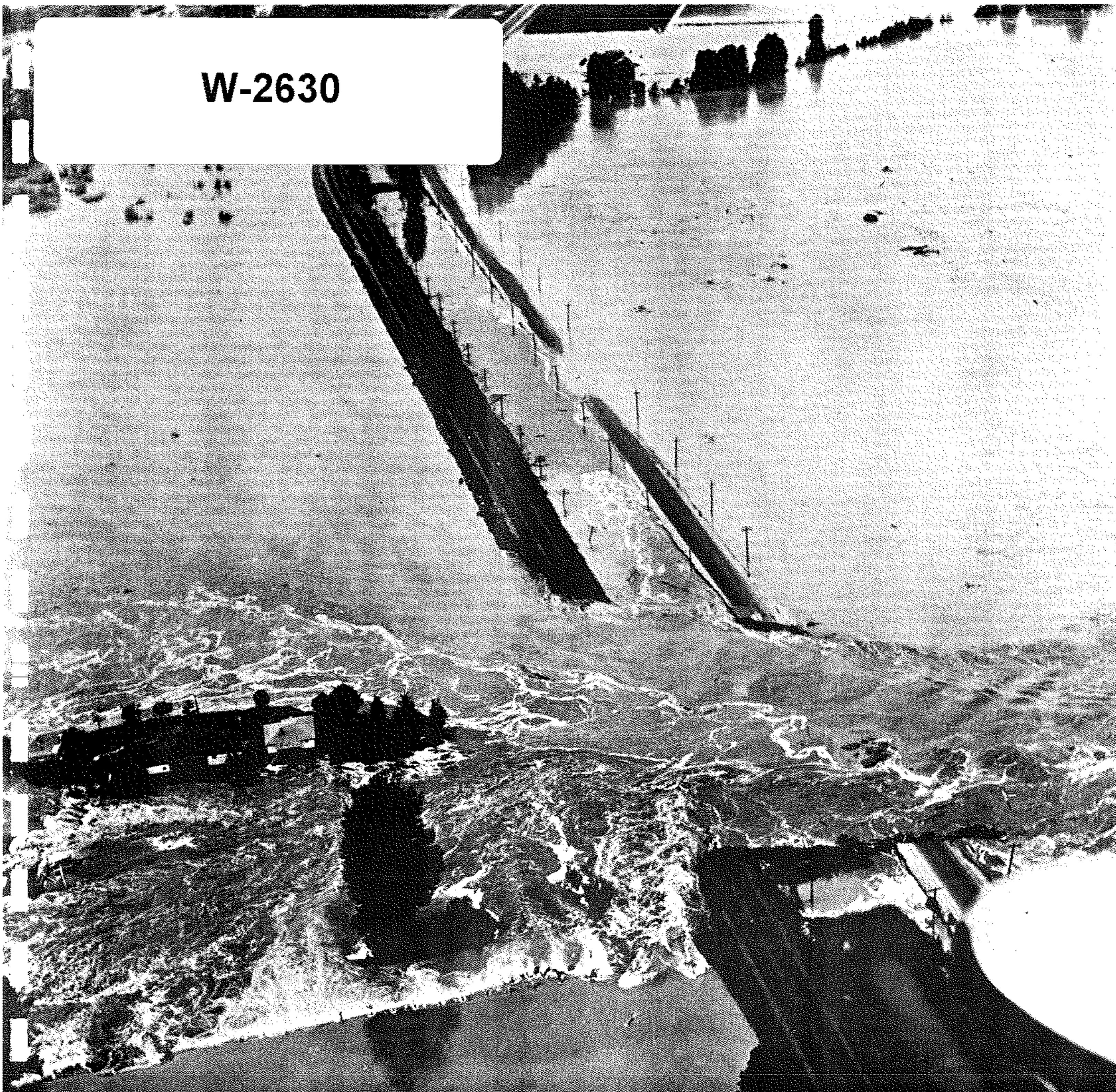

FRASER RIVER UPSTREAM STORAGE REVIEW REPORT

CANADA-BRITISH COLUMBIA
FRASER RIVER JOINT ADVISORY BOARD
VICTORIA, BRITISH COLUMBIA
DECEMBER 1976

COVER PICTURE: "The Hatzic Break"

The scene minutes after the Fraser River burst through the Canadian Pacific Railway embankment near Hatzic on June 3, 1948; this embankment then formed part of the Lower Fraser Valley dyking system.

Photo courtesy of the Vancouver Sun.

FRASER RIVER JOINT ADVISORY BOARD

British Columbia

G.E. Simmons
B.E. Marr
P.M. Brady

Canada

N.H. James
W.R. Hourston
E.M. Clark

December 31, 1976

The Honourable Roméo LeBlanc, P.C., M.P.,
Minister of Fisheries and the Environment,
House of Commons,
Ottawa, Ontario, K1A 0H3.

The Honourable James A. Nielsen, M.L.A.,
Minister of the Environment,
Parliament Buildings,
Victoria, British Columbia, V8V 1X5.

Gentlemen:

In fulfilment of Clause 26 of the Agreement Covering a Plan for Flood Control in the Lower Fraser Valley, British Columbia, made on May 24, 1968 between the Governments of Canada and of the Province of British Columbia, the Advisory Board is pleased to submit herewith copies of its "Fraser River Upstream Storage Review Report", dated December 1976.

The Board respectfully draws your attention to its recommendations contained in the Highlights and Chapter 8 - Conclusions and Recommendations.

Yours respectfully,

Members for Canada

N.H. James,
Director, Water Planning and Management,
Inland Waters Directorate,
Department of Fisheries & the Environment.

E.M. Clark,
Regional Director,
Pacific and Yukon Region,
Inland Waters Directorate,
Department of Fisheries & the Environment.

W.R. Hourston,
Director, Intergovernmental Affairs,
Fisheries Management, Pacific Region,
Department of Fisheries & the Environment.

Members for British Columbia

B.E. Marr,
Deputy Minister,
Ministry of the Environment.

G.E. Simmons,
Assistant Deputy Minister -
Water and Air
Ministry of the Environment.

P.M. Brady,
Director, Water Investigations,
Ministry of the Environment.

HIGHLIGHTS

The Fraser Valley faces a continuing and serious flood threat.

Floods greater than that of 1894 can and will occur, resulting in damages in the order of $500 millions, always with the attendant risk to human life.

The current dyking program will only increase the reliability of protection against floods up to the 1894 level.

Additional flood protection is essential.

This can be achieved by upstream storage or diversion.

RECOMMENDATIONS

1. Construct Lower McGregor Diversion.

2. Complete present dyking program.

3. Further develop flood forecasting procedures.

4. Continue present provincial flood plain management policies.

5. Formalize past reservoir operating arrangements for flood regulation.

CANADA - BRITISH COLUMBIA
FRASER RIVER JOINT ADVISORY BOARD

FRASER RIVER UPSTREAM STORAGE REVIEW REPORT

VICTORIA, BRITISH COLUMBIA
DECEMBER 1976

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ABBREVIATIONS

af	acre-feet
cfs	cubic feet per second
GWh	gigawatt-hours; 1 gigawatt = 1,000,000 kilowatts
hp	horsepower
kVA	kilovolt-amperes
Maf	million acre-feet
msl	above mean sea level
MW	megawatts; 1 megawatt = 1,000 kilowatts

CHAPTER 1

INTRODUCTION

1.1 The Flood Hazard

1.1.1 General

The Fraser River traverses its 90,000 square miles of drainage basin for 850 miles from its source in Mount Robson Provincial Park to its mouths at the Strait of Georgia (Plate 1-1). This drainage basin is essentially a plateau comprising most of south-central British Columbia, with extensive mountain ranges forming its eastern and western limits. The river is the largest in the Province, with a long term annual mean flow of 96,000 cubic feet per second (cfs) recorded at Hope, where it emerges from its deep gorge in the Coast Mountains and flows its final 100 miles through the Lower Fraser Valley to the sea.

The annual spring snowmelt freshets of the Fraser River system pose the principal flood hazard to those of its flood plain areas which have been encroached on by settlement and development. Autumn or winter rainfall flooding occurs in some locations, but its effects are localized and not generally disruptive. The same is true of occasional winter inundation resulting from channel obstruction due to ice jam formation. Extremely high tides sometimes cause or aggravate flood conditions near the mouths of the river, especially if they occur in association with storms.

The flood plain areas in the Fraser River drainage basin prone to inundation by spring snowmelt freshets occupy only about one-half of one percent of the total basin; but they include most of the Lower Fraser Valley, parts of the key interior communities of Kamloops, Prince George and Quesnel, and a portion of the Pemberton Valley on the Lillooet River. Segments of the principal railway and highway facilities serving the Province are located on these flood plains, as are two of the most important airports. The Lower Mainland economic region in and adjacent to the Lower Fraser Valley contains more than half of the population and much of the commercial and industrial development of the Province, as well as the principal port facilities serving Western Canada.

The annual threat of disruption in this economic region through inundation by the spring snowmelt freshet of part or all of the 185,000 acres of flood plain area in the Lower Fraser Valley constitutes the most serious flood hazard in the Fraser River system.

1.1.2 The Probable Maximum Flood

The probable maximum flood (pmf) is considered to be the greatest flood that could conceivably occur at a given location on a river system; and it is computed on the assumption that all contributing factors would reach their critical magnitudes simultaneously. The likelihood of simultaneous occurrence of critical magnitudes of all factors is extremely remote, hence pmf values do not serve as a foundation for design of flood protection or control measures.

A description of the method of computation of these values is contained in the background document on this subject (Reference: Annex II, 1-1); and the computed values for locations representing the four principal flood-prone areas in the Fraser River basin are given in Table 1-1.

TABLE 1-1

PROBABLE MAXIMUM FLOOD PEAKS AT REPRESENTATIVE LOCATIONS

Location	Peak Flow	Peak Elevation
	(cfs)	(feet msl)
Fraser River at Mission	1,400,000	40
Thompson River at Kamloops	350,000	1,160
Fraser River at Prince George	550,000	1,890
Fraser River at Quesnel	600,000	1,565

1.1.3 Major Floods of Record and Their Consequences

The greatest Fraser River flood in the past century occurred in 1894, when the flood plain areas were in the very early stages of settlement and development. The Lower Fraser Valley was sparsely populated; and Kamloops, Prince George and Quesnel were essentially frontier settlements. The Canadian Pacific Railway was the only surface transportation route spanning the Province, and it had been in operation for less than a decade. Damage estimates for this flood are lacking, but losses would have been comparatively small and local in nature, except possibly for those suffered by the railway. However, this flood demonstrated the hazard of Fraser River flood plain occupancy.

The continued presence of this hazard was emphasized in 1948, when the Fraser River flood was the greatest since that of 1894. The passage of five decades had witnessed the transformation of the Lower Fraser Valley into a highly developed agricultural area, with commercial and industrial development becoming appreciable and suburban residential areas beginning to make their appearance. The Canadian National Railway and the Trans-Canada and Lougheed Highways had been built through the Valley, and the largest airport in the Province had been developed on Sea Island. The 1948 flood inundated some 55,000 acres, nearly one-third of the entire Lower Fraser Valley flood plain area; and resulting costs of relief, rehabilitation and repairs approached $20 millions. All domestic surface transportation and communication facilities between the Lower Mainland region and the rest of the Province were severed; except for air transport, one-half of the Province's total population was virtually isolated from the rest of Canada. Only minor damage occurred in the Kamloops, Prince George and Quesnel areas, owing to the limited development on the flood plains in these areas at that time.

1.1.4 The Flood Hazard Today

Growth in all of these areas has progressed rapidly since 1948. The Lower Fraser Valley flood plain population and its commercial and industrial development have increased enormously; municipalities such as Chilliwack, Coquitlam, Richmond and Delta now have extensive suburban residential and associated service developments. Roberts Bank is the first superport in the Province and Kamloops and Prince George have become focal points for transportation and distribution in Central British Columbia. Substantial resource industries have been developed at both of these centres as well as at Quesnel, with much of this expansion taking place in the flood plains of these three communities. The scope and magnitude of the increases in development both in the Fraser River basin and elsewhere in the Province, coupled with the increasing interdependence of all regions on the transportation and communication networks, have intensified the significance of the Fraser River flood hazard of today compared with that of 1948.

Inundation of the Lower Fraser Valley flood plain by a flood of the 1894 magnitude could cause damage of more than $300 millions at mid-1972 development and price levels; and substantial damage could be expected at the interior communities. This potential damage is increasing each year, as the Valley and these interior communities are among the more rapidly developing areas of British Columbia. This more intensive development will result in correspondingly increased disruption of business, industry, utility operations and transport services whenever a major flood occurs, causing hardship and economic loss far beyond the limits of the flooded areas.

Greater floods than that of 1894 can and will occur in the Fraser River system; only the specific year or years of their occurrence cannot be predicted. The best estimate from statistical analyses indicates a one-in-three probability that the 1894 flood will be equalled or exceeded during the 60-year period (1973 to 2032) selected for this review of System E. This risk may be greater or less than has been stated, due to available data limitations; but the results of these analyses do indicate the very appreciable hazard from floods of the 1894 or greater magnitude.

The probability of occurrence of these large floods becomes increasingly remote as they become greater in size up to the probable maximum flood (pmf) as defined in 1.1.2. Occurrence of the pmf would inundate all river valley lands and probably cause extensive scouring action on the flood plains and adjacent river banks with consequent changes in river channel configuration, especially in the Lower Fraser Valley. A rough estimate of the damaging effect of the pmf is given hereunder to illustrate this extreme case.

Under mid-1972 development and price levels the damages resulting from occurrence of the pmf would aggregate $500 millions, of which $410 millions would be in the Lower Fraser Valley and the remainder in the Kamloops, Prince George and Quesnel areas. Residential damages would constitute the largest single damage category and would involve 26,000 homes, necessitating the evacuation of nearly 120,000 people. These figures would become 66,000 and 300,000 respectively by the year 2000, on the basis of current zoning policies and growth trends.

Occurrence of the pmf would cause complete severance of all domestic surface transportation and communication facilities connecting the Lower Mainland region with the rest of the Province. Partial or total interruption of air transport could be expected to result from airport and ground access route inundation. The complete disruption of industrial and commercial operations in the flooded areas, together with the lack of surface and probable lack of air transport, would cause widespread privation and severe economic loss over most of the Province; and the effects would extend far beyond provincial boundaries.

1.1.5 Explanation of the Hazard

The flood hazard in the Lower Fraser Valley flood plain is caused primarily by excessively high rates of spring snowmelt runoff; the seriousness of this hazard is due both to the magnitude and to the duration of the resulting high water levels.

The natural channel of the Fraser River in much of its course through the Lower Fraser Valley is bankfull when the water elevation at Mission, in the central portion of the flood plain, is about 18 feet msl. The annual peak water elevation recorded at Mission during the 80-year period from 1894 to 1973 has exceeded 18 feet in two of three years, 20 feet in one of three years, and 22 feet in one of eight years. On five occasions in the 25 years from 1948 through 1972, the annual peak elevation recorded at Mission approached or exceeded 23 feet, one of these occasions being the flood of 1948 (Table 1-2). The highest water level known to have occurred since settlement began in the Valley about 125 years ago was in 1894, when the peak elevation recorded at Mission was 26.00 feet.

The flood hazard in a dyked area is aggravated by the duration of high water levels; dykes tend to deteriorate when subjected to high river levels for extended periods, and so become a less reliable means of flood protection. The flood plain of the Lower Fraser Valley is dependent on dykes for protection when the water elevation at Mission exceeds 18 feet; and this condition usually prevails for a month or more during high freshets. River current velocities rise with rising water levels, increasing the occurrence of bank erosion and scour, which tend to weaken dykes. When high freshets occur, the rise in the water elevation at Mission from 18 feet to the peak usually extends over two to three weeks. Duration of peak or near-peak levels intensifies the tendency for dykes to deteriorate; and in high freshet years the water elevation at Mission has remained within one-half foot of the peak for from four days to two weeks. These duration conditions are shown in Table 1-2 for the six highest annual freshets recorded at Mission.

TABLE 1-2

FRASER RIVER AT MISSION

RECORDED DATA ON THE SIX HIGHEST ANNUAL FRESHETS - 1894 to 1973

Year	1894	1948	1950	1964	1967	1972
Peak Water Elevation (feet msl)	26.00	24.98	24.44	22.96	22.97	23.56
Days above 18 Feet	33	38	29	48	34	49
Days from 18 Feet to Peak (1)	12	18	8	16	20	24
Days Within 0.5 Foot of Peak (1)	4	14	6	9	7	4

NOTE: (1) Including day on which peak occurred.

The major dyke extension and improvement program now underway in the Lower Fraser Valley as described in Chapter 4 will relieve the recurrent flood threat to a large extent; but it cannot eliminate the possibility of dyke failure. Foundation conditions in the Valley limit the height to which dykes can be built safely without excessive costs; and the dyke heights involved in the current improvement program are considered to be approaching this limit in many locations. Flood control through upstream storage or diversion of water from the river system would provide added protection to the Lower Fraser Valley flood plain by reducing both the peak water elevations and the duration of high water levels. Such control also would offer protection to the interior communities if it were located upstream from them.

1.2 Previous Studies

1.2.1 Fraser Valley Dyking Board

The urgent need for immediate remedial action following the 1948 flood resulted in the establishment in July 1948 by the Governments of Canada and of British Columbia of the Fraser Valley Dyking Board to construct, repair, strengthen and reconstruct dykes in the Fraser Valley. Time did not permit the performance of exhaustive engineering investigations and economic studies; but this Board did develop dyke design standards and set the criterion that crest elevations of new or repaired dykes were to be two feet above the highest known water level. The rehabilitated system of dykes was completed just prior to the 1950 high water and successfully withstood that freshet, which was third highest of record at Mission, being exceeded only by those of 1894 and 1948.

1.2.2 Dominion-Provincial Board, Fraser River Basin

The damage and disruption caused by the 1948 flood emphasized the need for a greater measure of flood protection for the Lower Fraser Valley than would be provided by the Fraser Valley Dyking Board restoration program. This need, together with the growing demand for electric power, led to the establishment late in 1948 of the Dominion-Provincial Board, Fraser River Basin, to study and report on "the water resources and requirements of the area comprising the Fraser River watershed", with primary attention to power, fisheries, floods, water supply, and recreation. This was the first approach to multiple purpose examination of the Fraser River system.

From the outset the Board was seriously hampered in its endeavours by the lack of essential basic data. Its main effort was directed toward accelerating the systematic accumulation of these data, and several years of intensified activity by the appropriate agencies were required to remedy this deficiency as far as possible. In 1955 the two Governments replaced this Board under new Terms of Reference.

1.2.3 Fraser River Board

This Board was instructed to submit by June 1956 an interim report on flood control, and to provide by June 1958 a preliminary report of its findings with respect to the effective regulation of the river system for flood control and power and the resultant effects on navigation, fisheries, silting, erosion and irrigation.

The Board's June 1956 "Interim Report into Measures for Flood Control in the Fraser River Basin" was limited essentially to an examination of methods to provide flood control in the Lower Fraser Valley, with an indication of the limitations on flood control that may be imposed by other resource interests or by economic feasibility. In this report the Board noted the deterioration of the Lower Fraser Valley dykes and recommended their improvement, restoration and maintenance in accordance with the Fraser Valley Dyking Board design standards and criterion. The Board also recommended that no other program of permanent flood protection be initiated pending completion of studies to determine the effects of storage that would be provided by multiple purpose projects.

In its June 1958 "Preliminary Report on Flood Control and Hydro Electric Power in the Fraser River Basin" the Board pointed out that overall river system development plans would be in basic conflict with the preservation and enhancement of the fisheries resources of the system, which is the world's greatest spawning river system for salmon. The Board therefore recommended that further consideration of multiple purpose development of the river system be based on a partial development proposal to include storage and power projects that would: (a) provide a substantial degree of flood control; (b) interfere as little as possible with fish migration and reproduction; and (c) be economically viable from its production of electrical energy. The Board further recommended System A, one of the three partial development proposals outlined in its Preliminary Report, for further investigation and study, both of its projects and of its possible effects on various interests in the river basin. The Board repeated its 1956 warning that deterioration of the Lower Fraser Valley dykes had occurred, and again recommended their improvement and restoration.

In response to a further directive from the two Governments in 1959, the Board subsequently modified and revised System A, describing it as System E in its September 1963 "Final Report on Flood Control and Hydro-Electric Power in the Fraser River Basin" (Plate 1-2 and Reference: Annex II, 1-2). In this report the Board recommended: (a) that the existing Lower Fraser Valley dyking system be improved and maintained to withstand a flood crest of 26 feet at

Mission; (b) that appropriate arrangements be made for the operation of the existing Nechako River and Bridge River reservoirs to facilitate flood control whenever necessary; and (c) that the components of System E be considered as providing the minimum flood control required in conjunction with (a) and (b). Components of System E also would provide flood protection to the low-lying areas of Kamloops, Prince George, Quesnel and other smaller riverside communities.

1.2.4 Canada-British Columbia Committee

This Committee was established by the two Governments in 1966 to review the Lower Fraser Valley dyking improvement proposals contained in the Fraser River Board's 1963 Final Report and to determine requirements for sea dykes, improved drainage and pumping capacity, and erosion protection. In its 1967 report on this assignment, the Committee outlined a plan for protection including these items, at an estimated cost of $33 millions.

1.3 Authority for Review

On the basis of the plan for protection reported on in 1967 by the Canada-British Columbia Committee, the two Governments agreed to participate in the implementation of a program of flood control works in the Lower Fraser Valley, and in a review of the System E upstream storage and diversion projects. This implementation program and project review were authorized by the "Agreement Covering a Plan for Flood Control in the Lower Fraser Valley, British Columbia", dated May 24, 1968, and Amending Agreements Nos. 1, 2 and 3, dated April 11, 1969, April 29, 1974 and October 5, 1976 respectively (Annex I).

Clauses 25 to 27 of the May 24, 1968 Agreement provide for further studies; and Clause 26, which specifically directs the review covered by this report, states:

> 26. In any event, Canada and the Province, no more than two years after the date of this Agreement, shall jointly initiate a review of the program of upstream storage set out in the "Final Report of the Fraser River Board on Flood Control and Hydro-Electric Power in the Fraser River Basin", dated September 1963, including any additional measures, with a view to recommending further flood protection, utilization and control of the water resources of the basin.

1.4 Review Objective

In accordance with Clause 26 the Fraser River Joint Advisory Board initiated arrangements in November 1969 for this review of upstream storage and diversion proposals. Work in several areas of study commenced almost immediately, and terms of reference were developed and given formal Board approval in September 1971.

The objective of this review was to develop an integrated plan for further flood protection, utilization and control of the water resources of the Fraser River basin, with particular emphasis on flood protection for the Lower Fraser Valley, through utilization of dykes, upstream storage reservoirs and diversions.

1.5 Scope of Review

Completion of the system of dyking projects now under construction in accordance with the May 24, 1968 Agreement will provide most of the Lower Fraser Valley flood plain with a substantial degree of protection against inundation. This review of System E upstream storage and diversion projects and the examination of alternative possibilities have been conducted to evaluate the flood control that could be provided to supplement this protection. Additional field data have been obtained where required to confirm or alter the findings contained in the September 1963 Final Report of the Fraser River Board (Reference: Annex II, 1-2). The accumulation of additional hydrometeorological data during the period that has elapsed since preparation of the 1963 Final Report has given an improved basis for the hydraulic and related studies performed during this review.

Updated construction cost estimates have been developed for each project; its potential accomplishment has been examined in terms of flow regulation; and the benefits and damages ascribed to it have been assessed in monetary terms wherever possible. An assessment has been made of the flood control potential of the existing Nechako River and Bridge River developments.

Alternative combinations of these projects have been selected and the benefits and damages ascribed to each combination have been evaluated in both qualitative and quantitative terms. The magnitude of possible floods and the probable consequences of such extreme flow conditions have been described; and flood forecasting, flood routing and flood plain zoning have been discussed in relation to defence against the flood hazard.

In recognition of the importance of environmental aspects, special attention has been given to the environmental impact on local and regional resources that could be expected from the development of each project or combination of projects. The tangible ecological and environmental benefits and damages attributable to each project, singly or in combination, have been derived and considered in conjunction with the intangible ecological and environmental consequences of each in the process of project selection.

The performance of this review required the conduct of numerous new studies and the examination of previous studies and investigations. The report and documents covering these studies and investigations constitute background material for this review; and they are listed in Annex II at the end of this volume.

1.6 Limitations

The widely varying inflationary trend of the economy during the review and preparation period for this report has imposed a severe limitation on the current validity of the figures for cost estimates and benefit derivations contained herein. Mid-1972 price levels have been used for all of these figures.

Upstream project ecological assessment results reported herein reflect primarily the separate judgements of those agencies most involved with each resource, owing to the inability of the Board's Ecology Committee to reach consensus regarding several factors basic to resource evaluation.

1.7 Acknowledgements

The many agencies, consulting firms and individuals that have contributed to the studies and investigations forming the basis for this Review Report are too numerous to mention by name; but the Board wishes to acknowledge its debt and express its sincere appreciation to all of these participants, whose efforts made the production of this Report possible.

While these efforts have been most intensive during the past four years, the planning for the production of this Report commenced very soon after the establishment of the Board in 1968. Since that time the Board membership has changed substantially, and the present members believe that the contribution of these former members should be recognized:

For Canada		For British Columbia	
J.W. MacNeill	(1968-69)	A.F. Paget	(1968-69)
A.T. Davidson	(1969-70)	V. Raudsepp	(1968-72)
E.R. Tinney	(1968-72)		
K.C. Lucas	(1970-72)		
A.T. Prince	(1968-73)		

Finally, the Board wishes to commend the members of its Joint Program Committee, its Ecology Committee, and its Steering Committee for the most capable manner in which these Committees made their respective contributions to the development and prosecution of the review study program and to the preparation of this Report.

CHAPTER 2

FLOOD DEFENCE

2.1 Defence Against the Flood Hazard

Occupancy and use of flood plains or tidelands constitute an invasion of the natural domain of a river or the sea; and the continued success of this invasion depends on the adequacy of the defence measures provided to sustain it. The Fraser River system clearly illustrates such an invasion, particularly in the Lower Fraser Valley; and the experiences of floods and near-floods as in 1948 and 1972, coupled with the risk of greater floods, demonstrate the potential inadequacy of existing protective measures. Various methods of flood defence are defined briefly hereunder, followed by descriptions of existing Fraser River system defences.

2.1.1 Methods of Defence

Methods devised for defence against the hazard of inundation may be classified in four general categories: (1) containment of the river or sea; (2) control of river flow; (3) restriction of land use; and (4) prediction of high water levels. Methods included in the first two of these categories prevent or deter the occurrence of occasional or periodic inundation; those in the third category accept such occurrence but endeavour to minimize its effects; while those in the fourth category forecast or warn of the probability of such occurrence.

2.1.1.1 Containment of the River or Sea

Dykes are embankments built to protect adjacent land areas against inundation; they do not alter river flow or tidal range, but contain the river within a defined channel or channels, or restrain the sea from entry. They usually occupy only a small proportion of the protected land. The degree of protection provided by dykes depends on their height, which frequently is dictated by the prevailing foundation conditions. High water occurrence increases pressure against the dykes, accelerates their erosion, expedites their saturation and damage due to underseepage, and may cause overtopping. Any of these processes can result in dyke failure; and the reliability of the protection dykes offer is contingent on their continued systematic inspection and maintenance. Dyke construction frequently necessitates the installation of internal drainage and pumping facilities to minimize flooding of the protected land by seepage through and beneath the dykes, and to offset interference with the natural land drainage pattern.

Channel improvements include realignment to eliminate oxbows and sharp bends, dredging, removal of debris, installation of weirs or drop structures, and provision of bank protection. Each of these measures contributes to one or more of the following: stabilization of the route of the river; increases in its gradient; enlargement of its channel capacity; and reduction of bank or channel erosion. Increased gradient and capacity assist in lowering river levels upstream; while stabilization of banks and channel facilitate the river's passage.

2.1.1.2 Control of River Flow

Reduction or elimination of the inundation hazard often is accomplished through control or regulation of river flow by storage or diversion of water upstream from the flood-prone area. All rivers contain some natural storage in portions of their channels; and where the channels include lakes this natural storage can effect a significant reduction in peak flows downstream. However, this reduction rarely, if ever, is sufficient to prevent occasional inundation of low-lying downstream areas. Artificially created and controlled storage can be directed specifically toward this purpose; it may be contained in retention basins, storage reservoirs, or in space made available by lowering the natural water levels in existing lakes.

Retention basins are areas into which river flow can be diverted and held to reduce levels downstream, the stored water being returned to the river after the freshet. Although usually located adjacent to the river, they do not obstruct the channel. They occupy extensive areas of low-lying land to provide significant retention capacity readily accessible from the river. Use of their areas during other than high water periods is restricted to have them available on short notice for flood control whenever necessary. They provide a reliable means of flood control, but can be developed only in broad river valleys where space is available.

Storage reservoirs are artificially created holding areas of sufficient capacity to provide a significant measure of control on river flow downstream. They differ from retention basins in usually storing water to greater depths, often being located far upstream from the protected areas, and being formed by construction of a dam or dams that obstruct the river channel and raise the natural surface water levels. The stored water thus may be termed positive storage.

Negative storage is space made available by lowering the natural water levels of existing lakes before the onset of high water conditions. Where conditions preclude the creation of positive storage by construction of a dam, it may be possible to deepen the natural lake outlet or build a subterranean outlet and to install appropriate outlet works, permitting temporary lowering of lake levels to provide negative storage for flood control or other uses.

Diversion is the transfer of part or all of a river's flow either elsewhere in the river system or out of the system. It offers a reliable and positive degree of flood control through reduction in flow downstream. Development of a diversion may require the construction of a dam, particularly if the diversion is out of the river system; or the installation of inlet and outlet control works may be sufficient. Excavation of a diversion channel or improvement of an existing channel usually is necessary.

2.1.1.3 Restriction of Land Use

The methods referred to above for defence against the flood hazard are directed toward making flood plains or tidelands available for occupancy and use with little or no risk of inundation. Regulation of land use as a defence against the flood hazard is based on the premise that the lands involved will be inundated on occasion and therefore their use must be restricted to purposes that will suffer little or no damage from inundation. This is accomplished by reserving or zoning the lands for such purposes, and is least costly if implemented at an early stage of flood plain or tideland development.

The advantages of a shore location for some uses may offset or exceed the hazard of occasional inundation, particularly for industries that utilize the water body for transport purposes. Floodproofing of parts of such developments may permit their successful operation during periods of inundation; or it may be more economical for them to suspend operation when threatened with inundation than to relocate above the flood level, if these interruptions are infrequent.

The provision of flood insurance may be possible in some instances; however, insurance does nothing to reduce flood damage or disruption.

2.1.1.4 Prediction of High Water Conditions

Prediction of high water conditions may be long or short range. Normal high tides are predicted on a long range basis, and the anticipated levels are published yearly in advance of occurrence. Sharply-increased tide levels caused by storms can be forecast only for the brief period of advance storm warning. Tsunamis are extensive ocean waves caused by submarine earthquakes; their time of arrival and possible height at a location distant from their place of origin can be predicted only for the short interval between their occurrence and arrival.

Two types of prediction of high water conditions on rivers are in common use: high supply forecasting is relatively long range, predicting from an excessive winter snowpack the probable occurrence of abnormally large spring snowmelt runoff volumes during the ensuing several months, with the possible consequence of high river levels occurring in that period; high level warning is short range, predicting from high water levels recorded upstream the probable water levels to be expected downstream a few days later and their likely times of arrival.

Supply forecasting and water level warning services are key factors in avoiding loss of life and reducing damage to property during a flood. They also are essential to efficient flood control operation of retention basins, storage reservoirs, negative storage and diversion facilities, as the correct timing of use of these works is vital to securing the maximum benefits from their operation. Adequate river basin hydrometeorological data coverage is a prerequisite to the establishment of useful forecasting and warning systems; and their value will be enhanced with the advent of more precise long range weather forecasting.

2.2 Fraser River System Defences

Dykes and associated works have been the historic flood defences in the low-lying areas of the Fraser River system. Flood plain zoning in the Lower Fraser Valley became an active policy in 1949 with the declaration of the Lower Mainland as a planning area under the Town Planning Act. Hydroelectric power generation developments on the Nechako, Bridge and Stave Rivers include storage reservoirs which provide a further measure of defence, especially when operated for flood control purposes during the onset and occurrence of extremely high spring snowmelt runoff.

2.2.1 Existing Dykes

2.2.1.1 Lower Fraser Valley

The original efforts to protect Lower Fraser Valley lands for farming purposes were made by the early settlers, who in 1864 constructed dykes on Lulu Island, and by 1878 in the Chilliwack, Sumas and Matsqui Prairie areas. By 1960 these first efforts had grown to some 233 miles of river and sea dykes located from Agassiz to Steveston, protecting nearly 160,000 acres of the total 185,000 acres of Valley flood plains and tidelands.

More than 163 miles of these dykes were repaired or rebuilt by the Fraser Valley Dyking Board after the disastrous flood of 1948; and most of this work was completed prior to the 1950 spring freshet, when the peak water level at Mission was less than one foot below that of 1948 (Table 1-2). Haste in completion of this dyke repair and rebuilding program was essential to restore these flood protection works and so provide a degree of reassurance to occupants of the Valley; time did not permit the design and development of more permanent installations, nor the use of higher quality materials in the dykes than those immediately available. Deterioration of these dykes was noted in the Fraser River Board 1963 Final Report; but with the aid of emergency repairs they withstood the high freshet levels of 1964 and 1967.

Completion of the massive program of dyke extension and improvement, initiated under the May 24, 1968 Agreement (Annex I) and described in Chapter 4, will establish a dyking system of essentially uniform standard containing most of the Valley flood plain. This system will provide a significant degree of protection against the highest floods of record resulting from spring snowmelt runoff. The existing dykes and those completed under the new program successfully withstood the 1972 freshet levels, which exceeded those of 1964 and 1967.

2.2.1.2 Other Existing Dykes

Kamloops is located adjacent to the confluence of the North and South Thompson Rivers, and along the Thompson River downstream from the confluence. The city sewage lagoon installation is dyked, and some dykes exist in the city suburbs north and west of the confluence of these rivers. The protection afforded by these dykes was inadequate in 1972, when the suburb of Oak Hills was extensively damaged by flooding from the North Thompson River, and other areas of the city narrowly escaped inundation. Dykes protecting the Cinnamon Ridge area near Tranquille, west of Kamloops, had to be bolstered on an emergency basis, but withstood the 1972 freshet. Reconstruction of the Oak Hills dyke was completed in mid-1974; and emergency dykes were constructed in other flood-prone areas of Kamloops prior to the onset of 1974 peak water levels.

