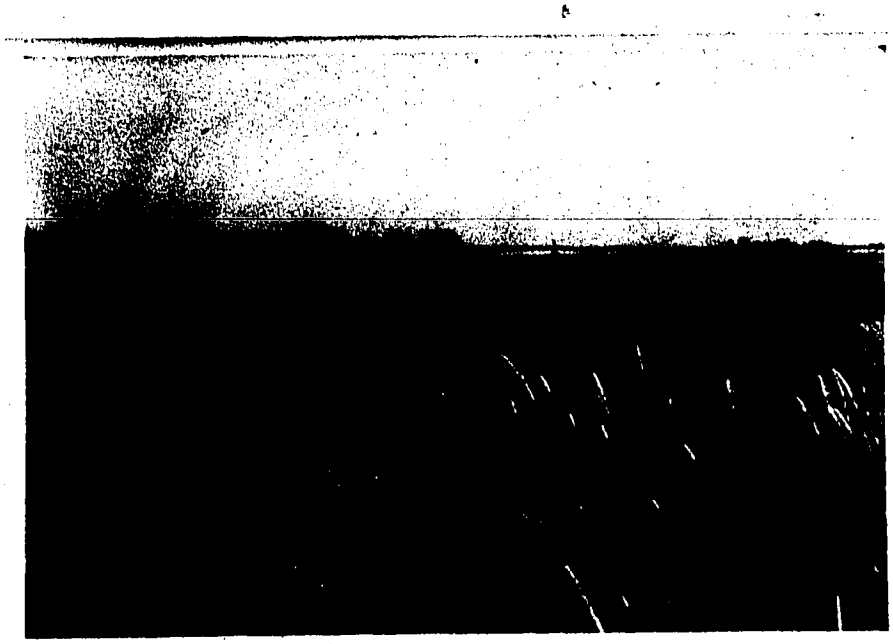


Plate V.1 Downstream view of Clearwater River near Butte.

Plate V.2 Broad, shallow channel of the Clearwater near Butte looking downstream.

uncontrolled flooding and diversion across the delta.

Using a weir to raise Clearwater stage would also increase the hydraulic gradient in the delta groundwater reservoir resulting in a small increase in discharge for the springs draining this reservoir. It appears, however, that to obtain any significant increase in groundwater transfer through the delta by this means, the Clearwater stage would have to be increased to such an extent that flow could not be retained within the confines of the existing channel. The ability to control the rate of transfer from the Clearwater must also be considered; a headgate on the diversion canal or pipeline and some diking along the banks of the Clearwater upstream of the weir would be required to prevent excessive diversion rates during high flow stages on the Clearwater.

The second means of directly withdrawing water from the Clearwater is pumping. The great advantage of this method is that a pumping unit could be installed, relocated and/or removed at relatively low cost and without causing significant disruption to the Clearwater. The range of possibilities concerning the number, location, capacity, and vertical lift required for pumping units on the Clearwater is large. Pumps could be used to divert water into three different streams, namely the Raven River, Stauffer Creek and Horseguard Creek. Pumps located near Butte could be used in connection with pipelines to transfer water to either Stauffer Creek, which would require a lift of only 1 to 2 meters, or to Horseguard Creek with a vertical lift of less than 12 meters. A pumping station situated near the Highway 54 bridge could be used to lift water 30 to 35 m from the Clearwater over the drainage divide into the Raven River basin. To supplement Clearwater transfer during exceptionally dry years pumps could be installed on the North Saskatchewan River to lift water 35 m over the drainage divide into the Lasthill Creek channel. The removal point would be about 9 km downstream from Rocky Mountain House and approximately 8 km of pipeline would be required.

Because installation of a pumping unit does not require major instream construction, streamflow would be affected only during periods of withdrawal. Conversely, installation of a weir would permanently alter streamflow and channel morphology in the immediate vicinity (whether or not water was being diverted) and would also act as an obstruction to canoeists. However, the lower impact and higher operational flexibility provided over the short term by pumps, as opposed to a weir, is traded off

against higher operating costs (ie. maintenance, energy and replacement costs) over the long run. If pumping is considered instead of a dam as a means of supplying water in dry years only (perhaps one in 5 to 10 years), the capital required to install a dam, need not be invested as soon.

The third method of water removal involves the withdrawal of groundwater from the Clearwater delta using a network of wells or withdrawing it directly from Butte Spring. This is still considered to be a withdrawal of Clearwater River water, albeit an indirect one. Water withdrawn by a network of shallow wells established throughout the delta could be conveyed by one or several small pipelines to Stauffer Creek. The advantage of this method is that no construction along the Clearwater River would be required and the timing and volume of withdrawal could easily be controlled. The effect this removal would have on Clearwater River flow is not known, but lowered groundwater tables in the autumn and winter as a result of well depletion, could cause a greater movement of water out of the Clearwater River than might be desirable during the low flow winter period.

A considerable volume of water could be diverted into either Stauffer or Horseguard Creek from Butte Spring. In order to lift water over the divide to Horseguard Creek, pumping and a pipeline would be needed. This method could also be used to transfer flow into Stauffer Creek although gravity diversion could be accomplished with a small canal requiring only limited excavation.

The combined use of several removal methods is also plausible. As previously mentioned, pumping units could be used in concert with either a gravity diversion or a well network to provide an extra increment of transfer should the need arise. In fact, to transfer water to either the Horseguard or the upper portion of the Raven, pumps would be needed and could be used simultaneously with gravity diversion structures diverting into Stauffer Creek.

In order to provide for future expansion a sequence of interbasin transfer developments can be envisioned. For instance, short term transfers of limited volume could be made during dry years using pumps and a pipeline. Conceivably, this temporary transfer arrangement could prove adequate for several years. If, and when larger volumes are required, this method could be expanded or replaced by larger scale and more frequent diversions (ie. utilizing weirs, canals and upstream storage on the Clearwater).

Eventually transfer from the North Saskatchewan may be included in the development sequence, with initial transfer on a similar, temporary, cost-effective basis involving pumping until larger scale transfers are needed.

Transfer Methods

The three physical means of transfer considered are canals, pipelines and underflow through the Clearwater delta. In conjunction with the transfer of water, the possibility exists for storing water diverted from the Clearwater during the high flow season for release into the receiving basins during the low flow season. The methods of storing diverted water are closely related to the method of transfer employed and may involve both surface and groundwater reservoirs.

Depending on the maximum rates of diversion and the importance placed on avoiding disturbance of Stauffer Creek, a canal could transfer water to a number of different locations on the creek. Three locations are considered: i) a point near the head of Stauffer Creek near the origin springs, ii) a point half way down the creek, and iii) a point on the Raven River near its confluence with Stauffer Creek. The respective canal lengths required for each of the above options are 4, 14 and 23 km. Detailed topographic surveys would be required to most advantageously locate the canal. A low-level aerial survey of Stauffer Creek was flown in May 1976 (ie. scale of 1:4800) which would prove useful for detailed topographic and environmental surveys in the area (Alta. Gov. Job No. 76-117). A survey of the Clearwater River from Ricinus to Dovercourt was flown in September 1974 and would also be of use in project design (Job No. 74-94, scale 1:12,000).

By transferring the water into the upper portion of Stauffer, the length of canal construction would be minimized, but at the expense of altering the streamflow regime for all of the creek. By introducing the diverted water at this location the conflict between competing uses of the stream for fishing and for water transfer would be most pronounced. Introducing the diverted water half way down the creek, where the channel capacity is greater and aquatic habitat is less suitable for sport fish, would reduce the chances of detrimentally impacting valuable fish stocks upstream and also enable increased transfer rates (ie. up to 4.4 cms). Increasing the discharge in this section of

Stauffer Creek could alter instream conditions (ie. water temperature, bottom substrate and velocity) in such a way that a more favourable habitat for trout is created.

Although the expense would be much higher, if it is decided that Stauffer Creek should be left untouched or that higher transfer rates are required, a canal could be constructed parallel to Stauffer all the way to the Raven River. With channel improvements to the lower Raven River a transfer capacity of 15 cms could be established for this route. Another option which might be developed is the creation of useable fish habitat within the canals themselves. This would require the development of an adequate pool and riffle sequence and suitable bottom substrate. References concerned with aquatic habitat enhancement are listed in Appendix 5 where potential environmental effects associated with alteration of aquatic habitat are presented. However, construction costs of such channels would be considerably greater than for those designed strictly for conveyance of diverted water.

Pipelines could be used to transfer water along the same routes for which canals have been suggested in addition to those routes for which canals would be unsuitable. The installation of pipelines is assumed to be the only method of transferring water to the Raven River from the Clearwater River at Highway 54 and the most efficient method for transferring water to Horseguard Creek from the Clearwater near Butte. For both of these transfer routes a considerable amount of uneven terrain must be traversed and pumping would be required. A pipeline 3.2 km in length could take water from the Clearwater near Highway 54 to a point on the Raven River 4 km upstream of Caroline. A 6.5 km pipeline would be enough to connect the Clearwater near Butte to Horseguard Creek somewhere in section 33-37-5W5.

The decision regarding the capacity of the various canals and/or pipelines is largely dependent on the channel capacity of the receiving stream at the tie-in location. The estimated maximum discharges for the potential receiving streams are discussed in Chapter four and restated in Appendix 4. However, by placing a limit on the maximum transfer rate, a tacit assumption is made concerning the relative importance of maximizing water diversion rates and mimimizing the local environmental impacts associated with such a transfer scheme. Undoubtedly larger canals and pipelines could be used to divert larger volumes of water into the receiving streams, but at the risk of permanently altering the

existing physical and biological character of these streams. This might be intended for Horseguard Creek which is at present a poor fish habitat, but for Stauffer Creek and the Raven River a stronger case can be made for preserving natural stream conditions. It is believed, in this case, that the use of separate pipelines or canals of requisite capacity would be the most cost-effective and lowest impact means of transfer.

Still greater flexibility could be built into the individual transfer alternatives that utilize a pipeline or canal to transfer water to lower Stauffer Creek or the lower Raven River. By diverting small amounts of the canal or pipeline flow at the proper time into the upper portion of Stauffer Creek, the natural streamflow regime could be modified to produce optimal streamflow conditions for trout.

Some storage of water following its withdrawal from the Clearwater could also be beneficially incorporated into some of the transfer alternatives. The possibility of storing water in one large lake or several small ponds located on the Clearwater delta has been mentioned previously. The benefits of such storage include: i) the ability to store diverted water during the spring for release during the fall when Clearwater flows are declining, ii) the ability to better regulate the transfer of water into Stauffer and/or Horseguard Creeks, and iii) providing a means of artificially recharging the delta groundwater reservoir and thereby increasing the groundwater discharge into Stauffer Creek. Another possible storage option which could be developed is the diversion of water from a canal or pipeline in the Stauffer Valley into the unnamed lake or slough at the head of Horseguard Creek. This lake apparently fluctuates in size throughout the year. Water transfer into the lake, along with installation of control structures at both the northern outlet (which supplies Horseguard) and the southern outlet (which infrequently supplies Stauffer), could provide lake level stabilization, reduce organic iron problems, and provide storage for release into Horseguard and/or Stauffer Creeks. It could also upgrade the dissolved oxygen content of the Medicine River which currently contributes to low oxygen levels on the Red Deer River. Interestingly, this shallow basin is the suggested location for the Horseguard Reservoir in the SNBB proposal for combined interbasin transfer from the North Saskatchewan and Clearwater Rivers to the Red Deer River.

Selection of Alternatives

Given the objective of augmenting water supplies in the South Saskatchewan basin and the fact that the Clearwater River could most beneficially provide this additional water, the following planning objectives and constraints are identified for the development of an interbasin transfer from the Clearwater to the Red Deer River:

- To provide quantities of water sufficient to support a suitable amount of irrigation development in the province and to allow for several increments of expansion as increases in demand may warrent.
- To keep to a minimum the detrimental social and environmental impacts of such development.
- To allow for operational flexibility as concerns the rate, timing and route of transfer.
- To provide opportunities within development alternatives for environmental enhancement in the local area.

Now that various physical components which could be included in a transfer scheme have been discussed, various alternatives can be developed to meet the proposed planning objectives. One approach for developing alternatives is to formulate alternatives that will meet each objective to the fullest extent possible (Johnson, 1974). By focusing on each objective the trade-offs between objectives can be more clearly identified.

In this study not all of the planning objectives can be considered to be of equal importance. Obviously the primary objective in such a transfer development is the provision of "significant" quantities of water. Therefore, individual alternatives should meet this objective first in order to be given further consideration. A dry year transfer efficiency of 30% was suggested as a minimum acceptable for initial transfer from the Clearwater. The transfer volume must be significant enough to justify starting interbasin transfer development at a lesser level than proposed by the SNBB.

Most of the physical alternatives appearing in Fig. 4 do not meet this objective on an individual basis. However, a transfer scheme which combines two or more of these alternatives or components could provide an acceptable level of transfer efficiency. Four

different combinations of these physical components are presented for evaluation as distinct transfer alternatives. In the formulation of each of these alternatives the primary objective is providing sufficient quantities of water. Secondary objectives are also considered, such as: limiting detrimental impacts, providing environmental enhancement, operational flexibility, future adaptability, and minimizing costs. Physical components which were not selected should not be considered eliminated from further study for any reason other than expediency.

Two longer term development options that would affect the operation of preceding transfer systems will also be assessed. One involves the addition of upstream storage potential on the Clearwater, the other involves additional pumping of water from the North Saskatchewan River into Lasthill Creek. One of the more obvious transfer alternatives which was not selected for evaluation is diversion of the entire Clearwater flow into the Stauffer Creek Valley using a weir. This would be a very economical method of obtaining a large volume of water. However, the environmental damage to the Clearwater and the receiving streams would be great. Although this method of transfer would likely be favoured by transfer proponents, environmentalist opposition to such transfer would be strong. Similarly, those alternatives which place such a heavy stress on environmental protection that virtually no transfer would occur, especially in the drier years, have not been given further consideration. Therefore, only transfer alternatives that provide some form of environmental protection and a reasonable transfer potential are selected for evaluation.

Hence, the six development alternatives to be evaluated are:

1. Removal of water from the Clearwater near Highway 54 and Butte with transfer by pipeline to the Raven River and Stauffer and Horseguard Creeks respectively.
2. Removal of water from the Clearwater near Butte by means of a canal connected to a storage reservoir on the Clearwater delta. Water stored in this reservoir would recharge the groundwater reservoir and be transferred by canal down the Stauffer Valley to the Raven River.
3. Construction of a weir on the Clearwater near Butte to divert flow into a canal that transfers flow down the Stauffer Valley to the Raven River.

4. Construction of a weir on the Clear water near Butte to divert flow into a canal that transfers flow into a storage reservoir at the head of Horseguard Creek. From this reservoir, water is released into both Stauffer and Horseguard Creeks.
5. Construction of an upstream dam on the Clearwater to provide storage and flow regulation for transfer using one of the preceding four transfer methods.
6. Pumping of water from the North Saskatchewan River to Lasthill Creek in order to supplement Clearwater transfer in dry years.

Each of these development alternatives is discussed in further detail in the following section where they are individually assessed. In Fig. 5 the possible location and areal extent of associated structures in the Clearwater delta area are indicated for transfer alternatives 2, 4 and a portion of 1.

C. Evaluation of Alternatives

The evaluation process for this study is entirely restricted to the "in-design" phase of the development planning process. According to McAllister(1982), it is useful to distinguish two distinct phases in the evaluation process - in-design and post-design, in which the style of evaluation is different. In-design evaluations such as this, must screen a large number of design ideas, filtering out the ones least likely to be successful and retaining the few that should receive detailed design and evaluation attention. Post-design evaluation involves detailed assessment of the few remaining alternatives.