No extensive dyking system exists in Prince George, located at the confluence of the Fraser and Nechako Rivers. Limited dyking had been done in the area known as cottonwood Island; but this was insufficient to prevent winter flooding from ice jam formation on the Nechako River. The area was completely inundated during the 1972 spring snowmelt freshet, following which many residents left the area permanently.

Quesnel, located at the confluence of the Fraser and Quesnel Rivers, has no dykes or other works to protect its low-lying areas from either river except for a limited amount of dyking in West Quesnel.

Some 20,000 acres of land in the Pemberton Valley of the Lillooet River are largely protected against inundation by works completed since 1946. The feasibility of augmenting and extending these works to include an additional 11,600 acres of land has been examined by the British Columbia Water Resources Service. Although the Lillooet River drains into the Fraser River via Harrison Lake and River, these improvements would not come under the May 24, 1968 Agreement (Annex I), as they would not affect water levels in the Lower Fraser Valley.

2.2.2 Flood Plain Zoning

The entire Lower Fraser Valley lies within the boundaries of the area declared by the Minister of Municipal Affairs on June 21, 1949 as a planning area within the meaning of Section 65 of the Town Planning Act. The Lower Mainland Regional Planning Board was established in 1949 and developed its Official Regional Plan for the area. Adoption of the Plan was approved by the Board and by the Executive Council in 1966, in accordance with the Municipal Act. Development in the area is controlled under this Plan which places restrictions on flood plain use and sets floodproofing requirements.

The general policies of this Plan require that flood plains be kept free of urban uses except where committed to urban development through early settlement, in which case further development for urban uses shall be contingent upon floodproofing. Flood plain areas not already in intensive use are to be reserved until detailed studies document the need for their more intensive use. Flood plains are to be developed only for uses that would suffer least from flooding.

The Lower Fraser Valley is the only flood plain area in the Fraser River system covered by a comprehensive system of flood plain zoning. The effectiveness of this zoning may be reinforced and the continuance of agricultural use of flood plains elsewhere in the Province may be enforced by British Columbia Land Commission action. The Commission was established early in 1973 by Provincial Government legislation, and an initial freeze placed on agricultural land has been followed by the establishment of agricultural land reserves.

The flood threat and damage caused in 1972 by the spring snowmelt freshet and accompanying rainfall demonstrated that extensive land developments for residential and commercial uses had taken place on flood plains and other areas subject to water damage. The British Columbia Land Registry Act, as amended, states that the prior consent of the Minister of the Environment is required for approval of subdivision plans where land within the subdivision is subject to or could reasonably be expected to be subject to flooding. As a condition of his consent, the Minister of the Environment may require that the subdivider enter into a covenant that the subdivided lands will not be built upon, or will or will not be used in such manner, having regard to the nature of the flooding, as may be specified in the covenant.

2.2.3 Existing Storage Developments

The Fraser River system contains no storage developments designed primarily for flood control. However, extensive storage reservoirs have been created on the Nechako, Bridge and Stave Rivers for hydroelectric power generation; and these reservoirs can provide a significant amount of flood control storage if losses in generation are acceptable. Data on the developments creating these reservoirs are contained in Table 2-1.

Kenney Dam on the Nechako River about 95 miles west of Prince George created the Nechako Reservoir on a chain of lakes previously known individually as Ootsa, Whitesail, Tahtsa, Eutsuk, Tetachuck, Natalkuz and Knewstubb Lakes. Water for power generation is conveyed out of the Fraser River system by tunnel from the west end of the reservoir to the Kemano I Generating Station on the Kemano River.

The Bridge River development about 120 miles north of Vancouver includes Lajoie Dam, creating Downton Lake; Lajoie Generating Station; Terzaghi Dam, creating Carpenter Lake; two diversion tunnels from Carpenter Lake through Mission Mountain to Bridge River Nos. 1 and 2 Generating Stations on Seton Lake. This development is completed by Seton River Dam, a regulating structure near the outlet of Seton Lake, and by Seton Generating Station near Lillooet.

The Stave-Alouette development about 35 miles east of Vancouver includes Alouette Dam, creating storage on Alouette Lake; Alouette Generating Station; Stave Falls Dams, creating storage on Stave Lake; Stave Falls Generating Station; Ruskin Dam, creating Hayward Lake; and Ruskin Generating Station.

2.2.4 Magnitude of the 1972 Freshet

Table 2-2 illustrates the magnitude of the 1972 spring snowmelt freshet in the Fraser River system by comparison of peak water elevations and/or flows attained at several key locations with those recorded in 1948 and 1950, the two previous highest freshet years for which data are available at all of these locations. Peak water elevations in 1972 at Prince George, Quesnel and Kamloops exceeded those recorded in 1948 and 1950; while the 1972 peak at Hope was between those in 1948 and 1950. At Mission the 1972 peak was lower than those in 1948 and 1950, due in part to lesser freshet runoff from the coastal zone as indicated by the Harrison River data.

Recorded peak water elevations given in Table 2-2 were obtained at Water Survey of Canada gauging stations, two of which were altered during the 1948 - 1972 period. The Thompson River at Kamloops station was relocated about 1,000 feet upstream in 1963; however, water elevations at the new location are estimated to be less than 0.1 foot higher than those occurring simultaneously at the former location. The Fraser River at Prince George station located on the railway-high-way bridge crossing the river was replaced in 1968 by the Fraser River at South Fort George station located about one mile downstream. Fraser River at Prince George water elevations appearing in this report are for the former Prince George location unless specifically stated as being for the South Fort George location.

TABLE 2-1

EXISTING STORAGE AND POWER DEVELOPMENTS IN THE FRASER RIVER BASIN

DEVELOPMENT	RIVER	MAIN DAM			RESERVOIR				SPILLWAY CAPACITY	
		Name	Type	Crest Elevation (feet msl)	Name	Drainage Area (square miles)	Live Storage (1,000 af)	At Elevation (feet msl)	At Elevation (feet msl)	Capacity (cfs)
Nechako-Kemano	Nechako	Kenney	Rockfill-clay core	2,825	Nechako	5,450	4,000	2,800	2,800	44,000
Bridge River	Bridge	Terzaghi	Earth & rockfill-clay core	2,148	Carpenter Lake	1,450	800	2,136	2,140	45,000
	Bridge	Lajoie	Rockfill	2,472	Downton Lake	330	570	2,460	2,467	20,000
	Seton	Seton River	Concrete gravity	781	Seton Lake	(1)	(1)	(1)	775	12,000
Stave-Alouette	Alouette	Alouette	Earthfill	422	Alouette Lake	80	170	412	417	30,000
	Stave	Blind Slough (2)	Concrete buttress	278	Stave Lake	450	471	270	270(3)	100,000
		Intake (2)	Concrete gravity	278					- (3)	-
	Stave	Ruskin	Concrete overflow gravity	150	Hayward Lake (4)	(4)	(4)	141	(5)	(5)

NOTES:
(1) Pondage only - up to 80% of water received from Bridge River development on Seton Lake.
(2) Two dams required for the two Stave Lake outlets.
(3) Spillway in Blind Slough Dam only.
(4) Pondage only - uses Stave Falls discharge.
(5) No spillway - overflow type dam.

TABLE 2-1 (CONTINUED)

EXISTING STORAGE AND POWER DEVELOPMENTS IN THE FRASER RIVER BASIN

DEVELOPMENT	GENERATING STATION							OWNER
	NAME	TURBINES			GENERATORS			
		Number	Rating (hp)	Operating Head (feet)	Number	Rating (kVA)	Total Capacity (kVA)	
Nechako-Kemano	Kemano I(1)	8	140,000	2,500	8	106,000	848,000	ALCAN(2)
Bridge River	Bridge River No.1(3)	4	62,000	1,118	4	50,000	200,000	BCHPA(4)
	Bridge River No.2(3)	4	82,000	1,264	4	65,250	261,000	
	Lajoie	1	30,000	176	1	24,444	24,444	BCHPA
	Seton (5)	1	58,500	147	1	42,000	42,000	BCHPA
Stave-Alouette	Alouette (6)	1	12,500	125.5	1	10,000	10,000	BCHPA
	Stave Falls	4	13,500	110	4	13,125	65,625	BCHPA
		1	15,000	110	1	13,125		
	Ruskin	3	47,000	135	3	44,000	132,000	BCHPA

NOTES:
(1) On Kemano River - water received by 10-mile tunnel diversion from west end of reservoir.
(2) Aluminum Company of Canada Limited.
(3) On Seton Lake - water received by 2-mile tunnel diversion from Carpenter Lake.
(4) British Columbia Hydro and Power Authority.
(5) On Fraser River - water received by 2-1/2-mile canal from Seton Lake.
(6) On Stave Lake - water received by 2/3-mile tunnel diversion from Alouette Lake.

TABLE 2-2

RECORDED PEAK WATER ELEVATIONS AND/OR FLOWS IN THE FRASER RIVER SYSTEM IN 1948, 1950 AND 1972

River	Location	1948			1950			1972		
		Date	Elevation	Flow	Date	Elevation	Flow	Date	Elevation	Flow
			(feet msl)	(cfs)		(feet msl)	(cfs)		(feet msl)	(cfs)
Fraser	Prince George	May 30	1,866.73	-	June 22	1,864.06	-	June 15	1,867.20(1)	-
Fraser	South Fort George	May 30	1,863.85(1)	-	June 22	1,861.35(1)	-	June 15	1,864.26	-
Fraser	Quesnel	May 30-31	1,547.11	-	June 22	1,543.97	-	June 15	1,547.80	-
Fraser	Hope	May 31	127.62	536,000	June 20	124.27	445,000	June 16	124.96	459,000
Fraser	Mission	June 10	24.98	590,000	June 20	24.44	558,000	June 17	23.56	507,000
Thompson	Kamloops	June 1	1,131.84(2)	-	June 24	1,128.64(2)	-	June 14	1,132.40(3)	-
Harrison	Harrison Hot Springs	June 11	-	76,300	June 23	-	71,500	June 12	-	49,500
Harrison	Harrison Hot Springs(4)	May 31	-	41,900	June 20	-	67,700	June 16	-	32,300

NOTES:
(1) Station relocated one mile downstream from original Prince George location to South Fort George in 1968; these elevations derived from correlation of water elevations occurring at the two locations.
(2) At former location; station relocated 1,000 feet upstream in 1963.
(3) At new location; high water elevations at this location estimated to be less than 0.1 foot above those occurring simultaneously at the former location.
(4) Flow on peak day at Hope.

2.2.5 Use of Existing Storage During the 1972 Freshet

Storage utilized for flood control may be classified generally as one of three types: anticipatory, flexible and emergency. Anticipatory storage is located far from the flood-prone area and therefore must be utilized in advance of the flood period. Flexible storage is located near enough to the flood-prone area to permit its effective operation during the approach to the flood crest. Emergency storage is adjacent or very close to the flood-prone area; and its use normally is limited to the period shortly before the flood peak to effect last-minute peak reduction or relief.

In response to requests made early in 1972 by the British Columbia Water Resources Service, both the Aluminum Company of Canada Limited (ALCAN) and the British Columbia Hydro and Power Authority (BCHPA) cooperated fully in making storage for flood control purposes available at their respective developments, and in decreasing generation at those locations where such action reduced inflows to the Fraser River.

ALCAN arranged for the discharge of 10,000 cfs more than normal spillage from the Nechako Reservoir during the period from April 13 to May 10, which lowered the reservoir level by an extra two feet and so provided about 400,000 acre-feet of anticipatory flood control storage. This storage was utilized during the period from May 11 to June 22, when outflow from the reservoir into the Fraser River system was curtailed completely.

BCHPA made the entire 1,370,000 acre-feet of storage capacity in Carpenter and Downton Lakes available as flexible flood control storage, most of which was utilized before and during the freshet. Output from Bridge River Generating Stations Nos. 1 and 2 was decreased to some extent during the period and to spinning reserve from June 13 to 17, reducing inflows to the Fraser River.

BCHPA also held the top six feet of Stave Lake storage capacity available, thus providing about 100,000 acre-feet of emergency flood control storage, which was utilized from June 13 to 17, the latter being the date when the peak of the freshet was recorded at Mission. Output from the Stave Falls and Ruskin Generating Stations was decreased to spinning reserve, which together with the decrease from the Bridge River Generating Stations obliged BCHPA to activate its Burrard Thermal Generating Station to replace lost generation.

2.2.6 Effect of Existing Storage During the 1972 Freshet

The effect of the use of existing Nechako River and Bridge River storage for flood control purposes prior to and during the 1972 freshet was to achieve a reduction of approximately 40,000 cfs in the peak flow of the Fraser River at Hope. This corresponds to a reduction of about 1.3 feet in the peak elevation at Hope, and a consequent reduction of perhaps one foot in the peak elevation at Mission. The use of existing Stave Lake storage achieved some additional reduction in peak elevations downstream from Mission.

Without the relief provided in 1972 by the existing upstream storage, the Fraser River at Hope peak elevation probably would have been about 126.25 feet, and the peak flow about 500,000 cfs; the peak elevation at Mission probably would have been about 24.5 feet. The corresponding risk of dyke failure in the Lower Fraser Valley would have been substantially greater.

2.2.7 Need for Additional Flood Protection

The recurrent flood threat to the settled and developed flood plain lands of the Fraser River system arising from its annual spring snowmelt freshets is one of disturbing frequency; five floods or near-floods have occurred in the 25 years from 1948 through 1972. The winter snowpack in the basin offers the potential for a spring snowmelt flood almost every year. Such occurrence depends primarily on the weather conditions before and during the freshet, which cannot be predicted on a long range basis. The hazard in dyked areas is increased by prolonged duration of high water levels.

This flood hazard was clearly demonstrated in 1972, when peak water elevations approached or exceeded the 1948 records. Substantial damage was sustained in Kamloops, Prince George and Quesnel, where flood defences were inadequate or non-existent. Major inundation and consequent extensive damage were averted in the Lower Fraser Valley flood plain; but seepage adversely affected crop production and caused grave concern for the safety of the dykes at numerous locations. This concern was intensified by the extended duration of high water conditions, the elevation at Mission remaining above 18 feet for seven weeks (Table 1-2).

The positive and appreciable degree of flood control provided by the use of storage on the Nechako and Bridge Rivers prior to and during the 1972 freshet illustrated the effectiveness of upstream storage in reducing this serious hazard to downstream flood plain areas. Diversion of flow upstream from these areas would be similarly effective.

The conditions experienced in the Fraser River system in 1972 emphasized the need for protection of its flood plain areas beyond that to be provided by the present dyking program, and hence the requirement for this review of upstream storage and diversion possibilities. The major thrust of this review has been directed toward further reduction of this flood hazard to the Lower Fraser Valley flood plain, as inundation of this area by a major flood would cause by far the greatest part of the consequent damage and disruption in the entire Fraser River system.

CHAPTER 3

ANALYSIS CONCEPTS AND TECHNIQUES

3.1 Overall Approach

Formulation of the System E program was based on the requirement in its terms of reference that the Fraser River Board report on "the engineering and economic feasibility of a partial hydro-electric power development of the Fraser River that would provide flood control on the Fraser River to the extent considered necessary....." (Reference: Annex II, 1-2). This review of the System E program was conducted ".....with a view to recommending further flood protection, utilization and control of the water resources of the basin." (May 24, 1968 Agreement - Annex I). The primacy assigned to measures for further flood protection and the need for special attention to the possible ecological consequences of river control works on local and regional resources dictated the approach to project analysis adopted for this review.

The following economic criteria were adopted to provide a uniform basis for achievement of comparable results by the several groups involved in the various analytical techniques:

a. The referent area for study purposes to be the Province of British Columbia.

b. All monetary evaluations to be at mid-1972 price levels.

c. The economic life of storage and diversion projects to be considered as 60 years.

d. The economic life of dyking projects to be considered as 35 years, with an allowance for rehabilitation of these projects to be included in the 36th year of project analysis.

e. The economic life of thermal and nuclear projects to be considered as 30 years.

f. A system time horizon of 60 years (1973 to 2032 inclusive) to be used in economic analysis. (Within this system time horizon, the various benefits and costs attributed to upstream projects were computed approximately in accordance with the assumed in-service dates of the projects.)

g. Costs and benefits to be incrementally increased for real growth in value to the time of their occurrence and discounted to 1972 present worth for comparison purposes.

h. A non-inflationary discount rate of seven percent per annum with a sensitivity indication at six percent and eight percent per annum to be used in all analyses.

i. An incremental real growth rate for each resource, over or under a base inflation rate determined as the average annual percentage increase in the Consumer Price Index for the period from 1967 to 1971 inclusive, to be developed and justified by the group studying the resource.

3.2 Hydrologic Evaluation

This section presents the methods used to calculate the effects of upstream storage on streamflows and flood levels in the Fraser River basin. Topics included are flood probability analyses for present conditions on the river and for various combinations of upstream storage developments, the selection of sample years of streamflow data in the Fraser basin, flood routing procedures, and the methods used in simulating storage reservoir operation during a flood period.

3.2.1 Flood Frequency Determination

To assess the damages that would result from floods over many years, it is necessary to determine the probabilities of occurrence of floods of any given magnitude. Such probabilities are determined by analysing all floods that have occurred in the recorded past and determining a cumulative frequency distribution of the flood peaks. This cumulative frequency distribution can be plotted as a "flood frequency curve" which gives the probability of any given magnitude of flood peak elevation or discharge being equalled or exceeded.

Flood frequency curves were prepared for four specific locations: Mission, Kamloops, Prince George and Quesnel, each representing one of the four principal flood-prone areas of the Fraser River system. At each of these locations a discharge-frequency curve for the river was derived utilizing all available flood records, some of which required adjustment to remove the effects of regulation by the Bridge River and Nechako River Reservoirs. This provided a base flood frequency curve representing the natural or unregulated flood regime of the river at that location.

A standard period of 1948 and 1950 through 1972 was adopted for studies of project flood control operation. Discharge-frequency curves then were derived for this study period for each of the above-noted locations, with the river: (a) under natural conditions; (b) under present conditions (incorporating the effects of existing upstream storage development); and (c) under the conditions that would prevail with each upstream project, or selected combination of projects, in operation. The discharges for several recurrence intervals were extracted from each of the (c) curves; and the results were converted to elevation-frequencies for inclusion in the report.

3.2.2 Study Flow Data Selection

There were two basically different requirements for streamflow data within the study. The first was to allow the simulation of generating station operation requiring values of mean monthly discharges for all months at all proposed power projects. The second was to allow the simulation of flood control operation of all proposed storage reservoirs, requiring mean daily discharge values at all reservoir sites and at sufficient other points within the Fraser basin to define the streamflow pattern.

The study period chosen for power determination was the 40 years beginning in July 1928 and ending in June 1968. This period included 1929, the year of lowest annual mean flow of record, as well as several high flow years, and also overlaps the period chosen for the flood control studies. This study period is compatible with the computer model of the British Columbia power system used to evaluate the power potential of the System E projects.

Mean flow values were computed for each month in the 1928 to 1968 period at each System E project site. For years when recorded data were not available, mean flow values were estimated by correlation to the nearest stream that had dependable records, using the Langbein method of streamflow correlation (Reference: Annex II, 3-1).

The study period adopted for flood control simulation was 1948 and 1950 through 1972, as insufficient daily flow data were available for the 40-year period to develop the more specific flows needed for this purpose. Mean daily flows were compiled for this period, which includes several large freshets. Several sets of synthetic records for large spring freshet flows also were used for the flood control analysis (Reference: Annex II, 3-1).

A base data network of 21 gauging stations in the basin and the computed natural inflow to the Nechako River Reservoir, was selected early in the study to define flows throughout the basin and to supply data for flood control studies. (Figure 3-1). Using these base stations, a mathematical model of the basin was assembled to compute the response at any point on the river to streamflow changes at any other point.

Work required to complete the data for each of these base stations included filling in periods of missing records, adjusting data to allow for the effects of existing storage developments, and computing inflows to the natural lakes. This work made daily streamflow data available for the freshet period at each of the base stations for natural conditions as well as for present conditions with the current pattern of regulation from the Bridge River and Nechako River developments.

3.2.3 Flood Routing Procedures

Flood routing simulates the attenuating effect of the river channel in changing the characteristics of the flood wave as it moves downstream. All changes in river flows due to the operation of upstream storage reservoirs are subject to these attenuating effects and were routed to the flood-prone parts of the basin as part of the regulation studies. The flood control benefits were based on the changes in the routed flows at the flood damage areas.

In the regulation studies, the routing was accomplished using a polynomial method of routing adapted from the UBC Watershed Model developed at the University of British Columbia (Reference: Annex II, 3-2). This method of routing utilizes a convolution calculation to determine the downstream flows from upstream flow values. Using this method, the effect of any upstream increment of streamflow can be determined at the downstream point from the relationship:

$$Q_{D,t} = \sum_{n=lag\,1}^{lag\,2} K_{n+1} \; Q_{U,t-n}$$

where Q = the increment of discharge,

K = empirically derived constants defining the routing characteristics,

U represents the upstream location,

D represents the downstream location,

t is the current time period,

lag 1 is the lag in days until the first significant contribution occurs,

lag 2 is the lag until the last significant contribution occurs,

n ranges between the value of lag 1 and lag 2.

This method of routing is particularly convenient for regulation studies, as reservoir holdouts (the amounts of water stored each day) can be routed directly to the flood control point and subtracted from the natural flows there. Most other methods can route only the total flows in a river and not such increments of flow.

The polynomial method is somewhat less precise than other routing methods, for there is no change in routing effect with changes in the magnitude of flow. Tests have shown, however, that this has negligible effect on routing in the Fraser River in the range of flows that occur during the flood regulation period.

The multiphase reservoir routing method used in the SSARR computer program of the United States Army Corps of Engineers was applied in preliminary routing tests and served to evaluate the polynomial method. This method is much more detailed and treats a river channel as consisting of many small lakes, each providing a small storage effect. It can easily be calibrated to match the observed routing effects in a river without any measurements of the river channel characteristics. A SSARR routing model was prepared for the Fraser River early in the study and was found to produce good routing results. However, the polynomial method was found to produce almost equivalent results; it was much more convenient for regulation tests and permitted a large saving in computer time; hence it was adopted for study use.

The Modified Puls Method of routing, which depends on the relationship between lake storage and lake outflows, was used where routing through lakes was necessary. This method also was used for backrouting lake flows: i.e. computing lake inflows from observed values of lake outflows.

FRASER RIVER BASIN BASE DATA NETWORK FOR REGULATION STUDIES

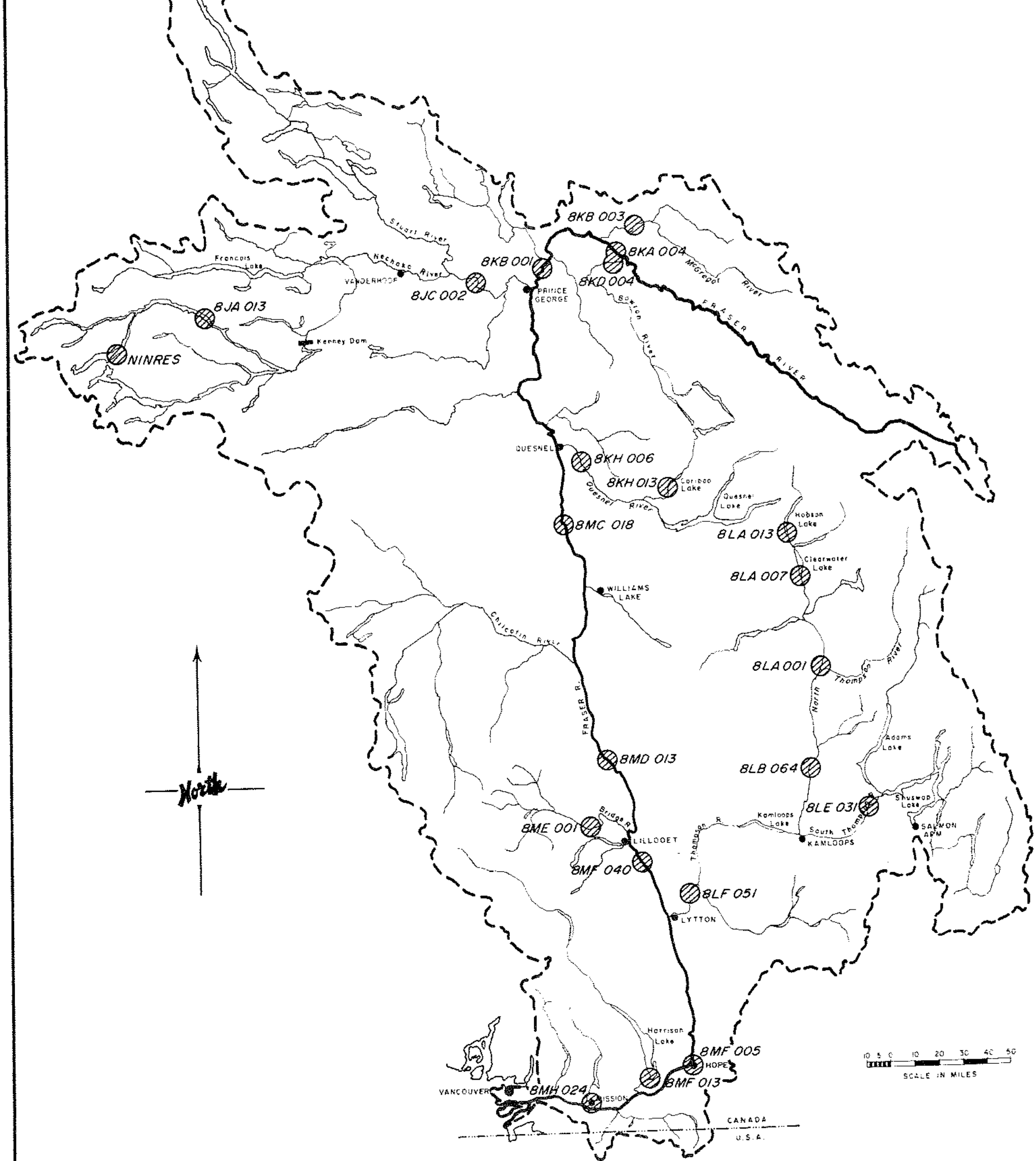


Figure 3-1

3.2.4 Flood Control Requirements

The protection afforded by flood control storage reservoirs would not be required in most years, as the spring freshets seldom reach damaging flood levels. Therefore, the full design storage volume of every reservoir need not be reserved each year for flood control purposes. However, the amount of storage to be made available for flood control must be decided early in each year; and this storage must be available at the beginning of May.

The amount of storage to be reserved each year for flood control depends on the total freshet volume forecast; and it must be adequate to check the worst flood that could be expected from the existing snowpack under adverse weather conditions. Flood danger exists in many years, but does not materialize because the adverse weather sequence does not occur. In the present studies, the volume of storage required each year at each reservoir was determined on the assumption that the reservoirs would be operated under a realistic set of rules to protect against forecast flood danger. This determination of storage volumes was accomplished by first simulating the operation of the reservoirs for flood control assuming that the total usable reservoir volume was available each year, measuring the volume that was actually needed to protect against the flood danger, and comparing this with the volume refilled after the flood danger was past. The volume needed to control the flood each year was compared to the volume forecast for that year to establish a relationship. For these tests, the danger level was considered to be 24.00 feet water elevation at Mission.

In actual storage reservoir operation, the decision as to the storage to be reserved each year is based upon the successive forecasts of the freshet volume for that year. Normally, in operating a reservoir to protect against a snowmelt flood situation, a forecast of the total freshet volume is made early in the year and a program of reservoir evacuation is followed as dictated by that forecast. As spring approaches more accurate forecasts are made, based upon the accumulated snow in the basin. The target flood control storage is adjusted to suit each new forecast and the evacuation program revised accordingly.

All proposed reservoir designs have sufficient outflow capacities to allow complete evacuation from full pool level to the lowest required flood control level during the period January through March. Reliable forecasts of the freshet volume are available each year at the beginning of April, giving time to adjust the reservoir level by the first of May if necessary, as the flood danger normally does not occur before mid-May. It has been assumed that in actual operation the reservoirs would be evacuated as outlined above to bring them to their required drawdown levels at the end of March. If these levels were not low enough to meet the requirements based on the April forecast value, sufficient further releases could be made during April to provide the required storage capacities by the end of April.

In the flood control simulation studies, the required storage was estimated on the basis of the April 1 forecast of the freshet volume. An envelope curve was developed for each reservoir site relating the storage required to the forecast freshet volume, based on all years of the study period. These curves were adjusted where necessary to ensure that the required storage would have been reserved in all flood years; and they provided the estimates of storage needed at each reservoir each year for flood control purposes.

3.2.5 Long Term Forecasting

A basic requirement of the flood control operation of a reservoir is an overall forecast of runoff giving an estimate of the total volume and of the probable time distribution of the runoff over the freshet period. These items are the only data available for seasonal planning and are the normal prime basis for flood control operating plans. Long term forecasts have two components; the April to September volume, and an estimated critical hydrograph shape function that defines the worst expected pattern of runoff.

The April to September volume forecasts were prepared for all years in the study period by the British Columbia Water Resources Services. Those for the later years had already been published, and those for the earlier years were recalculated using available snow records and applying current forecasting techniques. Such forecasts were prepared for various parts of the basin to provide predicted inflow volumes at each reservoir and freshet volumes in the Fraser River at Mission.

For computed years of synthetic streamflow data, it was necessary to produce synthetic forecasts of April to September volumes. A multiple regression model was developed interrelating historical forecasts at the various forecast points and relating these to the corresponding observed flow volumes. This regression model was used within a Monte Carlo technique, which adds random variations from the model to generate sets of forecasts for each synthetic year, based upon the synthetic flows and the observed errors in past forecasts. These volume forecasts were used in the studies, not only to estimate the size of the flood that could be expected, but also to check the probability of refill of the reservoir in each year and to indicate when refilling must begin to ensure a full reservoir at the end of the freshet.

The time distribution of runoff was estimated at Mission, the location representing the most important flood damage area in the basin, as a critical hydrograph shape that could be applied to any forecast volume. This hydrograph is defined as a series of straight lines rising to and falling from a single peak and fitting a base flow recession curve falling to a fixed point at the end of September. The volume under the hydrograph between April 1 and September 30 must equal the April to September forecast volume. The concept is illustrated in Figure 3-2.

The critical hydrograph was derived from the 1948 flood when warm weather persisted throughout the snowmelt period to produce a steeply rising runoff pattern. This gave an estimate of worst expectancy, comparable to that which would be obtained with more detailed modelling using a critical weather sequence.

The long term forecast is revised daily during the runoff season; and the remaining forecast volume is derived daily by subtracting the total runoff after April 1 from the original April to September forecast. Although the critical hydrograph shape factors remain constant, the predicted hydrograph changes in magnitude according to the remaining forecast volume.

DISTRIBUTION OF RUNOFF FOR LONG TERM FORECASTS

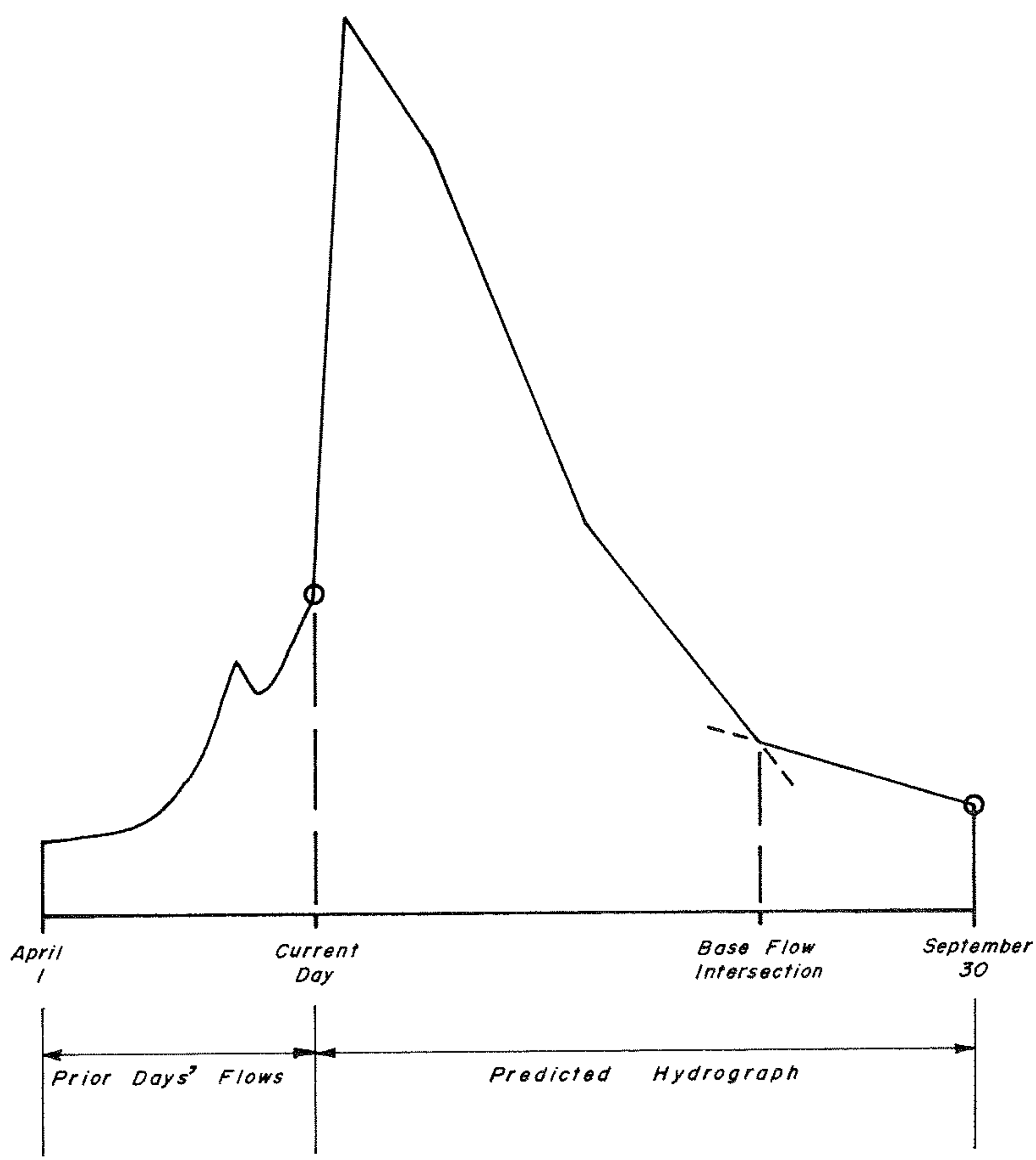


Figure 3-2

3.2.6 Short Term Forecasting

The proposed System E reservoirs are located so far upstream from the major flood area in the Lower Fraser Valley that changes in reservoir outflows do not reach the Valley until three to four days later. This time lag requires reservoir storage decisions to be made in anticipation of flows in the Valley three to four days later; thus short term forecasts of flows at Mission are essential to effective use of the storage.