In-design evaluations contain expert judgements and rule-of-thumb calculations whereas post-design evaluations often involve detailed scientific procedures for identifying, measuring and placing a value on environmental impacts. The following evaluation includes a comprehensive presentation of potential effects associated with each transfer alternative in addition to a general assessment of each in terms of planning objectives, potential transfer volume, cost, and other general concerns.

Several transfer design alternatives have been selected and will be evaluated in terms of the activities involved in various stages of project development and the potential environmental effects which may result. A matrix format is used to visually display the multitude of actions and related effects. The format for the matrix and many of the

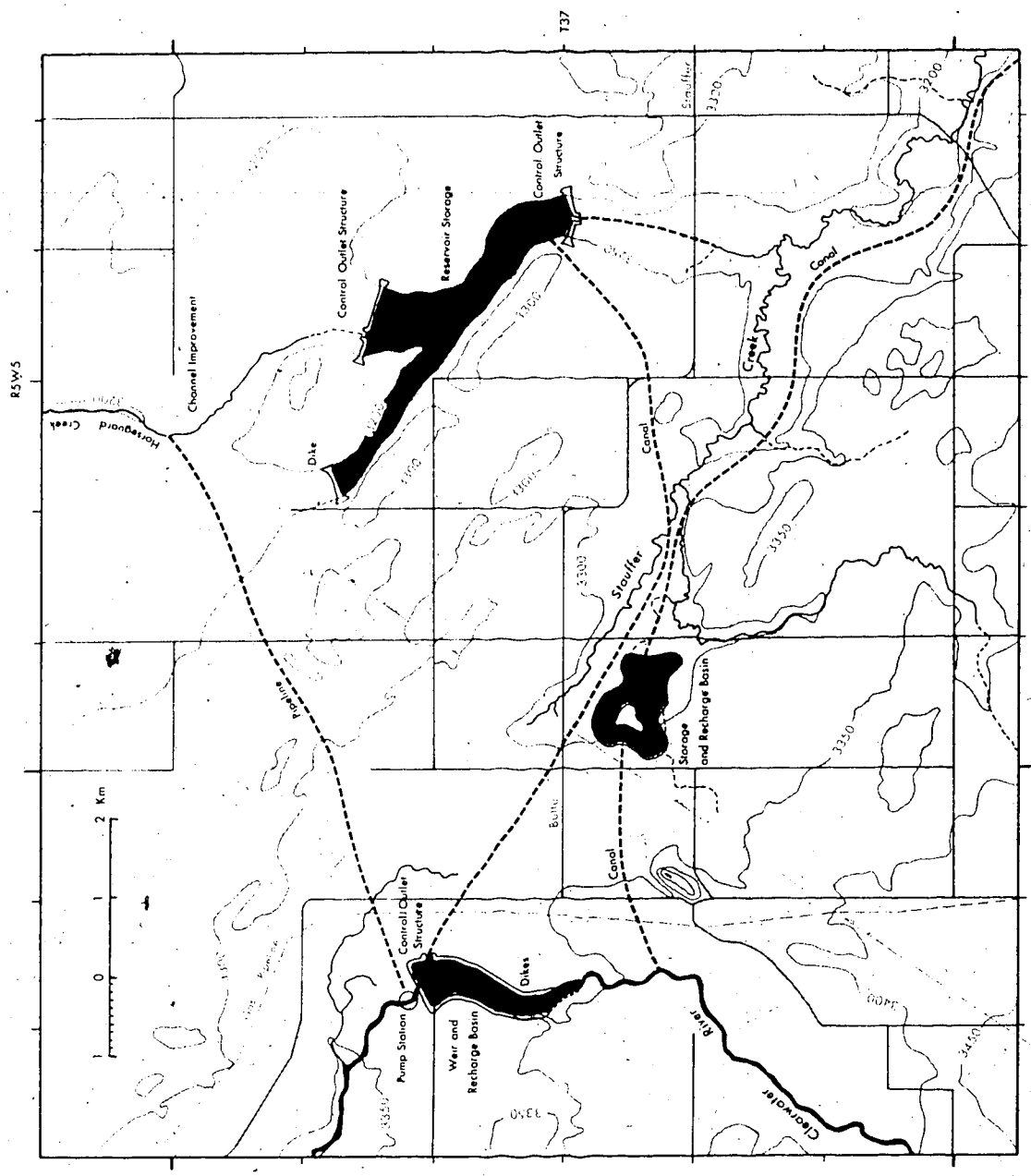


Fig.5 Potential Transfer Alternatives For Clearwater Delta Area

components within the matrix are drawn from a guide for environmental screening compiled by the Federal Environmental Assessment Review Office (Government of Canada, 1978). The screening document was designed to encourage departments and agencies to incorporate environmental considerations into the conceptual stage of project development.

In the matrix a list of project activities which may occur during various phases of project development are related to areas of potential environmental impact. These lists were developed with the intention of striking a balance between comprehensiveness and brevity. The matrix is intended to be flexible and can be modified to suit the needs of a particular reviewer. Blank rows and columns have been included to allow the addition of factors to the list if required. Identification of the relationships between activities and impact areas is assisted through the explanation of each activity and impact area in Appendix 5. The general criteria applied when making a decision as to the environmental effect of an activity and the possible screening decision categories used, are also discussed in Appendix 5.

Evaluation of the potential impacts related to particular development alternatives is only one of many important considerations involved in the overall evaluation process. Other important considerations relate to such things as: relative cost, operational efficiency and flexibility, future adaptability, and overall practicality. The resulting assessment of individual alternatives is highly dependent on the mix of planning objectives adopted and the importance assigned to each. What follows is an overall preliminary assessment of each of the six selected transfer alternatives. Each alternative will be assessed in terms of:

- The planning objectives it best supports, keeping in mind that provision of significant amounts of water is considered to be the prime objective of such transfer.
- The potential transfer volume available, allowing for variation in operational alternatives (ie. with and without restrictions on Clearwater withdrawal).
- The relative capital and operating costs involved.
- Potentially significant environmental and socio-economic effects which may result and are highlighted in the matrices.

- The general use of the alternative in relation to such topics as: flexibility, future adaptability, provision for compensation, and potential topics of conflict which may arise.

In order to easily compare and contrast alternatives, a composite comparison table is presented which is a summary of the text discussion for each alternative (see Table 1 at the end of this section). The merits of individual physical components (ie. removal location and method plus transfer methods and routes) have already been discussed and will not be repeated in detail here.

ALTERNATIVE 1

This alternative involves pumping water from two different locations on the Clearwater River and conveying it by pipeline into three receiving streams (ie. upper Raven River, lower Stauffer Creek and upper Horseguard Creek). The transfer capacity is limited to the sum of the individual receiving stream capacities (ie. 11.4 cms, see Appendix 4).

Objectives

The great operational flexibility of pumping systems is emphasized in this alternative. Other objectives such as minimizing capital investment and environmental impact apply to the Raven and Stauffer components but not to the Horseguard which would require extensive channel alteration. Provision for environmental enhancement is incorporated as an objective particularly for the Horseguard component of the system.

Potential Transfer Volumes

This alternative may incorporate a wide range of transfer volumes. Not only can the pumping rate be varied individually for each of the three components, but the amount of water made available for transfer from the Clearwater can also be varied. The following estimates are taken from Figs. 1 and 2. If the amount of water made available is restricted (ie. based on Montana method IFR) then the maximum volume that could be transferred operating all three components at maximum capacity in a low flow year is 107,000 dam^3. This amounts to a transfer efficiency of only 28% which could support 2.4 years of irrigation expansion. Operating without restriction could provide a maximum of 152,000 dam^3 which is equivalent to a 39% transfer efficiency and just over 3 years of irrigation expansion. Thus, it is apparent that in low flow years a compromise of IFR

restrictions on either the Clearwater or the receiving streams or both would be required to obtain a "significant" transfer of water. In high flow years operating at maximum capacity even with IFR restrictions would yield 167,000 dam³ which is equivalent to 43% of the Clearwater discharge for a low flow year like 1979 (ie. 3.3 years of expansion).

Relative Cost

This alternative is rated as having a "medium" level of capital investment this accounts for purchase of pumps, installation of pipelines and necessary headworks, construction of access roads, and channel improvements. The level of "operating" cost is assumed to be high, with rising energy costs becoming prohibitive over the longer term. The possibility of inordinate pump or pipeline failure requiring replacement should be considered in addition to continued maintenance of the Horseguard channel.

Potential Effects

In Fig. 6 the potential effects of developing and operating this transfer alternative are indicated. Although a great number of activities are indicated as having potential positive or adverse effects, the significance of most of these is unknown. Discussion is limited to the "significant" impacts only. The significant positive effects shown, relate primarily to channel improvements along Horseguard Creek and improved flow regime in both Horseguard and lower Stauffer Creek. Site clearing, channel straightening and streamflow augmentation could ultimately improve aquatic habitat for fish and the overall aesthetic appearance of Horseguard Creek. The only significant positive socio-economic effects foreseen are improvements in recreational opportunities along the two creeks and expansion of the secondary road network.

The significant negative effects are associated with: i) stream crossings (ie. both pipelines and roads) and their effect on stream conditions, ii) possible operational failure on the Horseguard component of the system would prevent the transfer of flows adequate to maintain suitable aquatic habitat, iii) possible flood damage on receiving streams resulting from flow augmentation, and iv) adverse affects on flow regime, fish populations and recreational opportunities on the Clearwater River in dry years when withdrawals may reduce instream flow below recommended levels.

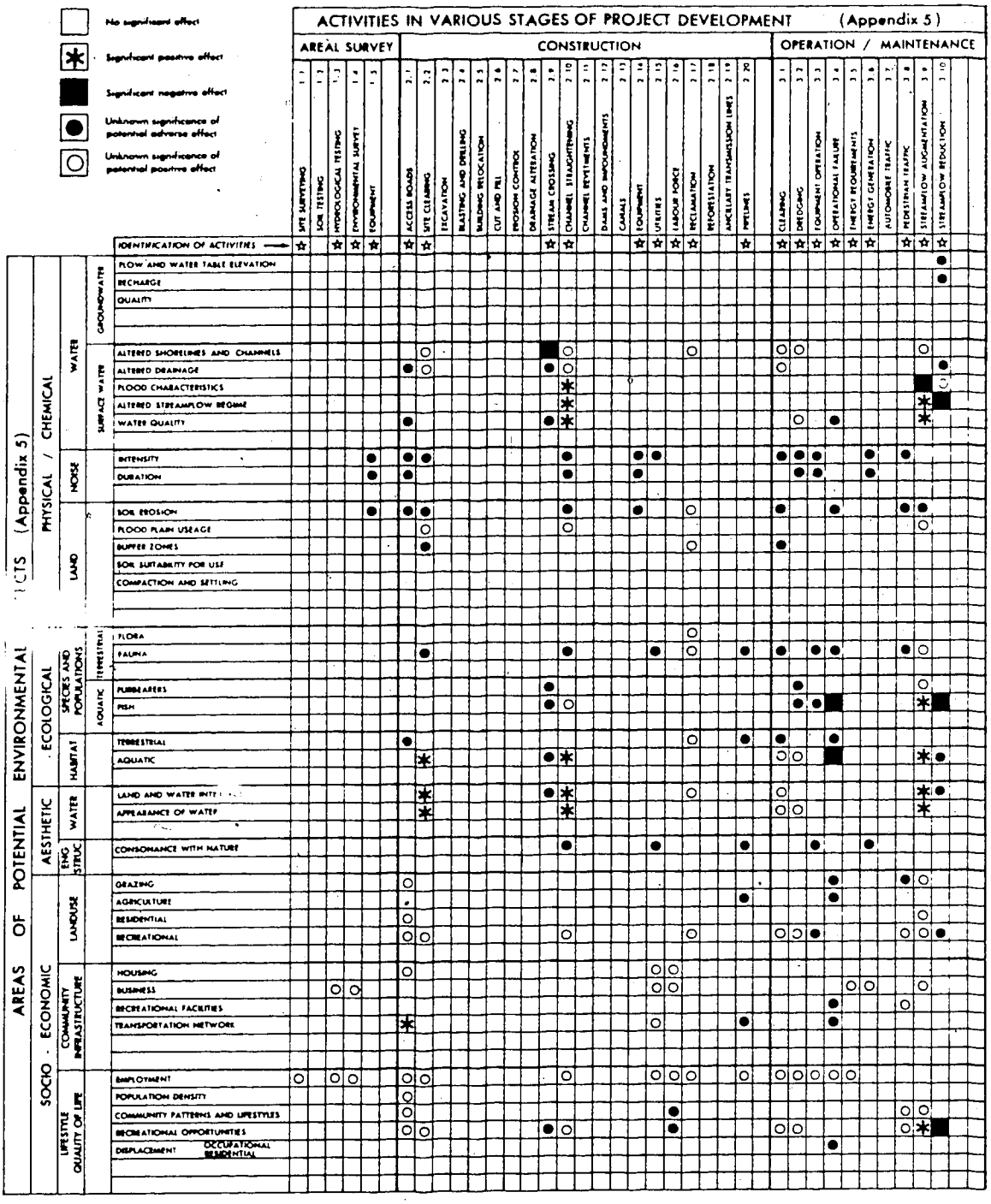


Fig.6 Screening of Alternative 1

General Concerns

The biggest advantage of this alternative is the operational flexibility it provides, transfer into receiving streams c be controlled on an individual basis. If for example, it was necessary to reduce the flow in Stauffer Creek for a short period, transfer could still be maintained in the other two components of the system. The transfer of water could also be shut-off at any time thus reducing the chances of uncontrolled diversion during high flow years. Largely as a result of this built in flexibility the system could be expanded, (cost may be prohibitive), abandoned, or adapted to future larger scale systems. If it was decided to abandon the system for a more permanent larger capacity system, pumps could be easily removed for sale or use elsewhere. The initial capital investment in channel improvements and pipelines would not be recoverable however. Aligning the timing and sequence of transfer development with growing demands in southern Alberta would not necessarily be simple. The actual demand for water is subject to large fluctuations. High demands in dry years might severely strain this transfer system and such years might then be followed by as much as a decade of wet years where no transfer would be required.

The disadvantages of this alternative are: i) the high cost required to expand the capacity , ii) the lack of off-stream storage potential, and iii) the inability of the system to maintain both Clearwater IFR and significant rates of transfer during dry years. In connection with these disadvantages a number of potential development conflicts can be foreseen. Detrimental impact on the Clearwater during low flow years versus maintaining significant rates of transfer would be a major issue. Consideration of the short term flexibility of pumping versus the lower operating cost of other gravity diversion methods is also important. Finally, the investment in environmental enhancement measures versus more cost effective transfer methods should be examined. Perhaps other forms of compensation would be more desirable.

ALTERNATIVE 2

In this alternative, water is diverted from the Clearwater into a canal which carries water into a storage reservoir situated on the Clearwater delta (see Fig. 5). From this reservoir the transfer is completed via a canal down the Stauffer Valley to the Raven River. Both removal of water from the Clearwater and release from the reservoir would be

controlled. It is anticipated that artificial recharge from the storage reservoir would occur, thereby increasing Stauffer Creek discharge.

Objectives

Two major objectives were emphasized in the formulation of this alternative, limiting of detrimental environmental impact and the enhancement of recreational opportunities associated with the water transfer development. Other objectives considered in the design are keeping operating cost to a minimum and maintaining operational flexibility.

Potential Transfer Volume

The maximum capacity of the proposed canal to the Raven River is 10.0 cms. Referring to Fig. 1, this yields a potential dry year transfer volume of 100,000 dam^3 with restrictions on withdrawal, and 131,000 dam^3 without. This translates as transfer efficiencies of 26% and 34% respectively, which would be enough to support 2.2 to 2.9 years of irrigation expansion. Although appropriate operation of the storage reservoir could improve these efficiencies, because of the small storage capacity, the increase is considered to be insignificant. A much larger storage capacity than that envisioned (ie. in the order of 30,000 dam^3) would be required to make a significant difference in transfer efficiency. The potential transfer volume during a high flow year could be as high as 150,500 dam^3 even with Clearwater IFR restrictions in effect (see Fig. 2). This could support 3.2 years of irrigation expansion.

It is evident that Clearwater withdrawal restrictions would have to be compromised in low flow years in order to obtain significant transfer volumes (ie. greater than 30% of total Clearwater discharge). It is also apparent that the suggested maximum capacity of the Raven River must be exceeded. The maximum recommended transfer capacity for the Raven is 6.0 cms (see Appendix 4), thus channel improvements would be required on the lower Raven to raise the transfer capacity to 10.0 cms.

Relative Cost

The capital cost of this alternative is rated as "medium" with the major investment being required for canal construction. Reservoir excavation and improvements to the Raven River could also become significant. Operating costs for this system are rated as "low" since gravity diversion is utilized. General maintenance activities on canals and the

storage reservoir could include clearing, repair and dredging.

Potential Effects

In Fig. 7 the potential effects of developing and operating this transfer alternative are indicated. The significant negative effects are primarily related to the physical alteration of streamflow in both the Clearwater and the Raven. These alterations (ie. flow reduction and augmentation) would necessarily have an effect on aquatic habitat (particularly for the Clearwater) and could adversely affect resident fish populations. In fact, similar effects are identified for all of the alternatives that involve compromising suggested Clearwater IFR (ie. alternatives 1, 2 and 4). This transfer alternative has the potential of adversely affecting the Raven River as well. The augmenting of streamflow in the Raven is not, however, expected to have a significant effect on fish populations. Other negative effects are related to residential displacement on the Clearwater delta and possible damages caused by failure of canals.

The potential positive effects that are felt to be of significance are associated with the possible environmental and recreational enhancement provided by the canals and storage reservoir. Not only could these provide new water-based recreational opportunities in the area (ie. swimming, boating, fishing, cottage development) but increased spring discharge, due to artificial recharge, could improve Stauffer Creek flow regime as well.

General Concerns

The low cost of operation and minimum interference with receiving streams are major advantages of this alternative. Existing conditions on Stauffer Creek are preserved (possibly even enhanced) through the use of a by-pass canal. The major disadvantage of the system is the flow reduction on the Clearwater during low flow years. Another disadvantage is the limited transfer capacity of the canal; future expansion would ultimately require canal enlargement at considerable cost. On a short term basis, total transfer capacity could be increased through the use of temporary pumping systems similar to those described in alternatives 1 and/or 6.

Potential development conflicts would be focused on such issues as preserving suitable instream conditions versus transferring large volumes of water and limiting detrimental impacts versus provision for future expansion.

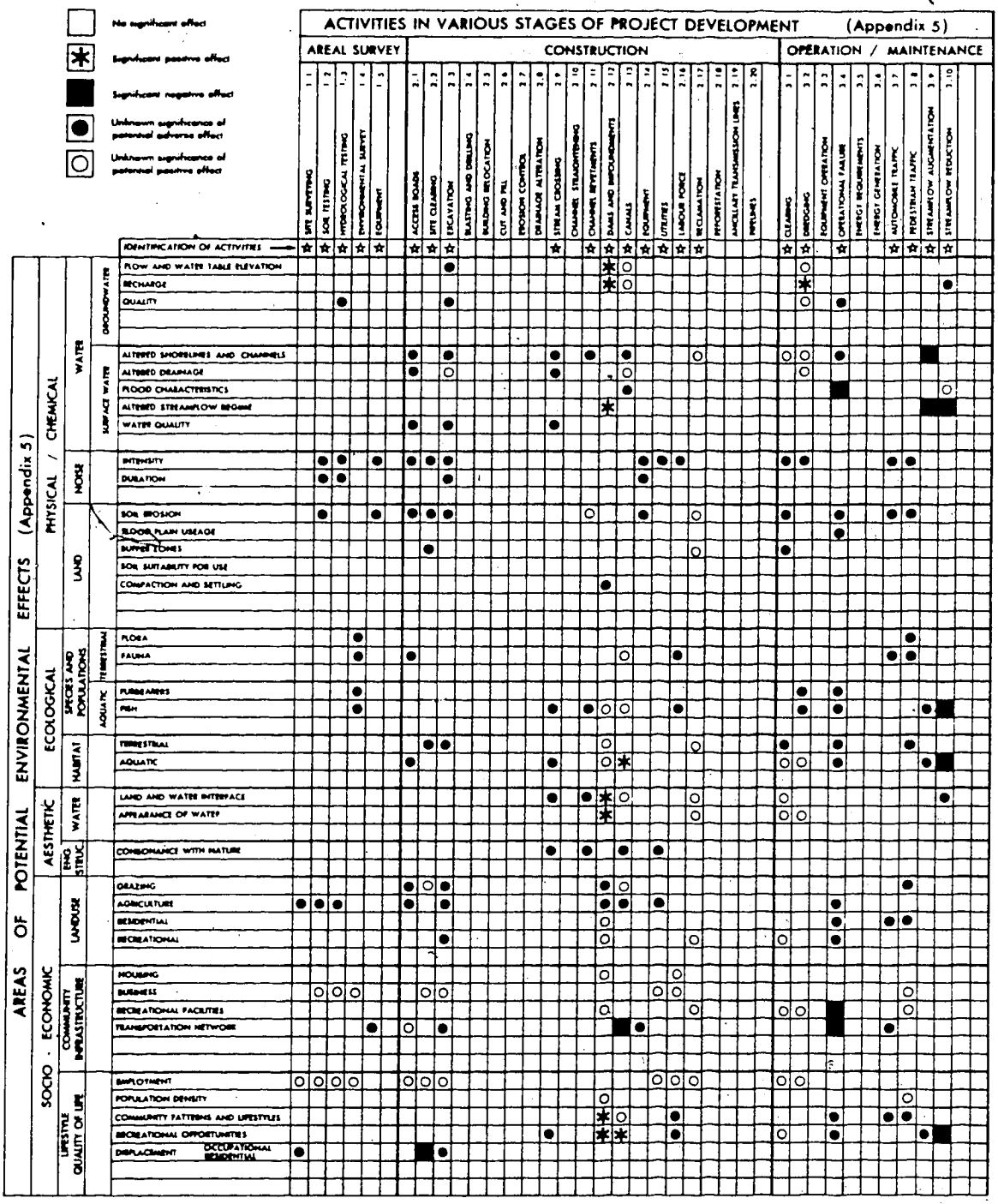


Fig.7 Screening of Alternative 2

ALTERNATIVE 3

This alternative includes a weir on the Clearwater River near Butte which would be used to divert flow into a 15.0 cms capacity canal that would transport water down the Stauffer Valley to the Raven River. Major channel improvements along the lower Raven would be required to increase the transfer capacity from 6 to 15 cms.

Objectives

The two major objectives considered in the development of this alternative are maximizing transfer volume and minimizing the detrimental environmental effects associated with operation of such a water transfer system. Because of the relatively large transfer capacity, the degree of operational flexibility and future adaptablility of the system is also improved.

Potential Transfer Volume

In a low flow year, a system with a maximum transfer capacity of 15 cms could provide 132,300 dam^3 of water (ie. 34% transfer efficiency) with Clearwater IFR in effect; in a high flow year 207,000 dam^3 could be transferred. By removing the IFR restriction the low flow year volume could be increased to 230,000 dam^3 or a transfer efficiency of 60%. Except for alternatives 5 and 6 which are considered as future expansion sequences, this is the only alternative being assessed that could achieve a low flow year transfer efficiency of greater than 30% without compromising Clearwater IFR. This volume (132,300 dam^3) would be enough to support approximately 3 years of irrigation expansion in the province (see Fig. 3).

Relative Cost

The capital cost of this alternative is rated as "medium"; this includes the construction of a weir, large canal and channel improvements on the Raven River. The operating costs are rated as "low" because it would be a gravity diversion with only routine maintenance required for the headworks, canal and lower Raven River channel. Regular operating maintenance might include such activities as clearing of riparian vegetation, canal cleanout, headgate repairs and bank stabilization along the river.

Potential Effects

The most important negative environmental effects shown in Fig. 8 are associated with flow augmentation. Since the maximum natural discharge on the Raven River in 1981

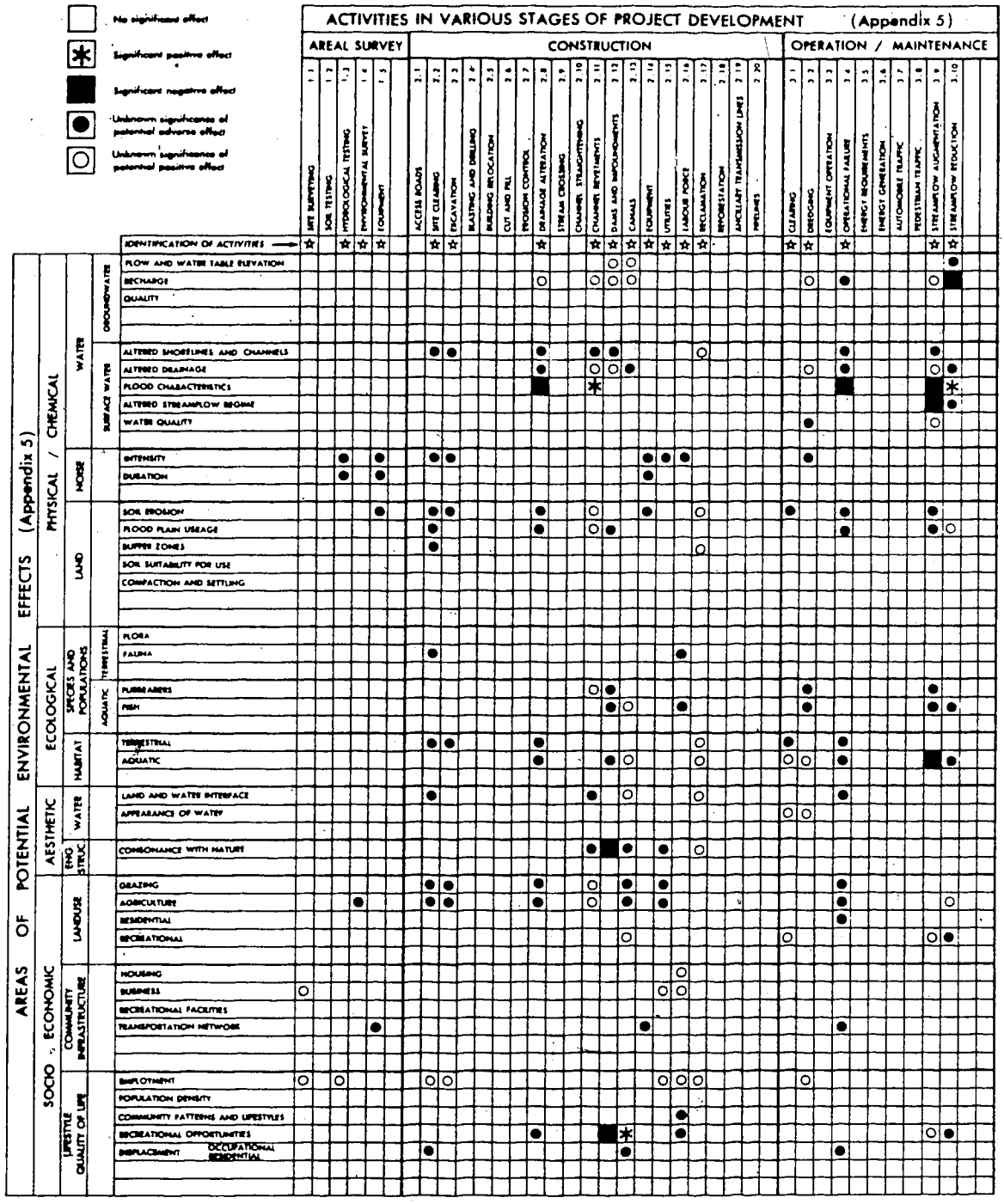


Fig.8 Screening of Alternative 3

was only 17 cms (Fig. IV. 5) and the maximum mean monthly discharge is less than 10 cms (Fig. IV. 3), it is obvious that extensive channel alterations would be required to enable the channel to safely convey augmented flows of 17 to 25 cms. During the spring snowmelt runoff period (April and May) transfer rates may have to be restricted to prevent flooding on the lower Raven. Severe summer precipitation events may also cause unusually severe flooding simply because streamflow would be kept at an artificially high level. The significant negative effects identified with flow augmentation in Fig. 8 indicate the general nature of the problem.

The possibility of flooding is indicated in relation to construction of the weir and in case of canal failure. The existence of instream structures on the Clearwater could have an adverse effect on the recreational use of the river for boating, and on fish populations. However, it is expected that the detrimental effect on the Clearwater, associated with this transfer alternative, would be much less than for alternatives which reduce instream flows far below recommended preservation flow levels (ie. alternatives 2 and 4).

The only significant positive effects foreseen are those associated with potential flood reduction on the Clearwater and the possible generation of new recreational opportunities along the canal similar to those mentioned for alternative 2.

General Concerns

In this alternative the most direct, lowest energy route and means of water removal are applied. The important advantage of this is the ability to provide significant quantities of water in a dry year without compromising instream conditions on the donor stream. The future adaptability of the canal system is another advantage. The addition of sufficient upstream storage could allow more even distribution of flow through the summer months, and this in turn could increase the potential transfer efficiency in dry years (ie. to perhaps 50%). The effect of upstream storage and Clearwater flow regulation is further discussed in relation to transfer alternative 5.

One disadvantage is the lack of provision for environmental enhancement. The transfer of water is treated as a simple resource extraction problem with no effort directed toward compensating the area-of-origin for any resulting development impacts.

ALTERNATIVE 4

The transfer system in this alternative consists of a weir on the Clearwater River near Butte which is used to divert water into a canal that conveys diverted water across the Clearwater delta to a storage reservoir (see Fig. 5). From this reservoir water would be released into both Horseguard and Stauffer Creeks. Channel improvements would be carried out on Horseguard Creek to allow transfer at a rate of 4 cms in this stream. This rate might conceivably be increased because later transfer from the North Saskatchewan would require a much larger capacity farther downstream on Lasthill Creek.

Objectives

The two planning objectives that this transfer alternative is designed to emphasize are operational flexibility and the incorporation of environmental enhancement features within a transfer system. In contrast to transfer alternative 1, in which a dual environmental protection/enhancement objective is adopted, the emphasis in this alternative is on enhancement alone. It is assumed that enhancement of receiving streams can partially compensate for detrimental effects on the Clearwater.

Potential Transfer Volume

The maximum transfer capacity of this system is 8.4 cms assuming simultaneous discharge into Horseguard Creek from the northern end of the reservoir at 4.0 cms, and into Stauffer Creek from the southern end at 4.4 cms. In a low flow year 90,000 dam^3 to 112,000 dam^3 could be obtained depending on whether Clearwater IFR is strictly enforced or not (refer to Fig. 1). The transfer capacity of this system is the smallest of the six alternatives assessed. As a result, the maximum transfer efficiency that could be achieved in a low flow year is 29%; this amount would support just over 2 years of irrigation expansion in Alberta. During a high flow year, the maximum transfer volume could be as high as 132,000 dam^3 even with restrictions on removal from the Clearwater, this translates as 3 years of irrigation expansion (refer to Fig. 3).

Relative Cost

The capital cost of this system is rated as "high". The investment in structures alone would be large, including: a canal, weir, dikes on the Clearwater, and dikes on the reservoir (two with outlet works). The cost of improving the Horseguard Creek channel could also be extensive. The operating costs involved with this system are rated as

"medium" and would cover continued maintenance of canals, headworks, and stream channels.

Potential Effects

A large number of both positive and negative effects are shown in Fig. 9. This is due, in major part, to the wide variety of construction activities aquainted with this alternative. Even though a large number of significant impacts are indicated in the construction stages, the impacts associated with operational activities are considered to be of greater importance.