Short term streamflow forecasts usually are made using basin modelling procedures in which weather forecasts are applied to the basin, and snowmelt and runoff are simulated by computer calculations to produce forecast values of streamflow. Such forecasts at a downstream point on a large river have two basic components; the water that is currently in the river at the upstream points routed to the downstream point several days later, and the simulated flows from the downstream areas of the basin routed a lesser amount of time later. The required weather forecasts applicable to the present study data could not be obtained for all study years, so a method of simulating streamflow forecasts was derived that is independent of weather data and based only on the prior several days' streamflow records.

Several procedures for simulated four-day forecasts at downstream points were tested. The procedure selected for use is based on routing the observed upstream flows and estimating the worst expected flows over the subsequent several days at other points in the basin. All the observed and estimated flows are summed in a convolution routing procedure to forecast the streamflow at the downstream point. This process was tuned so as to forecast the most rapid rise likely to occur on the river, thus providing synthetic short term forecasts similar to those that would occur if a warm weather forecast were applied to a basin model. As a large portion of the flow in the Lower Fraser Valley consists of water already in the system four days earlier, this approach provided workable forecasts for use in reservoir regulation studies.

3.2.7 Flood Control Operating Procedures

The day-to-day operation of the upstream storage works has been simulated using several years of streamflow records. The simulations have been based on reservoir operating rules similar to those which would be used under actual operation. These rules reserve most of the storage until the flood threat is greatest, then allocate the storage at all reservoirs to produce the largest possible reduction in the peak of the worst flood that could reasonably be expected. Some storage space is maintained as long as any appreciable flood threat remains.

In actual operation of such reservoirs, the only prior knowledge of the peak would be forecast information and this must be the basis of operating rules. Although recorded streamflow data have been used to test the effect of reservoirs, the simulation procedures have assumed no prior knowledge of these streamflows. All decisions within the simulations are made using only recorded flows from prior days and simulated forecasts of future flows or runoff volumes. Mathematical optimizing techniques were utilized prior to the simulation studies to aid in developing the operating rules used in the simulations and to establish the limits of the flood control capabilities.

In the flood control simulations, a day-to-day model has been applied to the freshet flows for each of the years in the study period. This model consists of a computer program that each day checks the storage contents and the expected inflows for each reservoir and decides when to store water at each of the reservoirs. For every day, the model carries out the following basic steps:

i. A prediction of the worst expected remaining freshet flow is made, as outlined in 3.2.5.

ii. A four-day forecast of the flow at the flood control point on the river is made, as outlined in 3.2.6.

iii. The predicted freshet runoff volume for inflow to each reservoir is checked; and if there is any significant chance that the reservoir could not refill before a specified date, storing is begun immediately at the maximum allowable rate.

iv. A target regulated discharge for the flood control point is computed by fitting the total available flood control storage into the peak of the predicted hydrograph.

v. Each reservoir is ranked in terms of its available storage volume relative to the predicted total inflow. Reservoirs having larger relative storages are called on first for flood control.

vi. If the four-day forecast at the control point exceeds the target flow, the amount by which the target is exceeded is scheduled for storage. This scheduled storage is allocated to each reservoir in sequence according to the relative-storage rankings, until the scheduled storage is contained, or all reservoirs are storing at their maximum allowable rates.

vii. All holdouts at the reservoirs are routed to the flood locations to calculate the regulated discharges at those points.

In this manner, the flood control operation at each reservoir is simulated using rules that attempt to maximize the flood protection according to the storage available. The target for flood control is tailored to the current available storage and to the long-term prediction of possible flood flows; however, the target is never allowed to exceed a specified maximum flow at which the water elevation would reach the dyke design level. Storage in each reservoir is limited by a specified minimum outflow requirement.

This procedure schedules flood control storage in terms of a single control point on the river. In most cases, this point has been selected as the Fraser River at Mission and has provided effective control at other locations in the system. When the Hemp Creek project was studied by itself or together with the Lower McGregor diversion project, the control point was selected as Kamloops and this procedure also gave effective control at Mission.

3.3 River Regime and Sediment Studies

3.3.1 Scope

River regime and sediment studies were carried out to evaluate the potential effects of System E construction on the river regime upstream and downstream from the proposed reservoirs, and of reservoir sedimentation; and to design a program to measure such effects (Reference: Annex II, 3-3).

3.3.2 General Aspects

The sedimentation effects of river damming are manifested in changes of the river regime upstream and downstream from the reservoirs and in each reservoir itself, as follows:

i. General raising (aggradation) of the river bed upstream from the reservoir, usually associated with flooding.

ii. Sediment entrapment by the reservoirs with corresponding loss of storage capacity.

iii. Reduction of the sediment load of the river downstream from the reservoirs and change in the geometry of the river, mainly degradation, due to sediment deprivation and to changes in the hydrograph of flow resulting from reservoir storage operation.

These effects may have serious consequences on existing developments with social and economic components and on the ecology of the river and its valleys. Naturally the magnitude and significance of these effects vary widely.

Some of the aforementioned effects are of a cumulative nature while others occur quickly in response to their causes. The loss of reservoir capacity due to siltation is a cumulative process continuing throughout the lifespan of the reservoir. The aggradation of the river bed upstream from the reservoir follows reservoir siltation up to a certain level and then more or less stabilizes in a "normal regime", manifested by a low rate of change. The alteration of river geometry downstream from dams is a much faster process and most of it occurs rather quickly; but the reduction of the sediment load of the river due to reservoir entrapment is a continuous process lasting for the lifetime of the reservoir. Consequently the delta of the river at its outlet suffers a continuous and equal reduction in its rate of nourishment; and this may result in reduction of its rate of advancement, or even in recession of its front. Therefore, planning of river damming should include serious consideration of sedimentation and should provide for the monitoring of change in order to allow for remedial measures in response to adverse effects.

3.3.3 Methodology

Mobile boundary hydraulics, which includes river engineering, is often termed an "inexact science" and this may constitute an euphemism. The greatest advances in the state-of-the-art have been made relatively recently; and some "empirical theories" have been devised which can be applied only in conjunction with field measurements and professional judgement.

However, these "theories" can be applied only in cases of canals, canalized rivers, and with some difficulty in tame rivers running through flood plains and carrying sediment consistent with that of the river bed and banks. This is not the case with the System E rivers; and therefore field measurement and professional judgement constitute the entire basis for evaluation of their sediment regime.

As existing data were sparse and inadequate, additional data were collected expressly for the present studies. A most important part of the investigation was the field inspection program carried out for visual evaluation and assessment of conditions, especially in the upper reaches of the Fraser River and its tributaries. The design of the program to measure change thus has been based on available data and professional evaluation.

Predictions of the consequences of System E development on the Lower Fraser River and its delta have been based mainly on available data which for this reach of the river are rather plentiful, and on the assessment of those effects of System E in the upper reaches that will be felt as far as the river delta.

3.4 Navigation Evaluation

3.4.1 Impacts on Navigation and Related Activities

The benefits and damages from Fraser River regulation were estimated on the basis of information collected in the field and from secondary sources (Reference: Annex II, 3-4). Records of high, average and low freshets and minimum monthly flows were examined in the context of their effects on navigation and related activities. Deep-sea shipping, towing, dredging and debris removal were identified as the operations most likely to be affected by river regulation.

The opinions of authorities involved with deep-sea shipping were combined with historical evidence to determine the effect of high water flows on shipping. The benefits of reducing these flows were then computed as a function of the physical changes that would occur with river regulation.

All mills and towing companies using the Lower Fraser River as a transportation artery were queried regarding traffic volumes and flows, log storage costs, and the effects of current velocity on towing costs. Their contributions of data were applied to the three freshet levels and to the low monthly mean levels to determine the benefits and damages resulting from reducing peak flows and from supplementing low flows.

Dredging costs and net revenues from the sale of river sand were assumed to be a direct function of the rate of sedimentation in the Lower Fraser River. Proportionate changes in net revenues and dredging costs were predicted from the estimated effects of regulation on sedimentation.

Rough calculations were made of the reduction in volume of Lower Fraser River debris that would result from regulation of peak freshet flows. These calculations formed the basis for estimates of change in debris collection and disposal costs and of reduction in damages to boats.

The navigation benefits to be credited to each upstream project or project combination were determined by prorating the maximum benefits available from complete system E development among the various projects and combinations in direct proportion to the respective project and combination capabilities in the reduction of peak freshet flows at Mission.

3.4.2 Future Impacts

Changes in the benefits and damages from river control over time were projected to the year 2000 on the basis of past trends and prospective developments. Regulation benefits were assumed to increase at the predicted rates of expansion of deep-sea shipping, towing and dredging operations. No real price changes were anticipated for these operations. However, price changes were expected to affect the size of debris disposal benefits because of the demand for more effective and costly disposal techniques, and changes were estimated accordingly.

3.5 Potential Flood Damage Evaluation

3.5.1 Costs of Floods and Benefits of Protection

3.5.1.1 Property and Income Losses

Floods destroy property and disrupt economic activity thereby inflicting losses on an economy. These losses are classified as "primary" and "secondary" damages. Primary damages occur directly to activities located on a flood plain. They include residential, agricultural, commercial, industrial and other property damages, losses of profits and income of those employed on the flood plain, and costs of transferring or deferring flood-disrupted production. Secondary damages are permanent income losses that occur in industries located off the flood plain as a consequence of flood-inflicted severances of linkages with suppliers and/or consumers. In this study, primary and secondary losses were considered true losses only if no British Columbia firms could compensate for the production setbacks (Reference: Annex II, 3-5).

Potential flood damages over a given period were calculated as the sum of average annual damages anticipated over that period. The computation was based on estimates of the probability of various river stages and damages occurring in any one year (3.5.4). Future changes in the level of flood plain development and damages that would occur in the absence of improved protection were incorporated into the analysis in the projection of the stream of annual damages. This stream of damages was discounted to its present value or worth. It was assumed that people would be willing to pay for flood protection an amount equal to the benefits they would receive, these benefits being calculated as the reduction in the present value of average losses over the specified period.

3.5.1.2 Risk-Taking

The average annual value measure of damages does not account for a second cost of floods - the cost associated with risk-taking. Besides being concerned with mean values, people may wish to avoid large losses in a catastrophic flood or they may wish to reduce the variance of the distribution of losses. If people are willing to pay a premium for avoiding risk-associated costs, then estimates based on the average value of damages and benefits understate the true benefits of flood prevention by the amount of the risk premium (unless alternative methods - such as insurance - are available to reduce risk at a lower cost).

3.5.1.3 Intangibles

A third cost of floods is labelled "intangibles". This includes costs difficult to describe in monetary terms, such as loss of life and psychological and social upheaval. Of these costs, loss of life frequently is claimed to be the most significant element in the justification of flood control projects. Few deaths actually have resulted from Fraser River floods; and it is questionable whether structural measures are an effective means of reducing this cost. Therefore intangibles were largely ignored in this flood damage study.

3.5.1.4 Cost of Restricted Use

A final cost associated with a flood plain location exists if floods prevent flood plains from being used for certain purposes. This cost can be lowered by building protective structures that reduce potential damages and enable more intensive development to occur on the flood plain. The benefits of this protection are enhancement benefits (or project-induced benefits). They are equal to the difference between the profits an activity could earn off the flood plain and those it could earn on the flood plain, given flood protection and the initial set of prices and rents. In the Lower Fraser Valley such potential benefits exist only in undyked areas. They represent a very small portion of the total flood prevention benefits.

3.5.2 Existing Damage Potential

Potential primary and secondary losses were estimated for all types of property and activities on the flood plains of the Lower Fraser Valley and of Kamloops, Prince George and Quesnel.

Residential damage estimates were based on an "average house" concept. Assessment rolls and field survey data were used to determine average unit structure and content damage functions for high (A), medium (B), and low (C) quality houses. These were combined to form total unit-damage curves for each house class in 34 flood plain areas. A single unit stage-damage function was developed for each area by combining the damage functions of A, B and C class houses weighted according to the numerical importance of the houses in each area.

Total potential commercial damages were estimated for each dyking area from sample field data. They were calculated using unit stage-damage functions per square foot of flood area that had been established for 20 commercial categories. Potential industrial damages were identified in a field survey of all flood plain firms.

Estimates of agricultural losses were based on generalized unit-damage functions. The crop mix in each floodable area was calculated and combined with information on the potential damage per crop type to obtain a weighted average of crop damage per acre for each area. This was, in turn, applied to the acreage floodable in various freshets to determine the total damage by dyking area in different floods. Estimates of other agricultural losses were derived largely from secondary sources.

Industrial field survey data were used to estimate primary and secondary income losses and transfer costs. Data were collected on outputs, inputs, and incomes of flood plain firms and on their capacity to transfer or defer production. Information to supplement the field survey data was obtained from Statistics Canada.

Estimates of other "miscellaneous" damage were based on information from individual companies (e.g. railways) and secondary sources.

3.5.3 Future Damages

3.5.3.1 Growth on Flood Plain and Real Value Changes

To determine the size of future potential damages, changes in the level of flood plain development were projected for the years 1973 through 2000. No changes were predicted beyond the year 2000 because of uncertainties underlying forecasts into the distant future. The "most likely" growth pattern for each dyking area was estimated by extrapolating historical trends that had been modified to account for factors such as zoning plans and land scarcities. The effect of a "zero growth" alternative on the size of damages also was determined to show the impact of stringent zoning restrictions on damage potential.

"Most likely" changes in the real value of losses were predicted for the years 1973 through 2000 by historical trends projected into the future. The sensitivity of the estimates to errors in price projections was tested by making two alternative forecasts: one with no changes of prices predicted; and the second with the real rate of change of agricultural crop prices assumed to be three percent per annum instead of the historical minus one percent.

3.5.3.2 Damages

Three principal projections of future potential flood damages were made, the first being the "most likely"; it was based on probable changes in growth, productivity and real values of flood plain activities. The second provided a minimum limit to the range of possible future damages; it was calculated on the assumption that the price structure and level of flood plain development would remain constant over time. The third illustrated the sensitivity of damage estimates to minor errors in projections; it was computed by raising the "most likely" rates of change for each damage category by one percent per annum (e.g. changing three percent to four percent).

Two secondary projections were made as described in 3.5.3.1. One of these was based on the assumption of zero price change, and the other on the assumption that agricultural crop prices would rise at the rate of three percent per annum.

3.5.4 Average Annual Damages

Estimates of the probability distribution of flood damages, used to determine the average annual value of losses, depend largely on information on streamflow characteristics. The traditional approach involves establishing the historical frequency of recurrence of yearly peak river discharges. A cumulative frequency distribution is developed to reflect the frequency at which specified rates of discharge are equalled or exceeded. Past events are assumed to mirror future conditions so that the historical probability distribution of discharges defines the probability of given discharges being equalled or exceeded in each consecutive year in the future. A typical frequency discharge curve is presented in Figure 3-3 as:

$$Q = Q(p) \qquad (1)$$

where Q = discharge in cfs and p = a measure of probability ranging between 0 and 1.0.

Associated with the discharge at a given point along a river is a unique water level or stage. Thus a relationship between discharge and stage can be established and described as the following function (Figure 3-4):

$$S = S(Q) \qquad (2)$$

where S = water level in feet. A stage-frequency curve is then created by substituting equation 1 into equation 2 (Figure 3-5). It describes the frequency with which a given water level is equalled or exceeded and is represented by:

$$S = S[Q(p)] \qquad (3)$$

When a river overflows its banks and inundates its flood plain, it causes flood damage. The amount of damage that occurs depends on the level of economic activity on the flood plain and on flood characteristics such as the velocity of the current and the depth of flooding. For any specific area, damage is assumed to be contingent on the stage to which the river rises. Thus a fourth function, a stage-damage function, is required in the analysis. It is shown in Figure 3-6 as:

$$D = D(S) \qquad (4)$$

where D = flood damage in dollars.

The final equation necessary to enable the computation of the average annual value of damages to be made is formed by substituting equation 3 into 4. This gives the result $D = D\ (S[Q(p)])$ or more simply:

$$D = P(p) \qquad (5)$$

where p = the probability of incurring damages. It ranges from 0 to 1.0. This last equation represents the damage-frequency function shown in Figure 3-7. It is interpreted as defining the probability that given magnitudes of flood damage will be equalled or exceeded in any one year. The area under this curve represents the average annual value of flood damage under the assumption that no changes in flood plain activities or prices occur over time.

DETERMINING THE AVERAGE ANNUAL VALUE OF FLOOD DAMAGES

Figure 3-3
DISCHARGE-FREQUENCY FUNCTION

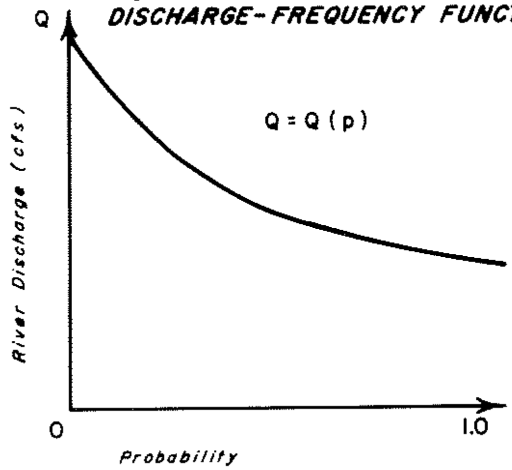


Figure 3-4
STAGE-DISCHARGE FUNCTION

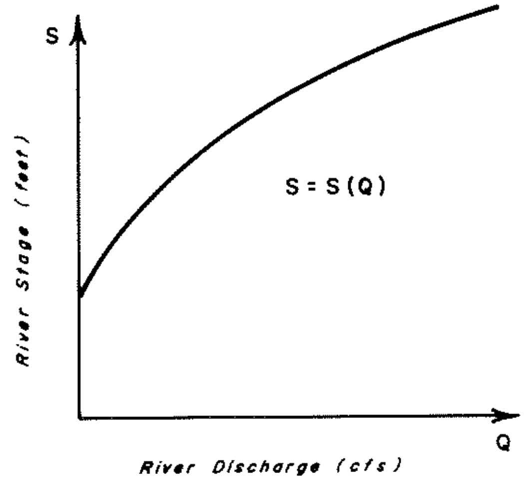


Figure 3-5
STAGE-FREQUENCY FUNCTION

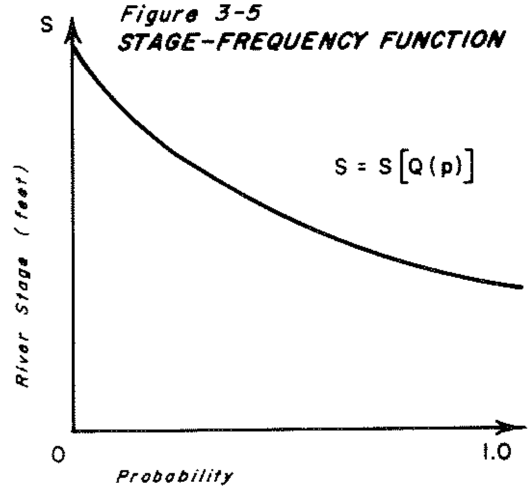


Figure 3-6
STAGE-DAMAGE FUNCTION

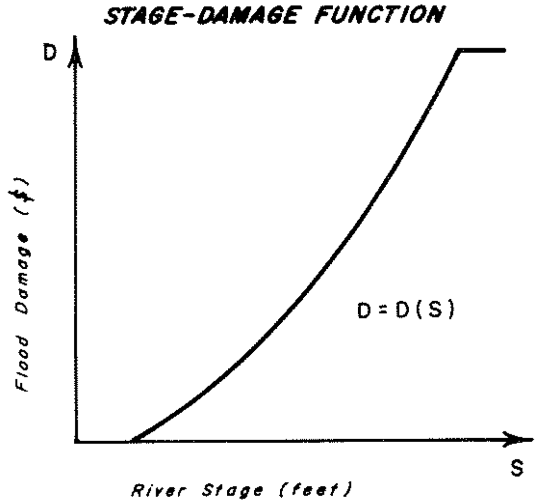
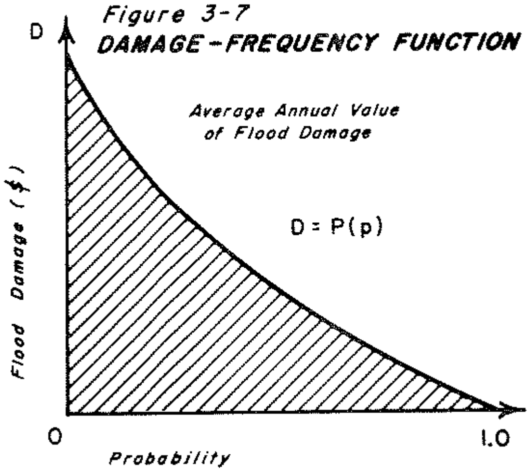


Figure 3-7
DAMAGE-FREQUENCY FUNCTION



Figures 3-3 to 3-7

Estimates of damages were required for a 60-year time period. Since normal growth in economic activity and relative price changes are expected to alter the structure of flood damages over this period, these factors had to be incorporated into the analysis. This was done by estimating the potential flood damage for each relevant flood and for each year under study, given projected changes in prices and economic activities on the flood plain. Thus a stream of damages was computed for each flood for a span of 60 years.

The current value of each element in this stream of damages was calculated and these values were summed to give the present worth of flood damages for each flood stage under the assumption that each stage occurs annually. The present worth of the total value of flood damages over the required 60 years was obtained by integrating the resulting "total present worth of damage-frequency" curve.

3.5.5 Allocation of Benefits Among Dykes and Upstream Projects

Determination of the economic feasibility of a flood control system requires both the derivation of the total benefits and the identification of the elements of this total provided by each component of the system. If dykes prevent damages, they must be credited with the value of these damages; if upstream storage or diversion projects reduce the frequency of occurrence of given water elevations downstream, appropriate damage prevention benefits must be attributed to each project.

Dykes may fail at water elevations lower than their design levels, and therefore they cannot be credited with preventing all damages that would occur with water elevations up to these levels. Ideally, the benefits would be measured as a function of the probability of dyke failure at various water elevations. Technical problems associated with the establishment of such probabilities dictated the adoption of an alternative "confidence level" criterion as a basis for estimating flood damage prevention benefits. Confidence levels for individual dykes were established as those water elevations up to which the dykes were considered to be reasonably reliable against failure; these were generally equivalent to the water elevations at which dyke patrols are intensified, equipment is committed for emergency action, and concern arises regarding dyke stability.

Elements of the dyking systems in the Lower Fraser Valley were classed as "unimproved" or "improved" dykes for analysis purposes. Unimproved dykes are those contained in the projects listed in Table 4-2 and are generally below the construction standard outlined in 4.1. Improved dykes are those contained in the projects listed in Table 4-1; they include those being rehabilitated or extended under the ongoing dyking program to the standard outlined in 4.1. Both Tables 4-1 and 4-2 list the projects as at May 24, 1975. It was assumed that unimproved dykes would prevent the occurrence of all damages when water elevations were below their established confidence levels, which ranged from 21 feet to 23 feet at Mission, and none of the damages when water elevations were above these confidence levels. Likewise it was assumed that dykes built or improved to the above-noted standard would prevent the occurrence of all damages when water elevations were below 24 feet at Mission, 50 percent of the damages when water elevations were between 24 feet and 26 feet at Mission, and none of the damages when water elevations were above 26 feet at Mission.

With this dyke "confidence level" criterion as a base, flood damage prevention benefits were allocated among dykes and upstream storage or diversion projects in the order in which these various components were expected to be added to the system. Figures 3-8 and 3-9 illustrate the mechanics of determining the benefits attributable to each component, assuming improved dykes and upstream projects as first added components, respectively. (Conditions under which Figures 3-8 and 3-9 would not be used for determining benefits are presented in the background document on this subject (Reference: Annex II, 3-5, page 19).

In both Figures 3-8 and 3-9 the damage-frequency function curve D_1 represents entirely natural river conditions, with no dykes or upstream projects in existence. The benefits credited to the unimproved dykes with the river system under natural conditions are represented by the area A_1 between the damage-frequency function curves D_1 and D_2; and these unimproved dykes prevent all damages that would occur with water elevations of a probability of P_1 or greater under these conditions.

The existing storage developments on the Nechako and Bridge Rivers described in 2.2.3 reduce the flood damage potential and probability existing under natural river conditions. They shift the entire damage-frequency function from Curve D_2 to D_3 and the probability from P_1 to P_2, and are credited with the benefits represented by Area A_2 in both figures. The damage-frequency function curve D_3 therefore represents present conditions, reflecting the flood damage prevention accomplishments of the unimproved dykes and the Nechako-Bridge storages.

Figure 3-8 illustrates how benefits are credited to improved dykes and to upstream projects, if dyke improvements precede upstream project construction. Improved dykes provide full protection against all water elevations up to 24 feet at Mission, with a probability of occurrence of P_3 under present conditions; they are credited with all benefits included in the area A_{31} between P_2 and P_3. In addition, these improved dykes are assumed to prevent 50 percent of the damages resulting from water elevations between 24 feet and 26 feet at Mission; and this 50 percent is represented by Area$_{32}$, with probabilities of occurrence ranging between P_3 and P_5 under present conditions. The total benefits accruing to the improved dykes thus are A_{31} plus A_{32}, and the damage-frequency function curve D_4 represents the system under these conditions. The residual damages under curve D_4 would be reduced by the upstream projects which would shift the damage-frequency function from curve D_4 to D_5 and receive credit for the benefits represented by Area A_4. (This area as illustrated indicates the effects of one or two upstream projects; if all of the System E projects were built, the area would extend almost to the vertical axis.) This figure portrays the actual situation in the Lower Fraser Valley, where dyke improvements will be essentially completed prior to upstream project construction.

Figure 3-9 illustrates the allocation of benefits between upstream projects and improved dykes if upstream project construction precedes dyke improvements. Upstream projects will shift the damage-frequency function curve from D_3 to D_4' and be credited with the benefits represented by Area A_3. The residual damages under curve D_4' would be reduced by dyke improvements, which would shift the damage-frequency curve to D_5 (the same as D_5 in Figure 3-8).

Figure 3-8

VALUE OF FLOOD CONTROL BENEFITS (IMPROVED DYKES FIRST ADDED)

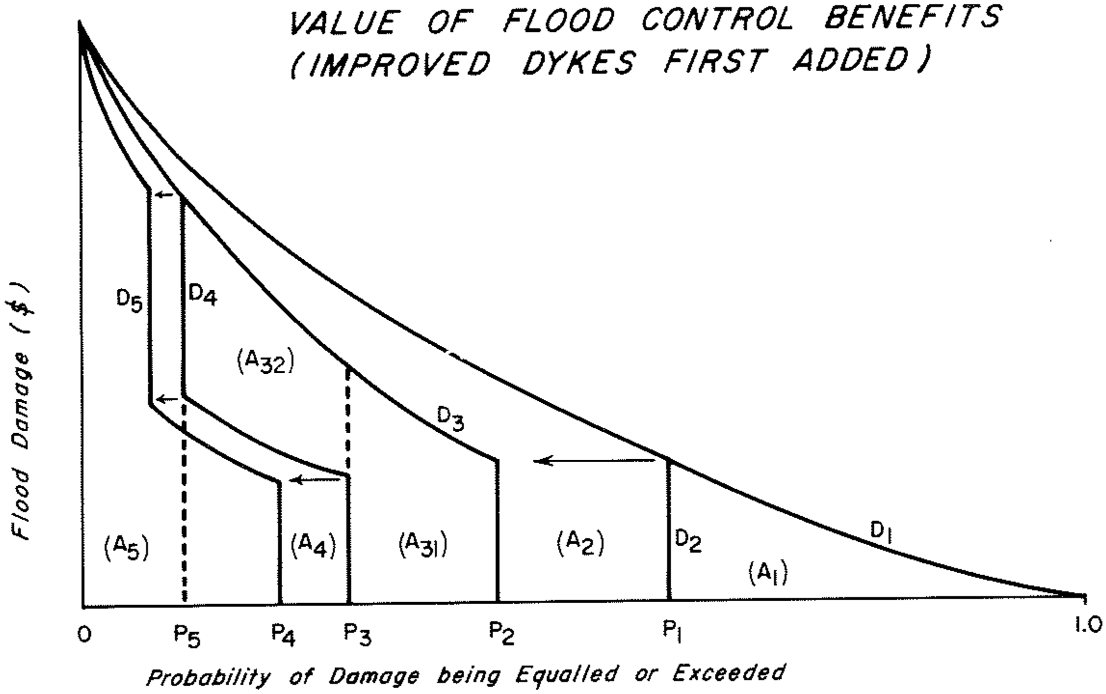
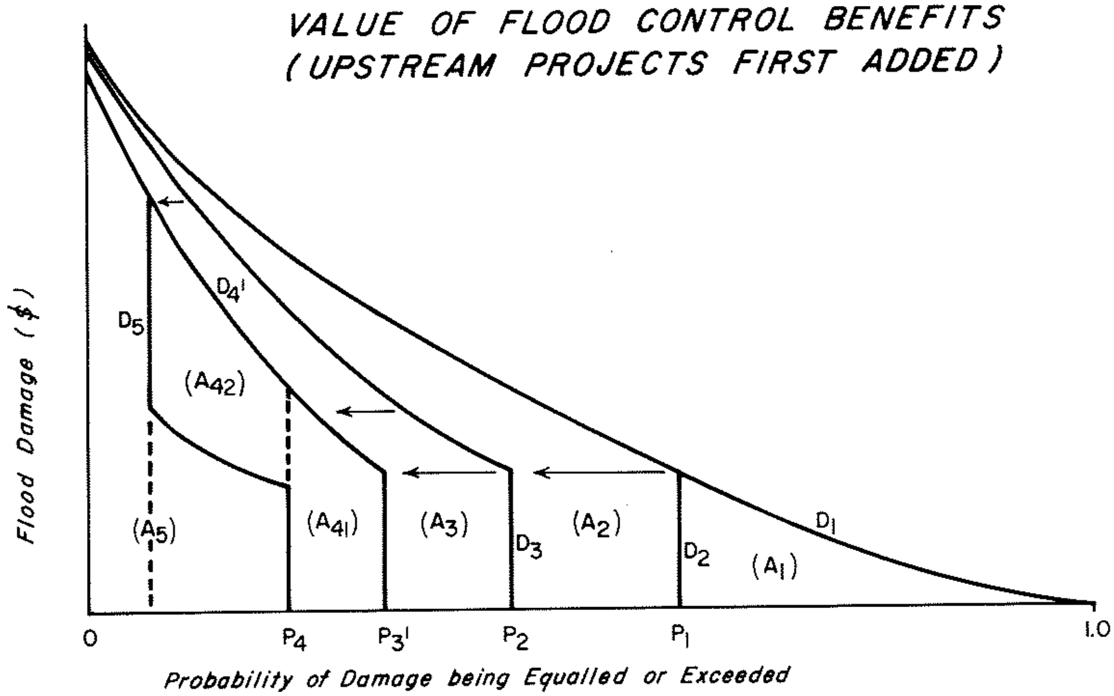


Figure 3-9

VALUE OF FLOOD CONTROL BENEFITS (UPSTREAM PROJECTS FIRST ADDED)



Figures 3-8 and 3-9

The dyke improvements would be credited with the benefits represented by areas A_{41} plus A_{42}, the latter area representing 50 percent of the damages between 24 feet and 26 feet at Mission.

The "confidence level" approach used to allocate the estimated flood damage prevention benefits among improved dykes and upstream projects produces correct results only if the improved dykes prevent exactly 50 percent of the damages resulting from water elevations in the range between 24 feet and 26 feet at Mission. If these dykes prevent more than 50 percent of the damages occurring from water elevations in this range, the actual property and income losses are overstated by the amount in excess of 50 percent; and this amount increases to a maximum of 50 percent if the dykes prevent all damage up to their design level of 26 feet at Mission. At its maximum, this amount would be equal to Area A_{32} in Figure 3-8, which has been determined from examination of the flood damage data to represent about 70 percent of the total damages under curve D_4. Therefore, up to 70 percent of the flood damage prevention benefits in the Lower Fraser Valley credited to upstream projects may represent a value assigned implicitly to risk aversion and intangibles (3.5.1.2 and 3.5.1.3), the percentage being contingent on the ability of the improved dykes to prevent more than 50 percent of the damages resulting from water elevations in the 24 feet to 26 feet range at Mission.

Both tidal and river conditions affect two Lower Fraser Valley municipalities, Richmond and Delta, which are protected by sea and river dykes and are divided by Highway 499. If river dykes fail during water elevations of 24 feet or less at Mission, this highway would act as a partial dyke, reducing flood damages in those parts of these municipalities lying west of it. The exact amount of this reduction could not be determined because of the unpredictability of such factors as the point during the tidal cycle at which the river dykes would break, the speed of dyke repair, and the duration of flooding. Allowance for the mitigating effects of the highway therefore was made by assuming that the areas west of it would suffer only one-half of the flood damages that would occur if there were no obstruction to water elevations of 24 feet or less at Mission.

3.6 Ecological Evaluation

Evaluation of the ecological consequences that would result from the development of System E involved a series of economic analyses to estimate, in monetary terms wherever possible, the environmental impact of each System E project on other resources utilizing the rivers and areas that would be affected by each project. The benefits and damages were determined by this procedure with the intent of making them comparable with other values attributable to the projects. General analysis criteria are stated in 3.1; and the principal background document for this evaluation is the Fraser River Ecology Committee Summary Report (Reference: Annex II, 3-6). The Ecology Committee did not reach consensus regarding several factors basic to evaluation of upstream project ecological consequences; hence its Summary Report reflects primarily the separate opinions of those agencies most involved with each resource.

The analysis techniques utilized in evaluating the impact of System E development on the anadromous fish, sports fish, wildlife, recreation and forestry resources of the project areas are outlined in 3.6.1 to 3.6.3 hereunder. The effects on mining and archaeological resources also were examined, and it was estimated that the impact on mining would be too slight to warrant quantification; also that adequate knowledge of the archaeological resources of the project areas could be retained by provision of an appropriate investigatory and artifact collection program at sites within these areas prior to project construction. For these reasons no further reference is made in this chapter to mining and archaeological resources.

3.6.1 The Anadromous Fish Resource

The Fraser River system provides spawning and rearing areas for all five species of Pacific salmon (chinook, sockeye, coho, pink and chum) and for steelhead trout. The young of these species migrate from their freshwater habitats to the ocean and return as adults to complete their life cycles. The steelhead are only a very small proportion (perhaps one or two percent) of the total anadromous population, and an even smaller part of the commercial catch; hence the evaluation was based entirely on the salmon.