Several significant negative effects on stream characteristics are identified in the construction stage. Alteration of the Stauffer Creek channel caused by stream crossings for the canal may be the most significant, other effects relate to canal excavation and possible flood damage during construction of the weir. Construction of the weir would reduce aesthetic quality of the Clearwater as well as affect boaters. In the operational stage, damages associated with flooding caused by operational failure of canals or dikes could be severe particularly for the receiving streams if control over reservoir outflow was lost. Streamflow augmentation might increase the chance of flooding while flow reduction on the Clearwater would severely damage fish populations and aquatic habitat and may even reduce the flow of groundwater through the delta.

Significant positive effects in the construction stage are related to Horseguard channel improvements that should improve drainage and aesthethics. Creation of a storage reservoir is assumed to create useable aquatic habitat plus improve the quality of water in Horseguard Creek through the dilution of existing slough water with higher quality Clearwater River water. The possibility of creating useable fish habitat and recreational opportunities in and associated with the reservoir and diversion canal is also considered.

All of the positive effects in the operational stage are associated with flow augmentation, principally on Horseguard Creek.

General Concerns

The major advantages of this alternative (ie. operational flexibility and provision for environmental enhancement) are outweighed by the strong disadvantages of its high capital cost and poor potential transfer efficiency. This combination of physical components, is on its own, apparently too restrictive. However, the future adaptability of such a system

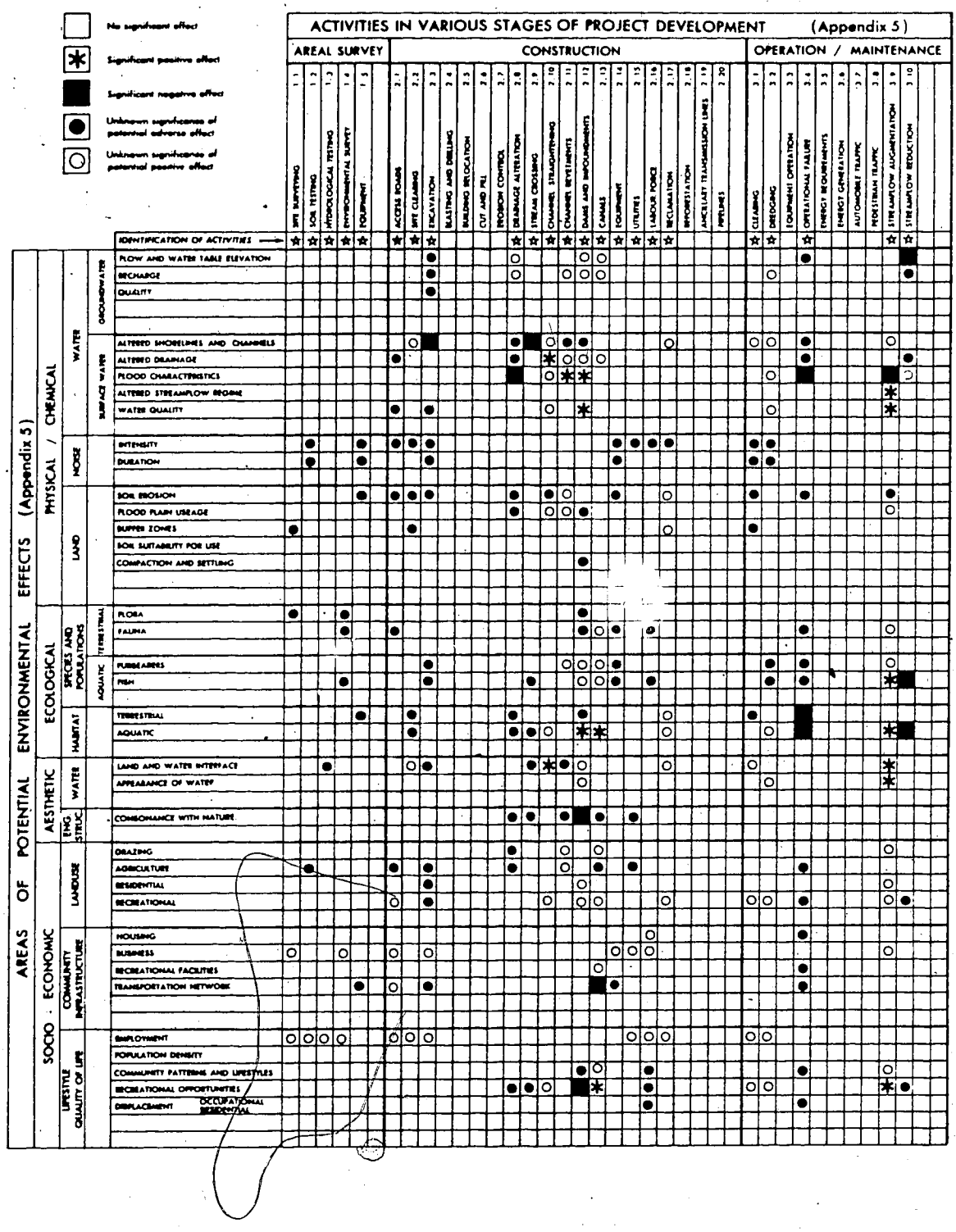


Fig.9 Screening of Alternative 4

is high. Future expansion involving larger capacity system components (ie. large canals) could make use of the existing weir and headworks and need not compromise the continued operation of the existing system. This alternative could serve as a continuing operation after North Saskatchewan diversion became important and it could also complement pipeline transfer in dry years. In contrast some of the other alternatives might be abandoned after North Saskatchewan transfer became efficient.

Potential topics of conflict could focus on the trade-off between cost reduction and providing for environmental enhancement, operational flexibility and future adaptablility, or between high transfer efficiency and preservation of existing environmental conditions.

ALTERNATIVE 5

This alternative involves the construction of an upstream dam on the Clearwater River and, as such, does not in itself incorporate means of transferring water into the Red Deer basin. It is presented as a potential expansion alternative to be operated in concert with any downstream interbasin transfer system that may exist. One possible location for this dam and reservoir is located about 50 km upstream of the Clearwater delta in section 2-35-10-W5. This site was surveyed as part of William Pearce's proposed North Saskatchewan Project and it is estimated that at this spot, a dam about 45 m high and 500 m wide could impound approximately 250,000 dam^3 of water (Russell, 1948: p. 44). There appear to be several other sites that might be developed for different amounts of storage.

Objectives

The objective in the use of this alternative is to provide flow regulation on the Clearwater River in order to increase the firm flow of water in the lower Clearwater during the growing season. Water stored in the spring would be released during the summer at a controlled rate thereby reducing discharge fluctuation and increasing minimum flow rates during the summer months. By doing so, suitable instream flow conditions could be maintained on the Clearwater, while at the same time improving the overall transfer efficiency and operational flexibility of existing transfer systems.

Potential Transfer Volume

It is assumed that upstream storage would be great enough that in all but the driest years (refer to Fig. IV. 3), regulated Clearwater discharge could be maintained at a minimum of 25 cms from May through September (refer to Fig. IV. 4). This would allow any of the preceding four transfer alternatives to operate at capacity without compromising a Clearwater IFR of 10 cms. This being the case, the minimum low flow year transfer volume would be 112,000 dam^3 (ie. alternative 4) and the maximum would be 198,000 dam^3 (ie. alternative 3). In a high flow year the reservoir may provide some peak flow reduction and thereby reduce flood damages along the Clearwater. However, flow regulation in a year such as 1981 would have little or no effect on the potential transfer efficiency of the transfer alternatives considered (refer to Fig. IV. 5). Thus the maximum potential high flow year transfer volume would range fro 2,000 dam^3 (alternative 4) to 207,000 dam^3 (alternative 3).

Providing such streamflow regulation would allow an additional transfer of 22,000 to 65,700 dam^3 in a low flow year. This would be equivalent to only an additional 0.5 to 1.5 years of future irrigation expansion which is not enough on its own to justify such an alternative. Therefore, unless a significant amount of storage from wet to dry years could be accomplished using this reservoir, flow regulation would provide little increase in transfer efficiency and irrigation development potential.

Relative Cost

The capital costs associated with this alternative would be much higher than for any of the other five alternatives considered. The cost of constructing this dam for the single purpose of improving transfer efficiency would be difficult to justify and yet multiple-purpose operation of the dam (ie. for hydropower generation and/or flood control) which could spread the investment, would require a compromise that may severely restrict the effectiveness of this alternative in terms of water transfer expansion.

The operating costs associated with this alternative are assumed to be "medium", including the maintenance and operation of actual structures and the cost of establishing and operating a reliable forecasting system to aid in reservoir operation.

Potential Effects

Because the actual development associated with this alternative occurs well outside the study area the only significant effects on the study area would result from the

actual operation of the reservoir. For this reason an environmental screening matrix was not completed for this alternative. Instead only the effects associated with alteration in streamflow in the study area are dealt with.

Clearwater flow regulation would affect the operation of existing transfer alternatives in two ways: i) by reducing fluctuations in Clearwater discharge and increasing summer minimum flows, and ii) by allowing transfer at system capacity throughout the summer period in both high and low flow years. The major positive effects for the Clearwater in the study area would be associated with improvements in flow regime (ie. reduction of peak flows and increased minimum flows) which could bring improvements in aquatic habitat and recreational opportunities during normally low flow years, and with potential flood reduction. No significant negative effects on the Clearwater in the study area are identified with flow regulation.

In regard to the effects of continuously operating various transfer systems at capacity, one should refer to the discussion and matrix related to each of the first four transfer alternatives (refer also to Table 1).

General Concerns

The major advantage of this alternative is the ability to regulate Clearwater discharge in such a way that existing transfer systems can be operated at capacity without compromising flow conditions on the Clearwater below the point of diversion. The major disadvantage is the high cost required to provide only a small increase in low flow year transfer efficiency. In order to obtain significant increases in low flow year transfer efficiency Clearwater IFR has to be compromised, upstream storage released to compensate (ie. total IFR from May through Sept. is equivalent to 132,200 dam^3) or a combination of both. For example, if the IFR was reduced to 6.8 cms from 10 cms (ie. satisfactory instead of excellent rating, see Appendix 3), only 42,300 dam^3 would be required from storage to maintain maximum transfer rates and satisfactory conditions in the Clearwater. However, if a number of low flow years occurred consecutively such as occurred in 1975, 1976 and 1977 (refer to Fig. IV. 2) storage would be, at best, severely strained. In this situation a serious compromise would be required between irrigation and environmental protection on the Clearwater.

A wide variety of conflicts could arise in relation to this alternative, not only in relation to the role it is designed to play in water transfer but also in relation to the effects of major dam construction and streamflow regulation on the Clearwater. Some of the potential topics of conflict would be: i) Major cost expenditures required to protect a short section of the Clearwater River and provide small increases in transfer efficiency, ii) Altering streamflow regime on a majority of the Clearwater in order to preserve the short reach below the diversion point, iii) multiple- or single-purpose operation of the dam, and iv) further expansion on the Clearwater River versus initial diversion from the North Saskatchewan River.

ALTERNATIVE 6

This alternative involves the installation of pumps on the North Saskatchewan River at a point 9 km downstream of Rocky Mountain House. From here water would be pumped through a pipeline to a point on Lasthill Creek above the confluence with Horseguard Creek. A vertical lift of about 35 m would be required to divert water out of the North Saskatchewan River Valley and over the drainage divide. Approximately 8 km of pipeline would be needed. Lasthill Creek flows in a large, well defined glacial spillway channel (see Figs. III. 2 and 3) and therefore minimal channel improvements would be required to contain transferred water within the confines of the spillway channel. However, the present creek channel is very small and highly sinuous therefore flows in excess of 1 or 2 cms would cause significant channel readjustment. Fish life in the creek is virtually absent.

Objectives

The sole objective of this alternative is to provide supplementary transfer of water from the North Saskatchewan River in dry years (ie. in southern Alberta as well) when Clearwater flows are low. Although the potential exists for providing environmental enhancement along Lasthill Creek through channel improvement and flow augmentation, in order to minimize costs no active program is included for this. Depending on the actual rate of transfer, significant flood damage and channel alteration may also occur. These detrimental effects are accepted in exchange for increased transfer volumes.

Potential Transfer Volume

Assuming that this pumping system would initially be operated only in low flow years when other transfers from the Clearwater are restricted, it would have to supply at most 25,000 dam^3 of water. This is the difference between the 30% low flow year transfer efficiency (ie. 115,000 dam^3) and the lowest potential transfer volume (ie. alternative 4 with restricted removal from the Clearwater, 90,000 dam^3). To provide this volume over the entire May - September period would require only a flow of 2 cms. Alternatively, the whole volume could be transferred over 2 months at a rate of 4.7 cms. If the system was operated in high flow years only to ensure that a minimum of 115,000 dam^3 was transferred without compromising Clearwater IFR, then only 4000 dam^3 would have to be transferred from the North Saskatchewan to supplement Clearwater transfer (ie. using alternative 4).

This volume of water is so small however (ie. 25,000 dam^3) that it could support only half a year of irrigation expansion (ie. 5500 ha) which would hardly justify the cost of constructing the system. However, this alternative would probably be developed at a later stage when target transfer volumes would be higher than the 115,000 dam^3 (ie. 30% transfer efficiency) suggested for Clearwater transfer. If transfer was maintained at, say 7 cms (May - Sept.), enough water to support a further two years of irrigation expansion could be provided (ie. 91,400 dam^3). If this volume of water was transferred in conjunction with the largest capacity transfer alternative on the Clearwater (ie. alternative 3), a maximum combined transfer of 223,700 dam^3 (ie. 132,300 from the Clearwater) could be realized without jeopardizing flows on the Clearwater. This volume of water would be enough to irrigate 49,000 ha supporting future irrigation expansion for approximately 5 years.

Removing water from the North Saskatchewan at this rate would not have any significant effect on that river since the mean monthly discharge at this time of year is no lower than 150 cms (see Fig. IV. 3). On the otherhand, the effect on the streamflow regime of Lasthill Creek and the Medicine River would be considerable. The mean monthly discharge of the Medicine is below 8 cms for all months except April.

Relative Cost

The relative capital cost of such a system is rated as "low" because only a pumping unit and construction of a pipeline would be needed. The relative operating costs would

also be low, at least on the short term. Over the long term, increased pumping rates and periods, coupled with rising energy costs may raise operating costs above acceptable levels.

Potential Effects

The potential effects associated with the construction and operation of this alternative are essentially the same as those for alternative 1 (refer to the matrix in Fig. 5). The only major difference between the effects resulting from the operation of these two alternatives is the lack of significant effects caused by either streamflow reduction or operational failure for alternative 6.

The significant operating effects would be entirely related to streamflow augmentation in the Medicine River basin. Transfer at a rate of 2 cms could significantly improve water quality and flow conditions in lower Lasthill Creek and the lower Medicine River. Transfer at rates greater than 4 cms would cause extensive overbank flooding but flow would easily be contained in the glacial spillway channel. Since this channel is only used occasionally for pasture, the damage caused by such flooding would be restricted to physical effects associated with channel readjustment (ie. soil erosion, flooded pasture, altered shorelines and channels) that are not considered to be of a seriously detrimental nature.

The Medicine River has a large channel capacity and very low summer discharge and therefore could easily convey flows of 15 cms without serious detrimental impact. In fact, increasing summer discharges would greatly improve water quality and regime in this river which has a very poor natural flow regime (refer to Figs. IV. 3, 4 and 5). Augmentation could increase the severity of flooding associated with large precipitation events and the potential of increasing the flood hazard in Markerville which is located on the Medicine River flood plain should be investigated. However, by restricting transfer by this route to dry years, the risk of flood damage would be lowered since most of the precipitation in dry years is used in recharging depleted soil moisture levels, leaving little to runoff. The minimal streamflow response in dry years relative to the response in wet years becomes apparent upon comparison of the precipitation and streamflow relationships for 1979 and 1981 (refer to Figs. IV. 4 and 5).