3.6.1.1 Present Stocks and Potential Capacity

A field survey of the streams that would be affected by System E was conducted during the summer and autumn of 1971 and 1972, with observations being made on species distribution, population size, stream bed composition, and water conditions. An inventory of salmon populations for the period 1957 to 1972 was obtained from field reports. Escapement figures were taken from records maintained by the Fisheries and Marine Service of Environment Canada and by the International Pacific Salmon Fisheries Commission (IPSFC). These records were compiled from counts conducted from fixed-wing aircraft during the spawning period. A tagging and recovery technique was utilized to estimate chum populations. Visual counts for many races were made from boats, shore and aircraft. The presence and distribution of juvenile chinook and coho were determined by sampling to augment available data on the fresh water rearing period and the timing of downstream migration.

The potential productive capacity of all streams in the Fraser River basin upstream from System E project sites was estimated on the basis of chinook spawning requirements, which were determined by evaluation of physio-chemical parameters and accessibility. Evaluation of potential rearing capacity was based on water quality, velocity, substrate characteristics, streamside cover and pool-riffle relationships, supported by sample catches of juvenile salmonids at a number of sites.

Existing water quality and water temperature regimes in the Fraser River and major tributaries downstream from the project sites were determined from data obtained during a field program conducted from May 12 to August 27, 1972, when eight sets of samples were taken at 14 sampling sites.

Hydrologic changes at the project sites and in downstream reaches of the rivers that would result from System E development were computed from the results of initial regulation studies to assess the impact on salmon stocks. Anticipated flows at Grand Canyon, Cariboo Falls, Clearwater and Mission, based on flood control requirements at Mission and assuming Nechako River and Bridge River storage facilities operated for flood control, were developed and analyzed for the freshet periods of a typical wet year (1967) and an average year (1965). Probable flows during the low flow periods of 1967-68, 1965-66, and a dry year 1955-56 were estimated on the basis of a preliminary assessment of power generation requirements.

3.6.1.2 Salmon Production Changes and Population Losses

The impacts of System E on salmon populations were derived from estimated reductions in egg-to-adult survival rates, based on early assessments of the physical effects of project development and the forecast changes in water quality and quantity. Losses to salmon populations in areas immediately downstream from projects were based on actual losses recorded for similar areas on other rivers in British Columbia and Washington. The impact on all Fraser River salmon populations further downstream was based on IPSFC research which has related the survival of Chilko Lake sockeye to the river discharge during the time of seaward smolt migration.

Estimated losses to the commercial fishery were developed by compiling for each geographical area the average annual escapement figures for each species, applying to these figures the appropriate catch to escapement ratio, followed by the estimated percentage reduction in survival rate. Losses to saltwater sport and tidal bar catches were calculated in terms of the reduction in total return expressed as percentages of the pre-development catch, assuming maintenance of escapement. Losses to river fisheries (Indian and sport catches) were estimated either by assuming them as proportionate to the commercial and saltwater loss, or by assuming maintenance of total escapement and no loss except where a project (such as Grand Canyon without fish passage facilities) would block the return of a race to its natural spawning area.

3.6.1.3 Present Worth Estimates

The present worth of the Fraser River commercial salmon fishery was calculated on the basis of net economic value, utilizing 1972 data. The net value computation was based on the assumption that society associates a social value with the fishing and related processing and wholesaling industries, that renders their operation less efficient than it would be with the application of their "most efficient" current technology. It is estimated that salmon could be caught by seines and weirs for approximately 15 percent of their landed value if society wished to forego social objectives; hence the net potential value of the fishing operation was calculated as 85 percent of the landed value. It also was estimated that in the absence of social goals, fish processing and wholesaling could be carried out for 50 percent of the current markup from the landed to the wholesale value. The combined net value of fishing, processing and wholesaling was reduced by 2.5 percent of the gross wholesale value to allow for management costs, and was increased by three percent of the gross wholesale value to account for retail profit accruing inside the referent area. The resulting net values per pound for the various salmon species were converted to values per fish, utilizing average weights for each species.

The United Nations Food and Agriculture Organization 1967 estimate of 2.7 percent annual increase in world food demand was used as the rate at which the price of fish would increase over and above that of other consumer commodities. It was assumed that achievement of the full potential production of Fraser River salmon would be realized in even increments over the 60 years following 1972. Net values of potential production and the losses to both present and potential production attributable to each project were calculated to yield annual catch loss values. The net loss ascribed to each System E component combination was projected for real growth and discounted to give the present worth of the loss to the commercial fishery.

Recreational and preservation values of the Fraser River system salmon resource were calculated from data obtained by direct questionnaire involving nearly 4,000 respondents to interviews in two zones, (1) the Lower Fraser Valley, and (2) the river system from Lytton upstream. Respondents were asked to evaluate swimming, boating, fishing and viewing activities in relation to local municipal services costs. Zone 2 respondents also were asked to evaluate the fishing activity separately, to determine what portion of the value of all other activities could be credited to fish. An annual increase of six percent in salmon recreation was applied over the ensuing 60-year period in developing recreational value figures based on the survey data. This six percent growth rate was based on increased participation, followed by real value appreciation should areal and catch opportunity reach saturation during the period. Preservation values also were derived from the survey data for all relevant component referent groups.

The loss to the Indian food fishery attributable to System E development was computed on the basis of an extensive study completed in 1972; the report thereon is entitled "Indian Fishing and its Cultural Importance in the Fraser River System", published jointly in 1973 by the Union of British Columbia Indian Chiefs and the Fisheries and Marine Service of Environment Canada.

3.6.2 The Sports Fish, Wildlife and Recreational Resources

Assessments of recreational use of the natural resource base are considered to constitute a valid basis for social and economic evaluation; and nearly all evaluations were made on this basis. As much of the Clearwater River basin lies within Wells Gray Provincial Park, more basic data for measurement of the physical resources were available for the Clearwater project areas than for those located elsewhere.

3.6.2.1 Measurement of the Physical Resources

Investigation of the sports fish resource was based primarily on available agency information, supplemented by additional field surveys as necessary. Lake characteristics and production capabilities were assessed from data on physical and chemical characteristics, nutrient content, area of food producing littoral zone, adjacent accessible spawning areas and resident fish species. Streams were examined above and below proposed floodlines to determine spawning habitat available in their existing state, after flooding, and as potential. Physical stream characteristics given specific attention were width, discharge, bottom composition, turbidity, and the presence of obstructions. Measurements of stream gradient were made, as this has been determined as a major factor in trout distribution.

Examination of the wildlife resource included assembly of available agency information on populations, resident hunting, guiding and trapping, airphoto interpretations and additional field surveys. Populations of game animals were estimated from examination of winter aerial counts and known hunter harvests. The limited use of traplines in the project areas was recognized in estimating sustained fur harvests. Loss of habitat is a major concern for wildlife in the project areas, and proposed reservoir areas were classified by vegetative types.

The outdoor recreation resource was assessed from available agency data, supplemented by a survey conducted in Wells Gray Park which included an enumeration of visitors, personal interviews, mail questionnaire and field observations. Information regarding visitors to other project areas was obtained from people familiar with their respective recreational resources. Recreational evaluations of areas were based on ground slope, soil drainage, aesthetics of vegetative cover, presence of historic and archaeological sites, existence of interesting natural phenomena, availability of wildlife viewing areas, navigability of watercourses and presence of fishing opportunities. These areas were classified into seven recreational classes, using as criteria the opportunities for camping, boating, fishing, viewing wildlife, seeing natural phenomena, visiting historic sites and examining man-made structures. Recreation activities evaluated included those now available in the project areas, those potentially available with preservation of the existing environment, and those which could be available after project development.

3.6.2.2 Evaluation of the Resources

The values of the sports fish, wildlife and recreational resources administered by the Province were assessed under two conditions: (a) with preservation of the existing environment; and (b) with development of System E projects. These values then were compared to ascertain the direction and extent of the impact of project development. Since many of the values of these resources could not be quantified meaningfully, they were separated for analysis purposes into quantifiable and non-quantifiable categories.

Quantifiable benefits include both the commercial values of the resources and the direct benefits to recreationists. The benefits from commercial use of the resources, such as trapping and the provision of guiding services, can be evaluated at market prices. No similar market process exists for the evaluation of direct benefits to recreationists, campers, canoeists, fishermen, hunters, hikers and visitors; consequently it was necessary to develop a representative measurement process for evaluation purposes.

Non-quantifiable benefits from these resources consist of the opportunities provided by the natural environment for such uses as general education and specialized research. The option value concept refers to the premium that people place on maintaining an area for such use, and so preserving their choice to use it in future. Preservation value refers to the premium that society might place on retention of certain areas in their natural state. Most of these non-quantifiable benefits depend on preservation of the natural environment.

Commercial use of the resources within the project areas is limited to trapping and guiding; and estimates of the magnitude of these activities were compiled from license and trophy fee records. An allowance was established for benefits arising from expenditures by non-resident hunters.

Evaluation of recreational benefits was based on use in terms of recreation-days; but there are no normal market processes to establish their value on a basis commensurate with that of other goods and services. Values for users residing in British Columbia were based on what they would have to be paid to willingly abstain from such recreation. Values for non-resident users were based on what they would be willing to pay per day of use of an area. Allowance was made for resource management costs where applicable.

3.6.2.3 Present Worth Estimates

Trends in the relative value or price of any commodity depend on the interaction of the forces of supply and demand. Forms of outdoor recreation depending on natural environment availability rely on a supply which can be augmented only to a limited extent; and the demand for them is increasing significantly, and presumably will continue to do so with a growing population possessing more leisure time and higher per capita income.

Studies indicated an expected annual rate of increase in the real value of recreation opportunities in the range from two to six percent, varying with the particular area. The increase in demand for hunting was forecast to be low to moderate, for fishing and boating moderate to high, for camping and hiking very high, also for visiting and viewing; and these forecasts were used in determining the estimated future rate of growth in real value for each activity in each project area. Present worth estimates were derived on the basis of the general analysis criteria stated in 3.1, with the intent of making them comparable with those derived for the other resources.

3.6.3 The Forestry Resource

The following assumptions were made in evaluating the impact of System E on forestry: all merchantable timber would be salvaged prior to flooding or would be made available for post-flooding cleanup operations, the costs to do so being considered as part of the reservoir clearing and logging costs; the effect of loss of land through inundation would be measured by the loss of annual yield from the flooded area, and the result of this loss on the local economy; the effect of the reservoirs on logging practices would be determined by comparison of the present development pattern with the possible pattern applicable after adjustment to the changed conditions imposed by reservoir formation.

The following items were not considered in the evaluation procedure: the effect of disruption of existing logging plans and patterns that would be caused by reservoir formation or by relocation of current operations as required to expedite the removal of merchantable timber from the reservoir areas; the possible future increases in allowable annual cut through improved forest management; the cost of storing large volumes of timber when water transport, adopted after reservoir formation, cannot be used due to ice or low water levels; and the possible delays in log transport owing to congestion of traffic on access roads during project construction.

3.6.3.1 Factors Governing the Physical Resource

The allowable annual cut is increasing, but the rate of increase cannot yet be predicted on the basis of past performance. The initial gain from rough to the present close utilization standard has been much greater than was anticipated; any continued uniform increase would significantly change the present worth of the estimated forestry losses. The indicated loss in the amount of allowable annual cut is an actual rather than a probable loss. All Public Sustained Yield Units involved have the cut fully committed and are located in areas of rapid forest industry expansion. The annual yield from Crown Lands was used as the basis for calculating yield from alienated timber lands.

3.6.3.2 Current and Future Values

The value of the lumber and chips produced by the sawmill was deemed to be the market level which best reflected the value of the forest industry to the Province. This is the value used to illustrate the economic losses to the forest industry that would result from System E development.

Future forest product values are difficult to forecast because of extreme price fluctuations. During the period from 1935 to 1971, the annual growth rate of the industry was about three percent; and in the period from 1952 to 1971, the annual rates of increase in timber cut and lumber production were 4.6 and 4.4 percent, respectively. In contrast the forest products price index rose 34 percent from 1970 to 1971, and rose a further 30 percent from 1971 to 1972.

The principal cause of these fluctuations in forest product prices is that some 80 percent of production is exported, with price levels determined by United States and world market conditions. Additional factors affecting prices include severe winters, long fire seasons, labour problems and rail car availability. A further condition affecting future prices is the approach of the annual timber cut towards the allowable maximum, when prices will be affected by external factors such as the cost of substitute materials and consumer preferences.

3.7 Provision of Project Cost Data

Appraisal of the various projects required the provision of cost data based on mid-1972 price levels. Adjustment of available cost estimates to reflect mid-1972 price levels was restricted to those estimates prepared since mid-1970; new cost estimates were prepared for projects costed prior to that time, and for alternative or new projects selected for consideration. The project costs finally adopted for review purposes and the background references thereto are contained in Chapter 4.

3.7.1 System E and Alternative Projects

The original design data compiled by the Fraser River Board were used to prepare new cost estimates for all of the System E projects except Lower McGregor. These new estimates were based on April 1971 price levels and were adjusted subsequently to reflect mid-1972 price levels. The original Lower McGregor Diversion project design was altered materially and the new design was costed to October 1972 price levels; the resulting cost data were accepted as comparable to those for the other System E projects which reflect mid-1972 price levels. Alternative projects for which designs and cost estimates were prepared on a comparable basis to those for the System E projects were Lower McGregor Non-Diversion, and Hobson Lake with an earthfill main dam.

Flowage and clearing costs for these projects were estimated from Fraser River Board data, using current timber inventory information and alienated land values together with recorded increases in highway and railway construction labour and equipment rates. Construction labour costs were derived by assessment of construction methods for each operation; computation of manpower requirements for major work items; and application of labour rates, fringe benefits and working conditions negotiated by the Construction Labour Relations Association of British Columbia. Equipment and material costs were obtained from manufacturers or from actual supply prices experienced on current construction projects in British Columbia. Indirect costs, such as mobilization, camps and overhead, were estimated in a similar manner, and together with a markup of 15 percent, were incorporated in the direct costs.

Engineering and administration costs, which include such items as extra field and laboratory examinations, office engineering and on-site supervision of construction, and accommodation for these purposes, were estimated as 10 percent of the total direct cost. Contingency allowance was set at 10 percent of the total direct, engineering and administration costs. The cost of interest during construction was based on a rate of 6.5 percent per annum, which was generally applicable in mid-1972, applied for the project construction period. The addition of the interest cost to the direct, engineering and administration costs, and to the contingency allowance, provided the total capital cost.

3.7.2 Dyking Projects

The present rehabilitation and extension program for the Lower Fraser Valley dyking system involves some 45 projects in and adjacent to the Valley. Cost estimates for each of these projects were prepared at various times since mid-1970 with close adherence to the design and construction standards given in 4.1. These estimates were adjusted where necessary as outlined in 3.7.4 to reflect mid-1972 price levels.

Dyke right-of-way costs were based on land values provided by provincial and municipal assessment authorities. Construction labour costs were derived by computation of manpower requirements and application of labour rates, fringe benefits and working conditions negotiated by the Construction Labour Relations Association of British Columbia. Equipment and material costs were obtained from suppliers or from actual supply prices experienced on local projects. An overall amount of 25 percent of the total construction cost was provided to cover engineering, administration and contingencies. Interest during construction was not provided in these estimates; most of the active construction periods are relatively brief, reducing the significance of this item in determining total capital costs.

The inclusion of the Kamloops area under the May 24, 1968 Agreement (Annex I) was formally approved in 1974 and resulted in the preparation of a redesigned dyking proposal for that area, replacing the one prepared originally for this review. The cost estimates for the redesigned Kamloops proposal were prepared on a basis essentially similar to that for the Lower Fraser Valley dyking project cost estimates. However, allowances of 15 percent for engineering and administration and of 25 percent for contingencies were provided in view of the lesser amount of subsurface and dyke materials data available for the Kamloops area. These estimates were prepared using December 1974 prices; and they were adjusted as outlined in 3.7.4 to reflect mid-1972 price levels.

Subsequent examination of the cost estimates for the original and the redesigned Kamloops dyking proposals indicated that the latter were more complete; also that the unit prices used in the preparation of the latter agreed more closely with those encountered on Oak Hills reconstruction and on Lower Fraser Valley projects completed or under construction. It was apparent that the cost estimates for the original proposal would have been substantially higher if they had been prepared on the same basis as those for the redesigned proposal.

Prince George and Quesnel dyking proposal cost estimates were prepared in the same way as those for the original Kamloops proposal, being based on preliminary designs and limited field data. Recomputation of the Quesnel proposal cost estimates on the basis used in preparing those for the redesigned Kamloops proposal gave an increase of about 35 percent in the direct construction costs, which was adopted and also applied to the Prince George direct construction costs. Allowances of 15 percent for engineering and administration and of 25 percent for contingencies were added to these increased direct construction cost figures, and the resulting total construction cost figures are given in Tables 4-4 and 4-5.

3.7.3 Other Projects

Several other flood protection measures were given limited examination, and preliminary or very approximate cost estimates were prepared for them to permit their comparison with projects included in System E and alternatives.

Cost estimates for the negative storage projects on the Clearwater River system were compiled using the same procedure as that outlined in 3.7.1 for the System E and alternative projects. However, the contingency allowance was raised from 10 percent to 15 percent in view of the limited topographical information available and the lack of geological and subsurface data for the project sites. The costs of access roads were allocated proportionately among the various projects; otherwise individual project construction was assumed in compiling the estimates and no reference was made to possible cost savings from concurrent construction of several projects. These estimates probably are less accurate than those for the System E and alternative projects; but they are considered adequate for benefit-cost comparison purposes.

The Kamloops Lake outlet by-pass channel cost estimate is very approximate, and serves only to illustrate the order of cost magnitude that might be involved in the provision of such a channel. The lack of surface and subsurface data along the tentatively selected by-pass channel route, and the absence of information on the possible erosion effects arising from changes in the natural flow pattern at high water levels did not permit preparation of a cost estimate of acceptable standard for benefit-cost analysis purposes.

The cost estimates for three alternative possibilities of storage regulation in Harrison Lake are very approximate; they are intended only to illustrate the order of cost magnitude involved in the development of one of these possibilities. The structure costs were derived by updating on an index basis the estimates for designs prepared in earlier Fraser River studies. The flowage costs were estimated from data compiled during limited field investigations in 1972. Preparation of a cost estimate of a standard acceptable for benefit-cost comparison purposes would necessitate the prior acquisition of detailed surface and subsurface data and probable redesign of the project.

3.7.4 Adjustment of Costs to Mid-1972 Levels

Construction costs experienced during the 1970-1974 period, both for projects in the Lower Fraser Valley dyking program and for other projects being built in British Columbia, demonstrated an increasingly rapid rate of rise. Examination of these costs suggested that this rate of rise approximated the following percentages on a per annum basis for the periods indicated: eight from 1970 through 1972; 12 in 1973; 16 from January to June 1974; and 20 from July 1974 forward. These rates were adopted, compounded annually, and applied to the nearest quarter year to obtain the adjustment factors shown in Table 3-1, which were used to adjust cost figures to mid-1972 price levels.

TABLE 3-1

FACTORS FOR COST ESTIMATES ADJUSTMENT TO MID-1972 LEVELS

Original Cost Estimate Date	Factor for Mid - 1972 Cost Level	Original Cost Estimate Date	Factor for Mid - 1972 Cost Level
Jul 1/72	1.0000	Jul 1/72	1.0000
Apr 1/72	1.0200	Oct 1/72	0.9804
Jan 1/72	1.0400	Jan 1/73	0.9615
Oct 1/71	1.0600	Apr 1/73	0.9335
Jul 1/71	1.0800	Jul 1/73	0.9071
Apr 1/71	1.1016	Oct 1/73	0.8821
Jan 1/71	1.1232	Jan 1/74	0.8585
Oct 1/70	1.1448	Apr 1/74	0.8255
Jul 1/70	1.1664	Jul 1/74	0.7949
		Oct 1/74	0.7571
		Jan 1/75	0.7227

3.8 Power Output Determination

The determination of individual project power outputs was approached on the basis that each project would be connected to the entire British Columbia interconnected power system as anticipated by the British Columbia Energy Board (BCEB) to be operational in 1980. This system would comprise virtually all of the existing generating stations in British Columbia and those proposed for operation by that time. Each generating station would be operated for the greatest benefit to the capabilities of the entire interconnected system, thus taking advantage of the flexibility of operation possible in such a large system.

The power production capabilities of each project or combination of projects were determined in the manner used in the BCEB 1972 studies of power development in British Columbia. This was accomplished by simulating in a mathematical model the operation of the interconnected system both with and without the projects under review, and by determining from these simulations the differences in the energy load carrying capabilities of the system.

The basic tool used for these study tests was the mathematical model "Simulation of Hydro Resources under Monthly Operation" (SHRUMO), developed by International Power and Engineering Consultants Limited (IPEC) for BCEB and operated by IPEC for the present study (Reference: Annex II, 3-7). SHRUMO simulates the operation of a selected group of generating stations representing a system, using a sequence of historical streamflow records to meet a specified annual energy load distributed on a monthly basis. The generating station operations in the simulations are those required to meet the assigned loads within specified turbine flows and reservoir elevations. Stored water is drafted as required to meet the loads on a predetermined priority basis. Energy from each generating station is computed using the average of the reservoir elevations at the beginning and end of each month. Station capacity is computed using end-of-month elevations. SHRUMO does not optimize system output, but optimization is approximated by judgement in establishing operating rules. The effect of changing operating rules can be tested readily, and these rules were changed during the progress of the power study.

All study tests were made using streamflow data for the 40-year period from July 1928 to June 1968 inclusive. Most of the available data for the project sites were recorded between 1948 and 1968; and these data were extended where necessary to cover the entire 40-year period, using the correlation techniques outlined in 3.2.2. The study test period also included the 1928-1958 period which has been used in other studies of power developments in British Columbia.

Using the SHRUMO model, the output of each combination of projects was determined by the following procedure. First, the system load carrying capability without the projects under review was determined by running the simulation using all the 40 years of streamflow data repetitively, each time increasing the energy load to be met by the system until the point was reached where any larger load could not be met without violating the specified system limitations. The annual load level at that point was defined as the system firm load carrying capability. Next, the projects under review were added to the simulation and the same procedure was used to determine the modified system firm load carrying capabilities.

Several different project combinations and reservoir level and outflow constraints were tested in this manner. However, it was not necessary to test all projects separately because the average energy potential and dependable capacity for each project do not vary in such a large system unless the amount of storage available changes upstream or at the site. Each project under review was credited with the average at-site energy it produced over the 40-year period in the simulation run that produced maximum system firm energy. Each project also was credited with a dependable generating capacity equal to that it was capable of providing in the critical month of the tested period, i.e. the month having the highest load demand in a period of low streamflow.

It was determined that constraints imposed by operating requirements for flood control had no significant effect on power potential; and it therefore was unnecessary to develop revised power output determinations incorporating such constraints.

3.9 Power Value Derivation

Any System E or alternative project development almost certainly would be carried out by the British Columbia Hydro and Power Authority (BCHPA), the preeminent electrical energy production and distribution agency in the Province. BCHPA therefore was requested to propose an appropriate at-site value for power produced by these projects to be used in project evaluation. In response to this request BCHPA provided power benefit data for each project under review, based on the costs of obtaining equivalent energy and capacity from the two lowest cost alternative sources which could serve the same purpose with respect to BCHPA system requirements. BCHPA also provided cost estimates of the transmission construction required to connect each project with the BCHPA transmission system, and of project and transmission operating costs. The economic criteria used in computing these data were essentially those outlined in 3.1.

The lowest cost alternative power sources selected by BCHPA for determination of power benefit data for the projects under review were the initial phases of its Revelstoke hydroelectric and Hat Creek thermal electric projects, which are scheduled in its recommended generation plan to begin service in 1981 and 1983 respectively. The Revelstoke project would be located on the Columbia River about three miles upstream from Revelstoke, and its initial installed capacity would be 1,800 MW in four units operating under 420 feet of head. Project operation would be essentially run-of-river, as almost three-quarters of the flow through the project would consist of regulated storage releases from the upstream Mica development. The average annual energy production of this initial phase would be 7,970 gigawatt-hours (GWh).

The Hat Creek project would be located adjacent to and would utilize BCHPA's estimated 478 million-ton coal deposit in the Upper Hat Creek Valley nearly 20 miles east of Lillooet. The four-unit 2,000 MW generating station would consume about 11.4 million tons of coal per year, involving the annual removal of some 32 million tons of waste rock and overburden. Water supply would be conveyed by pipeline from the Thompson River. The average annual energy production would be 13,680 GWh.

In determining power benefits, construction of all projects was assumed to commence in April 1972. In-service dates for the projects under review were not scheduled on a unit basis, as the total installed generating capacity of each of these projects is less than that of a single unit of either Revelstoke or Hat Creek. Comparison of the average annual energy production from any of these projects with the BCHPA planning forecast of energy demand from 1975 through 1980 showed that the output from any of the projects could be fully utilized in a relatively short time in meeting the incremental energy demand.

September and October 1978 were the respective in-service dates assumed for the first units of Revelstoke and Hat Creek, compared to those of October 1976 and July 1977 assumed for the projects under review. The alternative energy supply during the interim periods between the in-service dates of the projects under review and those of Revelstoke and Hat Creek could be provided by the existing Burrard thermal electric generating station. The estimated cost of this provision was included when costing Revelstoke and Hat Creek.

The BCHPA generating system is forecast to be capacity critical from 1986 onward; and it was necessary to estimate the cost of providing supplementary capacity where Revelstoke or Hat Creek would be capacity deficient when compared with the projects under review. This was done on the basis of providing peaking units at the Mica generating station to be in service by 1986. The estimated cost of this provision was included where necessary when costing Revelstoke and Hat Creek.

The cost of Hat Creek coal was derived by BCHPA on the assumption that this coal could command the same mine mouth price as equivalent quality coal purchased in Montana and North Dakota for thermal electric generation in the United States. Four samples of similar types of sub-bituminous coal mined in these two States were selected and their average mine mouth price was adjusted by the relationship between their average heat content value and that of Hat Creek coal. The result was further adjusted to 1972 price levels, giving $2.17 per ton as the cost of Hat Creek coal.

In developing the cost estimates of energy and capacity from Revelstoke and Hat Creek, BCHPA applied real cost escalation rates estimated from Statistics Canada price index data for the period from 1961 to 1974 inclusive. United States wholesale price index data also were used in estimated real cost escalation rates for fuels used in thermal electric generation.

The system time horizon used in determining the power benefits is somewhat shorter than the assumed economic life for hydroelectric projects, but longer than that for thermal electric projects; hence replacement of the Hat Creek project was included during this time horizon. The real cost of thermal electric energy has declined steadily over the past half century owing to decreased cost per unit of capacity and to increased efficiency in fuel utilization, and this trend was projected into the future. The replacement thermal electric project would not necessarily use the same fuel as the original; but it would incorporate technological improvements achieved during the economic life of the original. These improvements were estimated by BCHPA to average two percent annually in reduction of real capacity and energy costs.

A new thermal electric generating station enters a power system with a certain load factor; but its rate of use declines as it ages, and as further new capacity capable of higher efficiency in operation is added to the system. This decay in the load factor was assumed by BCHPA to average one percent annually over the economic life of the station.

These various real cost escalation rates and technological change factors are listed in Table 3-2 for the most likely rates of real growth and price change projected to occur in the referent area during the system time horizon.

Interest during construction represents the cost of capital invested in a project during its development. BCHPA assumed that all such investment during a year was made and therefore borrowed at the end of that year. This cost was incorporated as the present worth in 1972 of the sum, at the end of the project completion year, of the total capital investment plus the interest on each annual increment plus one year's interest on these two items.

TABLE 3-2

ESTIMATED REAL COST ESCALATION RATES

AND TECHNOLOGICAL CHANGE FACTORS (1)

Average Escalation Rate or Change Factor	Variation Per Year (2)
	(%)
Construction Cost Escalation Rate (Hydro and Thermal)	0.35
Operation Cost Escalation Rates (Hydro and Thermal)	
Operations and Maintenance	2.25
Administration and General	2.25
Interim Replacement	0.35
Operation Cost Escalation Rates (Thermal only)	
Coal 1972-1974	17.0
1975-2000 (3)	1.0
Burrard Fuel 1972-1974	13.8
1975-1978 (4)	2.0
Variable Maintenance	2.25
Decrease in Capital Costs per Unit of Capacity (Thermal)	2.0
Decrease in Operating Costs per Unit of Capacity (Thermal)	2.0
Decay Factor of Generating Station Use (Thermal)	1.0

NOTES:
(1) As developed by BCHPA.
(2) For most likely rates of real growth and price change.
(3) Relative prices assumed to remain constant after 2000.
(4) Burrard operation required only until 1978, when Revelstoke or Hat Creek is assumed to come into service.

Annual fixed operating cost allowances used by BCHPA are given in Table 3-3 for both hydroelectric and thermal electric projects and for transmission facilities.

TABLE 3-3

ANNUAL FIXED OPERATING COST ALLOWANCES

Fixed Operating Cost	Percentage of Construction Cost		
	Hydroelectric Project	Thermal Electric Project	Transmission Facilities
Operations and Maintenance	0.15	1.45	0.6
Administration and General	0.0375	0.3625	0.15
Interim Replacement	0.2	0.35	0.1
Insurance	0.1	0.25	0.1

The foregoing costs are referred to as fixed operating costs which apply regardless of continuity of project operation. Thermal electric projects also are subject to variable maintenance costs which have been estimated by BCHPA as 0.3 mills per kWh plus fuel costs.

The data from BCHPA that were utilized in the assessment of the projects under review appear in 6.4 and 6.7.

CHAPTER 4

PROJECT DESCRIPTIONS AND COSTS

4.1 Lower Fraser Valley Dyking Projects

In accordance with the terms of the May 24, 1968 Agreement and Amending Agreements (Annex I), the dyking system in the Lower Fraser Valley is undergoing systematic rehabilitation and extension under a sixteen-year program to provide more adequate protection against inundation of Valley flood plain lands (Plate 4-1). Projects involving about 159,000 acres of the approximate total of 185,000 acres of Valley flood plain lands are under examination, design, construction, or are essentially complete (Table 4-1). Projects involving a further 21,000 acres of Valley flood plain lands remain under consideration (Table 4-2).

About 155,000 acres of the total of 159,000 acres involved in the 22 projects in active progress under this dyke rehabilitation and extension program would be affected by development of the upstream storage or diversion projects reviewed in subsequent chapters of this report (Table 4-1). Another 19,000 acres involved in 17 of the 21 projects for further consideration likewise would be affected by development of these upstream storage or diversion projects (Table 4-2).

Two projects considered under the May 24, 1968 Agreement are located in adjacent drainage areas south of the Lower Fraser Valley (Plate 4-1). The Serpentine-Nicomekl Rivers Project (No. 44) includes repair of two river dams, and reconstruction of 10 miles of sea dykes and of 49.4 miles of river dykes. Repair of the dams protecting 12,280 acres of land has been authorized; but reconstruction of the river dykes proved to be uneconomic, and this part of the project therefore did not receive approval. The very small Crescent Beach Project (No. 45) is one for further consideration.

Under Amending Agreement No. 2, dated April 29, 1974 (Annex I), the provisions of the May 24, 1968 Agreement were extended to cover the Kamloops area. An outline of dyke reconstruction already completed and of possible further dyking to protect other low-lying parts of Kamloops is given in 4.2.1.

The projects in Table 4-1 involve more than 220 miles of dykes along the Fraser River and its principal tributaries, the Harrison, Vedder, Sumas, Alouette, Pitt and Coquitlam Rivers, and the Strait of Georgia. These projects are being designed and constructed to provide a dyking system and associated bank protection with minimum variation in dyke crest elevations and in uniformity of design and construction standards. This dyking system will offer a substantial degree of protection to 85 percent of the flood plain lands in the Lower Fraser Valley against inundation from spring snowmelt floods up to levels equivalent to 26.00 feet at Mission, the maximum 1894 flood level, with two feet of freeboard at these levels. The sea dykes bordering the western delta lands also are to be improved where necessary to prevent entry of the sea during extremes of the tidal cycle, even when aggravated by storm occurrence.

TABLE 4-1

LOWER FRASER VALLEY DYKING PROGRAM UNDER MAY 24, 1968 AGREEMENT

PRIORITY PROJECTS COMPLETE, IN PROGRESS, OR UNDER ACTIVE CONSIDERATION (1)

No. (2)	Location or District	Area Involved (Acres)	River Dykes (3) (Miles)	Estimated Total Cost(4) ($1,000)
	Projects Affected by Upstream Storage or Diversion			
1	Kent (Agassiz-Harrison Mills)	7,450	11.9	2,491
2	Harrison Hot Springs	250	0.9	160
3	East and West Nicomen	5,320	21.7	6,000
5	South Dewdney	5,170	7.3	2,111
6	Mission	300	1.8	520
8	Maple Ridge	8,380	14.3	3,546
10	Pitt Meadows No. 2	1,060	5.4	(5)
13	Coquitlam	3,050	8.3	2,580
16	Chilliwack	26,560	20.5	6,200
17	Abbotsford (formerly Sumas)	22,140	14.7	6,858
18	Matsqui	10,040	7.2	2,614
19	Glen Valley	2,350	6.3	1,400
20	Salmon River (Fort Langley)	1,232	0.8	427
23	South Westminster	1,500	4.2	2,456
24	Delta	29,000	10.0	8,181
25	Richmond (excluding Sea Island)	30,000	19.0	11,668
31	New Westminster (Queensborough)	700	4.3	1,365
36	Chilliwack I.R. Nos. 3 & 4 (6)	890(7)	2.8	849
	Sub-Total	155,392	161.4	59,426
	Projects Unaffected by Upstream Storage or Diversion			
33	Delta Sea Dykes	(8)	29.8	(8)
34	Richmond Sea Dykes	(9)	21.3	(9)
42	Coquitlam River	2,350	4.7	1,568
43	Vedder River	1,245	6.0	1,577
	Total	158,987	223.2	62,571

NOTES:
(1) As at May 24, 1975.
(2) Program project numbers as shown on Plate 4-1.
(3) Except for Projects Nos. 33 and 34.
(4) At mid-1972 price levels.
(5) Estimated Total Cost included in figure for Project No. 8.
(6) To be financed with Federal funds.
(7) Includes 228 acres of non-reserve land.
(8) Area and Estimated Total Cost included in figures for Project No. 24.
(9) Area and Estimated Total Cost included in figures for Project No. 25.

TABLE 4-2

LOWER FRASER VALLEY DYKING PROGRAM UNDER MAY 24, 1968 AGREEMENT

PROJECTS FOR FURTHER CONSIDERATION (1)

No.(2)	Location or District	Area Involved (Acres)	River Dykes (Miles)	Estimated Total Cost(3) ($1,000)
Projects Affected by Upstream Storage or Diversion				
4	North Nicomen	250	2.3	700
7	Silverdale	900	2.5	623
9	Albion	200	1.7	544
11	Pitt Meadows No. 1	1,175	6.2	2,016
12	Pitt Polder	6,200	11.7	5,473
14	Colony Farm	700	5.5	1,098
15	Trapp Road	150	1.5	210
21	West Langley	425	1.8	485
22	Barnston Island	1,400	6.2	1,810
26	Tretheway	465	2.8	854
27	Alouette	1,625	6.2	1,890
28	Derby	900	3.3	1,464
29	East Langley	600	1.6	1,262
30	Maple Ridge Road 13	235	0.2	92
35	Seabird Island I.R.	3,540	9.3	3,704
36	Chilliwack I.R. No. 5	398	2.3	1,288
37	Katzie I.R. No. 1	42	0.8	280
38	Coquitlam I.R.	94	0.9	191
	Sub-Total	19,299	66.8	23,984
Projects Unaffected by Upstream Storage or Diversion				
39	McMillan Island I.R. (4)	740	-	201
40	Matsqui I.R. (4)	1,000	-	419
41	Popkum I.R. (4)	200	-	117
	Total	21,239	66.8	24,721

NOTES:
(1) As at May 24, 1975.
(2) Program project numbers as shown on Plate 4-1.
(3) At mid-1972 price levels.
(4) Projects consisting of bank protection only.

New dykes in this system are designed to meet these basic requirements, while improvement of existing dykes to do so involves primarily three general work components: raising dyke crest elevations and establishing minimum crest widths of 12 feet; building up the dyke side slopes to suitable grades; and providing seepage control for dyke stability through the provision of filtering trenches, wells or berms.

An integral part of dyke rehabilitation and construction is the provision of bank protection wherever erosion occurs to threaten dyke stability. Some 50 miles of new and improved bank protection required under this program involve the placement of rock riprap in sizes up to 2,000 pounds in water up to 60 feet deep, with current velocities up to 15 feet per second (ten miles per hour).

Achievement of relatively uniform design and construction standards for all projects from the widely varied conditions of the many existing elements has required detailed investigation of each existing element and each site of new work. The fulfillment of this requirement and the conduct of essential negotiations have been very time-consuming; consequently the sixteen-year program is in its ninth year, but actual construction and reconstruction are in their seventh year. Nevertheless substantial progress has been made, with projects costing about $63 millions at mid-1972 price levels being completed, or under construction, design or active consideration (Table 4-1).

4.2 Other Dyking Projects

In accordance with the objective of this review of upstream storage and diversion projects in the Fraser River system, primary emphasis has been directed toward the provision of additional flood protection for the Lower Fraser Valley. However, the inclusion of the Kamloops area under the May 24, 1968 Agreement by the April 29, 1974 Amending Agreement No. 2 (Annex I), and the growing importance of Prince George and Quesnel to the provincial economy, warrant consideration of protective measures to minimize the flood hazard existing in the low-lying areas of these communities. Brief outlines of preliminary plans for this purpose are given hereunder; these plans are very tentative and may be altered substantially before a decision is reached regarding the construction of any of them.

4.2.1 Kamloops

The City of Kamloops, with a population of 55,000, occupies 88,500 acres along and adjacent to the confluence of the North and South Thompson Rivers (Plate 4-2). Low-lying areas of the city are subject to spring snowmelt freshet inundation. The highest freshet elevation in 60 years of record occurred in 1972, when the Oak Hills area was flooded due to dyke failure and other city areas narrowly escaped inundation. Fragmentary available data indicate that this 1972 recorded peak elevation was about five and one-half feet lower than that of the 1894 flood, which was adopted as the basis for the Oak Hills dyke reconstruction completed in mid-1974.

Preliminary designs and cost estimates have been prepared for a dyking system to protect other city areas from a flood with an average recurrence interval of 200 years (Reference: Annex II, 4-1). This system includes nearly

15 miles of dyke in 11 sections shown on Plate 4-2, together with nearly one-half mile of flood wall, for protection of 3,000 acres of flood-prone city land. Each dyke section would protect a separate area and could be constructed independently.

The basic dyke design provides a top width of 12 feet, side slopes of 3:1 (horizontal to vertical), and two feet of freeboard allowance plus a six-inch gravel layer as maintenance road surface. Steeper riverside dyke slopes (1.5:1) with riprap cover would be used where space is limited, or flood walls of steel sheet piling or of concrete would be built instead. Dykes replacing existing roads would have a top width of 32 feet and freeboard allowance of one foot plus a nine-inch gravel layer, plus paving where necessary. Two small channel dams, one including a boat-way, would be built at the entrances to McArthur Slough. No subsurface investigations were made to confirm dyke foundation conditions.

The estimated total capital cost of this dyking system, based on mid-1972 price levels, is $9.6 millions, including an allowance of $3.0 millions for dyke right-of-way acquisition. The construction cost figures given in Table 4-3 include allowances of 15 percent for engineering and administration, and of 25 percent for contingencies.

TABLE 4-3

KAMLOOPS DYKING SYSTEM COST ESTIMATE

Dyke Section	Area Protected	Dyke Length	Flood Wall Length	Construction Cost
	(acres)	(100 feet)	(100 feet)	($1,000)
T1	550	129	16	1,501(1)
T2	430	124	-	534
T3	1,090	187	3	1,456
T4	238	75	-	126
NT1	172	133	-	1,268
NT2	28	33	-	280
NT3	45	32	-	182
NT4	350	75	-	494
ST1	43	48	-	624
ST2	21	18	1	167
ST3(2)	-	-	-	11
Total	2,967	854	20	6,643

NOTES: (1) Includes $232,000 for the two channel dams, and $223,000 for the boat-way.
(2) Consists of very minor work in Dallas to protect several residences.

4.2.2 Prince George

The City of Prince George, with a population of 34,500, occupies 16,000 acres adjacent to the confluence of the Fraser and Nechako Rivers (Plate 4-3). Low-lying areas of the community are subject both to spring snowmelt freshet inundation and to winter flooding from ice jam formation. The most severe inundation in the past 60 years occurred during the 1972 freshet; there is no record of the 1894 flood level at this location.

Preliminary designs and cost estimates have been prepared for a dyking system that would protect these low-lying areas from a flood with an average recurrence interval of 200 years under natural river flow conditions (Reference: Annex II, 4-2). Some 22,400 feet of dyke shown on Plate 4-3 would be required to protect the four areas A to D, totalling 1,300 acres of flood-prone land.

The basic dyke design for this sytem is almost identical to that for Kamloops (4.2.1), the main difference being that the inboard slope of the dykes is 2.5:1 throughout, and the riverward slope is increased to 2.5:1 where space for dyke construction is limited. The same provisions have been made for riprap protection where necessary. No subsurface investigations were made to confirm dyke foundation conditions.

Area A is completely separate from Areas B, C and D; hence dyking to protect Area A would be an independent project. Areas B, C and D abut one another in portions of their respective boundaries; any one of them could be protected independently, or two or all three dyked in combination, thus offering several alternatives for consideration.

The estimated total capital cost of the dyking system required to protect all four Areas A, B, C and D, based on mid-1972 price levels, is $4.7 millions. The construction cost figures given in Table 4-4 include allowances of 15 percent for engineering and administration, and of 25 percent for contingencies.

TABLE 4-4

PRINCE GEORGE DYKING SYSTEMS COST ESTIMATES

Area(s) Included	Area Protected (acres)	Dyke Length (100 feet)	Construction Cost ($1,000)	Right-of-Way Cost ($1,000)	Total Cost ($1,000)
A	70	58	638	56	694
B	885	120	1,327	204	1,531
B,C	1,200	151	1,649	277	1,926
B,D	957	134	3,323	268	3,591
B,C,D	1,272	166	3,646	340	3,986
A,B,C,D	1,342	224	4,284	396	4,680

4.2.3 Quesnel

The Town of Quesnel, with a population of 6,300, occupies 3,500 acres adjacent to the confluence of the Fraser and Quesnel Rivers, and includes the settlement formerly known as West Quesnel located on the right bank of the Fraser River opposite the confluence (Plate 4-4). Low-lying areas of the community are subject to spring snowmelt freshet inundation. The most severe flooding in more than 40 years of record occurred in 1972; there is no record of the 1894 flood level at this location.

Preliminary designs and cost estimates have been prepared for a dyking system that would protect these low-lying areas from a flood with an average recurrence interval of 200 years under natural river flow conditions (Reference: Annex II, 4-3). Some 16,500 feet of dyke in five sections shown on Plate 4-4 would be required to protect 150 acres of flood-prone land.

The basic dyke design for this sytem is essentially identical to that for Kamloops (4.2.1); and the same provisions have been made for rock riprap protection where necessary. No subsurface investigations were made to confirm dyke foundation conditions.

The estimated total capital cost of this dyking system, based on mid-1972 price levels, is $1.4 millions. The construction cost figures given in Table 4-5 include allowances of 15 percent for engineering and administration, and of 25 percent for contingencies.

TABLE 4-5

QUESNEL DYKING SYSTEM COST ESTIMATE

Section & Note	Area Protected	Dyke Length	Construction Cost	Right-of-Way Cost	Total Cost
	(acres)	(100 feet)	($1,000)	($1,000)	($1,000)
A(1)	37	49	503	Nil	503
B(1)	27	30	242	Nil	242
C(2)	28	31	184	48	232
D(1)	24	27	235	72	307
E(1)	31	28	51	27	78
Total	147	165	1,215	147	1,362

NOTES: (1) Sections A and B are interdependent; they must be built as a unit to protect the area involved. The same condition applies to Sections D and E.

(2) Section C is independent; it protects an individual area.

4.3 System E Upstream Storage and Diversion Projects

Lower Fraser Valley development in mid-1972 was such that some $300 millions damage would have resulted from total inundation of its flood plain lands; and Valley development is continuing its rapid expansion. Completion of the dyking program outlined in 4.1 will provide 85 percent of these flood plain lands with substantial protection against inundation from spring snowmelt floods up to the 1894 level. This degree of protection approaches the maximum that can be provided by dyking, due both to the limitations on dyke heights imposed by soil and foundation conditions, and to the lowered reliability of dykes when saturated for extended periods of time. Flood levels higher than that of 1894 can and will occur; with the occurrence of such floods the failure of dykes designed to the 1894 level becomes increasingly probable.

Spring snowmelt flood occurrences at Kamloops, Prince George and Quesnel closely parallel those in the Lower Fraser Valley (Table 2-2). Flood plain development in these communities is increasing steadily; and their growth intensifies concern regarding possible flood plain inundation. Dyking projects for their protection are outlined in 4.2; but the limitations of dykes as protection against inundation of these flood plains are similar to those prevailing in the Lower Fraser Valley.

Additional and more reliable protection against flood plain inundation can be provided by the development of upstream storage and diversion projects. The emergency operation for flood control purposes of the existing storage developments on the Nechako and Bridge Rivers as described in 2.2.5 has demonstrated the effectiveness of this means of flood control on the Fraser River. The one diversion and five storage projects contained in System E (Table 4-6) would, in conjunction with the dyking and drainage program now under way, reduce the flood hazard in the Lower Fraser Valley to a relatively remote possibility; and those of the projects situated upstream from Kamloops, Prince George and Quesnel, respectively, would offer corresponding protection at these locations.

The following summary descriptions of System E and alternative projects incorporate the results of the current review, which included office reassessment of the diversion and storage projects, and additional site investigations at Lower McGregor Diversion (104) and Hemp Creek (142) - (References: Annex II, 4-4, 4-5, 4-6). Substantial changes were made in the former design for Lower McGregor Diversion (104); and new designs and cost estimates were developed for an alternative Lower McGregor Non-Diversion project and an alternative dam for the Hobson Lake (153) project. Only minor modifications of the former designs for some of the other projects were found to be desirable.

The project description and cost estimate for Lower McGregor Diversion (104) are based on those prepared by consultants (References: Annex II, 4-7 and 4-8), as are those for the Lower McGregor Non-Diversion and Hobson Lake alternatives (Reference: Annex II, 4-8). The other project descriptions are condensed from those prepared by the Fraser River Board (Reference: Annex II, 1-2), with their cost estimates adapted from consultant reports (References: Annex II, 4-8 and 4-9). All cost estimates given herein are at mid-1972 price levels.

TABLE 4-6

SYSTEM E AND ALTERNATIVE PROJECTS

PROJECT		RIVER	FUNCTION	MAIN DAM			RESERVOIR					SPILLWAY				
														Gates		
Name	Fraser River Board Number		Diversion - D Storage - S Generation - G	Type	Height (feet)	Crest Elevation (feet msl)	Drainage Area (square miles)	Surface Area (acres)	Live Storage (1,000 af)	Operating Elevations (feet msl)		Crest or Sill Elevation (feet msl)	Crest Length (feet)	Number	Width (feet)	Height (feet)
										Max.	Min.					
System E Projects																
Lower McGregor	104	McGregor	D	Zoned Earthfill	460	2,495	1,840	50,000	-	2,470	2,455	2,480(1)	650(1)	-	-	-
Grand Canyon	111	Fraser	S G	Concrete Gravity	180	2,140	5,500	49,700	1,961	2,135	2,080	2,087	-	4	50	48
Cariboo Falls	89	Cariboo	S G	Zoned Earthfill	240	2,840	1,200	15,140	1,157	2,830	2,745	2,788	-	2	41	42
Hobson Lake	153	Clearwater	S G	Concrete Buttress	110	2,883	352	13,360	811	2,880	2,810	2,772	-	4	15	16
Clearwater-Azure	142A	Clearwater	S G	Zoned Earthfill	275	2,395	1,180	23,300	2,263	2,375	2,270	2,375	900	-	-	-
Hemp Creek	142	Clearwater	S G	Rockfill	450	2,020	3,840	6,870	788	2,005	1,865	1,974	-	5	50	31
Granite Canyon	194A	Clearwater	G	Concrete Gravity and Zoned Earthfill	225	1,592 1,595	-	585	(2)	1,585	-	1,535	-	3	42	50
Clearwater	141	Clearwater	G	Concrete Gravity	125	1,412	-	160	(2)	1,405	-	1,355	-	3	42	50
Alternative Projects																
Lower McGregor		McGregor	S G	Zoned Earthfill	440	2,475	1,840	43,500	4,060	2,450	2,320	2,430	-	2	40	20
Hobson Lake		Clearwater	S G	Zoned Earthfill	122	2,895	352	13,360	811	2,880	2,810	2,855	-	2	30	25

NOTES: (1) Emergency overflow structure and high and low level outlets.
(2) Pondage only.

TABLE 4-6 (CONTINUED)

SYSTEM E AND ALTERNATIVE PROJECTS

PROJECT	DISCHARGE CAPACITY					TURBINES				GENERATING CAPACITY			TIME	COST
								Head		Generators				Mid-1972
Name	At Elevation (feet msl)	Spillway (cfs)	Control Works (cfs)	Turbines (cfs)	Total (cfs)	Number	Rating (hp)	Operating (feet)	Maximum Gross (feet)	Number	Rating (kW)	Total Capacity (kW)	Construction Period (Years)	Estimated Capital Cost ($1,000)
System E Projects														
Lower McGregor	2,493.2	104,000(1)	24,900(1)	-	128,900	-	-	-	-	-	-	-	5	136,445
Grand Canyon	2,135.6	226,300	48,300	14,000	288,600	3	52,660	107	132	3	48,000	144,000(2)	3	119,225
Cariboo Falls	2,830.0	59,500	6,200	6,500	72,200	3	58,880	236	274	3	42,167	126,500	3	55,335
Hobson Lake	2,880.0	69,200	-	2,000	71,200	1	120,000	489	548	1	72,000	72,000	4	49,405
Clearwater-Azure	2,382.4	55,000	17,900	6,000	78,900	2(3) 2(4)	57,450 46,400	157 121	222 123	2 2	45,250 33,250	90,500 66,500	4	91,585
Hemp Creek	2,005.0	136,000	28,700	12,000	176,700	4	147,650	411	420	4	92,000	368,000	5	154,225
Granite Canyon	-	-	-	-	(5)	3	69,000	178	180	3	49,500	148,500	2½	62,025
Clearwater	-	-	-	-	(5)	2	41,500	70	72	2	29,750	59,500	3½	28,765
Alternative Projects														
Lower McGregor	2,463.3	60,700	20,300	10,000	91,000	3	125,000	333	400	3	92,000	276,000	5	180,390
Hobson Lake	2,883.0	21,000	3,600	2,000	26,600	1	120,000	489	548	1	72,000	72,000	4	49,290

NOTES:
(1) Emergency overflow structure and high and low level outlets.
(2) Generation capacity increased from 97,500 kW provided in original System E design for greater output when reservoir is at or near maximum operating elevation. New turbines are not required. Estimated extra cost of $793,000 for larger generators is only 0.7% of the $119,225,000 total, and can be absorbed therein.
(3) Upper generating station.
(4) Lower generating station.
(5) Equivalent to that at Hemp Creek.

4.3.1 Lower McGregor Diversion (104)

This project consists of a dam and associated works located in the Lower Canyon of the McGregor River, about 20 miles upstream from its confluence with the Fraser River and 50 miles northeast of Prince George; and a diversion to the Peace River system via James Creek and the Parsnip River. Project data are shown in Table 4-6 and the general project arrangement on Plates 4-5 to 4-8.

The McGregor River - Peace River diversion route is via James Creek and Pacific and Portage Lakes through the divide to Arctic Lake near the headwaters of the Parsnip River, which flows into Williston Lake (Plate 4-8). A spillway structure would be installed at the divide to reduce channel scour during passage of McGregor River flood flows, and to prevent the migration of pike from the Peace River system to the Fraser River system. This structure, with crest elevation of 2,455 feet and crest length of 450 feet, would be protected against erosion by a concrete wall across its downstream end extending 30 feet below the water surface.

The reservoir created by the project would extend some 45 miles upstream on the McGregor River, and about 25 miles upstream on Herrick Creek from the McGregor-Herrick confluence. The diversion would carry the probable maximum flood peak inflow of 182,000 cfs without raising the reservoir elevation beyond 2,480.3 feet (Reference: Annex II, 4-10). However, if the diversion were blocked the emergency overflow structure and the low level and high level outlets would carry this peak inflow without raising the reservoir elevation above 2,493.2 feet, which is 1.8 feet below the crest of the dam as designed; the crest could be raised a minor amount if considered necessary.

Future return of McGregor River water to its natural course downstream from the main dam, if desirable, could be through a hydroelectric power generating station. The design provides sufficient space for intakes and tunnels through the left abutment, and for a generating station on the left bank downstream from the diversion tunnel outlet. Minor rock benching 400 feet northeast of the left abutment could be done during main dam construction to facilitate future underground power intake excavation under full reservoir conditions.

The project construction schedule extends over a five-year period. The estimated total capital cost, based on mid-1972 price levels, is $136.4 millions, as shown in Table 4-7.

TABLE 4-7

LOWER McGREGOR DIVERSION PROJECT COST ESTIMATE

Item	Estimated Cost
	($1,000)
Reservoir Clearing	8,500
Flowage	7,200
Access and Site Preparation	5,100
Diversion Tunnel and Low Level Outlet	15,300
Main Dam	37,500
Cutoff Trench, Blanket and Slope Protection	10,500
Emergency Overflow Structure and High Level Outlet	5,300
Excavation for Future Power Intake	600
Divide Channels and Spillway	7,000
Total Direct Cost	97,000
Engineering and Administration	9,700
Contingencies	10,670
Total Construction Cost	117,370
Interest During Construction	19,075
Total Capital Cost	136,445

4.3.2 Grand Canyon (111)

This project consists of a dam, fishway and generating station located on the Fraser River about one mile downstream from the entrance to the Grand Canyon, eight miles upstream from Sinclair Mills and 50 miles east of Prince George; and a low saddle dam near Longworth, about eight miles upstream from the main structure. Project data are shown in Table 4-6 and the general project arrangement on Plate 4-9. This site was selected from three possible alternatives in this reach of the Fraser River: Grand Canyon, Olsson Creek and Giscome Canyon (Reference: Annex II, 4-11).

The reservoir created by the project would extend 50 miles upstream to the vicinity of Crescent Spur. The probable maximum flood peak inflow of 295,000 cfs would be passed by the discharge facilities without raising the reservoir elevation above 2,135.6 feet, which is 4.4 feet below the crest of the dam (Reference: Annex II, 4-10).

The spillway located in the main river channel would discharge into pondage created by a low concrete barrier dam upstream from the tailrace. Entrance from the river to the fishway on the left bank would be through a junction pool adjacent to the barrier dam. The tailrace area on the right bank would be connected to the junction pool by a transportation conduit in the barrier dam. The auxiliary water supply required during the adult fish migration period would be provided from the pondage created by the barrier dam.

The project construction schedule extends over a three-year period. The estimated total project cost, based on mid-1972 price levels, is $119.2 millions, as shown in Table 4-8.

TABLE 4-8

GRAND CANYON PROJECT COST ESTIMATE

Item	Estimated Cost
	($1,000)
Reservoir Clearing	17,340
Flowage	20,330
Access and Site Preparation	485
Diversion	2,035
Saddle Dam	2,530
Main Dam, Spillway, and Fishway Exit	15,500
Power Intake	10,010
Generating Station	5,770
Generating Station Equipment	11,045
Outlet Works	2,660
Fish Facilities and Barrier Dam	1,905
Switchyard	25
Permanent Staff Housing	165
Total Direct Cost	89,780
Engineering and Administration	8,980
Contingencies	9,875
Total Construction Cost	108,635
Interest During Construction	10,590
Total Capital Cost	119,225

4.3.3 Cariboo Falls (89)

This project consists of a main dam and a saddle dam located on the Cariboo River about two and one-half miles downstream from Cariboo Lake, eight miles northeast of Likely and 45 miles southeast of Quesnel, together with a generating station on the left bank of the river about 2,000 feet downstream from the dam. Project data are shown in Table 4-6 and the general project arrangement on Plate 4-10.

The reservoir created by the project would include Cariboo Lake and about 14 miles of the Cariboo River channel upstream from the Lake. The probable maximum flood peak inflow of 66,000 cfs is less than the total discharge capacity; hence the design could be modified by reducing the size of the spillway channel, and that of the two gates to one-half of their present capacity. The resulting total discharge capacity would carry the probable maximum flood peak inflow without raising the reservoir elevation above 2,837.0 feet, which is 3.0 feet below the crest of the dam (Reference: Annex II, 4-10).

The project construction schedule extends over a three-year period. The estimated total project cost, based on mid-1972 price levels, is $55.3 millions, as shown on Table 4-9.

TABLE 4-9

CARIBOO FALLS PROJECT COST ESTIMATE

Item	Estimated Cost
	($1,000)
Reservoir Clearing	4,300
Flowage	630
Access and Site Preparation	930
Diversion	1,840
Main Dam	3,495
Saddle Dam	2,120
Spillway	4,800
Power Intake	3,025
Power Conduits	4,170
Generating Station	2,540
Generating Station Equipment	10,870
Control Works	2,645
Switchyard	100
Permanent Staff Housing	205
Total Direct Cost	41,670
Engineering and Administration	4,165
Contingencies	4,585
Total Construction Cost	50,420
Interest During Construction	4,915
Total Capital Cost	55,335

4.3.4 Hobson Lake (153)

This is the farthest upstream of the three storage and power projects on the Clearwater River, all of which are situated within or adjacent to Wells Gray Provincial Park. Two additional power projects are located on the Clearwater River downstream from the southern boundary of the Park.

The Hobson Lake project is located on the Clearwater River 60 miles upstream from its confluence with the North Thompson River and 120 miles north of Kamloops. It consists of a main concrete buttress dam containing the spillway, nearly one mile downstream from Hobson Lake; a concrete arch dam on Lickskillet Creek, which enters the Clearwater River about one and one-half miles downstream from the main dam; an underground generating station near the left bank of Lickskillet Creek; and a secondary rockfill dam at Summit Lake, in a low valley leading from the northwestern shore of Hobson Lake to the Quesnel Lake drainage. Project data are shown in Table 4-6, and the general arrangement on Plate 4-11.

The reservoir created by the project would include Hobson Lake and three miles of the Clearwater River upstream from the Lake. The probable maximum flood peak inflow of 29,000 cfs is less than the total discharge capacity; hence the design could be modified by replacing the four spillway gates with two somewhat smaller ones, so that the resulting total discharge capacity would carry the probable maximum flood peak inflow without raising the reservoir elevation above 2,880 feet, which is 3.0 feet below the crest of the dam (Reference: Annex II, 4-10).

The project construction schedule extends over a four-year period. The estimated total project cost, based on mid-1972 price levels, is $49.4 millions, as shown in Table 4-10.

The much greater rise in cost of concrete construction than in that for earthwork during the period from 1963 to 1972 prompted examination of one of the System E projects to determine whether a substantial saving in cost could be achieved through replacement of concrete dams by earthfill or rockfill ones. Hobson Lake was selected for this purpose, as suitable materials for earthfill construction are available within reasonable haul distance of the site.

The main concrete buttress dam containing the spillway was replaced by an earthfill dam and separate concrete spillway. The Lickskillet Creek concrete arch dam was not changed, as the site was not considered suitable for an earthfill structure without extensive excavation. The spillway structure capacity was reduced from that of the original design, which had been shown to be of much larger capacity than necessary. Project data are shown in Table 4-6, and the changes in the original general arrangement on Plate 4-12.

The construction schedule for the revised project extends over a four-year period. The estimated total project cost, based on mid-1972 price levels, is $49.3 millions, as shown in Table 4-10.

The difference in estimated total cost between the original and the revised designs is less than one-quarter of one percent, without allowing for possible lowering of the original design cost by reduction of the spillway capacity as outlined above. It is apparent that no saving in cost would be achieved through replacement of the concrete main dam by an earthfill one.

TABLE 4-10

HOBSON LAKE PROJECT COST ESTIMATES

Item	Estimated Cost	
	Concrete Main Dam	Earthfill Main Dam
	($1,000)	($1,000)
Reservoir Clearing	3,965	3,965
Flowage	Nil	Nil
Access and Site Preparation	1,805	1,805
Diversion	450	980
Concrete Main Dam and Spillway	4,145	-
Earthfill Main Dam	-	1,525
Spillway	-	1,520
Summit Lake Rockfill Dam	2,960	2,960
Lickskillet Arch Dam	2,460	2,460
Power Tunnel Intake	1,065	1,065
Surge Tunnel Intake	750	750
Power Tunnel and Penstock	6,270	6,270
Surge Tunnel	1,075	1,075
Generating Station	3,080	3,080
Generating Station Equipment	4,520	4,520
Tailrace Tunnel	2,255	2,255
Tailrace Channel	1,170	1,170
Outlet Works	-	490
Switchyard	105	105
Permanent Staff Housing	55	55
Total Direct Cost	36,130	36,050
Engineering and Administration	3,615	3,605
Contingencies	3,975	3,965
Total Construction Cost	43,720	43,620
Interest During Construction	5,685	5,670
Total Capital Cost	49,405	49,290

4.3.5 Clearwater-Azure (142A)

This is the second of the three storage and power projects on the Clearwater River along its southerly course through Wells Gray Provincial Park.

The Clearwater-Azure project is located on the Clearwater River 40 miles upstream from its confluence with the North Thompson River and 100 miles north of Kamloops. It consists of the main dam and upper generating station three miles downstream from Clearwater Lake, three saddle dams upstream from the main dam, a diversion dam downstream from the main dam, and a power canal leading to the lower generating station. Project data are shown in Table 4-6 and the general arrangement on Plates 4-13 and 4-14.

The reservoir created by the project would include Clearwater and Azure Lakes, and extend upstream to the tailrace of the Hobson Lake Generating Station (4.3.4). The probable maximum flood peak inflow of 91,000 cfs could be carried by the total discharge capacity without raising the reservoir elevation above 2,382.4 feet, which is 12.6 feet below the crest of the dam; hence the design could be modified by reducing the spillway width to 230 feet. The resulting total discharge capacity would then carry the probable maximum flood peak inflow without raising the reservoir elevation beyond 2,388.5 feet, which is 6.5 feet below the crest of the dam. Some further reduction in spillway width might be considered in the final design (Reference: Annex II, 4-10).

The upper generating station discharge would be diverted from the river channel by a rockfill dam with crest elevation of 2,163 feet, built about 4,000 feet downstream from the main dam and immediately upstream from the reservoir spillway discharge re-entry point. A power canal on the left bank extending 6,000 feet downstream from the rockfill dam would convey the water to the lower generating station. This power canal with bottom elevation of 2,113 to 2,115 feet would carry only the maximum upper generating station discharge, and would contain an ungated spillway 300 feet wide with crest elevation of 2,154 feet and an adjacent sluiceway containing three gates 9 feet wide by 15 feet high with sill elevation of 2,144 feet to return releases from the upstream site outlet works to the river.

The project construction schedule extends over a four-year period, with construction at the upper and lower sites being undertaken simultaneously. The estimated total project cost, based on mid-1972 price levels, is $91.6 millions, as shown in Table 4-11.

TABLE 4-11

CLEARWATER-AZURE PROJECT COST ESTIMATE

Item	Estimated Cost
	($1,000)
Reservoir Clearing	3,455
Flowage	100
Access and Site Preparation	1,685
Upper Development	
Diversion	4,445
Main Dam	6,260
Saddle Dams	2,395
Spillway	9,820
Power Intake	1,615
Power Tunnel and Penstocks	2,475
Generating Station	2,865
Generating Station Equipment	8,205
Control Works	3,880
Switchyard	45
Lower Development	
Diversion	95
Canal Entrance	480
Spillway	305
Power Canal and Forebay	3,860
Intake Bulkhead and Penstocks	5,995
Generating Station	2,725
Generating Station Equipment	6,200
Switchyard	20
Permanent Staff Housing	55
Total Direct Cost	66,980
Engineering and Administration	6,700
Contingencies	7,370
Total Construction Cost	81,050
Interest During Construction	10,535
Total Capital Cost	91,585

4.3.6 Hemp Creek (142)

This is the farthest downstream of the three storage and power projects on the Clearwater River in its course through Wells Gray Provincial Park. Most of the reservoir would be within the Park, although the project structures would be situated a short distance downstream from its southern boundary. Project data are shown in Table 4-6 and the general project arrangement on Plate 4-15.

The Hemp Creek project consists of a dam and generating station located on the Clearwater River 15 miles upstream from its confluence with the North Thompson River and 80 miles north of Kamloops.

The reservoir created by the project would extend about 20 miles upstream on the Clearwater River a short distance above its confluence with the Murtle River. The probable maximum flood peak inflow of 136,000 cfs is less than the total discharge capacity; hence the design could be modified by reducing the size of the spillway channel and replacing the five gates with three somewhat smaller ones or two larger ones, so that the resulting total discharge capacity would carry the probable maximum flood peak inflow without raising the reservoir elevation above 2,015.0 feet, which is 5.0 feet below the crest of the dam (Reference: Annex II, 4-10).

The project construction schedule extends over a five-year period. The estimated total project cost, based on mid-1972 price levels, is $154.2 millions, as shown in Table 4-12.

TABLE 4-12

HEMP CREEK PROJECT COST ESTIMATE

Item	Estimated Cost
	($1,000)
Reservoir Clearing	2,125
Flowage	85
Access and Site Preparation	1,930
Diversion	10,215
Spillway	9,970
Dam	26,730
Grouting	9,045
Power Intakes and Gateshaft	4,110
Power Tunnel and Penstocks	6,770
Generating Station	7,970
Generation Station Equipment	19,850
Control Works Intake and Gateshaft	2,050
Control Works Tunnel	4,225
Control Works	3,535
Switchyard	410
Permanent Staff Housing	620
Total Direct Cost	109,640
Engineering and Administration	10,965
Contingencies	12,060
Total Construction Cost	132,665
Interest During Construction	21,560
Total Capital Cost	154,225

4.3.7 Granite Canyon (194A)

This is the upper of two run-of-river power projects on the Clearwater River downstream from the Hemp Creek storage and power project (4.3.6). Energy production at these two projects would depend on the rate of discharge from the Hemp Creek project.

The Granite Canyon project consists of a dam and generating station located on the Clearwater River six miles upstream from its confluence with the North Thompson River and 72 miles north of Kamloops. The site is near the upper end of a canyon where a small island divides the river into two channels. Project data are shown in Table 4-6 and the general project arrangement on Plate 4-16.

The 585-acre headpond would have a normal maximum elevation of 1,585 feet, with inflow thereto being regulated by Hemp Creek operation. The spillway capacity provided at Granite Canyon was based on the spillway capacity at Hemp Creek; and reduction of the latter as proposed in 4.3.6 would indicate a corresponding reduction in the Granite Canyon spillway section.

The project construction schedule extends over a two and one-half year period. The estimated total project cost, based on mid-1972 price levels, is $62.0 millions as shown in Table 4-13.

TABLE 4-13

GRANITE CANYON PROJECT COST ESTIMATE

Item	Estimated Cost
	($1,000)
Reservoir Clearing	225
Flowage	Nil
Access and Site Preparation	350
Diversion	380
Earth Dam	1,455
Intake	18,410
Spillway	13,175
Generating Station	2,315
Generating Station Equipment	10,325
Switchyard	15
Permanent Staff Housing	55
Total Direct Cost	46,705
Engineering and Administration	4,670
Contingencies	5,140
Total Construction Cost	56,515
Interest During Construction	5,510
Total Capital Cost	62,025

4.3.8 Clearwater (141)

This is the lower of two run-of-river projects on the Clearwater River, where energy production would depend on the rate of discharge from the Hemp Creek project upstream.

The Clearwater project consists of a dam and generating station located at the head of a short rock-walled canyon on the Clearwater River three miles upstream from its confluence with the North Thompson River and 70 miles north of Kamloops. Project data are shown in Table 4-6, and the general project arrangement on Plate 4-17.

The 160-acre headpond would have a normal maximum elevation of 1,405 feet, with inflow thereto being regulated by Hemp Creek operation. The spillway capacity provided at Clearwater was identical to that provided at Granite Canyon; and reduction of the latter as proposed in 4.3.7 would indicate a corresponding reduction in the Clearwater spillway section.

The project construction schedule extends over a three and one-half year period. The estimated total project cost is $28.8 millions, based on mid-1972 price levels, as shown in Table 4-14.