Depending on the extent to which water quality and flow regime were improved by augmentation, some new recreational opportunities in particular fishing, could be created on parts of Lasthill Creek and the Medicine River.

General Concerns

The major advantage of this alternative is the ability to obtain small yet significant increases in transfer volume at relatively low cost. A trade-off between the growing operating cost of pumping and the very high carrying charges on a dam development is involved. Postponement of dam development for even a few years could be very important, especially because pumping would not be required in all years. An expanded range of operational alternatives for Clearwater transfer systems is made possible since back up supplies could always be provided by this system. By diverting water from the North Saskatchewan in dry years satisfactory flows could be maintained on the lower Clearwater River without compromising the volume of water transfer. Eventually, this system might be replaced by a dam and gravity diversion from the North Saskatchewan. Considerable potential also exists for enhancing conditions in the Medicine River. The disadvantages of this alternative are associated with potential flood damages along the receiving streams and the dependence on an energy intensive means of transferring the water.

	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3	ALTERNATIVE 4	ALTERNATIVE 5	ALTERNATIVE 6
POTENTIAL TRANSFER VOLUME [1]	• LOW FLOW YEAR 107,000(28) 149,900(39) • HIGH FLOW YEAR 150,000(20) 168,000(22)	• LOW FLOW YEAR 100,000(26) 130,900(34) • HIGH FLOW YEAR 130,900(17) 150,000(20)	• LOW FLOW YEAR 132,300(34) 197,000(51) • HIGH FLOW YEAR 195,000(25) 207,000(27)	• LOW FLOW YEAR 90,000(23) 112,000(29) • HIGH FLOW YEAR 111,000(14) 132,000(17)	• LOW FLOW YEAR 112,000(29) 198,000(51) • HIGH FLOW YEAR 132,000(17) 207,000(27)	• LOW FLOW YEAR 115,000(30) 223,700(58) • HIGH FLOW YEAR 115,000(15) 207,000(27)
RELATIVE COST	• CAPITAL - Medium due to purchase and installation of pumps and pipelines, construction of access roads and channel improvements on Horseguard Creek. • OPERATING - High due to continued channel maintenance and the possibility of inordinate pump or pipeline failure requiring replacement. Rising energy costs could become prohibitive.	• CAPITAL - Medium with construction of canals (headgates, lining grading and Raven channel improvements) and excavation of storage lake on delta. • OPERATING - Low due to gravity diversion and general maintenance of canals and lake.	• CAPITAL - Medium including the construction of a weir, large capacity canal and significant channel modifications on the lower Raven. • OPERATING - Low due to gravity diversion and only routine maintenance to headworks, canal and Raven channel.	• CAPITAL - High due to the number and extent of structures (weir, dikes, outlet works, canals), land purchase and considerable channel improvements. • OPERATING - Medium due to continual maintenance on canals, reservoir and stream channels. The possibility of dike or canal failure is also of consideration.	• CAPITAL High with construction of a major dam and clearing for the reservoir. Cost sharing might be considered with multi-purpose use of the dam for hydropower, flood control and general flow regulation. • OPERATING - Medium including maintenance and operation of the dam and costs related to the establishment and operation of runoff and flood forecasting systems.	• CAPITAL - Low, with only the cost of a single pumping unit and the construction of a pipeline involved. • OPERATING - Low with short term costs involving only pumping. Over the long term increased pumping rates and periods coupled with rising energy costs could raise costs above acceptable levels.
POTENTIAL ENVIRONMENTAL EFFECTS [2]	• Flow reduction on the Clearwater would adversely affect flow regime and resident fish populations. • Augmenting flow in receiving streams might cause increased flooding. • If the transfer of water was stopped, any artificially created habitat would deteriorate thereby threatening fish populations. * Channel improvements and flow augmentation might improve aquatic habitat enough to allow establishment of fish populations in at least the upper portion of Horseguard Creek. * Flow augmentation on lower Stauffer Creek might increase amount of suitable fish habitat.	• Flow reduction on the Clearwater would adversely affect flow regime and resident fish populations. • Augmenting flows in the Lower Raven might damage aquatic habitat and cause increased flooding. • The canal must cross the southern branch of Stauffer Creek and this may detrimentally affect existing fish habitat. Construction of the canal in Stauffer Valley may adversely affect resident wildlife populations. Operational failure of canals could cause extensive soil erosion and adversely affect water quality. * The storage lake may provide new fish and wildlife habitat. Artificial recharge of the underlying aquifer may improve flow regime on Stauffer Creek. However if lake levels cannot be reasonably maintained, water quality may deteriorate. Periodic dredging would be required to maintain infiltration rates.	• Augmentation of Raven River flow would increase the risk of flooding along the lower section of this stream. Increased stream velocities and depths may adversely affect aquatic habitat for both fish and furbearers. • During construction of the weir drainage alteration may cause significant flooding.	* Channel improvements and flow augmentation on Horseguard Creek would improve drainage, flow regime and water quality. * Improved flow regime on both Horseguard and lower Stauffer Creeks could create viable aquatic habitat for fish. Additional aquatic and riparian habitat could be created in association with the reservoir and canal. • Streamflow augmentation would increase the potential for flooding on receiving streams. • Construction of the main weir and a canal stream crossing on upper Stauffer Creek may damage existing fish populations and cause minor flooding.	* Flow regulation would reduce the fluctuation in Clearwater discharge over the summer period increasing minimum flows would improve aquatic conditions. Decreasing maximum flows would reduce the impact of flooding on fish populations and bank erosion. • Flow augmentation (continually at maximum rates) would greatly increase the potential for flooding, particularly on the lower Raven River, which would be subjected to discharges significantly larger than normal. * The danger of not being able to maintain transfer into Horseguard Creek in dry years would be removed, thus protecting any artificially created aquatic and riparian habitat.	* Augmenting flows in Lasthill Creek and the Medicine River would improve flow regime, water quality and perhaps create viable aquatic habitat. • Transfer at high rates into Lasthill Creek would cause flooding, channel alteration and extensive soil erosion in the initial stages. But as new channels are formed and stabilized, flooding and soil erosion would decrease. • Flood potential in the Medicine River would increase, particularly during wet years.
POTENTIAL SOCIO-ECONOMIC EFFECTS [2]	• Detrimental effect of flow reduction on recreational use of the Clearwater, particularly in low flow years. * Possible improvement of recreational opportunities in the area and employment opportunities during construction. * Extension of the transportation network with new secondary roads.	* Creation of a small lake could provide new recreational opportunities in the area (ie boating, camping, cottage developments). Canals might also be used for fishing and viewing. The combination of lake and canals might improve the aesthetic quality of the delta area. • Streamflow reduction on the Clearwater could reduce recreational use of the river. Canal construction and potential operational failure would affect the local transportation network. • If the lake is built in the existing gravel pit as suggested, then a farm residence would have to be appropriated.	• The existence of a weir or instream obstruction on the Clearwater could cause difficulties for recreational boaters and may detract from the general aesthetics of the stream at this location. * The canal might provide additional recreational opportunities within the area for such activities as floating, viewing and perhaps fishing.	* Improved recreational opportunities along upper Horseguard and lower Stauffer Creeks. New recreational potential around the reservoir and canals could be created if they are developed accordingly. * Improved aesthetic value of Horseguard Creek and lake. • Detrimental effect of weir on boater's use of the Clearwater, plus possible flood damage during its construction. • Disruption of transportation during canal construction and also in the case of structural failure.	* Higher flow levels in the summer could improve recreational potential for boating and fishing on the Clearwater. • Potential damages associated with flooding along the lower Raven River would be increased.	* Improved water quality and flow regime in the Medicine system would improve the aesthetic beauty of the stream. Depending on th extent of the enhancement, new recreational opportunities may be created on Lasthill Creek and the lower Medicine River, in particular fishing. • Flood damage potential would increase possibly affecting Markerville located on the Medicine River flood plain.
OPERATIONAL FLEXIBILITY	• High with ability to precisely regulate timing and rate of transfer, as well as operate each component individually or in combination. Transfer can occur only when pumps are operating thus the danger of uncontrolled diversion is minimal. Limited transfer capacity and lack of storage is a problem in dry years.	• Low with transfer restricted to one route and possibility of uncontrolled diversion during Clearwater peak flow periods. Limited transfer capacity and lack of adequate storage is a problem in dry years.	• Low with tranfer restricted to one route and possibility of uncontrolled diversion during Clearwater peak flow periods. Lack of storage could prove to be a problem in later years, but in the short term a large transfer capacity effectively eliminates the need for storage.	• Medium with ability to transfer by one or two routes and precisely control the timing and rate of transfer. Limited transfer capacity is a problem during dry years with minimal storage capability. Possibility of uncontrolled diversion during peak flow stages on the Clearwater. Lack of sufficient transfer capacity in dry years is restrictive.	• Variable depending on whether the dam is operated solely to regulate Clearwater flow, or other conflicting purposes are also involved. If consistent flows high enough to meet IFR and transfer capacity are provided, the operational flexibility for each transfer alternative will be improved.	• High with ability to precisely regulate timing and rate of transfer. There is no danger of uncontrolled diversion. Transfer can continue at capacity without restriction on removal, thus providing a safety valve for Clearwater transfer systems in dry years.
FUTURE ADAPTABILITY	• Medium due to the relative ease with which structures could be removed, expanded or adapted to future larger scale schemes. However the cost of such expansion would likely be high.	• Medium with the addition of pumping systems for short term expansion and ultimately costly canal enlargement to increase system capacity.	• High with the addition of upstream storage this system could perhaps divert 50% of the total Clearwater discharge in a low flow year. The constructed canal and Raven channel improvements could remain as important components in an expanded system with little loss of initial capital investment.	• High with future expansion making continued use of existing components (ie weir, headworks, reservoir and Horseguard channel improvements) to supplement expanded transfer systems. Thereby preserving initial capital investments.	• Variable depending on whether further expansion involves further development of Clearwater potential or rapid development of transfer from the North Saskatchewan River directly. If Clearwater potential is further exploited then the adaptability of this alternative would be high, but in terms of contributing to North Saskatchewan transfer the adaptability would be low.	• High, the system could always be used to supplement transfer from the Clearwater. It could be expanded or removed easily depending on future expansion requirements.

[1] Estimates are in dam³ and were made in section "Potential Transfer Volume". The range of transfer volumes is dependent on whether or not removal restrictions are applied; the percentage transfer efficiency appears in brackets.

[2] These effects were indicated as "significant" in the preceding matrices; "•" for positive effects and "•" for negative effects.

Table V. 1 Composite Comparison of Selected Transfer Alternatives

VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

In this study, the thesis that Clearwater transfer (to meet growing demands in Southern Alberta) may be developed in a number of ways with minimal damage and possible enhancement to the donor and receiving streams, was promulgated and investigated. Six plausible transfer development alternatives were selected from a broad range of transfer means and submitted to a preliminary evaluation. The alternatives were evaluated and discussed in terms of the planning objectives they support, the potential transfer volumes available, relative cost, potentially significant environmental and socio-economic effects, and other general concerns in regard to flexibility of operation and future adaptability.

The major impetus behind interbasin water transfers and several of the major points of controversy surrounding the issue were discussed in chapter two. In both the Western United States and Alberta, attempts to maintain and expand agricultural production through irrigation have provided the incentive for most water transfer proposals. The various large scale transfers proposed for Alberta, like those proposed for international transfer, are essentially engineering reconnaissance studies. Several international transfer proposals and a specific Saskatchewan-Nelson Basin Board transfer proposal for transferring water from the North Saskatchewan and Clearwater Rivers were briefly discussed. Poor benefit-cost relationships, environmentalist opposition and political disfavour, especially in the basin-of-origin areas, were just some of the factors responsible for the shelving of such transfer plans. However, current activity in Alberta on behalf of the Water Resources Committee is indicative of the continued interest in developing interbasin transfers of water from northern rivers into the South Saskatchewan basin to support further irrigation development. In the past, the review of alternative means of increasing water supplies in the southern basins has been weak. Therefore, before interbasin transfer (especially on a large scale) can be genuinely considered a more thorough investigation of the alternatives is necessary, including modifying the water demand and adjusting the water supply within the South Saskatchewan basin. A brief discussion of the water supply and demand conflicts in southern Alberta and the related water management issues was presented. Several of the

existing proposals for Clearwater transfer were also reviewed.

Existing conditions in the study area were described in chapter three with particular emphasis upon the physiographic features and their effect on land use in the area. The Clearwater River was at one time a tributary of the Red Deer River and still contributes groundwater flow to the Red Deer basin. The unique hydrologic character of the Clearwater delta area was described and a brief explanation of the processes involved in its formation was also offered. Although the majority of the land use is related to agriculture, the agricultural potential of the area is only marginal due to the short growing season and marginal soil conditions. Local soil conditions, native plant communities and the local population and community were described briefly in separate sections.

Variations in streamflow were discussed in chapter four with reference to local variations in water balance, drainage basin characteristics and groundwater contributions. Streamflow regime was found to vary significantly between streams in the North Saskatchewan and Red Deer basins and several possible implications for diversion were mentioned in this regard. Clearwater discharges were found to fluctuate considerably on an annual and seasonal basis; thus a representative "low" flow year and a representative "high" flow year were selected to represent the entire range of discharge for calculations of potential transfer volume. The importance of underflow from the Clearwater River in relation to Stauffer Creek streamflow and the possibility of enhancing this form of transfer through an artificial recharge scheme was also discussed. In relation to the potential future use of transferred water, it was suggested that developing even a small percentage of the total Clearwater transfer potential could supply enough water to support a reasonable amount of irrigation development in the province.

Fish and wildlife and recreational resources related primarily to riparian environments in the study area were also described in chapter four. It was found that several of the streams in the area are highly rated for trout fishing. The possible positive and negative impacts of development on fish populations and aquatic habitats were discussed in relation to Stauffer and Horseguard Creeks. Stauffer Creek is one of the best trout streams in the province; through the Buck For Wildlife program the Alberta Government has set a strong precedent to maintain valuable trout habitat on this stream. Therefore, it was recommended that transfer into this stream be highly restricted to

prevent damage, and/or to improve existing aquatic habitat. Suggestions for enhancing instream conditions along the Horseguard were also made. The importance of instream flow requirements was discussed with reference to both donor and receiving streams. Three different methodologies for determining acceptable instream flows for various instream uses were described, the Montana method was used in later calculations. However, it was suggested that during dry years a real trade-off between instream flow uses in the study area and out-of-stream uses such as irrigation may be required. Environmental enhancement along Stauffer and Horseguard Creeks was suggested as a possible compensation for any detrimental impacts that might occur on the Clearwater River as a result of flow reduction.

In chapter five the potential volume of water which could be transferred from the Clearwater was discussed assuming various restrictions on the rate of removal and transfer. These volumes were then compared to the amount of irrigation development they could support. A broad range of physical transfer components was also described. Four Clearwater transfer alternatives were developed, each with a different combination of removal and transfer methods, storage options, and transfer routes. Two expansion alternatives were also suggested. These six alternatives were selected for preliminary evaluation because they each reflect a different mix of the planning objectives set out for Clearwater transfer. It was suggested that in order for planners to realistically consider developing a Clearwater transfer, ultimately alternatives would have to be capable of transferring at least 30% of the Clearwater discharge in dry years when demand would be greatest. In connection with this proviso, Clearwater instream flow recommendations were found to be too restrictive for smaller alternatives in low flow years. Three options were suggested to improve transfer efficiency during low flow years: i) reduce or remove restrictions on the removal of water from the Clearwater, ii) increase the level of Clearwater discharge through upstream storage and flow regulation, or iii) supplement Clearwater transfers with transfer of water from the North Saskatchewan River.