TABLE 4-14

CLEARWATER PROJECT COST ESTIMATE

Item	Estimated Cost
	($1,000)
Reservoir Clearing	70
Flowage	Nil
Access and Preparation	110
Diversion	2,360
Spillway	5,430
Impervious Blanket	715
Power Canal and Intake Bulkhead	2,040
Generating Station	4,555
Generating Station Equipment	5,965
Switchyard	25
Permanent Staff Housing	70
Total Direct Cost	21,340
Engineering and Administration	2,135
Contingencies	2,350
Total Construction Cost	25,825
Interest During Construction	2,940
Total Capital Cost	28,765

4.4 Other Projects

Several alternative possibilities for upstream storage and channel improvements were examined during this review of the Fraser River Board's System E program. These included a Lower McGregor non-diversion project, improvements to the outlet of Kamloops Lake, and the provision of negative storage or a combination of positive and negative storage on Stuart, Quesnel, and the Clearwater Basin Lakes. Examination of these alternatives was preliminary in scope, but was sufficient to determine whether any of them warranted further consideration.

4.4.1 Lower McGregor Non-Diversion

In earlier studies described in its 1958 Preliminary Report, the Fraser River Board had formulated its System A program, which included Lower McGregor as a non-diversion project. System E as presented by this Board in 1963 was evolved from System A, but included a Lower McGregor diversion project similar to the one described in 4.3.1. Review and updating of the non-diversion project has been conducted to allow comparison of the respective merits of each of these alternative development possibilities.

This non-diversion project consists of a dam and generating station in essentially the same location as that proposed for the main dam of the diversion project, in the Lower Canyon of the McGregor River about 20 miles upstream from its confluence with the Fraser River and 50 miles northeast of Prince George; and a small saddle dam located at the divide between Portage and Arctic Lakes. Project data are shown in Table 4-6, and the general arrangement on Plate 4-18.

The reservoir created by the project would extend more than 40 miles upstream on the McGregor River, and more than 20 miles upstream on Herrick Creek from the McGregor-Herrick confluence. The discharge facilities would carry the probable maximum flood peak inflow of 182,000 cfs without raising the reservoir level above 2,463.3 feet, which is 11.7 feet below the crest of the dam (Reference: Annex II, 4-10).

The project construction schedule extends over a five-year period. The estimated total project cost, based on mid-1972 price levels, is $180.4 millions, as shown in Table 4-15.

TABLE 4-15

LOWER McGREGOR NON-DIVERSION PROJECT COST ESTIMATE

Item	Estimated Cost
	($1,000)
Reservoir Clearing	11,000
Flowage	Nil
Access and Site Preparation	3,100
Diversion Tunnel	10,550
Main Dam	30,300
Saddle Dam at Divide	50
Right Bank Cutoff	18,200
Spillway	6,155
Outlet Works	4,855
Power Intake	16,460
Penstocks	5,975
Generating Station	7,930
Generating Station Equipment	13,555
Switchyard	75
Permanent Staff Housing	45
Total Direct Cost	128,250
Engineering and Administration	12,825
Contingencies	14,110
Total Construction Cost	155,185
Interest During Construction	25,205
Total Capital Cost	180,390

The $11 millions figure given in Table 4-15 above for the estimated cost of reservoir clearing was provided by the British Columbia Forest Service as a revision of the $6.5 millions figure used in preparing the original cost estimate (Reference: Annex II, 4-8).

The total capital cost figures of $136.4 millions given in 4.3.1 for the Lower McGregor Diversion project and of $180.4 millions given above for the alternative non-diversion project are not directly comparable, as the former figure includes no costs for generation facilities. The estimated total capital cost of the storage features of the non-diversion project is $118.4 millions. As a storage project it might be comparable in some respects with the diversion project; but it would not provide water for additional generation at existing stations.

The figure of $118.4 millions should not be considered to represent the cost of a project designed to provide flood control only, as the total live storage capacity provided by the non-diversion project is greater than the project flood control storage requirement. A single-purpose flood control project at this site would require a smaller dam and probably lesser seepage control treatment, with a consequent reduction in cost from the $118.4 millions figure. No design and cost estimate were made for this smaller project, as it still would involve a relatively large investment providing for no use of the storage except on an occasional basis for flood control purposes. The higher cost and lesser benefits of the non-diversion project, when compared to those of the diversion project, indicated that the non-diversion project did not warrant further consideration.

4.4.2 Negative Storage Possibilities

The risk of recurring flood plain inundation in the Lower Fraser Valley and at Kamloops, Prince George and Quesnel can be reduced to some extent by the construction of dykes and associated works. Further reduction of this risk requires the development of headwater diversions and/or the creation of upstream storage. The construction of dams for either of these purposes has varying ecological and environmental consequences on local and regional resources. The provision of negative storage capacity beneath the normal surface elevations of existing lakes may have lesser consequences on the natural environment.

4.4.2.1 Stuart and Quesnel Lakes

Two of the largest natural lakes in the Fraser River system are Stuart and Quesnel Lakes, with approximate surface areas of 89,000 and 67,000 acres, respectively. These lakes are an attractive size for possible negative or positive storage development; but they both are on the routes of major salmon runs. The creation of storage on either of them would result in river flow regime changes and interference with free passage of the upbound adult spawners and the downbound smolts. These resulting effects were deemed to be so adverse as to preclude further consideration of these lakes for storage purposes.

4.4.2.2 Clearwater River System Lakes

Five Clearwater River system lakes were examined for possible creation of negative storage: Murtle, Hobson, Clearwater, Azure and Mahood. All of these lakes are within Wells Gray Park; and the creation of positive storage on any of them would cause substantial disturbance to the natural environment of this Class A Provincial Park. The Clearwater River system does not contain any major salmon spawning areas nor form part of any important salmon migration route.

Flood control storage in the Clearwater River system would have substantial effect in the Kamloops area about 100 miles downstream, and lesser effect in the Lower Fraser Valley some 300 miles away. Preliminary examination of negative storage possibilities (Reference: Annex II, 4-12) therefore was based on the provision of sufficient storage capacity to reduce the Thompson River at Kamloops 1894 flood peak of about 300 years average recurrence to the 1972 freshet peak of about 30 years average recurrence. This reduction from an estimated peak water elevation of 1,138.1 feet msl and flow of 178,000 cfs to the 1972 recorded peak elevation of 1,132.4 feet msl and flow of 148,000 cfs would require storage capable of lowering the peak flow by 30,000 cfs. Such a peak flow reduction at Kamloops would lower the 1894 flood peak at Mission by perhaps 0.2 to 0.3 feet. Analysis indicated that accomplishment of this 30,000 cfs peak flow reduction would require more than 400,000 acre-feet of negative storage, the specific amount depending on the natural inflows and the outlet capacities provided at the selected storage locations.

All negative storage would be beneath the natural high water levels of the lakes, with adequate outlet control works provided to lower lake levels to their maximum drawdown condition prior to the onset of forecast high freshet occurrence, the available storage then being used at the approach of maximum runoff conditions. Full use of the storage would be infrequent, possibly once in 10 years on the average.

Each project would consist of gated outlet control works capable of passing stipulated flows at maximum drawdown level and of eliminating outflows from the lake between maximum drawdown and full storage levels, the latter being the natural high water levels. An ungated overflow weir would be incorporated in each project where practical to provide self-regulation of lake levels during the extended periods when storage would not be required for flood control. The weir crest level would be such that natural high water level would not normally be exceeded during periods of heavy runoff. Flashboards would be provided for installation on the weir crest when forecasts indicated the need for the full range of flood control storage.

During the examination it became apparent that the construction of the required outlet control works for Azure Lake would not be practicable. The small difference (five to eight feet) between Azure Lake levels and those of Clearwater Lake immediately downstream would necessitate very extensive dredging of the connecting channel to establish a drawdown level for Azure Lake sufficiently below its natural low water level to provide appreciable negative storage. This site therefore was given no further consideration.

The Wells Gray Park location of these projects requires that their visual impact be minimal. The possibility of eliminating the overflow weirs from the project designs through lowering the outlet works was examined by limited review of the designs for Clearwater and Mahood Lakes. The Clearwater Lake outlet channel would require substantial lengthening and deepening in rock; the resulting cost increase and the greater visual impact of the extended channel adjacent to a Provincial campground were considered to make this alteration impractical. The Mahood Lake outlet tunnel and works could be lowered without adverse visual impact; but the required additional length of tunnel and related channel improvements downstream would drastically increase the project cost. Partial lowering of the outlet works at either project would not be as costly as full lowering; but it would not provide the same amount of controlled storage. Thus more projects or larger ones would be required to achieve the proposed degree of flood control. It was concluded that elimination of the overflow weirs is not a practical alternative.

Project data for the designs incorporating overflow weirs are given in Table 4-16 for Hobson, Clearwater, Murtle and Mahood Lakes. These data include two storage capacities at Hobson Lake, and one at each of the other three locations. A two-year construction period was estimated for each project; however, several of them could be built during the same period. Estimated costs are based on mid-1972 price levels, and the method of cost derivation is outlined in 3.7.3.

TABLE 4-16

NEGATIVE STORAGE PROJECT DATA

Lake	Surface Area	Approximate Natural Levels(1)		Daily Flow at Outlet(2)		
		High	Low	Maximum	Average of Maxima	Minimum
	(acres)	(feet)	(feet)	(cfs)	(cfs)	(cfs)
Hobson	8,600	2,820	2,810	10,300	6,800	181
Hobson	8,600	2,820	2,810	10,300	6,800	181
Clearwater	8,500	2,228	2,218	31,300	23,800	520
Murtle	19,100	3,502	3,495	11,000	7,100	182
Mahood	8,000	2,059	2,051	9,630	5,700	56

Lake	Outlet Works					Overflow Weir		
	Capacity at Max. Drawdown Level	Gates				Length	Crest Level	Flash-Board Height
		No.	Width	Height	Sill Level			
	(cfs)		(feet)	(feet)	(feet)	(feet)	(feet)	(feet)
Hobson	8,700	5	30	35	2,790	150	2,817.0	3.0
Hobson	8,700	5	30	20	2,805	150	2,817.0	3.0
Clearwater	30,000	6	28	28	2,205	600	2,222.5	5.5
Murtle	11,000	3	30	28	3,477	150	3,496.0	6.0
Mahood	8,000	1	21	21	2,012(3)	120	2,053.0	6.0

Lake	Negative Storage				Estimated Capital Cost(4)
	Maximum Drawdown Level	Storage Range	Full Storage Level	Capacity	
	(feet)	(feet)	(feet)	(1,000af)	($1,000)
Hobson	2,797	23	2,820	198	17,070
Hobson	2,812	8	2,820	69	10,070
Clearwater	2,218	10	2,228	85	6,370
Murtle	3,491	11	3,502	210	8,510
Mahood	2,039	20	2,059	160	3,890

NOTES: (1) Obtained from topographic maps--precise msl elevations not available.
(2) Obtained or computed from published records.
(3) Tunnel outlet--others are open channels.
(4) At mid-1972 price levels.

The projects for which data are given in Table 4-16 were selected for examination from the numerous variations of outlet capacity and related storage capacity tested for each site during the analysis; and several combinations of these projects would provide the required 30,000 cfs peak flow reduction at Kamloops. Three of the most likely combinations are shown in Table 4-17.

TABLE 4-17

NEGATIVE STORAGE PROJECT COMBINATIONS

Combination	Lake	Storage		Estimated Capital Cost
		Range	Capacity	
		(feet)	(1,000 af)	($1,000)
A	Hobson	8	69	10,070
	Clearwater	10	85	6,370
	Murtle	11	210	8,510
	Mahood	20	160	3,890
	Total		524	28,840
B	Hobson	23	198	17,070
	Murtle	11	210	8,510
	Mahood	20	160	3,890
	Total		568	29,470
C	Hobson	23	198	17,070
	Clearwater	10	85	6,370
	Murtle	11	210	8,510
	Total		493	31,950

Each combination in Table 4-17 would cost about $30 millions and would accomplish the required 30,000 cfs peak flow reduction at Kamloops. No further consideration of these negative storage possibilities appeared to be warranted, in view of their high cost and adverse environmental effect on Wells Gray Park to provide a limited measure of flood control downstream.

4.4.3 Kamloops Lake Outlet Improvement

High water elevations at Kamloops are increased to some extent by the backwater effect which occurs naturally on Kamloops Lake during excessive inflow periods. This backwater effect might be reduced by improvement of the existing outlet channel, or by construction of a by-pass channel at the outlet to convey part of the outflow occurring under high runoff conditions.

The Fraser River Board examined the possibility of improving the existing channel at the outlet and for some distance downstream. The extensive channel modification required would be costly and would increase water velocities both upstream and downstream, intensifying the erosion process in this reach where unstable bank areas are numerous. The channel is on the migration route of one of the largest Fraser River salmon runs; and the increased velocities and intensified erosion probably would have an adverse effect on fish migration. This Board therefore concluded that the channel improvement possibility warranted no further consideration (Reference: Annex II, 1-2).

In the present review, preliminary examination was made of the possibility of constructing a by-pass channel at the Kamloops Lake outlet to provide sufficient additional outflow capacity to reduce the 1894 flood peak elevation of the lake to the 1972 freshet peak of about 30 years average recurrence, which was recorded at Savona as 1,129.98 feet msl. This reduction in peak elevation would require by-pass channel capacity in the 37,000 cfs range and total capacity of the natural and by-pass channels in the 180,000 cfs range at lake elevation of 1,130 feet msl.

Reconnaissance of six possible by-pass channel routes indicated that the least costly would be 3,500 feet long, with inlet invert elevation of 1,110 feet msl. The selected route would require about two million cubic yards of excavation, and construction of highway and pipeline crossings. The channel would be trapezoidal in cross-section, with longitudinal slope of 1:700, bottom width of 60 feet, and side slopes of 1:1; it would be concrete-lined to withstand water velocities of up to 25 feet per second. The inlet and outlet works would have concrete wingwalls and aprons; gates in the inlet works would regulate channel use, which would be infrequent, perhaps only once in 10 years.

Data limitations precluded the compilation of a cost estimate sufficiently accurate for benefit-cost analysis, and dictated allowances of 15 percent for engineering and administration and 25 percent for contingencies. It was assumed that the construction period might be three years. A rough estimate of the total project cost, at mid-1972 price levels, is $13.4 millions, as shown in Table 4-18.

TABLE 4-18

KAMLOOPS LAKE OUTLET BY-PASS CHANNEL PROJECT
APPROXIMATE COST ESTIMATE

Item	Estimated Cost
	($1,000)
Right-of-way	30
Channel - Excavation	3,400
- Lining	4,000
- Underdrains and Filter Blanket	150
- Crossings (Highway and Pipeline)	665
Inlet Works and Gates	150
Outlet Works	90
Total Direct Cost	8,485
Engineering and Administration	1,275
Contingencies	2,440
Total Construction Cost	12,200
Interest During Construction	1,200
Total Capital Cost	13,400

Only part of the reduction in backwater effect achieved at Kamloops Lake outlet by construction of a by-pass channel would be felt at Kamloops, which is about 25 miles upstream from the lake outlet. The substantial cost of providing only minor relief to the Kamloops area, which would be limited to periods of extreme flood conditions, indicated that this possibility did not warrant further consideration.

4.4.4 Harrison Lake Regulation

Harrison Lake, with an approximate surface area of 55,000 acres, and with substantial tributary inflow, is strategically located for the development of flood control storage to reduce peak water elevations in the Lower Fraser Valley downstream from Chilliwack. The Harrison Hot Springs townsite and resort area are located on the flood plain at the south end of the lake, near its outlet into the Harrison River, which flows southwesterly about 12 miles to its confluence with the Fraser River. The general flood plain elevation is about 40 feet msl, and it is protected by a dyke with crest elevation approximately 45 feet msl located between the beach foreshore and the main street of the town. Harrison Lake and River are used extensively for log transport and barge supply to lakeshore logging camps and settlements; and they form part of the migration route of the Birkenhead River salmon run, while the lake provides rearing area for salmon spawned in the river tributaries.

Under 1948 water conditions, storage in Harrison Lake could be regulated to reduce the peak water elevation at Mission by up to 1.1 feet, as shown in Table 4-19, considering three regulation possibilities.

TABLE 4-19

FLOOD CONTROL ACCOMPLISHMENT OF HARRISON LAKE REGULATION

ON FRASER RIVER AT MISSION UNDER 1948 WATER CONDITIONS

Level of Development	Daily Mean Water Elevations - 1948			
	Harrison Lake		Fraser River at Mission	
	Maximum	Minimum	Maximum	Reduction
	(feet msl)	(feet msl)	(feet msl)	(feet)
Natural (recorded) Conditions	43.5	28.3	24.87	-
Present Conditions (with Nechako and Bridge Reservoirs)	43.0	28.3	23.87	1.00
With Regulation Possibility				
A - Positive Storage	49.5	28.3	23.36	0.51
B - Positive Storage	63.5	28.3	22.76	1.11
C - Negative Storage and Pumping (15,000 cfs pumps)	43.5	11.2(1)	22.76	1.11

NOTE: (1) Pumping would have commenced on March 1, 1948 to lower the lake to this elevation. In a year of high January-to-April runoff, 15,000 cfs pumping capacity would not have been sufficient to reduce the lake elevation by the required amount. In 1968 the January-to-April runoff was the highest of record, and the minimum lake elevation achieved with 15,000 cfs pumping capacity would have been 21.5 feet msl.

Regulation of Harrison Lake outflow by any of the three possibilities listed in Table 4-19 would necessitate the construction of a dam with spillway, fishway and associated works at the lake outlet, the dam crest height depending on the adopted possibility. The provision of negative storage suggested in possibility C also would require pumping facilities of at least 15,000 cfs capacity, which could be installed adjacent to the dam and spillway.

Possibility A or B would involve the construction of a higher dyke at the south end of the lake; with possibility C, use of the existing dyke would require that it be rebuilt and raised in places to provide adequate freeboard. The existing dyke interferes to some extent with ground floor lake views from the resort facilities; and even minor raising of this dyke at intervals would aggravate this adverse effect.

Minimization of the visual impact of the required dyke and preservation of the aquatic recreational and service facilities would require replacement of the existing dyke in all possibilities with a new paved, lighted and landscaped promenade dyke about one-quarter mile offshore, forming a recreational lagoon fronting on the town. The existing service facilities on the southeast shore would be relocated outside the promenade dyke and adjacent to it, and would be sheltered by a new breakwater. In possibilities A and B the access road to these facilities would be raised above maximum storage level, while in possibility C the new location would be dredged to permit low water access to these facilities.

Elsewhere on Harrison Lake residential and recreational development is confined mainly to the southeast and southwest shores and adjacent offshore islands. Logging camps and operations are distributed around the lakeshore. An Indian reserve with village and church extends along the shore of Little Harrison Lake and over the Lillooet River delta between Harrison and Little Harrison Lakes. Shorelines are relatively steep except at river outlets. Flowage costs arising from impairment of these developments would be substantial for any of the three regulation possibilities; A and B would involve numerous structure and access relocations, while C would require major wharf extensions and a retention weir with fishway at the Lillooet River delta. Many nagivation markers would have to be raised for possibilities A and B, and additional markers would be needed for possibility C.

Data limitations precluded the compilation of cost estimates sufficiently accurate for benefit-cost analysis, and dictated allowances of 15 percent for engineering and administration and 25 percent for contingencies. The rough estimates given in Table 4-20 are based on rockfill dams, concrete spillway structures, fishways and associated works; and in addition, a concrete pumphouse for possibility C. A three-year construction period was assumed in all cases. The estimated total costs of these three possibilities, based on mid-1972 price levels, range from $40.4 millions to $51.7 millions, as shown in Table 4-20.

TABLE 4-20

HARRISON LAKE REGULATION APPROXIMATE COST ESTIMATES

Regulation Possibility	A	B	C
Reduction of 1948 Peak Water Elevation at Mission (feet)	0.5	1.1	1.1
Maximum Harrison Lake Water Elevation (feet msl)	49.5	63.5	43.5
Elevation of Dam Crest (feet msl)	54.0	68.0	49.0
Estimated Cost	($1,000)	($1,000)	($1,000)
Reservoir Clearing	600	2,000	-
Promenade Dyke and Flowage in vicinity of Harrison Hot Springs	5,500	7,000	3,800
Flowage -- elsewhere on Harrison Lake	6,000	7,000	5,000
Control Structure - Dam, Spillway, Fishway and Associated Works	13,500	16,700	12,500
Pumphouse and 15,000 cfs Pumps	-	-	11,500
Total Direct Cost	25,600	32,700	32,800
Engineering and Administration	3,800	4,900	4,900
Contingencies	7,400	9,400	9,400
Total Construction Cost	36,800	47,000	47,100
Interest During Construction	3,600	4,600	4,600
Total Capital Cost	40,400	51,600	51,700

In addition to the foregoing capital cost estimate, possibility C would involve estimated pumping costs of $280,000 for any year when provision of negative storage is necessary.

The foregoing estimates include no specific cost allowance for navigation facilities at the lake outlet. It was assumed that the control structure could be designed to permit water traffic passage at all times except for periods when it must be used for flood control. In 1948, this period would have been from six weeks to two months in June and July for possibilities A and B, respectively; but it would have been about four months from March to June inclusive for possibility C. Flood control operation probably would be required on an average of only one such period in five or ten years; and the periods could be somewhat briefer in those years when flood danger exists, but is of lesser magnitude than in 1948.

If navigation requirements dictate the provision of a separate lock and associated facilities, the additional construction cost might be $15 millions for a lock 300 feet long and 60 feet wide, with eight feet minimum draft and up to 35 feet lift. Provision of a separate lock would not necessarily lengthen the assumed construction period. The annual costs of lock operation might be $100,000, depending on the operational schedule.

Harrison Lake storage regulation could contribute significantly to flood control in the Lower Fraser Valley; but its development and operation undoubtedly would be considered to have adverse effects on the great recreational potential of the area, as well as on water transport and fish rearing and migration. For these reasons it was not given further attention.

CHAPTER 5

POTENTIAL PROJECT ACCOMPLISHMENT

5.1 Flow Regulation by Diversion or Reservoir Operation

The upstream projects considered in this report and listed in Table 4-6 provide flood control either by diversion of tributary river flow from the Fraser River basin or by reservoir storage. These flood control methods differ to some extent, but both are effective in reducing peak river flows and levels downstream.

Total diversion of a river from its natural system, such as that proposed in the Lower McGregor Diversion project, provides the most dependable flood control downstream because the entire flow at the point of diversion, excepting only releases for local or ecological needs, can be removed from the original river system at all times. Such removal throughout the freshet period effects maximum reduction in the main stem flow downstream. Optimum operation for main stem flood control downstream is assured, eliminating any need for detailed forecasts of flows in the diverted stream.

Reservoirs are limited in capacity and frequently cannot store all of their inflow during the entire freshet period; hence their use must be rationed as decided from forecasts of the magnitude and timing of the flood peak downstream, to have their capacity available at the most opportune time to reduce this peak. Reservoirs of small capacity in relation to their inflow require precise operational timing for effective flood control, while more flexible operation is possible for reservoirs with larger capacity-inflow relationships. Two of the reservoirs reported on herein, Grand Canyon and Hemp Creek, possess small capacities in relation to their respective inflows; the remaining project reservoirs have large capacity-inflow relationships, and in all but extreme flood years their flood control effects are limited only by their inflows.

Low level outlet capacity is an important factor in the effectiveness of flood control reservoirs, particularly those with small capacity-inflow relationships. If the outflow capacity is less than the inflow rate prior to the high water period, early reservoir storage occurs, reducing the capacity available for flood control. The small amounts of this involuntary storage found to occur in a few of the years used in the flood control testing procedure were insufficient to have any significant effect on the results of these tests.

All of the flood control tests were conducted using streamflows representing present conditions in the Fraser River system, with regulation of the Nechako River at the Nechako Reservoir and diversion to the Kemano River, and of the Bridge River at the Downton and Carpenter reservoirs. The current Nechako-Kemano development consists of a reservoir with a large capacity-inflow relationship, together with a partial diversion out of the Fraser River system. In years of normal flow some water is released into the Nechako River during the freshet period; but in all recent high water years there has been sufficient reservoir capacity to hold all of the net inflow during the high water period.

Net inflow is the total inflow less the quantity diverted out of the Fraser River system. In all of the flood control test years the Nechako Reservoir could be operated to withhold all of the net inflow during the entire flood period; and when flood control was desired it was assumed that there would be no spill from the reservoir into the Fraser River system. The Bridge River reservoirs also have large capacity-inflow relationships; and under normal operation they store all of the inflow throughout the flood period except releases for power generation purposes.

5.2 Flood Routing and Flood Forecasting

The methods used for flood routing and flood forecasting were described in 3.2; and the effects of these two factors on the flood control that could be provided by the proposed reservoir and diversion projects are discussed hereunder.

The flood routing effect consists of two components, lag and smoothing, both of which have been simulated in determining the regulated flows that would result from flood control operation of the various projects. Lag is the time required for a specific change of flow to traverse a reach of the river; and the lag component is very important as flow adjustments at the reservoirs are not reflected downstream in the Lower Fraser Valley until several days later. This lag between flood control action at the reservoirs and its effect in the Lower Fraser Valley requires all operating decisions to be made on the basis of streamflow forecasts.

Smoothing of river flow is the reduction in magnitude and expansion in duration downstream of significant and rapid changes in flow upstream; it is caused by changes of stream gradient and channel storage capacity. It is most noticeable in rivers with extensive reaches of gradual gradient and gently sloping banks where any appreciable rise in flow substantially increases the occupied cross-section. Few such reaches occur on the Fraser River main stem upstream from the Lower Fraser Valley, or on its principal tributaries; hence the smoothing component is small and has little overall effect on the regulation process. However, it does tend to compensate to a minor extent for lack of precision in streamflow forecasts. All simulated reservoir operations routed through the river system downstream incorporated both lag and smoothing components in the computation of regulated flows at Mission.

Two types of forecasts are involved in flood control simulations. The long term forecast of seasonal runoff provides a basis for estimating target regulated flows. In most years, these target flows will be higher than the regulated flow that could be utilized if completely accurate forecasts were possible. These target flows also must allow for adequate protection against the worst flood that could occur under the given conditions. The second type of forecast is the short term forecast made a few days in advance, which serves as the basis for decisions to store water. Again, in order to protect against the worst expected condition, these forecasts usually are higher than the flows that actually occur. Although there are errors in the forecasts in terms of predicting actual flows, their use together with a rational set of operating rules gives a realistic simulation of flood control obtainable under actual conditions, while providing protection against the worst likely occurrence.

The loss of efficiency in use of storage in the years when the worst conditions do not occur is the price of such protection. Such loss is small for reservoirs with large capacities relative to their inflows; but it is significant for the Grand Canyon and Hemp Creek reservoirs, which are small in relation to their inflows.

5.3 Characteristics of Flood Control Operation

The System E project storage capacities listed in Table 4-6 were those designed by the Fraser River Board to meet both flood control and power generation requirements. If the design maximum reservoir operating elevations were maintained, the active storage capacities of several of these projects could be reduced and still satisfy flood control requirements without seriously affecting power generation potentials. However, such storage reductions would not achieve significant savings in project costs nor substantial reductions in environmental effects for those projects which provide flood control requirements and incorporate rational designs for power generation. It may be possible to reduce project sizes if power generation facilities are excluded, with some savings in project costs and perhaps some reduction in resource damages.

Table 5-1 illustrates the project flood control storage requirements, which vary from year to year depending upon the forecast volume of the spring freshet. If there is likelihood of a large freshet, a large amount of storage space must be reserved for flood control. Conversely, if there is likelihood of only a small freshet, there may be no need to reserve any flood control storage. The prime criterion is that there be available at the beginning of May (prior to the freshet) enough storage space in the reservoirs to meet the flood threat indicated by the volume of the freshet as forecast early in the year. However, the operating rules used in these studies and described in 3.2 require a small amount of flood control storage to be available in all years to protect against unforeseen events.

The rules governing the reservation of project flood control storage are summarized in Table 5-1. These storage amounts have been selected in relation to the forecast freshet volumes to ensure adequate space for flood control purposes in the simulations of reservoir operation. The reserved storage amounts vary considerably from year to year; and representative amounts are shown in this Table in terms of "large, moderate and small" freshets. In this context, the maximum amount of storage to protect against a large freshet would be required about once in eight years and the amount for a moderate freshet about once in five years; the minimum amount would suffice for about half of all the freshets. The need to provide some protection against possible occurrence of the worst flood that could occur under the given conditions is recognized in these criteria.

The large freshet storage requirements shown in Table 5-1 were used in the studies leading to the derivation of all of the maximum water elevations given in Tables 5-2 to 5-5 inclusive for various recurrence intervals, with the projects in operation individually and in combination.

TABLE 5-1

REPRESENTATIVE STORAGE REQUIREMENTS FOR PROJECT FLOOD CONTROL STORAGE OPERATION

Project	Design Power and Flood Control Storage	Flood Control Storage Required(1) If Forecast Freshet Is			Reservoir Refill Period For Large Freshet Flood Control Storage(3)	Minimum Outflow During Refill Period
		Large (2)	Moderate (2)	Small (2)		
	(Maf)	(Maf)	(Maf)	(Maf)		(cfs)
Hobson Lake	0.81	0.5	0.3	0.2	May 15 - Jun 30	500
Cariboo Falls	1.16	0.8	0.4	0.4	Jun 1 - Jun 30	500
Hemp Creek	0.79	0.8	0.8	0.3	Jun 1 - Jun 20	1,300
Clearwater-Azure	2.26	1.0	0.7	0.3	Jun 1 - Jun 30	500
Lower McGregor Non-Diversion	4.06	2.0	1.0	0.5	Jun 1 - Jun 30	1,000
Grand Canyon	1.96	2.0	1.2	0.8	Jun 1 - Jun 20	1,800

NOTES:
(1) Assumed to be available by May 1 each year.
(2) Recurrence intervals of freshets: large - once in eight years;
moderate - once in five years;
small - once in two years.
(3) Approximate period--assumed to be refilled by July 15 each year.

The periods in which the reservoirs would be storing water varied in each of the simulated freshets, depending upon when the peak occurred and the accuracy of the forecasts of freshet volumes and of daily streamflows. It was assumed that the reservoirs should always be completely refilled by mid-July to satisfy other needs. This criterion was included as a constraint in the operating rules for the simulations. Table 5-1 shows the approximate period in which storing occurs at each reservoir in the large freshet years. These periods might shift five or ten days in time from one year to another, but they would be of the same general duration. Minimum outflows as listed in Table 5-1 were used during these refill periods.

5.4 Potential Flood Control Accomplishment

The flood control accomplishment of each System E diversion or storage project and of the alternative Lower McGregor Non-Diversion storage project was assessed individually and in various project combinations over a wide range of flow conditions. Peak flows as modified by simulated flood control operations of each project and combination were computed for each of four locations in the river system adjacent to developed flood plain areas: Fraser River at Prince George, Quesnel and Mission; and Thompson River at Kamloops. Figures 5-1 and 5-2 illustrate the effects of project flood control operation.

Figure 5-1 depicts the 1948 freshet hydrographs for the Fraser River at Grand Canyon and at Mission: (a) under present conditions (Mission adjusted to incorporate the effects of Nechako and Bridge River reservoir regulation); and (b) modified to include the effects of Grand Canyon project flood control operation. Figure 5-2 contains the 1948 flood period flow hydrographs for each System E diversion or storage project: (a) under present conditions; and (b) modified to include the effects of project flood control operation. This figure also shows the flow hydrograph for Fraser River at Mission for the same period: (a) under present conditions; and (b) modified to include the effects of all of the System E diversion and storage projects in combined flood control operation.

Flood frequency curves based on the modified peak flows derived for each of the four locations defined above were converted to water elevation frequency curves. Tables 5-2 to 5-5, extracted from these curves, give comparable maximum water elevations at key locations for several recurrence intervals under natural and present conditions, and with the various projects operated for flood control individually and in combination, listed in order of increasing flood control effect at Mission. The illustration immediately following Table 5-2 shows these curves for the Fraser River at Mission: under natural conditions; under present conditions; and with the following projects in operation - Lower McGregor (Diversion or Non-Diversion), Grand Canyon, Lower McGregor Diversion and Grand Canyon, and the complete System E. In Table 5-2 the differences between water elevations for "natural conditions" and those for "present conditions" represent the effects at Mission of flood control operation of the existing Nechako River and Bridge River storage developments. Those in Tables 5-4 and 5-5 represent the respective effects at Prince George and Quesnel of Nechako River development operation only, as these communities are upstream from the Bridge River confluence. No significant storage developments exist in the Thompson River system; hence in Table 5-3 water elevations for "natural conditions" at Kamloops are the same as those for "present conditions".

Table 5-6 illustrates the flood control accomplishment of each project individually and in combination assuming the occurrence under natural conditions of the floods that were used as the basis for dyke design in the project described in 4.1 and 4.2. This accomplishment is expressed in terms of reduction of maximum water elevations at Mission, Deas Island, Kamloops, Prince George and Quesnel from those that would occur under present conditions. The elevations at Deas Island are included as being more representative for Richmond and Delta than those upstream at Mission. The average recurrence interval of 140 years at Mission under natural conditions is that for the 1894 flood at that location; for the same flood the average recurrence interval at Hope is 200 years under natural conditions. Data on 1894 flood elevations at Kamloops are fragmentary; but the flood with an average recurrence interval of 300 years gives elevations approximating those believed to have occurred in 1894. No such data exist for Prince George and Quesnel; the flood with an average recurrence interval of 200 years was selected for dyke design as probably being representative of 1894 conditions at these locations.

Table 5-6 shows that either of the two Lower McGregor projects would have greater flood control effect at Prince George than at Quesnel, while the Grand Canyon project would have greater effect at Quesnel than at Prince George. This apparent reverse effect is due to the operating procedure being designed to achieve the greatest possible reduction in the peak flow far downstream at Mission, rather than at intermediate locations such as Prince George and Quesnel. The effect results from the limited storing period available at the Grand Canyon project, where storage capacity is small relative to inflow. The regulated peak at Prince George would in fact occur after the Grand Canyon reservoir had been filled and the entire inflow thereto was being spilled. As this peak moves toward Quesnel it becomes somewhat smoothed by the routing effect, giving a lower regulated peak and hence a greater net peak reduction there than at Prince George.