A broad range of means for transferring water from the Clearwater was suggested and discussed, including: four different removal locations, four removal methods, three transfer methods, and three transfer routes. It was found that a combination of the smaller individual transfer methods could result in significant rates of

transfer. However, in order to achieve transfer efficiencies greater than about 45% a large capacity transfer (probably using a canal) would be necessary.

Transfer alternatives were selected based on recommendations made after calculation of potential transfer volume and identifying potential planning objectives and constraints. Subsequent evaluation of the selected alternatives revealed the advantages and disadvantages of each and led to the suggestion of a possible sequence of transfer development making use of various transfer components at different stages. However, none of the alternatives were eliminated from future consideration based on this preliminary evaluation which was designed to assess the attributes of each alternative.

Conclusions

As a result of this study, three distinct yet interrelated conclusions have been reached concerning the potential for developing an interbasin transfer from the Clearwater River to the Red Deer River. These are summarized below.

First, it is concluded that water transfer from the Clearwater River could be developed in such a way that a sequence of progressively larger transfer schemes is used to alleviate water supply shortages in the South Saskatchewan basin. Initially, when demand for additional water would be small and would coincide with dry years in the south, the most cost effective means of transferring sufficient volumes of water from the Clearwater would be by pumping. Pumping would be required in dry years only – in the wetter (higher flow and lesser demand) years, the southern basin supplies would be more than adequate. However, as the demand for additional water increases so would the pumping costs and at some point the development of a gravity diversion system using canals would provide a more effective means of transferring increased volumes of water from the Clearwater. Pumping systems could be retained and operated together with the gravity diversion system in later years in order to provide supplementary transfer capacity in dry years.

Eventually, with a continued increase in demand, flow regulation on the Clearwater might be warranted in order to increase the volume of water available for transfer during the irrigation season. At some stage it may be decided that the remaining transfer potential of the Clearwater should be developed. The use of smaller transfer alternatives,

singly or in combination could provide enough water to support irrigation expansion at the current rate for five to seven years. With future improvements in irrigation efficiency and changes in agricultural practices, the need for large scale transfers of water may be postponed much longer.

In the future, if and when actual consumptive use in the South Saskatchewan basin reaches high enough levels, the development of large scale transfer alternatives such as those outlined in the SNBB and PRIME programs could justifiably be considered. However, the development of this remaining potential would entail an increasing amount of investment to acquire a decreasing portion of the remaining transfer potential. As a result, in keeping with the idea of sequential development, pumping first from the North Saskatchewan River in very dry years could be gradually incorporated to provide a more effective means of increasing the volume of transfer. Construction of a dam enabling gravity diversion from the North Saskatchewan to the Red Deer River might be the next step. If replacement supplies are needed in the North Saskatchewan basin, the transfers from more northerly basins could again be modest in the initial stages.

Second, it is concluded that transfer from the Clearwater could be conducted so that the range of detrimental environmental and social impacts associated with such development is much less than if only transfer objectives are considered. By identifying areas of potential detrimental impact and selecting transfer alternatives which effectively reduce impact in these areas, compromises may be achieved which are acceptable to both transfer development and environmental protection proponents. The development of transfer alternatives which avoid disturbing the highly valued fish resources in Stauffer Creek might be considered an acceptable compromise in regard to Clearwater transfer, at least in the initial stages. If further development is warranted or a suitable compromise cannot be found, unavoidable detrimental impacts could be at least partially compensated for by operating the transfer so that certain stream environments in the area are actually enhanced. Environmental damage to the lower Clearwater could conceivably be compensated for, at least in part, by enhancing the environmental quality of Horseguard Creek and the lower Medicine River. Alternatively, timely development of transfer from the North Saskatchewan into the Medicine River basin could supplement Clearwater transfer thereby maintaining suitable environmental conditions on the lower Clearwater

while at the same time enhancing conditions in the Medicine River. By developing a Clearwater transfer in this way, a portion of the benefits associated with transfer could be directly assigned to the local area, thereby improving the distribution of costs and benefits connected with transfer development in the immediate area (ie. as opposed to the region or province as a whole). Thus, despite the fact that water transfers are usually designed and operated to fulfill a single purpose, possibilities for developing multi-purpose transfers do exist and should be investigated.

Third, up until now the development of interbasin transfers in Alberta has been strongly directed towards the use of a single means of diversion (ie. large scale dams) for a single purpose (ie. irrigation expansion). In the light of the preceding conclusions it is proposed that the viability of water transfer as a valid water development strategy can be improved through the incorporation of a multi-means, multi-purpose approach to transfer development. Thus, it is concluded that a Clearwater transfer could be developed in such a way that it could be used as a prototype or initial model for other sequential transfer development in Alberta.

Recommendations for Development

Recommendations for future transfer development of the Clearwater River are made below. Although these result from this study, they may apply in varying degrees to other transfer developments in Alberta.

First, there is a need for consideration of a broader range of alternatives in water management planning in general and interbasin transfer specifically. Past transfer proposals which focus on large scale means allow little flexibility for the future by foreclosing a large number of lesser transfer alternatives. The potential of smaller scale transfer alternatives has been demonstrated. Initiating transfer on a small scale not only opens up a wider range of alternative transfer means; it allows for more flexibility in regard to actual operation of the transfer and future adaptation.

Second, transfer development should take place slowly, in response to more accurate short term projections of actual consumptive water use, rather than in leaps and bounds in reaction to forecasts of long term demand which are often promotional. Long term forecasts cannot accurately predict changes in the efficiency of water use or the

expansion of irrigation. Therefore, transfers constructed to meet a particular projected demand may not be required to do so for many years.

Third, the majority of the measurable benefits of transfer typically occur in the receiving basin, often far removed from the diversion location and the basin-of-origin where most of the significant detrimental effects occur. Thus, a regional disparity between the beneficial and detrimental effects of transfer can be expected. However, an attempt should be made to both reduce the detrimental effects associated with transfer and provide compensation (including environmental enhancement) to those areas most affected for unavoidable damages.

Fourth, it has been shown that Clearwater transfer can be developed for the purpose of supporting irrigation development in the receiving basin in addition to enhancing the environmental quality of receiving streams. Other possibilities should be explored in Alberta for developing transfers so that they serve a variety of purposes such as flood control and recreational development.

Fifth, Alberta government departments responsible for the planning and development of interbasin tranfer schemes should provide for public input into the design and selection of alternatives. In effect, the process of formal evaluation of transfer alternatives should be incorporated into the planning process much earlier – in the design phase. If evaluation and public participation were brought into the planning process in the design stage, information could be provided which would allow designers to develop superior design alternatives as well as, compromise solutions and mitigating measures that may help avoid major objections to future recommended plans.

Recommendations for Further Study

As research for this study progressed, it became apparent that there is a need for more research related to the development of a Clearwater transfer. Several recommendations for future research are outlined below.

First, the actual feasibility of enhancing stream conditions in the Medicine drainage system should be investigated. The actual amount and type of channel improvements that would be required to develop this stream for transferring flows of 4 cms and supporting a viable sport fish population are undetermined. The costs of such alteration could be

high. Several studies have been done in regard to stream alteration and fish habitat by the United States Fish and Wildlife Service (Headrick, 1976; Griswold et al, 1978; Marzolf, 1978). Information gathered in regard to the Stauffer Creek habitat maintenance program would also be of use in this regard although a post development study has not been carried out to assess the effects of the program.

Second, the actual engineering feasibility and cost of the various suggested removal, transfer and storage methods should be established. Information gathered from such studies could be used in the preliminary screening of alternatives. Investigations along these lines may also expand the range of transfer means under consideration by suggesting new alternatives.

Third, before any transfer development takes place it is recommended that environmental and recreational baseline studies be completed in order to document the existing condition and use of these water-related resources in the study area. A key area of concern would be the Clearwater River below the point of diversion. The significance of this reach of the river to resident fish populations is virtually unknown and information on the recreational use of this section of the Clearwater is not available. This information would be useful in establishing the instream flow recommendation for the Clearwater. Detailed information concerning the recreational use of other streams in the area would also be helpful in planning for their use in a future transfer scheme.

Fourth, a stream routing study and establishment of a denser network of stream gauges in the area could be used to determine the effect of various operational scenarios on components of both the natural and man-made environment (ie. streams, canals, reservoirs, etc.). Such studies could perhaps lead to improved operating efficiency and increased precision in regulating instream flows on both donor and receiving streams. The significance of downstream storage of diverted flows in the Red Deer basin on the operation of a transfer as well as the effects on the North Saskatchewan River should be studied.

In this study, the potential for development of a Clearwater interbasin transfer has been investigated. Although the discussion has been focused primarily on alternative means of water transfer, it is recognized that other development and operational considerations are also important and recommendations for future development and

research have been made. Water transfer from the Clearwater is not sufficient to support increasing water demands in the South Saskatchewan basin over the long term. However, in conjunction with improved management of water use and storage of existing water supplies in the basin, a gradual sequence of water transfer development could be used to alleviate future water supply shortages which might restrict future development in the region. Past investigations aimed at developing a sequence of interbasin transfers in Alberta focused on the use of a single means of transfer - gravity diversion utilizing large dams and diversion canals. By considering only one means of transfer the practical range of choice available to planners on this issue has been restricted to large scale development such as that proposed by the SNBB and PRIME, and alternatively, no development which has been the official government stance since the PRIME program was shelved in 1971. In theory, the range of choice for any particular transfer is much larger; a range of transfer alternatives may be considered from: large scale transfer with little consideration for environmental quality, to a compromise situation between transfer and maintenance of environmental quality, to transfer development with provision for compensatory environmental enhancement. The full range of alternatives should be studied pending the decision to go ahead with interbasin transfer in Alberta, including studies of how existing supplies might be used more efficiently, and whether or not there might be some cut-back in the low flow years rather than the expansion in use that does take place and which is so very expensive to provide.

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APPENDIX 1

The water balance equation can be simply written as:

$$P = (PE - D) + S \pm \Delta ST$$

where:

P = **precipitation** =
water falling as rain or snow (mm water equivalent)

PE = **potential evapotranspiration** =
amount of water that would be evaporated and transpired from a plant cover if sufficient water were available in all seasons for the process to continue at the optimum rate (mm)

D = (PE − AE) = **water deficit** =
amount by which the supply of water available for evaporation and transpiration is exceeded by plant needs (mm)

S = **water surplus** =
that water which percolates at levels beyond root depth or moves in surface flow toward streams and depressions after soil moisture storage capacities have been recharged to a specified level (ie. 12, 50, 100, 150, or 250 mm)

Δ ST = **storage change** =
net amount of water withdrawn from the soil (soil moisture utilization) or infiltrating into the soil (soil moisture recharge) in the equation period

AE = (PE − D) = **actual evapotranspiration** =
amount of water actually disappearing directly into the atmosphere from evaporation and plant transpiration

The Thornthwaite procedures for 1948 have been applied. Utilizing monthly temperature and precipitation data the PE levels were estimated; based on a simple accounting procedure periods of surplus and deficit are determined. Detailed procedures are described by Thornthwaite(1948). Meteorological data was obtained from Environment Canada Monthly Meteorological Records from 1951 through 1980.

The Thornthwaite procedure was used to calculate the water balance for Rocky Mountain House on a monthly basis for the 30 year period 1951−1980. The resultant annual water balance for each of five different soil moisture capacities appears in Appendix 2. The actual monthly water balance for a 150 mm soil moisture storage capacity for an eleven year period from 1971 through 1981 appears in Fig. IV. 2. The mean annual water balance for the entire 30 year period appears in Fig. IV. 1 and is based on the mean monthly precipitation and temperature values for the period.

APPENDIX 2

Water Balance – Rocky Mountain House (12 mm storage)

YEAR	P	PE	D		ΔST	AE
1951	703	445	18	271	+ 5	427
52	502	527	136	179	−68	391
53	644	489	84	253	−14	405
54	711	462	83	341	− 9	379
55	473	479	201	162	+33	278
56	534	510	146	174	− 4	364
57	392	476	219	117	+18	257
58	419	544	231	111	− 5	313
59	555	488	87	129	+25	401
1960	476	515	168	134	− 5	347
61	454	522	169	114	−13	353
62	493	518	95	91	−21	423
63	587	540	162	202	+ 7	378
64	550	503	126	159	+14	377
65	744	495	26	292	−17	469
66	580	483	85	177	+ 5	398
67	381	494	272	130	+29	222
68	570	502	71	168	−29	431
69	557	506	99	133	+17	407
1970	550	523	131	157	+ 1	392
71	532	523	177	218	−32	346
72	707	475	130	311	+51	345
73	477	507	180	175	−25	327
74	641	522	51	199	−29	471
75	482	474	159	125	+42	315
76	634	529	80	220	−35	449
77	627	526	93	192	+ 2	433
78	555	502	65	117	+ 1	437
79	357	478	257	89	+47	221
1980	616	513	34	163	−26	479
AVG.	550	502	128	177	− 1	375

Water Balance – Rocky Mountain House (50 mm storage)

YEAR	P	PE	D	S	ΔST	AE
1951	703	445	0	217	+41	445
52	502	527	42	141	-124	485
53	644	489	46	215	- 14	443
54	711	462	21	265	+ 5	441
55	473	479	163	127	+ 30	316
56	534	510	70	109	- 15	440
57	392	476	181	54	43	295
58	419	544	193	98	- 30	351
59	555	488	49	91	+ 25	439
1960	476	515	124	90	- 5	391
61	454	522	131	71	- 8	391
62	493	518	54	55	- 26	464
63	587	540	111	151	+ 7	429
64	550	503	48	104	- 9	455
65	744	495	0	254	- 5	495
66	580	483	14	113	- 2	469
67	381	494	234	97	+ 24	260
68	570	502	0	96	- 28	502
69	557	506	32	46	+ 37	474
1970	550	523	67	113	- 19	456
71	532	523	101	147	- 37	422
72	707	475	56	199	+ 89	419
73	477	507	138	171	- 63	369
74	641	522	9	157	- 29	513
75	482	474	121	87	+ 42	353
76	634	529	0	120	- 15	529
77	627	526	13	110	+ 4	513
78	555	502	27	94	- 14	475
79	357	478	219	58	+ 40	259
1980	616	513	0	106	- 3	513
AVG.	550	502	76	125	- 2	427

Water Balance – Rocky Mountain House (100 mm storage)

YEAR	P	PE	D	S	Δ ST	AE
1951	703	445	0	167	+ 91	445
52	502	527	0	124	-149	527
53	644	489	0	190	- 35	489
54	711	462	0	198	+ 51	462
55	473	479	113	127	- 20	366
56	534	510	14	53	- 15	496
57	392	476	131	4	+ 43	345
58	419	544	143	48	- 30	401
59	555	488	0	41	+ 26	488
1960	476	515	74	41	- 6	441
61	454	522	81	21	- 8	441
62	493	518	4	5	- 26	514
63	587	540	61	101	+ 7	479
64	550	503	18	54	+ 11	485
65	744	495	0	211	+ 38	495
66	580	483	0	106	- 9	483
67	381	494	184	91	- 20	310
68	570	502	0	46	+ 22	502
69	557	506	0	46	+ 5	506
1970	550	523	17	99	- 55	506
71	532	523	44	90	- 37	479
72	707	475	6	133	+105	469
73	477	507	88	137	- 79	419
74	641	522	0	107	+ 12	522
75	482	474	71	78	+ 1	403
76	634	529	0	70	+ 35	529
77	627	526	0	110	- 9	526
78	555	502	0	81	- 28	502
79	357	478	169	31	+ 17	309
1980	616	513	0	56	+ 47	513
AVG.	550	502	41	89	0	462

Water Balance – Rocky Mountain House (150 mm storage)