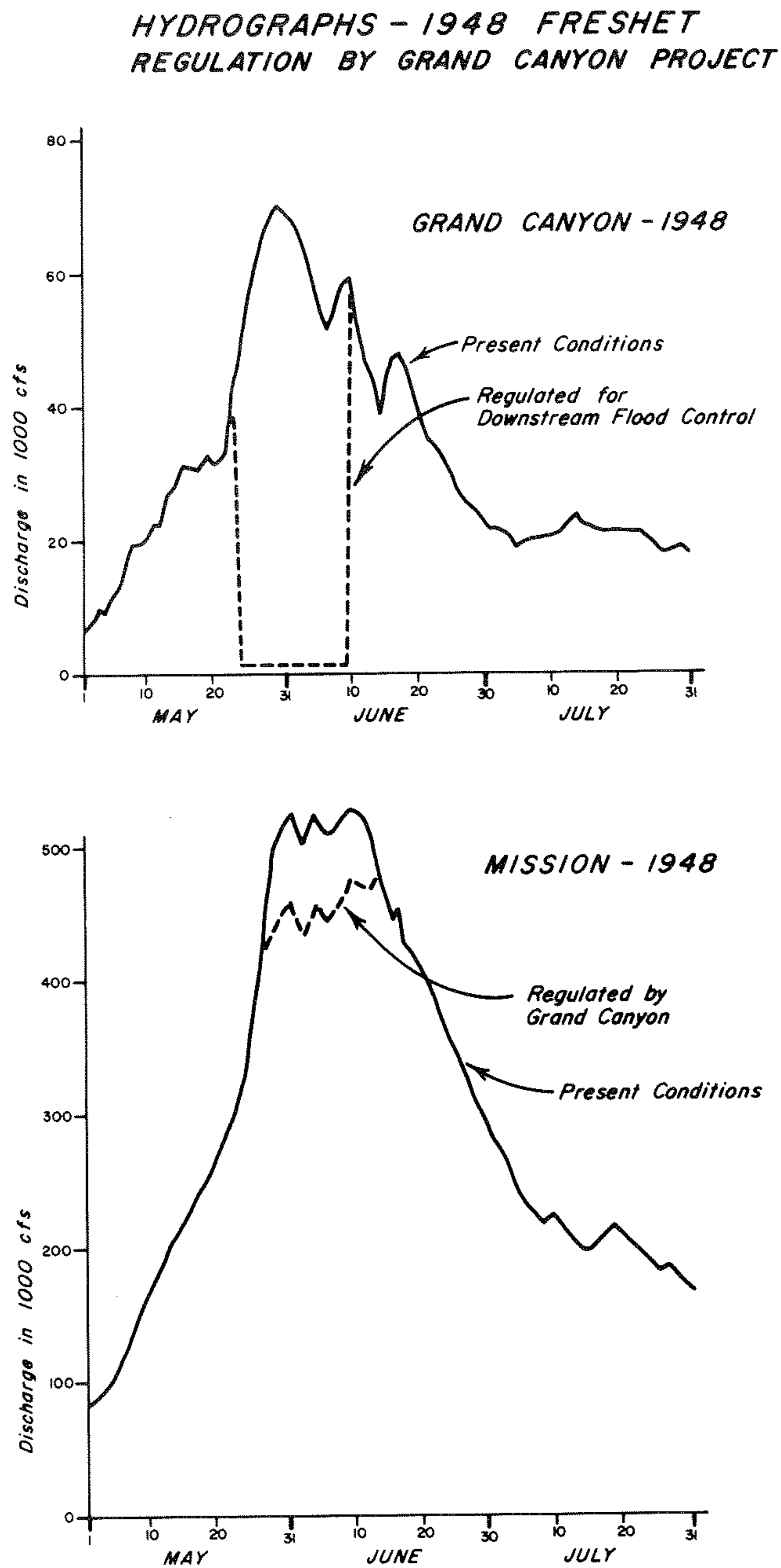

HYDROGRAPHS - 1948 FRESHET
REGULATION BY GRAND CANYON PROJECT
GRAND CANYON - 1948
Present Conditions
Regulated for Downstream Flood Control
Discharge in 1000 cfs
0
20
40
60
80
1
10
20
31
10
20
30
10
20
31
MAY
JUNE
JULY
MISSION - 1948
Regulated by Grand Canyon
Present Conditions
Discharge in 1000 cfs
0
100
200
300
400
500
1
10
20
31
10
20
30
10
20
31
MAY
JUNE
JULY

Figure 5-1

HYDROGRAPHS - 1948 FRESHET
REGULATION BY ALL SYSTEM E PROJECTS

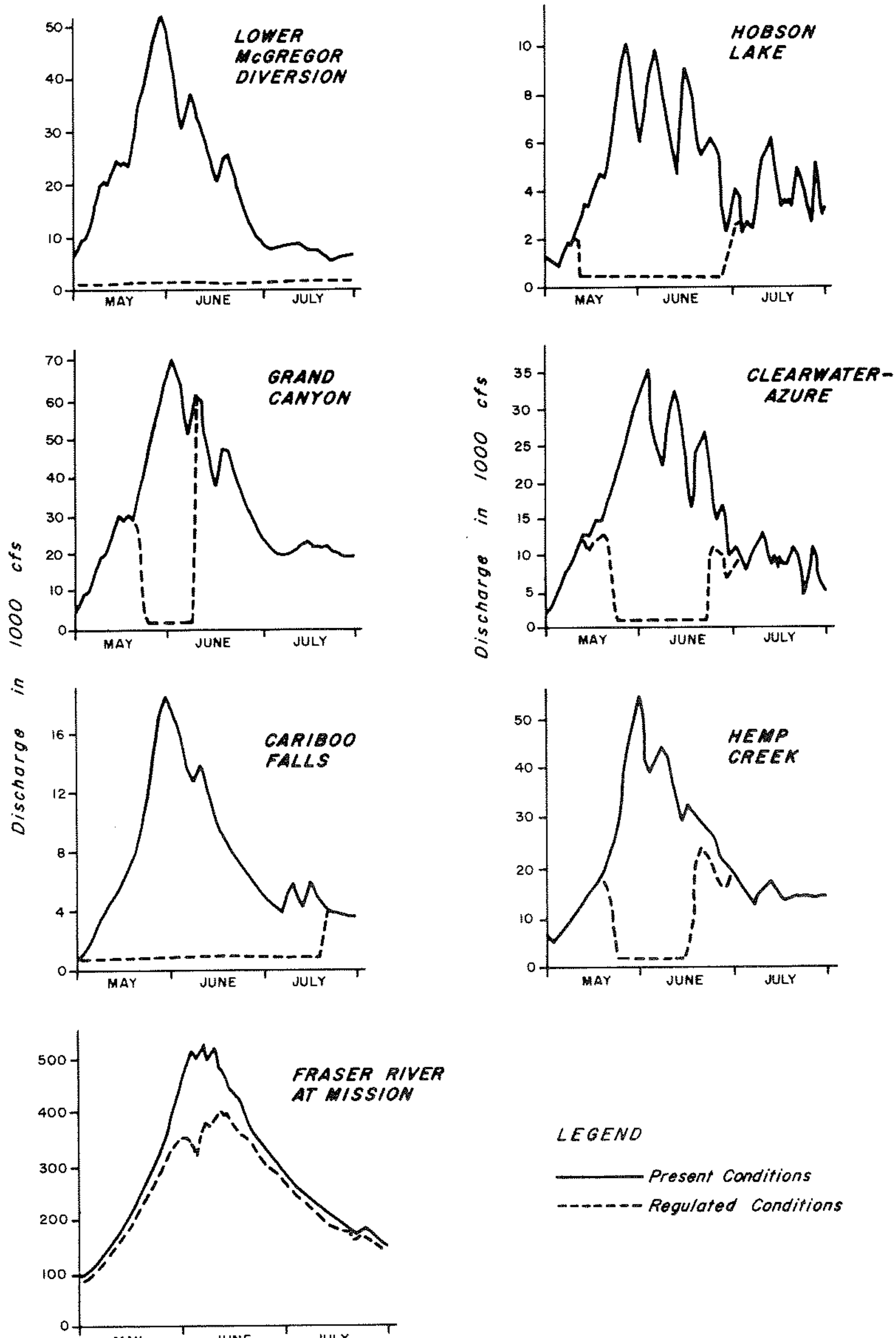


Figure 5-2

TABLE 5-2

FRASER RIVER AT MISSION

MAXIMUM WATER ELEVATIONS FOR VARIOUS RECURRENCE INTERVALS

WITH FLOOD CONTROL OPERATION OF PROJECTS INDIVIDUALLY AND IN COMBINATION

Level of Development	Maximum Water Elevation (feet msl) Average Recurrence Interval (years) 20	50	140	200	1000
Natural Conditions	23.9	25.0	26.0	26.4	27.8
Present Conditions (with Nechako and Bridge Reservoirs)	23.1	24.2	25.3	25.6	27.2
Project(s)					
Hobson Lake	22.9	24.1	25.2	25.5	27.0
Cariboo Falls	22.7	23.9	25.0	25.3	26.8
Hemp Creek	22.6	23.8	24.8	25.2	26.6
Clearwater-Azure	22.5	23.7	24.8	25.2	26.6
Lower McGregor Non-Diversion	22.3	23.5	24.6	25.0	26.4
Lower McGregor Diversion	22.3	23.5	24.6	25.0	26.4
Lower McGregor Diversion and Cariboo Falls	21.8	23.1	24.2	24.6	26.0
Lower McGregor Diversion and Hemp Creek	21.8	23.0	24.2	24.6	26.0
Grand Canyon	21.8	23.0	24.1	24.5	25.8
Grand Canyon and Hemp Creek	21.5	22.8	23.9	24.3	25.7
Lower McGregor Diversion, Cariboo Falls, and Hemp Creek	21.3	22.6	23.8	24.1	25.6
Lower McGregor Diversion and Grand Canyon	20.9	22.3	23.5	23.9	25.3
Complete System E	19.6	21.2	22.6	23.0	24.6

ILLUSTRATION OF TABLE 5-2

FRASER RIVER AT MISSION

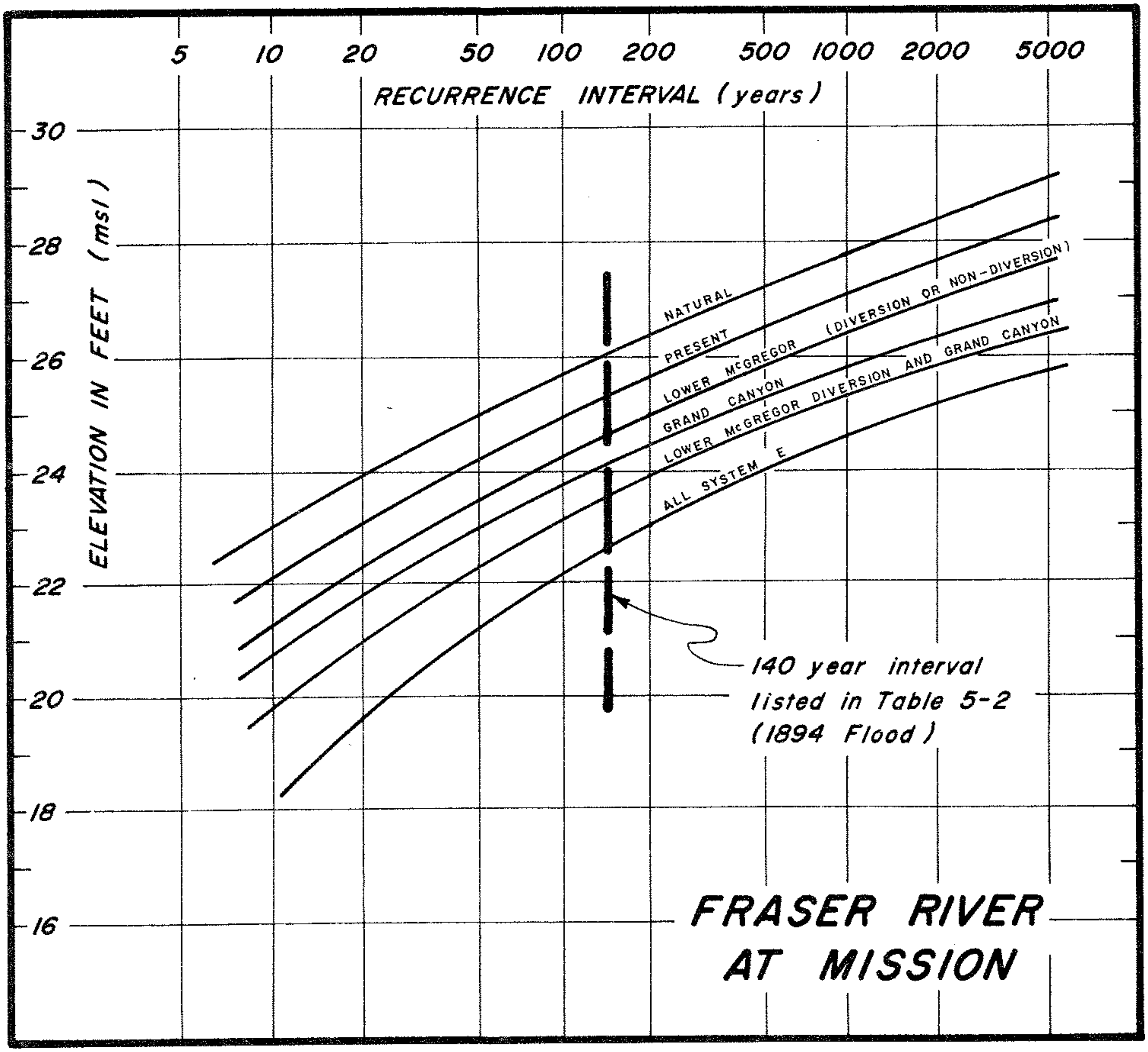


TABLE 5-3

THOMPSON RIVER AT KAMLOOPS

MAXIMUM WATER ELEVATIONS FOR VARIOUS RECURRENCE INTERVALS

WITH FLOOD CONTROL OPERATION OF PROJECTS INDIVIDUALLY AND IN COMBINATION

Level of Development	Maximum Water Elevation (feet msl) Average Recurrence Interval (years) 20	50	300	1000
Natural Conditions	1131.0	1133.2	1138.1	1141.1
Present Conditions (with Nechako and Bridge Reservoirs)	1131.0	1133.2	1138.1	1141.1
Project(s)				
Hobson Lake	1129.9	1131.7	1136.4	1139.3
Cariboo Falls	1131.0	1133.2	1138.1	1141.1
Hemp Creek	1128.0	1128.8	1131.9	1134.1
Clearwater-Azure	1128.6	1129.8	1133.9	1136.6
Lower McGregor Non-Diversion	1131.0	1133.2	1138.1	1141.1
Lower McGregor Diversion	1131.0	1133.2	1138.1	1141.1
Lower McGregor Diversion and Cariboo Falls	1131.0	1133.2	1138.1	1141.1
Lower McGregor Diversion and Hemp Creek	1128.0	1128.8	1131.9	1134.1
Grand Canyon	1131.0	1133.2	1138.1	1141.1
Grand Canyon and Hemp Creek	1128.0	1128.8	1131.9	1134.1
Lower McGregor Diversion, Cariboo Falls, and Hemp Creek	1128.0	1128.8	1131.9	1134.1
Lower McGregor Diversion and Grand Canyon	1131.0	1133.2	1138.1	1141.1
Complete System E	1126.9	1127.9	1130.6	1133.0

TABLE 5-4

FRASER RIVER AT PRINCE GEORGE

MAXIMUM WATER ELEVATIONS FOR VARIOUS RECURRENCE INTERVALS

WITH FLOOD CONTROL OPERATION OF PROJECTS INDIVIDUALLY AND IN COMBINATION

Level of Development	Maximum Water Elevation (feet msl) Average Recurrence Interval (years) 20	50	200	1000
Natural Conditions	1868.3	1869.9	1872.4	1875.5
Present Conditions (with Nechako and Bridge Reservoirs)	1865.5	1866.8	1868.9	1871.4
Project(s)				
Hobson Lake	1865.5	1866.8	1868.9	1871.4
Cariboo Falls	1865.5	1866.8	1868.9	1871.4
Hemp Creek	1865.5	1866.8	1868.9	1871.4
Clearwater-Azure	1865.5	1866.8	1868.9	1871.4
Lower McGregor Non-Diversion	1862.9	1864.4	1866.4	1869.1
Lower McGregor Diversion	1861.4	1862.6	1864.4	1866.6
Lower McGregor Diversion and Cariboo Falls	1861.4	1862.6	1864.4	1866.6
Lower McGregor Diversion and Hemp Creek	1861.4	1862.6	1864.4	1866.6
Grand Canyon	1863.0	1864.3	1866.3	1868.6
Grand Canyon and Hemp Creek	1863.0	1864.3	1866.3	1868.6
Lower McGregor Diversion, Cariboo Falls, and Hemp Creek	1861.4	1862.6	1864.4	1866.6
Lower McGregor Diversion and Grand Canyon	1859.6	1860.7	1862.4	1864.5
Complete System E	1859.8	1861.0	1862.8	1865.0

TABLE 5-5

FRASER RIVER AT QUESNEL

MAXIMUM WATER ELEVATIONS FOR VARIOUS RECURRENCE INTERVALS

WITH FLOOD CONTROL OPERATION OF PROJECTS INDIVIDUALLY AND IN COMBINATION

Level of Development	Maximum Water Elevation (feet msl) Average Recurrence Interval (years)			
	20	50	200	1000
Natural Conditions	1547.4	1548.8	1551.2	1554.6
Present Conditions (with Nechako and Bridge Reservoirs)	1545.6	1547.2	1549.6	1552.7
Project(s)				
Hobson Lake	1545.6	1547.2	1549.6	1552.7
Cariboo Falls	1544.3	1545.7	1547.8	1550.7
Hemp Creek	1545.6	1547.2	1549.6	1552.7
Clearwater-Azure	1545.6	1547.2	1549.6	1552.7
Lower McGregor Non-Diversion	1543.4	1544.8	1547.2	1550.1
Lower McGregor Diversion	1542.3	1543.7	1545.7	1548.4
Lower McGregor Diversion and Cariboo Falls	1541.0	1542.3	1544.2	1546.7
Lower McGregor Diversion and Hemp Creek	1542.3	1543.7	1545.7	1548.4
Grand Canyon	1543.4	1544.7	1546.7	1549.4
Grand Canyon and Hemp Creek	1543.4	1544.7	1546.7	1549.4
Lower McGregor Diversion, Cariboo Falls, and Hemp Creek	1541.0	1542.3	1544.2	1546.7
Lower McGregor Diversion and Grand Canyon	1540.5	1541.7	1543.5	1546.0
Complete System E	1539.4	1540.4	1542.0	1544.3

TABLE 5-6

PROJECT FLOOD CONTROL ACCOMPLISHMENT IN REDUCTION OF MAXIMUM WATER ELEVATIONS

FROM THOSE UNDER PRESENT CONDITIONS WITH DYKE DESIGN FLOOD OCCURRENCE

Level of Development	Average Recurrence Interval									
	140 years (1) Fraser River Mission		140 years (1) Fraser River Deas Island		300 years (2) Thompson River Kamloops		200 years (2) Fraser River Prince George		200 years (2) Fraser River Quesnel	
	Elevation (feet msl)		Elevation (feet msl)		Elevation (feet msl)		Elevation (feet msl)		Elevation (feet msl)	
Natural Conditions	26.0		8.9		1138.1		1872.4		1551.2	
Present Conditions (with Nechako and Bridge Reservoirs)	25.3		8.6		1138.1		1868.9		1549.6	
Project(s)		Reduction (feet)		Reduction (feet)		Reduction (feet)		Reduction (feet)		Reduction (feet)
Hobson Lake	25.2	0.1	8.5	0.1	1136.4	1.7	1868.9	-	1549.6	-
Cariboo Falls	25.0	0.3	8.4	0.2	1138.1	-	1868.9	-	1547.8	1.8
Hemp Creek	24.8	0.5	8.3	0.3	1131.9	6.2	1868.9	-	1549.6	-
Clearwater-Azure	24.8	0.5	8.3	0.3	1133.9	4.2	1868.9	-	1549.6	-
Lower McGregor Non-Diversion (3)	24.6	0.7	8.2	0.4	1138.1	-	1866.4	2.5	1547.2	2.4
Lower McGregor Diversion (3)	24.6	0.7	8.2	0.4	1138.1	-	1864.4	4.5	1545.7	3.9
Lower McGregor Diversion and Cariboo Falls	24.2	1.1	8.0	0.6	1138.1	-	1864.4	4.5	1544.2	5.4
Lower McGregor Diversion and Hemp Creek	24.2	1.1	8.0	0.6	1131.9	6.2	1864.4	4.5	1545.7	3.9
Grand Canyon	24.1	1.2	8.0	0.6	1138.1	-	1866.3	2.6	1546.7	2.9
Grand Canyon and Hemp Creek	23.9	1.4	7.9	0.7	1131.9	6.2	1866.3	2.6	1546.7	2.9
Lower McGregor Diversion, Cariboo Falls, and Hemp Creek	23.8	1.5	7.8	0.8	1131.9	6.2	1864.4	4.5	1544.2	5.4
Lower McGregor Diversion and Grand Canyon (4)	23.5	1.8	7.7	0.9	1138.1	-	1862.4	6.5	1543.5	6.1
Complete System E (4)	22.6	2.7	7.3	1.3	1130.6	7.5	1862.8	6.1	1542.0	7.6

NOTES:
(1) Interval for 1894 flood at Mission.
(2) Approximate interval for 1894 flood at Kamloops; no data on this flood available for Prince George and Quesnel.
(3) Either Lower McGregor project, operated alone or in combination, has the same flood control effect at Mission, but not at Prince George or Quesnel.
(4) The Lower McGregor Diversion-Grand Canyon project combination has greater flood control effect at Prince George than that from all of System E, because of changes in Grand Canyon project operation when System E is optimized for maximum flood control effect at Mission.

5.5 Potential Generation Accomplishment

The generation accomplishment of each project was determined by its ability to produce electrical power, using the procedures described in 3.8 and the project characteristics as outlined in 4.3 and listed in Table 4-6. The power output for each project was determined under three conditions of operation: (a) for optimum firm power production; (b) to meet flood control requirements; and (c) incorporating releases for mitigation of effects on anadromous fish. The same conditions were observed in examining project combinations. The minimum project water releases used in determining power outputs under these three conditions are given in Table 5-7; and the results of these determinations are contained in Table 5-8. The power studies conducted to develop this information are described in the consultant's report (Reference: Annex II, 3-7).

All of these power studies were performed on the basis of maximizing firm rather than average generation; otherwise in some instances greater average figures would have been derived with accompanying lesser amounts of firm production. However, the results have been given in Table 5-8 only in terms of average generation and dependable capacity, as these are considered to be the best overall measure for evaluation of power production. The average generation values shown in this Table represent the ability of the projects to generate electrical energy under the given water conditions. The use of these values to express generation accomplishment is based on the assumption that all energy produced in the British Columbia power system is salable, which is in accord with the planning policy of the British Columbia Hydro and Power Authority. Firm energy requirements are more of a factor in the design and operation of the British Columbia power system than in individual project consideration.

The initial power studies were conducted with the projects operated for optimum firm power production; and for these studies it was assumed that the entire live storage capacities of the reservoirs could be used for flow regulation as necessary. Only nominal minimum releases as listed in Table 5-7 were maintained from each diversion or storage project; special conditions of this nature are outlined in 5.5.1 to 5.5.9 where they apply.

Further power studies were performed to determine the effects on power production of project storage operation for flood control. The results are based on the assumption that the same reservoir storage capacities as those for the initial studies were available for flow regulation. An added requirement was that the amounts of project flood control storage specified in Table 5-1 were available for use by May 1 each year, the amounts depending on whether a large, moderate or small freshet was forecast to occur in that year. In these studies the minimum releases maintained from each project were those listed in Table 5-7 for flood control operation. The results are given in Table 5-8, and they show that power production losses incurred by the flood control restriction on storage utilization were negligible. The greatest loss occurred at the Grand Canyon project and averaged less than one megawatt (MW).

TABLE 5-7

MINIMUM PROJECT WATER RELEASES USED IN DETERMINING POWER OUTPUTS

Project	For Optimum Power Output (1)	For Flood Control Operation	For Mitigation of Effects on Anadromous Fish	
			As Specified by Fisheries Service	As Modified for Study Use (2)
	(cfs)	(cfs)	(cfs)	(cfs)
Lower McGregor Diversion	300	1,000	Nil	300
Grand Canyon	300	1,800	30,000 during freshet; 40,000 during week of Bowron run; 6,000 August through October; 2,000 at other times; 10,000 maximum daily change	As specified, except during large freshets (3)
Cariboo Falls	300	500	500--also store for only one week during freshet	Lesser of turbine discharge (6,500) or inflow during May and June; 2,000 in July and August; 500 at other times; except during large freshets (3)
Hobson Lake	Nil	500	500	500
Clearwater-Azure	Nil	500	Downstream--see Hemp Creek	Lesser of turbine discharge (6,000) or inflow during May and June; 2,000 July through September; 500 at other times; except during large freshets (3)
Hemp Creek	300	1,300	Sufficient to maintain 15,000 at Clearwater when natural flow there would be 15,000 or more; except during large freshets	Lesser of turbine discharge (12,000) or inflow during May and June; 4,000 July through September; 1,300 at other times; except during large freshets (3)
Lower McGregor Non-Diversion	300	3,000 July through September; 1,000 at other times	3,000 July through September; 1,000 at other times; 10,000 during freshet if with Grand Canyon (4)	10,000 in May and June; 3,000 July to September; 1,000 at other times; except during large freshets (3)

NOTES:
(1) The 300 cfs is an arbitrary allowance for possible service water uses, leakage, etc.
(2) Modified in consultation with Fisheries Service. The modified releases would reduce losses in flood control effect and power output resulting from the use of the specified releases, without greatly increasing the risk of damage to anadromous fish.
(3) When a large freshet is forecast, infringement on the releases for mitigation would be necessary to achieve maximum flood control; partial infringement might occur about once in 10 years and maximum infringement about once in 30 years. In most such years operational procedures could be adjusted to minimize the effects on smolt migration.
(4) For explanation of the 10,000 cfs release see 5.5.9.

TABLE 5-8

PROJECT GENERATION ACCOMPLISHMENT

Level of Development	Installed Generating Capacity	Live Storage Capacity	Average Generation			Dependable Capacity
			Optimum Power Output	With Flood Control Operation (1)	With Mitigating Releases (1) (2)	
	(MW)	(Maf)	(MW)	(MW)	(MW)	(MW)
Individual System E Project						
Lower McGregor Diversion	Nil (3)	Nil	365	365	365	Nil
Grand Canyon	144	1.96	92	92	72	110
Cariboo Falls	126.5	1.16	55	55	52	120.5
Hobson Lake	72	0.81	59	59	59	72
Clearwater-Azure (Upper and Lower Stations)	157	2.26	110	110	110	157
Hemp Creek	368	0.79	193	193	193	336.5
Granite Canyon	148.5	(4)	103	103	103	148.5
Clearwater	59.5	(4)	40	40	40	59.5
Complete System E	1,075.5	6.98	1,063 (5)	1,037 (6)	1,007 (7)	1,004
Combinations of System E Projects						
Lower McGregor Diversion and Grand Canyon	144	1.96	457	457	437	110
Lower McGregor Diversion and Cariboo Falls	126.5	1.16	420	420	417	120.5
Lower McGregor Diversion and Hemp Creek	368	0.79	558	558	558	336.5
Grand Canyon and Hemp Creek	512	2.75	285	285	265	446.5
Lower McGregor Diversion, Cariboo Falls and Hemp Creek	494.5	1.95	613	613	610	457
Individual Alternative Project						
Lower McGregor Non-Diversion	276	4.06	205	203	213 (8)	276

NOTES:
(1) These average generation values used in project assessment.
(2) As modified for study use -- see Table 5-7.
(3) At G.M. Shrum and Site One Generating Stations -- see 5.5.1.
(4) Run-of-river project dependent on upstream storage -- see 5.5.7 and 5.5.8.
(5) Includes 239 MW from Hemp Creek as run-of-river project -- see 5.5.6.
(6) Includes 213 MW from Hemp Creek using upstream storage -- see 5.5.6.
(7) Includes 206 MW from Hemp Creek using upstream storage -- see 5.5.6.
(8) For explanation see 5.5.9.

From the foregoing studies it also was determined that if the design maximum reservoir operating elevations were maintained, active storage capacities of projects with large capacity-inflow relationships (all of those listed in Table 4-6 except Grand Canyon and Hemp Creek) could be reduced to the capacities required for flood control only without seriously affecting power generation potentials. There would be no measurable effect on the average generation and dependable capacity values used in project assessment, except at the Hobson Lake project, although there would be some reduction in firm power potential. The original designs for these projects were used in this review because, as noted in 5.3, there is no apparent economic or environmental advantage to be gained by reducing their sizes. Average generation values given in Table 5-8 were determined using either the original project live storage capacities or the reduced capacities needed to meet flood control requirements. The use of the alternative capacities made no essential difference in the resulting values.

A third series of power studies was carried out with the same assumption regarding reservoir storage capacities as that for the initial series. The minimum releases and related conditions of operation outlined in the "as modified" column of Table 5-7 were applied for mitigation of project effects on anadromous fish; and the results are contained in Table 5-8. Individual project conditions and results are outlined briefly hereunder.

5.5.1 Lower McGregor Diversion

All McGregor River flow was considered to be diverted to the Peace River system except the minimum releases shown in Table 5-7, and no flow regulation was provided by the project. Generation listed in Table 5-8 is at G.M. Shrum and Site One Generating Stations on the Peace River; development of Sites C and E downstream in British Columbia would increase this generation by 35 percent. Downstream benefits from sites in Alberta would bring further returns from this diversion project, the amount depending on development of these sites. The average energy gain at G.M. Shrum and Site One Generating Stations is five MW per 100 cfs of diversion.

5.5.2 Grand Canyon

The total live storage capacity of 1.96 million acre-feet (Maf) is only about 30 percent of the average May through July runoff volume; hence operation to obtain maximum flow regulation for optimum firm power production requires the reservoir to be fully drawn down every year before commencement of the high inflow period, usually late in May. Generation at maximum turbine capacity during this period would permit assured reservoir refill by mid-July.

The 30,000 cfs fish mitigation minimum requirement during the freshet period, as specified in Table 5-7, is more than twice the 14,000 cfs maximum turbine capacity, necessitating substantial spillage during the May-July interval. This mitigation release requirement reduces project average generation by 20 MW, as shown in Table 5-8, or about 22 percent. A further fish mitigation requirement is that if both the Grand Canyon and Lower McGregor Non-Diversion projects are built, the minimum total release from both projects over the freshet period is to be 40,000 cfs, except during large freshets.

5.5.3 Cariboo Falls

The total live storage capacity of 1.16 Maf is about 85 percent of the average May through July runoff volume, permitting sufficient flow regulation to allow concentration of generation from September through April for optimum firm power production. The average generation values given in Table 5-8 are valid both for the 1.16 Maf storage capacity and for the 0.80 Maf flood control storage requirement, provided that the maximum reservoir operating elevation is the same in each case. The fish mitigation release requirements reduce average generation by about three MW, or five percent. The original specified fish mitigation requirement limiting storage accumulation to one week during the freshet period would have limited the use of storage for flood control to about 0.30 Maf during a large freshet, and for power production to about 0.13 Maf annually, resulting in a substantial loss in average generation.

5.5.4 Hobson Lake

The total live storage capacity of 0.81 Maf is about 120 percent of the average May through July runoff volume, permitting sufficient flow regulation to minimize generation at this project during periods of high inflow and so avoid spillage at the downstream run-of-river projects. The average generation values given in Table 5-8 are based on the use of 0.81 Maf of storage.

5.5.5 Clearwater-Azure

This project includes the upper generating station at the main dam and the lower generating station about 10,000 feet downstream. The total live storage capacity of 2.26 Maf is slightly greater than the average May through July runoff volume; and this capacity, together with the 0.81 Maf of storage at Hobson Lake upstream, would permit sufficient flow regulation to provide a degree of storage carryover from year to year. Generation at this project would be concentrated from August through April for optimum firm power production and to minimize releases at the upper station during periods of high inflow, thus avoiding spillage at the downstream run-of-river projects. The average generation values given in Table 5-8 are valid both for the 2.26 Maf storage capacity and for the 1.00 Maf flood control storage requirement, provided that the maximum reservoir operating elevation is the same in each case.

The 2.26 Maf live storage capacity of the Clearwater-Azure project is sufficient in itself (without Hobson Lake storage upstream) to permit operation for optimum firm power production at the project itself and at downstream projects while maintaining the minimum releases for fish mitigation given in Table 5-7. These releases with tributary inflow downstream would be sufficient to maintain the larger minimum releases for fish mitigation required at the Hemp Creek project.

5.5.6 Hemp Creek

If the total live storage capacities of the Hobson Lake and Clearwater-Azure projects upstream were available, no storage at Hemp Creek would be required for flow regulation to minimize spillage or to maintain the minimum releases for fish mitigation shown in Table 5-7. Under these conditions Hemp

Creek could be operated as a run-of-river project at full reservoir level to obtain the maximum head for optimum firm power production. The results of Hemp Creek operation on this basis are included in Table 5-8 only for the complete System E under optimum power output. In this case Hemp Creek average generation is 239 MW, and its dependable capacity is 368 MW. In the other cases with the complete System E, Hemp Creek storage is used in conjunction with that upstream to produce average Hemp Creek generation of 213 MW with flood control operation, and 206 MW with mitigating releases; in both of these cases the dependable capacity is 336.5 MW.

The total live storage capacity of 0.79 Maf at the Hemp Creek project is less than 25 percent of the May through July runoff volume. If Hemp Creek were the sole storage project on the Clearwater River system, this storage would be operated to provide maximum firm energy. In this case Hemp Creek average generation is 193 MW and its dependable capacity is 336.5 MW.

5.5.7 Granite Canyon

The results given in Table 5-8 for this run-of-river project are based on the assumption that at least 2.0 Maf of storage upstream is operated for flow regulation to produce maximum firm energy. If only the 0.79 Maf Hemp Creek storage were available upstream, the Granite Canyon average generation values given in Table 5-8 would be reduced by about 12 percent; there would be no change in its dependable capacity. Minimum releases from this project are as shown in Table 5-7 for the Hemp Creek project.

5.5.8 Clearwater

As in the case of the Granite Canyon project immediately upstream, the results given in Table 5-8 for this run-of-river project are based on the assumption that at least 2.0 Maf of storage upstream is operated for flow regulation to produce maximum firm energy. If only the 0.79 Maf Hemp Creek storage were available upstream, the Clearwater average generation values given in Table 5-8 would be reduced by about 12 percent; there would be no change in its dependable capacity. Minimum releases from this project are as shown in Table 5-7 for the Hemp Creek project.

5.5.9 Lower McGregor Non-Diversion

This alternative to the Lower McGregor Diversion project referred to in 5.5.1 has a total live storage capacity of 4.06 Maf, which is about 155 percent of the average May through July runoff volume. This capacity would permit sufficient flow regulation to allow concentration of generation from September through April for optimum firm power production. The average generation values given in Table 5-8 are valid both for the 4.06 Maf storage capacity and for the 2.00 Maf flood control storage requirement, provided that the maximum reservoir operating elevation is the same in each case. The slightly higher figure of 213 MW obtained with the mitigating releases reflects more effective utilization of freshet flows to give additional average energy, but with an accompanying reduction in attributable firm energy.