YEAR	P	PE	D	S	Δ ST	AE
1951	703	445	0	117	+141	445
52	502	527	0	124	-149	527
53	644	489	0	190	- 35	489
54	711	462	0	198	+ 51	462
55	473	479	63	127	- 70	416
56	534	510	0	3	+ 21	510
57	392	476	91	0	+ 7	385
58	419	544	95	0	- 30	449
59	555	488	0	0	+ 67	488
1960	476	515	20	32	- 51	495
61	454	522	60	0	- 8	462
62	493	518	0	0	- 25	518
63	587	540	11	52	+ 6	529
64	550	503	0	4	+ 43	503
65	744	495	0	193	+ 56	495
66	580	483	0	106	- 9	483
67	381	494	134	90	- 69	360
68	570	502	0	0	+ 68	502
69	557	506	0	42	+ 9	506
1970	550	523	0	70	- 43	523
71	532	523	0	73	- 64	523
72	707	475	0	89	+143	475
73	477	507	38	131	-123	469
74	641	522	0	57	+ 62	522
75	482	474	21	78	- 49	453
76	634	529	0	20	+ 78	529
77	627	526	0	110	- 9	526
78	555	502	0	81	- 28	502
79	357	478	119	31	- 33	359
1980	616	513	0	6	+ 97	513
AVG.	550	502	22	68	+ 2	481

Water Balance – Rocky Mountain House (250 mm storage)

YEAR	P	PE	D	S	ΔST	AE
1951	703	445	0	17	+241	445
52	502	527	0	124	-149	527
53	644	489	0	190	- 35	489
54	711	462	0	198	+ 51	462
55	473	479	0	127	-133	479
56	534	510	0	0	+ 24	510
57	392	476	51	0	- 33	425
58	419	544	95	0	- 30	449
59	555	488	0	0	+ 67	488
1960	476	515	0	0	- 35	515
61	454	522	52	0	- 16	470
62	493	518	0	0	- 25	518
63	587	540	0	0	+ 47	540
64	550	503	0	0	+ 47	503
65	744	495	0	128	+121	495
66	580	483	0	106	- 9	483
67	381	494	34	90	-169	460
68	570	502	0	0	+ 68	502
69	557	506	0	0	+ 51	506
1970	550	523	0	23	+ 4	523
71	532	523	0	73	- 64	523
72	707	475	0	89	+143	475
73	477	507	0	131	-161	507
74	641	522	0	19	+100	522
75	482	474	0	78	- 70	474
76	634	529	0	0	+105	529
77	627	526	0	110	- 9	526
78	555	502	0	81	- 28	502
79	357	478	19	31	-133	459
1980	616	513	0	0	+103	513
AVG	550	502	8	54	+ 2	494

APPENDIX 3

METHODS FOR ESTIMATING INSTREAM FLOWS FOR FISH AND WILDLIFE

These three different methods of determining instream flow recommendations are briefly described in chapter four and the Montana method is applied in chapter five when calculations are made of potential Clearwater transfer volume. The Montana method is generally the least restrictive of these methods.

MONTANA METHOD:

Based upon flow studies and numerous observations, Tennant(1976) suggests the following semi-annual discharge regimens:

- **Satisfactory Flow Range**: 20% of the average annual flow October-March and 40% April-September.
- **Excellent Flow Range**: 40% October-March and 60% April-September.
- **Minimum Flow Range**: 10% of average annual flow, considered adequate to sustain short-term survival of aquatic life.

The average annual discharge (1976-1981) for the Clearwater River at Dovercourt is 17 cms, this translates into:

Satisfactory Flow = 3.4 cms October-March and 6.8 cms April-September

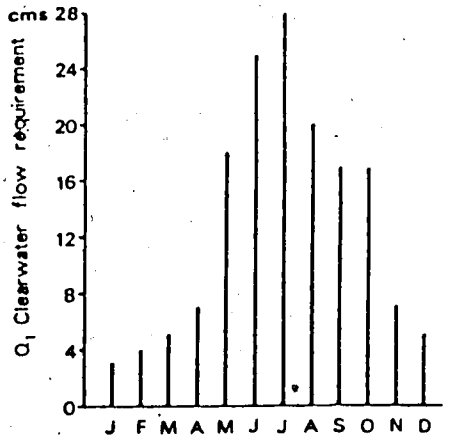
Excellent Flow = 6.8 cms October-March and 10.2 cms April-September

Minimum Flow = 1.7 cms

UNITED STATES FISH AND WILDLIFE SERVICE METHOD:

This procedure was based first upon estimates of stream flow needs related to average hydrologic conditions for each specific month, and secondly, on estimating flow needs for extremely dry periods (Anonymous, 1974). A flow duration curve for each month in the year is constructed using daily discharge values for a particular month and all the years of record. The six-year period from 1976 through 1981 was used to construct the monthly flow duration curves for the Clearwater River at Dovercourt. The recommended instream flow is set at that flow exceeded 90% of the time as determined from each monthly flow duration curve. This flow is referred to as the 10 percentile flow; adjustments were made upwards for spawning times (September and October on the Clearwater) when the mean annual flow of record was recommended (ie. 17 cms).

The resulting flow recommendation for the Clearwater using this method would be:



UNITED STATES FOREST SERVICE METHOD:

Data (biological and physical) from studies conducted on Rocky Mountain trout streams in Colorado were compared with average annual flow records and discharge percentile recommendations were then made (Stalnaker and Arnette, 1976). A flow duration curve using mean monthly discharge values is constructed and percentiles recommended for preservation of various aquatic life-cycle requirements, such as: fish food production (80 percentile flow), spawning (40 percentile flow), and spawning area flushing (15 percentile flow for at least a 48-hour period). The latter is necessary for removal of fines from the gravel beds and intragravel water movement.

Using this method the Clearwater flow requirement for food production would be 6.5 cms, for spawning it would have to be increased to 18 cms and for a short flushing period a flow of 35 cms is recommended.

APPENDIX 4

POTENTIAL ANNUAL TRANSFER VOLUMES

These are the variables that were used to determine the potential transfer volume, they are discussed in chapter five. The 1979 and 1983 mean daily discharge hydrographs were used to make the calculations; these appear in Figs. IV. 4 and 5.

Variables:

Q = Clearwater River discharge (cms)

Q_1 = Minimum flow recommendation, all flow above this level on the Clearwater is available for diversion (ie. Montana, USFS and USFWS methods, see Appendix 3)

Q_2 = Maximum flow recommendation, composite natural plus diverted flow in receiving stream

Q_3 = Actual diversion rate from Clearwater River which can be maintained without exceeding Q_2 in the receiving stream (ie. 1 – 6 cms)

V = Total volume of water diverted given specified values for Q_1 and Q_3 applied to a specified annual hydrograph for the Clearwater River (dam^3)

NOTE:
It is assumed that when Q is greater than Q_1 all flow up to the specified rate Q_3 will be diverted.

Postulated Variable Values

	Q_2	Q_3
Upper Stauffer Creek	2.0 cms	1.7 cms
Lower Stauffer Creek	5.0	4.4
Horseguard Creek	5.0	4.0
Raven River at Raven	10.0	6.0
Upper Raven River	5.0	3.0

APPENDIX 5

ACTIVITIES IN VARIOUS STAGES OF PROJECT DEVELOPMENT

The following descriptions are provided to aid in the evaluation of the water transfer alternatives in question. Each "activity" listed along the top of the assessment matrix is described in a manner which defines the activity, and possibly when and for what reason it is likely to occur, and then lists a number of "relevant factors" associated with the activity. These factors need to be considered when making a decision as to whether a significant impact is likely. The activity descriptions are those used in the Government of Canada(1978) document "Guide for Environmental Screening". The descriptions have been modified where such changes were felt to be appropriate. The descriptions are intended merely as starting points in the screening process. The list of factors is not all-inclusive and the list can be modified to more effectively assess individual projects.

For example, if the activity is an access road, the screener is told that the access road may be temporary or permanent and is used to carry men, material and equipment to the project site. Then, looking at the "relevant factors" listed below the definition, he is reminded that the road may have to cross a small stream which could affect a downstream spawning area (creation of barriers, increased turbidity, sediment deposition in spawning bed).

1. AREAL SURVEY

During the pre-construction stage of projects there is usually a period of site investigation (either intensive or superficial, depending on the project size and complexity). Activities associated will normally consist of various types of data collection surveys requiring survey crews, equipment (for transportation and/or testing) and associated services.

1.1 Site Surveying

That activity associated with the physical layout of a construction project including such activities such as line clearing operations.

Relevant Factors:

a. Extent of cutting and clearing operations.
b. Disturbance of residents, traffic patterns.
c. Type of transport equipment required.
d. Duration of survey and size of survey team.

1.2 Soil Testing

Involves the operation and movement of equipment such as drills, seismic equipment, etc. to determine soil characteristics.

Relevant Factors:

a. Size and extent of survey.
b. Nature of area being surveyed (wilderness, urban, developed, or rural).
c. Groundcover sensitivity to damage.
d. Size, noise levels of equipment.

1.3 Hydrological Testing

Conducting surveys to measure characteristics of streams and other bodies of water within an area, including locations, areal extent, depth and course of streams, streamflow and groundwater monitoring (quantity and quality).

Relevant Factors:

a. Type and size of equipment required (transportation, operation in sensitive aquatic areas, ground cover damage from test well drilling operations).
b. Extent of survey.
c. Types and quantities of die tracers used.

1.4 Environmental Survey

Conducted to determine background data on water quality, lifeforms and ecological relationships.

Relevant Factors:

a. Type of equipment and survey vehicles used.
b. Effect of sampling flora and fauna.

1.5 Equipment

That which may be used for earthmoving, clearing, surveying, service operations and associated activities.

Relevant Factors:

a. Existing off-site traffic density and patterns.
b. Duration of equipment operation.
c. Suitability of roads for truck traffic.

2. CONSTRUCTION

The construction phase of a project may have associated with it a wide variety of activities. The list provided is a representative sample of some of the activities commonly associated with water development projects.

2.1 Access Roads

Those roads, either temporary or permanent over which men, materials and equipment will be transported to the construction site.

Relevant Factors:

a. Type of road surface (dust levels expected).
b. Size of roads (traffic levels, degree of clearing required).
c. Character of terrain (vegetation, stream crossings, habitats, landuse, soil suitability).

2.2 Site Clearing

Relevant Factors:

a. Size and type of equipment.
b. Likelihood of soil erosion.
c. Modification of habitat.
d. Surface water bodies.
e. Vegetation.

2.3 Excavation

Relevant Factors:

a. Extent and depth of excavation.
b. Character of underlying sediments.
c. Requirements for water table modification.
d. Surface drainage alteration.
e. Topography.

2.4 Blasting and Drilling

Relevant Factors:

a. Duration, frequency and intensity of operations.
b. Soil and underlying sediment characteristics.
c. Water well supply and/or quality alterations.
d. Wildlife populations (beaver dams, spawning areas, nesting sites).

2.5 Building Relocation

Relevant Factors:

a. Are building relocations likely to result in aesthetic deterioration of the site?
b. Historic value of structures and relation to original setting.
c. Disruption of local operations.

2.6 Cut and Fill

Relevant Factors: Same as apply to excavation operations with the added concerns associated with depositing the excavated material.

2.7 Erosion Control

May be carried out during construction by physical methods (rip-rap, minimum clearing procedures, check dams, etc.) or by chemical methods (soil binders, mulches).

Relevant Factors:

a. Toxicity of chemical binders.
b. Impediments to fish movement resulting from instream structures.

2.8 Drainage Alteration

Alteration of the quantity and/or direction of surface drainage intentionally to permit other construction operations to be performed.

Relevant Factors:

1. Extent of alteration: quantities of groundwater removed from aquifer or quantities of water introduced by recharging.

a. Sensitivity of receiving water to increased turbidity, sediment deposition.
b. Wetland habitat for fish, waterfowl and furbearers.
c. Downstream water users.

2.9 Stream Crossings

Relevant Factors:

a. Flow characteristics (crossings impede flow resulting in possible upstream flooding).
b. Watercraft uses.
c. Short-term or permanent structures.
d. Use of stream by fish and wildlife (spawning gravel, fish rearing areas, fish movement, waterfowl nesting).

2.10 Channel Dredging and Straightening

Relevant Factors:

a. Effects on water quality, flora and fauna.
b. Water uses (irrigation, livestock watering, recreation).
c. Spoil disposal areas.

2.11 Channel Revetments

Those structures designed to protect the land bordering channels (levees and dikes).

Relevant Factors:

a. Streamflow characteristics.
b. Sediment transport and deposition.
c. Habitat (feeding areas, protective shelters).

2.12 Dams and Impoundments

Required to permit construction activity in areas normally covered by water. For example, water would have to be impounded or diverted to construct a weir on the Clearwater River.

Relevant Factors:

a. Character of bed normally submerged.
b. Effects on fish.
c. River traffic disruption, recreational use.
d. Flooding.
e. Silt deposition.
f. Groundwater changes in quantity and quality.
g. Duration of impoundment.

2.13 Canals

Relevant Factors:

a. Dimensions of canal.
b. Type of lining (seepage, failure, maintenance, possible in-canal fish habitat).
c. Amount of excavation required along route.
d. Number of road crossings.

2.14 Equipment

Same considerations as for I.5.

2.15 Utilities

Support services required for the labour force, for equipment storage and repair, for material storage, etc. Such services may include temporary housing with associated waste disposal facilities, water power supplies.

Relevant Factors:

a. Quality of wastewater treatment facililities.
b. Quality of solid waste disposal.
c. Air emissions.
d. Size of work camp.
e. Fragility of environment.

2.16 Labour Force

Relevant Factors:

a. Size of labour force.
b. Economic and social interference in the area.
c. Recreational activities (increased hunting and fishing pressures, use of vehicles in wilderness areas).
d. Expected duration of labour force pressure.

2.17 Reclamation

Attempt to restore or, if possible, improve on the original state of the construction site following construction.

Relevant Factors:

a. Changes in surface water drainage.
b. Altered wildlife habitat.
c. Introduction of different species in revegetation.

2.18 Reforestation

Relevant Factors:

a. Change in wildlife habitat.
b. Change in hydrologic character of surface (infiltration rates, evapotranspiration).

2.19 Ancillary Transmission Lines

Transmission lines and pipelines may be required to bring electricity and fuel to the project.

2.20 Pipelines

Some of the alternatives utilize pipelines to transfer the water to receiving streams. Many of the concerns associated with canal construction apply here also.

3. OPERATION AND MAINTENANCE

The operation of a facility refers to the actions and procedures required to run a facility while maintenance refers to the necessary functions required to keep a facility in running order (ie. upkeep of pumps and headworks gates).

3.1 Clearing

The periodic removal of vegetation from within canals and reservoirs and along the route of canals and pipelines will likely be required.

Relevant Factors:

a. Method of clearing.
b. Extent of clearing.
c. Susceptibility of cleared areas to erosion.
d. Aesthetics.
e. Habitat alteration.
f. Adjacent land and water use.

3.2 Dredging

The periodic removal and disposal of bottom sediments from an area in a water course may be required to insure efficient operation of the facility (ie. canals, storage ponds, stream channels, etc.).

Relevant Factors:

a. Timing and frequency of operations.
b. Extent of dredged and disposal areas.
c. Effects on water quality, flora and fauna.

3.3 Equipment Operation

Although the equipment required to maintain the facility may vary from that required in the construction phase, the same concerns apply.

3.4 Operational Failure

Relevant Factors:

a. Availability of back-up equipment.
b. Results of failure (flooding, operational inefficiency, threatened fish and wildlife, facility damage, property damage).
c. Probability of failure.
d. Contigency plans and safeguards.

3.5 Energy Requirements

Relevant Factors:

a. Requirement vs. availability of energy.
b. Periods of peak demand.
c. Efficiency of energy use.
d. Conservation practices.

3.6 Energy Generation

The production of power both to supply the operation and as a product of the operation through the use of hydro and/or fossil fuels.

Relevant Factors: Fossil Fuel Power Generation

a. Type and quantity of fuel expended.
b. Noise.
c. Generated on-site (ie. gas powered water pumps and/or electric generators) or off-site (electrical transmission required).

Relevant Factors: Small-scale Hydro

a. Rate and timing of discharge.
b. Efficiency of generation (energy required to lift water vs. energy generated by falling water).

3.7 Automobile Traffic

Relevant Factors:

a. Noise.
b. Dust.
c. Water and adjacent land use.

3.8 Pedestrian Traffic

The amount of pedestrian traffic in the area may increase if additional recreational opportunities are provided.

Relevant Factors:

a. Numbers.
b. Adjacent land use.
c. Type of ground cover.
d. Disturbance.

3.9 Streamflow Augmentation

Relevant Factors:

a. Timing and quantity of augmentation.
b. Method of transfer.
c. Altered aquatic habitat.
d. Channel alteration.
e. Existing instream water uses.

3.10 Streamflow Reduction

Relevant Factors:

a. Timing and quantity of reduction.
b. Altered aquatic habitat.
c. Altered recreational potential.
d. Downstream uses.

AREAS OF POTENTIAL ENVIRONMENTAL EFFECTS

With each activity identified for a project, there may be associated one or more areas of potential environmental effect. An "environmental effect" is defined as a process (such as erosion of soil, dispersion of pollutants, displacement of persons) that is set in motion or accelerated by man's actions. An "environmental impact" is defined as the net change (good or bad) in man's health and well being (including the well-being of the ecosystems on which man's survival depends) that results from an environmental effect and is related to the difference between the quality of the environment as it would exist "with" and "without" the same action.

The list of environmental effects in the assessment matrix is by no means all-inclusive. The following descriptions and s egories are intended to supply the screener with a starting point, listing those ar cern which should be considered when assessing alternatives. Again, the cts has been taken from the Government of Canada(1978) publication "Gu onmental Screening" with various additions and deletions made to improve the of water development projects. In addition to the brief description of each po ect, specific references are listed for some of the categories in which significant impacts are foreseen. Detailed discussion of these individual environmental impacts is beyond the scope of this research, however, many of the significant issues are addressed in those references cited. There are several general criteria that can be used when making a decision as to the environmental effect of an activity. These critieria are by no means mutually exclusive:

- **Magnitude**: defined as the probable severity of each potential impact. Will the impact be irreversible? If reversible, what is the recovery rate or adaptiblity of an impact area? Will the activity preclude the use of the impact area for other purposes?

- **Prevalence**: defined as the extent to which the impact may eventually extend as in the cumulative effects of a number of stream crossings. Each one taken separately might represent a localized impact of small importance and magnitude but a number of them could result in a widespread effect. Coupled with the determination of ulative effects is the remoteness of an effect from the activity causing it. The oration of fish production resulting from access roads could affect shing in an area many miles away and for months or years after project letion.

- **tion and Freque** will the activity be long term or short term? If the activity is intermittent, will it allow for recovery during inactive periods?

- **Importance**: This is defined as the value that is attached to a specific area in its present state. For example, the study area has a stream which is of regional, provincial and perhaps even national importance in terms of premier trout fishing.

- **Mitigation**: Are solutions to problems available? Existing technology may provide a solution to a silting problem expected during construction of an access road or of bank erosion resulting from a new stream configuration.

- **Compensation**: Are there possibilities for providing beneficial modifications to an area in an effort to at least partially compensate for losses due to negative impacts associated with the project? Who benefits and who losses as a result of the development?

An impact typically represents a comparison between two states. One state is the condition that results from implementing the subject action. The impact description compares this state to some reference r state. For this study the "reference state" or "null alternative" is taken as the state would evolve in the absence of the action (Peterson, Gemmell and Schofer, 1974). Based on the general criteria identified and comparison to the imagined reference state, a number of possible screening decisions can

be made:

- **No significant effect** – It should be very ce t an activity is not expected to have an effect on an area of the enviroment. ample, it is fairly safe to say that "soil testing" in itself will not have any significant effect on "housing" in the community.

- **Significant positive effect** – Any effect which provides benefits "easily recognizable" by both the public and professional community. For instance, the reduction of annual flood damages to a community or quality improvement in a town's domestic water supply.

- **Significant negative effect** – Any effect which results in "easily recognizable" detrimental impacts. Such as, pollution of domestic water supplies and resultant human health problems or loss of a highly valued sportfish population. The related actions should be further investigated to determine whether the adverse effects can be mitigated within the confines of the project design. If not, these effects should be given particular attention in any further post-design evaluation.

- **Unknown significance of potential adverse effect** – If for any activity there is reason to believe that adverse impacts may result but there is lack of knowledge concerning the significance and precise nature of the impacts, then the activity should be rated as having unknown significance. For example, it is known that removal of stream bank vegetation adversely affects both aquatic and riparian terrestrial habitats. But the magnitude and prevalence associated with the activity and the importance placed on the habitats is not known and therefore, the significance of such effects is, in this case, unclear.

- **Unknown significance of potential positive effect** – any activity beneficial impacts are believed to result but there is insufficient ormation concerning the nature and significance of the impacts, then the activity should be rated as having unknown significance. As an example, it is assumed that the service industry in the area will benefit from construction activity and possibly increased recreational use of the area. But the magnitude and prevalence of the improved business is unclear.

1. PHYSICAL/CHEMICAL EFFECTS

Physical/chemical environmental impact areas are those elements of the environment which are always present to some degree, namely: water, noise and air. For this study it is assumed that any effect the water transfer project might have on the atmosphere is negligible.

1.1 WATER

Areas of concern asociated with water may be summarized as follows:

1.1.1 Groundwater

a. **Flow and Water Table Elevation** – Sources of groundwater may change (decrease or increase) as a result of a variety of activities. Major uses of groundwater may also change (ie. from local domestic and agricultural uses to use for streamflow augmentation and/or recreational purposes).

b. **Recharge** – The interaction of groundwater with surface drainage through the processes of infiltration, evapotranspiration, recharge and discharge may be affected. Artificial recharge is an obvious example; some of the factors affecting infiltration and recharge are reviewed by Williams and Allman(1969), while the feasibility of artificial recharge in a small groundwater basin is

discussed by Jones, et al 1968

c. **Quality** – changes in groundwater may occur resulting in increased user costs (for treatment) or possibly abandonment of sources. Conflicts may arise with regulations or standards. Alternate sources may not be available; crops may concentrate chemicals in irrigation return flows.

1.1.2 Surface Water

a. **Altered Shorelines and Channels** – may result directly from construction activities as well as indirectly from processes of erosion and deposition brought on by a change in geomorphic controls (ie. channel slope, lake outlet elevation, stream stage, stream dimensions, stream discharge, etc.). There has been a great deal of research carried out in regard to analysis of fluvial processes; selected references which could prove useful in further study, are: Abbott(1976), Kellerhals, et al(1976), Harvey(1969), and Neill and Galay(1967).

b. **Drainage and Flood Characteristics** – may change as a result of altered soil and topographic features. Watershed areas may be increased or decreased (interbasin diversion), runoff routes may be disrupted, flow rates and water levels may fluctuate to a greater extent and affect users or structures on the route (ie. bridges, buildings, etc.).

c. **Altered Streamflow Regime** – may result from changes in the storage and subsequent release of surface water. Interbasin transfer of water necessarily involves the alteration of streamflow regime.

d. **Water Quality** – changes may occur resulting in improved or restricted water use. There may be chemical changes, biological changes, and physical changes (temperature, turbidity) in water quality the impact of each should be assessed.

1.2 NOISE

a. **Intensity** – or loudness of a particular noise is one aspect affecting both man and wildlife. The intensity also determines the distance over which the noise is heard.

b. **Duration** – of a noise can have a great effect on whether it will be accepted by those affected. Short bursts of noise can be especially disruptive.

1.3 LAND

a. **Soil Erosion** – can be damaging in agricultural areas; damage shoreline properties and structures; affect recreational fishing; change drainage characteristics, wildlife habitats, etc.

b. **Flood Plain Usage** – may be altered by changes in watershed drainage characteristics. Flood plain delineation may change; soils may change as a result of deposits; agricultural use may be enhanced or reduced; waterfowl habitat may be modified.

c. **Buffer Zones** – built up by natural means are those zones which provide windbreaks, erosion control along rivers, sediment traps, and wildlife shelter.

d. **Soil Suitability for Use** – Some locations may have limited areas with soil conditions suitable for agricultural use, solid waste disposal or use in construction. If such is the case, special concern should be shown to ensure that those areas are not made unusable.

e. **Compaction and Settling** – could occur as a result of structures or materials (water reservoirs) being placed on the surface. Underlying geology may be affected with resulting damage to project and other structures in the area.

2. ECOLOGICAL EFFECTS

Ecological effects pertain to the distribution and abundance of plant or animal species. Because of the complex inter-dependency which exists between plant and animal communities in an area, effects are rarely limited to those immediately impacted. Indirect impacts may be important. For example, a change in water quality may immediately impact aquatic macroinvertebrates, but the indirect impact on fish which feed on them may take a long time to occur or may never occur.

2.1 SPECIES AND POPULATIONS

A species consists of groups of organisms which interbreed or are potentially capable of doing so and which are reproductively isolated from all other organisms. A population is a group of individuals of any one species. For example, a stream may contain a population of brook trout and a forest may consist of populations of white spruce and balsam poplar.

2.1.1 Terrestrial

a. **Flora** – Rare species may be adversely affected or unusal local populations totally destroyed by project activities (eg. an exceptionally old stand of white pine or boreal forest species).

b. **Fauna** – Populations of migratory birds or mammals may be adversely affected through failure to map concentration locations and failure to reduce adverse impacts through project timing and location, noise reduction, use of natural vegetation buffers, establishment of wildlife refuges, etc. Certain wildlife species are rare or locally unusual because of natural factors or, increasingly, because of habitat loss and degradation. The impact that operation of a water diversion would have on terrestrial wildlife is not known but several references that deal with streamflow/wildlife relationships are listed by Kadlec(1976).

2.1.2 Aquatic

a. **Furbearers** – Many aquatic species are important to local economies (muskrat, beaver). Existing or potentially exploitable populations and their aquatic and shoreland habitat need to be identified. Alternatively, beavers may be considered a nuisance species in some areas, in which case, removal of favourable beaver habitat might be considered a positive impact.

b. **Fish** – Failure to map the location of populations as well as their movements and failure to take the necessary corrective action when adverse impacts are likely, may result in the destruction of a local population and may ultimately lead to species extermination over a larger area. Salmonids, for instance, are sensitive to many kinds of habitat modification including increases in water temperature, increases in nutrient and sediment loading and changes in water flow rates and levels. Poor project timing may result in iterference with fish spawning.

Interference may also result from using culverts that are too small, improper placement and use of culverts and erosion control devices.

2.2 HABITAT

a. **Terrestrial** – Natural vegetation buffers should be left between the project and the habitats of important wildlife. In this case buffers along stream courses and canal/pipeline routes are of particular concern. The possibility exists for increasing habitat diversity in the area through the creation of wetland habitat (ie. surface water storage on Clearwater delta). In biologically homogeneous agricultural areas wetlands act as islands of wildlife habitat. They are important to the survival of many species, including waterfowl and many kinds of furbearers.

b. **Aquatic** – Inadequate drainage control and soil stabilization near water bodies can destroy spawning beds. Many of the effects which might occur in the construction phase of a project have already been experienced along Stauffer Creek as a result of local clearing and agricultural activities. Inadequate knowledge regarding the effects of altered streamflow regime in both the receiving and donating streams are of major concern. An excellent starting point for further investigation of the problems and impacts associated with alteration of aquatic (particularly riverine) habitats is the section on instream flow needs for fish and other aquatic wildlife by Stalnaker and Arnette(1976). Papers by Schoof(1980) on the impact of channel modification, by Marzolf(1978) on the effects of clearing instream vegetation, and by Eicher(1976) on the effects of flow stabilization on fish habitat all present valuable insight into the problems involved with water development and consequent effects on aquatic habitat. A good general reference for stream ecology is that of Hynes(1971).

3. AESTHETIC EFFECTS

Aesthetics is a branch of philosophy dealing with beauty and the beautiful. Beauty is a combination of qualities which provide an enjoyable sensation or a pleasurable state of mind (visual: pleasant forms or colours; olfactory: pleasant smells; auditory: pleasant sounds; etc.). The perception of beauty is subjective and reflects personal feelings as well as social attitudes. A particular locale because of its aesthetic qualities (clean air and water, beaches, wildlife, vegetation) may be ideally suited for some particular landuse such as a park or wildlife reserve. An adjacent development (eg. pipeline along Stauffer Creek Valley) may adversely affect such qualities and thereby decrease the attractiveness of the locale. Examples of some relevant concerns associated with aesthetic qualities follow.

3.1 WATER

a. **Land and Water Interface** – zones include sandy beach areas, rocky sea coasts, mountains sharply abutting seashores, wooded shorelines, etc. The attractiveness of such areas may be reduced by the physical intrusion of a facility or the deposit of debris. By the same token, unattractive areas (bogs, vegetation choked streams, barren stream banks, etc.) could be improved through revegetation, clearing and draining operations where appropriate.

b. **Appearance of Water** – may be affected by changes in colour and turbidity as well as changes in quantity and flow. Waterfalls, cataracts and fast flowing streams are pleasing in their grandeur, while slow moving watercourses may be attractive in the solitude and peacefulness they engender.

3.2 ENGINEERING STRUCTURES

a. **Consonance With Nature** - Man-made objects may have an aesthetic attractiveness in their form, uniqueness, age and historical significance. The significance of man-made objects may be detrimental to overall aesthetic quality of an area if attention is not paid to blending them into the landscape (ie. use of colour, texture, material and landscaping to improve visual appearance).

4. SOCIO-ECONOMIC EFFECTS

The effects of a project and associated environmental modifications on human health, welfare and social organizations are considered in this section. The implementation and operation of any development project will affect man and society in many ways: direct effects on economic, and social conditions and on health and welfare; indirect effects through modification of various environmental elements (ie. wildlife, vegetation, inorganic elements, etc.). These effects may be immediate or only appear at a later time.

4.1 LANDUSE

Will the temporary or permanent use of land in or around the project affect future landuse planning and development in the area?

a. **Grazing** - cattle on pasture land bordering streams is common in the study area and with further development and protection of stream courses the opportunities for grazing cattle in these areas may be reduced.

b. **Agriculture** - Overland structures built to convey water (canals, pipelines), as well as any wells, storage reservoirs and roads that might be built would remove some land from agricultural production. In some areas, a landuse shift from that of agricultural production to recreational use is possible.

c. **Residential** - landuse might shift from primarily farmstead residences to more cottage-type residences.

d. **Recreational** - landuse in the area is currently very restricted and subordinate to agricultural use of the land. Creation of new recreational opportunities in the area might result in a more intensive use of the existing recreational areas and a change in landuse in some areas (ie. creation of a storage pond on the delta would remove land from agricultural production).

4.2 COMMUNITY INFRASTRUCTURE

Additional infrastructure (housing, business, recreational facilities, hospitals, schools, utilities, and transportation facilities) may be added to the landscape in or surrounding a community in the area of the project. Obvious benefactors could include Rocky Mountain House, Caroline and perhaps Raven. Changes in community infrastructure could alter land values and, inturn, affect the level of taxation in the area.

a. **Housing** - may be required in some of the local communities in connection with the project. Some farm houses might be lost as a result of the project.

b. **Business** - may improve in the area, at least in the service sector where additional services would be required during the construction phase and possibly after given increased recreational use of the area.

c. **Recreational Facilities** – might include picnic shelters, pathways, footbridges, toilets, campgrounds, river access points, etc.

d. **Transportation Network** – expansion and/or upgrading might result from project development.

4.3 LIFESTYLE/QUALITY OF LIFE

Impacts on economic activity in and around the development area which may change the lifestyle and associated socio-economic activity of the community.

a. **Employment.**
b. **Population Density.**
c. **Community Patterns and Lifestyles.**
d. **Recreational Opportunities.**
e. **Displacement: Occupational and Residential.**