Reference was made in 5.5.2 to the further fish mitigation requirement that if both the Lower McGregor Non-Diversion and Grand Canyon projects are built, the minimum total release from both projects is to be 40,000 cfs during the freshet period. This requirement would necessitate releases of up to 10,000 cfs or more from Lower McGregor Non-Diversion during the freshet period, depending on the simultaneous releases from Grand Canyon. This condition was included with those in the modified minimum releases for study use given in Table 5-7, except during large freshets.

5.5.10 Project Combinations

In addition to containing the results of the individual project power output determinations, Table 5-8 includes average generation and dependable capacity values for those combinations of individual projects which have their respective flood control accomplishments given in Table 5-6. These average generation and dependable capacity figures for the various combinations were derived in the same manner and with the same operational and release limitations as those for the individual projects.

CHAPTER 6

POTENTIAL FLOOD DAMAGES, PROJECT BENEFITS AND ECOLOGICAL CONSEQUENCES

6.1 Potential Flood Damages

The occurrence of high water conditions in the Fraser River system causes flood damage primarily in its four principal flood plains, located in the Lower Fraser Valley and at Kamloops, Prince George and Quesnel. Table 6-1 illustrates the magnitude, at mid-1972 development and price levels, of the potential flood damages in these locations with the occurrence of various water elevations. The method used to determine these potential damages is described briefly in 3.5; and the detailed findings and supporting data are contained in the background document on this subject (Reference: Annex II, 3-5).

The potential flood damages shown in Table 6-1 and succeeding tables for the areas included in the Lower Fraser Valley Priority Projects (4.1 and Table 4-1) are residual damages that could occur after completion of these dyking improvement projects under the program described in 4.1. The same is true of the damage shown in Table 6-2 for the completed Oak Hills project in Kamloops referred to in 4.2. The potential flood damages shown for the other areas are based on their respective present conditions, either undyked or with dykes below the standards set forth in 4.1 and 4.2 for the various locations.

Table 6-2 gives the present worths of potential damages from all floods assumed to occur from 1973 to 2032 in the dyking improvement project areas and in the undyked areas of the Lower Fraser Valley, Kamloops, Prince George and Quesnel. These potential flood damages are based on the most likely rates of growth and price change projected to take place in these areas. The procedure for determining the total present worths of these potential damages is illustrated graphically in Figures 6-1 and 6-2, which relate the total present worths of damages over the period to the probability of their being equalled or exceeded.

The total present worths of the potential flood damages from 1977 through 2032 for the several classifications of project and undyked areas given in Table 6-2 are shown in Table 6-3 for five projections of growth and price change. Projection A, the most likely, is based on a combination of historic and probable future changes in growth, productivity and real values of flood plain activities and development. This projection is shown using discount rates of six, seven and eight percent per annum to indicate discount rate sensitivity. Projection B provides the lowest possible limit to the range of potential flood damages, being based on unchanged level of development and constant price structure. Projection C illustrates the effect of more rapid development and greater increase in real values than those considered most likely; it is based on growth and price change rates one percent per annum higher than those used in Projection A. Projection D denotes the result of development proceeding as forecast without change in real values; it is based on the most likely growth rate and constant price structure. Projection E indicates the effect on potential damage of a greater rise in the real value of agricultural production than is assumed in the most likely projection; it is based on the most likely growth rate and on real agricultural product price changes of three percent per annum.

TABLE 6-1

POTENTIAL FLOOD DAMAGES AS OF 1972 WITH OCCURRENCE OF VARIOUS WATER ELEVATIONS

Lower Fraser Valley Areas					Kamloops Area		Prince George Area		Quesnel Area	
Water Elevation at Mission	Damages				Water Elevation	Damages	Water Elevation	Damages	Water Elevation	Damages
	Priority Projects (Table 4-1)	Projects For Further Consideration (Table 4-2)	Undyked (1)	Total						
(feet msl)	($1,000)	($1,000)	($1,000)	($1,000)	(feet msl)	($1,000)	(feet msl)	($1,000)	(feet msl)	($1,000)
21	-	1,295	-	1,295	1,129.0	24				
22	-	2,007	128	2,135	1,131.8	670	1,864.2	12		
23	-	2,404	830	3,234	1,132.4	4,052	1,866.7	75		
24	194,303	2,784	1,815	198,902	1,135.0	10,846	1,867.3	2,136	1,547.1	8
25	285,767	3,108	3,663	292,538	1,137.0	20,916	1,868.9	5,258	1,549.6	121
26	313,352	3,507	4,398	321,257	1,138.1	24,810	1,872.4	10,251	1,551.2	430
30	338,997	3,874	4,923	347,794	1,150.0	45,620	1,878.0	15,147	1,558.2	1,254

NOTE: (1) Includes damages in areas of Projects Nos. 29, 35 and 37 (Table 4-2).

TABLE 6-2

PRESENT WORTH IN 1972 OF POTENTIAL FLOOD DAMAGES FOR DYKING PROJECT AREAS AND FOR UNDYKED AREAS (1)

Lower Fraser Valley

Areas of Priority Projects (2)	(Table 4-1 No.)	Damages (3) ($1,000)
Kent (Agassiz-Harrison Mills) & Harrison Hot Springs	1 & 2	1,763
East and West Nicomen	3	592
South Dewdney	5	1,029
Mission	6	160
Maple Ridge & Pitt Meadows No. 2	8 & 10	1,626
Coquitlam	13	1,208
Chilliwack & Chilliwack I.R. Nos. 3 & 4	16 & 36	23,631
Abbotsford (formerly Sumas)	17	5,593
Matsqui	18	2,242
Glen Valley	19	247
Salmon River (Fort Langley)	20	63
South Westminster	23	1,333
Delta (including Westham Island)	24 & 33	9,346
Richmond (excluding Sea Island) & New Westminster (Queensborough)	25,31 & 34	45,725
Total		94,558

Areas of Projects for Further Consideration (2)	(Table 4-2 No.)	Damages ($1,000)
North Nicomen	4	353
Silverdale	7	189
Albion & Maple Ridge Road 13	9 & 30	587
Pitt Meadows No. 1	11	843
Pitt Polder	12	1,696
Colony Farm	14	486
Trapp Road	15	83
West Langley & Derby	21 & 28	163
Barnston Island	22	729
Tretheway	26	214
Alouette	27	105
Total		5,448
Undyked Areas (4)		2,350
Lower Fraser Valley Total		102,356

Kamloops

Project Areas (Table 4-3)	Damages ($1,000)
T1 & NT1	3,876
T2	967
T3	555
NT2	101
ST1	135
Sub-Total	5,634
Oak Hills (3)	499
Sub-Total	6,133
Undyked Areas	949
Total	7,082

Prince George

Project Areas (Table 4-4)	Damages ($1,000)
A	1
B	950
C	30
D	60
Sub-Total	1,041
Undyked Areas	79
Total	1,120

Quesnel

Project Areas (Table 4-5)	Damages ($1,000)
A	2.8
B	5.7
C	15.2
D	14.0
E	0.4
Sub-Total	38.1
Undyked Areas	6.9
Total	45.0

NOTES:
(1) For most likely growth and price change projection for period from 1973 through 2032, discounted at seven percent per annum to 1972.
(2) As at May 24, 1975.
(3) Figures are for residual damages - see 6.1.
(4) Includes damages for Projects Nos. 29, 35 and 37 (Table 4-2).
(5) Total damages for all areas = $110,603,000.

PRESENT WORTH IN 1972 OF DAMAGE-FREQUENCY FUNCTION LOWER FRASER VALLEY (1)

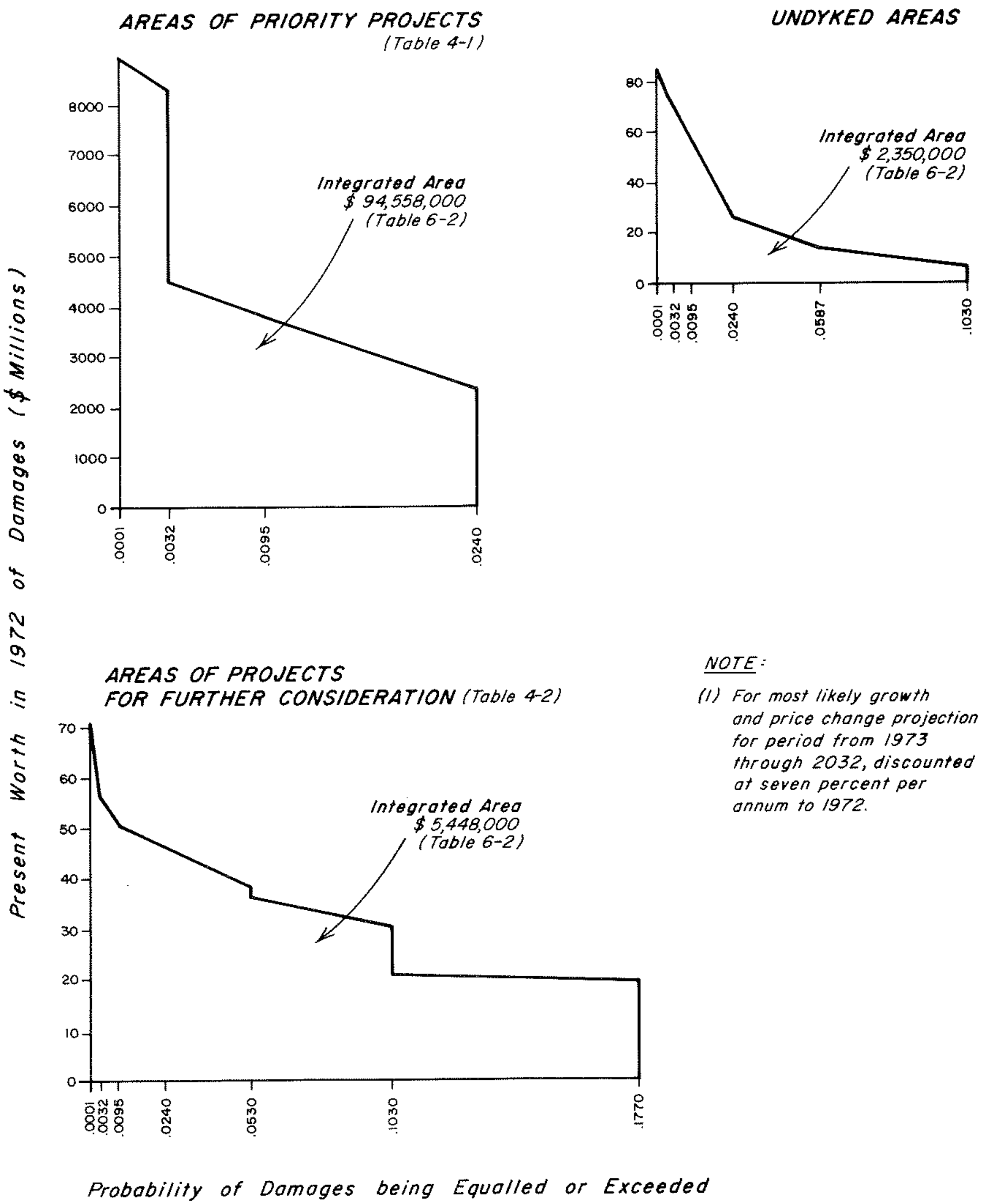
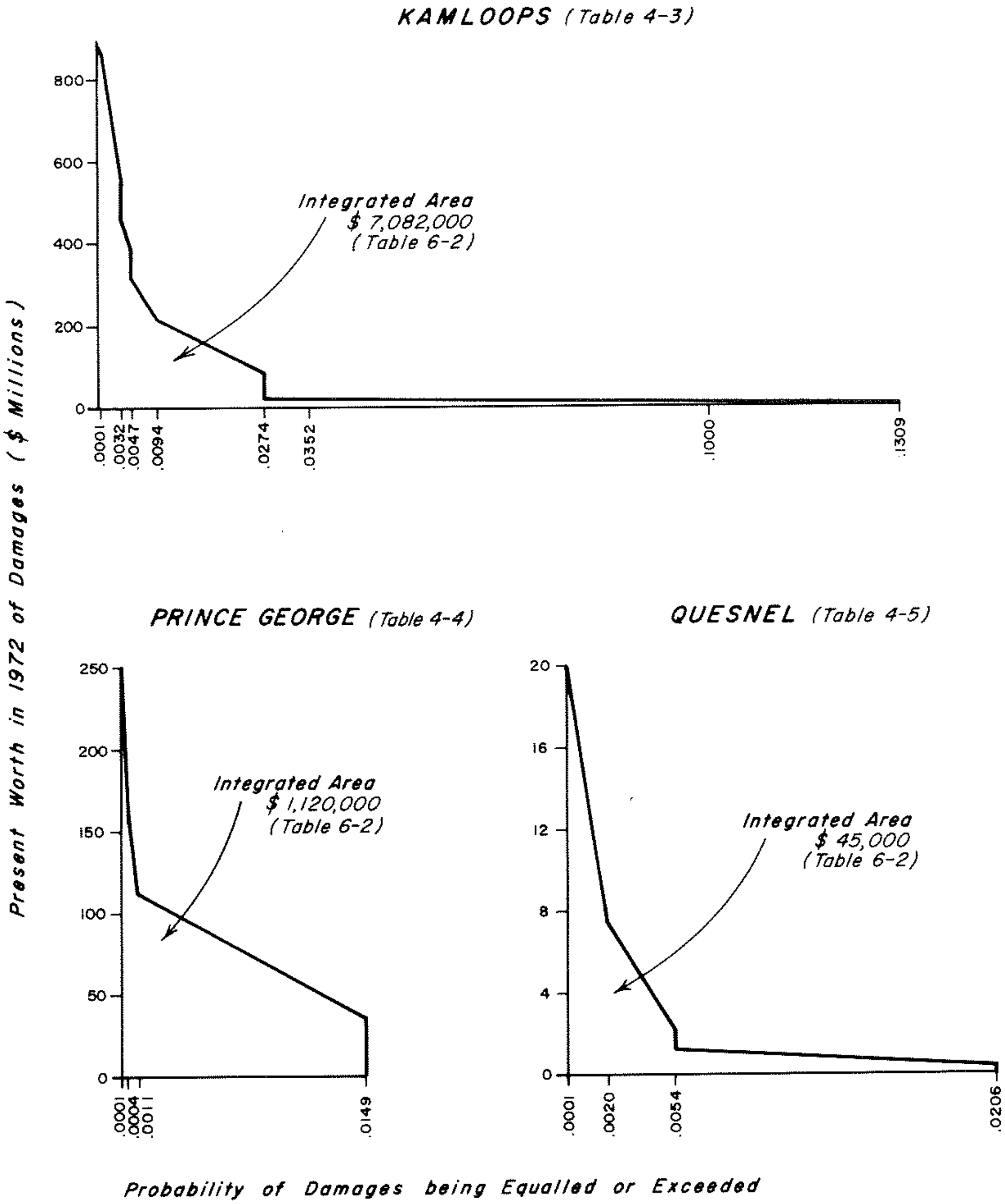


Figure 6-1

PRESENT WORTH IN 1972 OF DAMAGE-FREQUENCY FUNCTION (1)



NOTE: (1) For most likely growth and price change projection for period from 1973 through 2032, discounted at seven percent per annum to 1972.

Figure 6-2

TABLE 6-3

PRESENT WORTH IN 1972 OF POTENTIAL FLOOD DAMAGES FROM 1977 THROUGH 2032 UNDER VARIOUS PROJECTIONS OF GROWTH AND PRICE CHANGE RATES (1)

Projection	Discount Rate Per Annum	Area Damages (2)							Total Damages For All Areas
		Lower Fraser Valley				Kamloops	Prince George	Quesnel	
		Priority Projects	Projects For Further Consideration	Undyked (3)	Total				
	(%)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)
A - Most Likely Growth and Price Change	7	80,946	4,258	1,740	86,944	5,648	799	36	93,427
	6	100,486	5,099	2,094	107,679	6,894	959	44	115,576
	8	66,308	3,612	1,468	71,388	4,708	676	31	76,803
B - Zero Growth and Price Change	7	38,854	3,704	1,444	44,002	3,671	671	28	48,372
C - 1% Higher Rate of Change than Most Likely Growth and Price Change	7	94,707	4,854	1,914	101,475	6,495	911	41	108,922
D - Most Likely Growth and Zero Price Change	7	61,519	4,173	1,566	67,278	4,688	567	33	72,546
E - Most Likely Growth with Real Agricultural Price Change of 3%	7	84,184	5,919	2,144	92,243	5,704	799	36	98,782

NOTES: (1) Discounted to 1972 at discount rate shown.

(2) Areas as in Table 6-2.

(3) Figures include damages for Projects Nos. 29, 35 and 37 (Table 4-2).

Comparison of the figures contained in Table 6-3 reveals the sensitivity of damage estimates to errors in projection, as illustrated by the following examples from the Lower Fraser Valley Priority Projects column. If Projection D rather than Projection A were to prevail, the most likely growth rate would occur but real prices would remain constant; and the most likely damage estimate given in A for the same discount rate would be about 30 percent too high. Likewise if Projection C rather than A were to prevail, the actual growth and price change rates would be one percent per annum higher than the most likely rates; and the most likely damage estimate given in A for the same discount rate would be nearly 15 percent too low.

The effect on potential flood damages of a zoning policy prohibiting further development can be illustrated by comparing the figures for Projections B and D in the Lower Fraser Valley Priority Projects column of Table 6-3. Enactment of such a policy could reduce the potential flood damages in these areas by more than 35 percent. On this basis the decrease in the most likely damage figure given in Projection A for these areas would be nearly $30 millions.

6.1.1 Lower Fraser Valley

The potential flood damages in the Lower Fraser Valley flood plain associated with the occurrence of a water elevation of 26 feet msl at Mission are estimated to total $321 millions, as shown in Table 6-1. Nearly 98 percent of this total, or $313 millions, would be residual damages experienced in the areas of Priority Projects (4.1 and Table 4-1). About one percent of this total, or $3.5 millions, would take place in the areas of Projects for Further Consideration (4.1 and Table 4-2). The remaining damages, approximately one percent or $4.4 millions, would occur in the undyked areas.

The approximate proportions of the total potential flood damages in the dyking improvement project areas (Tables 4-1 and 4-2) are 50 percent residential damages, 20 percent industrial and commercial property and income losses, 15 percent agricultural losses, and 15 percent miscellaneous, including damage to railways and highways. In the undyked areas more than 70 percent of the damages occur in the industrial category.

The total present worth of potential damages in the Lower Fraser Valley from all floods assumed to occur from 1973 through 2032 is estimated to be $102.4 millions (Table 6-2 and Figure 6-1). Damages in the areas of Priority Projects would aggregate $94.6 millions, or nearly 93 percent of this total; those in the areas of Projects for Further Consideration would amount to $5.4 millions, or five percent; and those in the undyked areas would be $2.4 millions, or two percent. More than one-half of the total damages would occur in the Richmond and Delta Priority Project areas.

The figures in Table 6-2 also demonstrate the preponderance of the potential flood damages in the Lower Fraser Valley when compared to those at Kamloops, Prince George and Quesnel. The present worth of these damages in the Lower Fraser Valley is $102.4 millions, or nearly 93 percent of the $110.6 millions total for all of these areas.

6.1.2 Kamloops

The potential flood damages associated with the occurrence of a water elevation of 1138.1 feet msl at Kamloops are estimated to total $24.8 millions (Table 6-1). All of these potential damages would be experienced within the city boundaries, as shown on Plate 4-2. More than one-half of these damages would occur in the areas of dyking projects T1 and NT1 (Table 4-3 and Plate 4-2), located immediately northwest of the confluence of the North and South Thompson Rivers. The remaining damages would occur in the other project areas, the undyked areas, and Oak Hills. These potential flood damages would be nearly 75 percent residential, more than 15 percent industrial and commercial, and about 10 percent miscellaneous.

If no further dyke construction or improvement is carried out, the total present worth of potential damages in Kamloops from all floods assumed to occur from 1973 through 2032 is estimated to be $7.1 millions (Table 6-2 and Figure 6-2). Completion of dykes T1 and NT1 to the design standard outlined in 4.2.1 would reduce this damage figure to residual damages of $4.4 millions.

6.1.3 Prince George

The potential flood damages associated with the occurrence of a water elevation of 1868.9 feet msl at Prince George are estimated to total $5.3 millions (Table 6-1). All of these potential damages would be experienced within the city boundaries, in the areas shown on Plate 4-3; and about 85 percent of them would be commercial and industrial losses.

If no dyke construction is carried out, the total present worth of potential damages in Prince George from all floods assumed to occur from 1973 through 2032 is estimated to be $1.1 millions (Table 6-2 and Figure 6-2). Completion of the dykes required to protect Area B (Table 4-4 and Plate 4-3) to the design standard outlined in 4.2.2 would reduce this potential damage figure to residual damages of $300,000.

6.1.4 Quesnel

In comparison to those at other locations, the potential flood damages at Quesnel are quite limited; with the occurrence of a water elevation of 1549.6 feet msl they are estimated to total $121,000 (Table 6-1). All of these potential damages would be experienced within the town boundaries, as shown on Plate 4-4; and more than 60 percent of them would be in the residential category. If no dyke construction is carried out, the total present worth of potential damages in Quesnel from all floods assumed to occur from 1973 through 2032 is $45,000 (Table 6-2 and Figure 6-2).

6.2 Allocation of Flood Damage Prevention Benefits

The method used to allocate flood damage prevention benefits among dykes and upstream diversion or storage projects is described in 3.5.5. In the Lower Fraser Valley it was assumed that the Priority Projects (Table 4-1) were completed and would prevent all damages in their areas when Mission water elevations are below 24 feet, one-half of the damages when Mission water elevations are between 24 feet and 26 feet, and none of the damages when Mission water elevations exceed 26 feet. Existing dykes in the Projects for Further Consideration (Table 4-2) were assumed to prevent all damages up to their individually established confidence levels ranging from Mission water elevations of 21 feet to 23 feet, and none of the damages when Mission water elevations exceed these individual confidence levels.

In Kamloops the completed Oak Hills dyking project was assumed to prevent all damages from water elevations up to 1137 feet, one-half of the damages when water elevations are between 1137 feet and 1138.1 feet, and none of the damages when water elevations exceed 1138.1 feet. Existing dykes in Projects T1, NT1 and T2 (Table 4-3) were assumed to prevent damages when water elevations are below 1132.4 feet, provided that any essential emergency work is done on these dykes in anticipation of flood conditions. Other existing dykes in the Kamloops area were assumed to prevent no damages.

The flood damages assumed to be prevented by dykes were excluded from Tables 6-2 and 6-3; hence the figures in these tables provided the general basis for derivation of the flood damage prevention benefits to be credited to the upstream diversion and storage projects (Table 6-4). The time horizon for Tables 6-3 and 6-4 is from 1977 through 2032, in accordance with criterion f in 3.1. The benefits shown in Table 6-4 are referred to as flood control benefits since they are obtained from control of downstream water elevations by upstream project operation.

6.3 Potential Flood Control Benefits from Upstream Projects

Table 6-4 shows the present worth of the flood control benefits attributed to the upstream projects, singly and in combination, in the reduction of potential flood damages in the four principal flood plain areas of the Fraser River system. This table illustrates the relative values of these projects in terms of flood control capability; for example, the Grand Canyon project would produce the largest flood control benefits of any single project, and nearly 69 percent of the total flood control benefits produced by the complete System E.

The figures in Table 6-4 demonstrate that the bulk of the flood control benefits attributed to any of the projects, singly or in combination, would occur in the Lower Fraser Valley. The Hemp Creek project would give the greatest individual project flood control benefits in Kamloops, but these benefits are only about 15 percent of the project total; the remaining 85 percent would occur in the Lower Fraser Valley. Similarly, about one percent of the Grand Canyon project flood control benefits would be experienced in Prince George and Quesnel, and the other 99 percent in the Lower Fraser Valley. Flood control benefits in Richmond and Delta constitute more than one-half of the Lower Fraser Valley benefits in all cases, and more than one-half of the total benefits in all cases except for the three individual Clearwater River projects.

TABLE 6-4

PRESENT WORTH IN 1972 OF UPSTREAM PROJECT FLOOD CONTROL BENEFITS (1)

Level of Development	Lower Fraser Valley			Kamloops	Prince George	Quesnel	Total For All Areas
	Richmond and Delta (2)	Remainder of Valley	Total				
	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)
Individual System E Project							
Lower McGregor Diversion	23,282	18,303	41,585	-	779	34	42,398
Grand Canyon	33,407	26,142	59,549	-	672	31	60,252
Cariboo Falls	11,407	9,087	20,494	-	-	24	20,518
Hobson Lake	4,776	3,827	8,603	2,571	-	-	11,174
Clearwater-Azure	18,098	14,215	32,313	4,493	-	-	36,806
Hemp Creek	15,772	12,347	28,119	5,227	-	-	33,346
Complete System E	45,139	36,016	81,155	5,424	795	36	87,410
Combinations of System E Projects							
Lower McGregor Diversion and Grand Canyon	40,290	31,928	72,218	-	798	36	73,052
Lower McGregor Diversion and Cariboo Falls	31,454	24,777	56,231	-	779	36	57,046
Lower McGregor Diversion and Hemp Creek	31,753	24,988	56,721	5,227	779	34	62,761
Grand Canyon and Hemp Creek	36,161	28,408	64,569	5,227	672	31	70,499
Lower McGregor Diversion, Cariboo Falls and Hemp Creek	37,678	29,809	67,487	5,227	779	36	73,529
Individual Alternative Project							
Lower McGregor Non-Diversion	23,281	18,303	41,584	-	635	28	42,247

NOTES: (1) For period from 1977 through 2032 for most likely growth and price change projection, discounted at seven percent per annum to 1972.

(2) Richmond includes Projects Nos. 25 and 31, and Delta is Project No. 24 in Table 4-1.

The first project built would receive its full credit for flood control benefits, while the second one built on the same river system would receive only the difference between the credit for the combined projects and that for the first project alone. A third project would receive only the difference in credits between the combination of three and that of the first two. Thus from Table 6-4: Lower McGregor Diversion built first, total benefits $42.4 millions; Cariboo Falls second, benefits $14.6 millions; Hemp Creek third, benefits $16.5 millions. In contrast: Cariboo Falls built first, total benefits $20.5 millions; Hemp Creek first, benefits $33.3 millions. The decrease in benefits for second-and third-added projects is evident.

The overall effect of the complete System E in flood damage prevention is illustrated by its total flood control benefits of $87.4 millions (Table 6-4). This is about 93 percent of the $93.4 millions of the potential flood damages in all areas (Table 6-3). The flood control benefits of $73.0 millions credited to the Lower McGregor Diversion - Grand Canyon project combination are 78 percent of the potential flood damages in all areas, although this combination would be of no benefit to Kamloops.

6.4 Potential Generation Benefits from Upstream Projects

The potential benefits to be derived from hydroelectric power generation at or associated with the upstream diversion and storage projects under review (Table 4-6) were developed by the British Columbia Hydro and Power Authority (BCHPA). These benefits were based on the costs of obtaining equivalent energy and capacity from the BCHPA Revelstoke and Hat Creek projects, which are the two lowest cost alternative sources that would serve the same purpose with respect to BCHPA system requirements. The method utilized by BCHPA to develop these generation benefits is outlined in 3.9.

6.4.1 Hat Creek Alternative Source

The Revelstoke project was not considered to offer an appropriate basis for comparative derivation of generation benefits for the project under review, as the BCHPA 1975 to 1990 generation plan indicates that Revelstoke would be in service before either the Hat Creek or the Lower McGregor Diversion projects; and BCHPA has applied for a water license for the Revelstoke project. The in-service sequence of the Hat Creek and Lower McGregor Diversion projects depends on the time required to resolve environmental problems associated with McGregor River diversion. The BCHPA generation benefit data derived from Hat Creek costs therefore were adopted as the basis for power benefit data for the projects under review. Table 6-5 gives the assumed in-service dates and average annual energy production for the Hat Creek project.

TABLE 6-5

HAT CREEK UNIT IN-SERVICE DATES AND AVERAGE ANNUAL ENERGY PRODUCTION (1)

Unit Number	Installed Generating Capacity	In-Service Date (2)	Average Annual Energy
	(MW)		(GWh)
1	500	Oct/78	3,420
2	500	Apr/79	3,420
3	500	Oct/79	3,420
4	500	Apr/80	3,420

NOTES: (1) Data supplied by BCHPA.

(2) Assumed for this analysis with construction beginning in April 1972.

The BCHPA Hat Creek project construction schedule extends over a six and one-half year period from construction authorization to the first unit being in service. The estimated station construction cost, based on 1972 price levels, is $473.3 millions; and the associated transmission construction cost is $19.5 millions, for an estimated total development construction cost of $492.8 millions, as shown in Table 6-6.

The Hat Creek costs used by BCHPA to derive generation benefits for the projects under review are subject to a number of limitations which result in the derived benefits being somewhat lower than would be anticipated if data associated with Hat Creek project development were more nearly complete. These limitations include:

(a) The mine mouth price of $2.17 per ton (1972 dollars) derived for Hat Creek coal as outlined in 3.9 may be low, as the cost of burning coal to provide energy should be based on the opportunity value of the same coal in its best alternative use. Coal gasification and coal export are among the alternative uses of Hat Creek coal which have been discussed, but the best alternative use has not been decided at this time.

(b) The Hat Creek proven and probable coal reserves of 478 million tons are little more than sufficient to supply a 2,000 MW generating station for its assumed 35-year life. This could mean that Hat Creek would provide low-cost power only on a relatively short-term basis, unless further coal reserves are proven to exist in the vicinity.

TABLE 6-6

BCHPA HAT CREEK PROJECT COST ESTIMATE

Item	Estimated Cost
	($1,000)
Generating Station	
Turbine Generators	89,435
Steam Generators	100,620
Precipitators	26,225
Coal Handling Plant	10,580
Ash Handling Plant	16,135
Station CW Equipment	7,190
Fresh Water Supply	19,165
Boiler Feed Pumps	4,790
HP Pipework and Valves	8,785
LP Pipework and Valves	1,120
Insulation	1,685
Fire Protection	445
Water Treatment Plant	1,280
Fuel Oil Storage and Distribution	430
Heating and Ventilation	1,685
Miscellaneous Mechanical Equipment	1,600
Installation	3,435
Transformers	18,640
Switchyard Equipment	5,540
Station Instrumentation and Controls	9,770
Installation	3,395
Power Generation Structures and Works	77,105
Stacks	4,550
Cooling Water Supply System	12,535
Switchyard	1,285
Site Access	5,990
Total Station Direct Cost	433,415
Engineering and Administration	17,335
Contingencies	22,540
Total Station Construction Cost	473,290
Transmission	
Kelly Lake - Nicola (500 kV line)	8,585
Microwave	1,430
Kelly Lake - Hat Creek (500 kV line)	7,575
Kelly Lake Station	1,935
Total Transmission Construction Cost	19,525
Total Development Construction Cost	492,815

(c) The assumed decrease in capital and operating costs of two percent per year attributed to technological improvements seems high for a coal-fired generating station; however, it is recognized that the replacement station after 35 years might not be a coal-fired one.

(d) The Hat Creek generating station cost estimate (Table 6-6) includes no provision for the supply and installation of stack emission pollution control and abatement equipment. If the sulphur content of the coal is such as to require removal of the sulphur dioxide from the stack emissions, the installation of limestone-based process equipment for this purpose probably would add $100 millions to the station construction cost. Operation of this process also is expensive.

(e) The allowances in the Hat Creek generating station cost estimate for engineering and administration (four percent of the total direct cost), and for contingencies (five percent of the total direct cost plus engineering and administration) seem low, particularly as this is the first such station considered for development in British Columbia.

(f) No allowance for environmental damages anticipated from Hat Creek station construction and operation is contained in the BCHPA analysis, although these damages could be substantial. For example, some 5,500 acres of valley grazing and cultivated pasture land would be utilized in project development and operation. About 700 acres of this total would contain the generating station and the water supply reservoir; the remaining 4,800 acres would be adversely affected by open pit mining and by overburden, waste rock and ash disposal.

6.4.2 Power Demand and Project Scheduling

Comparison of the BCHPA forecast annual increase in energy demand from 1975 through 1980 (Table 6-7) with the annual energy production of the Hat Creek units (Table 6-5) and that of the projects under review (Table 6-8) shows that any of these Hat Creek units or projects under review could be fully utilized in a short period of time, probably within one year of completion. Even if the annual increase in energy demand is only one-half that forecast by BCHPA, or approximately equivalent to that forecast by the British Columbia Energy Commission, any of the projects under review could be fully utilized within two years of completion. This is a very brief period of time compared to that required for the planning, licensing, authorization and construction of a project, which frequently totals ten years under present conditions. Hence adjustment of project construction schedules to fit the forecast energy demand was unnecessary.

6.4.3 Upstream Project Generation Benefits

The BCHPA measure of the generation benefits to be credited to each upstream project under review was the total of the costs over the upstream project operating period involved in providing equivalent energy and capacity from the Hat Creek project and supplementary sources, and of transmitting this energy to the BCHPA transmission system. These costs were derived as described in 3.9, and were expressed in terms of their present worth in 1972 as the upstream project generation benefits. Table 6-9 shows these benefits for each upstream project and selected combination for the average annual generation throughout its operating period, both with flood control operation and with flow releases for mitigation of effects on anadromous fish (Table 5-8).

TABLE 6-7

BCHPA PLANNING FORECAST OF TOTAL ELECTRIC ENERGY DEMAND

Fiscal Year (1)	Forecast Demand	Annual Increment in Demand
	(GWh)	(GWh)
1975	23,400	-
1976	26,200	2,800
1977	29,200	3,000
1978	32,600	3,400
1979	36,500	3,900
1980	40,100	3,600

NOTE: (1) BCHPA fiscal year begins on April 1; fiscal year 1975 extends from April 1, 1975 to March 31, 1976.

TABLE 6-8

IN-SERVICE DATES AND AVERAGE ANNUAL ENERGY PRODUCTION OF UPSTREAM PROJECTS

Level of Development	In Service Date (1)	Average Annual Energy (2)
Individual System E Project		(GWh)
Lower McGregor Diversion	Jul/77	3,197
Grand Canyon	Oct/76	806
Cariboo Falls	Oct/76	482
Hobson Lake	Oct/76	517
Clearwater-Azure (Upper and Lower Stations)	Oct/76	964
Hemp Creek	Oct/76	1,691
Granite Canyon	Oct/76	902
Clearwater	Oct/76	350
Complete System E	Jul/77	9,084
Combinations of System E Projects		
Lower McGregor Diversion and Grand Canyon	Jul/77	4,003
Lower McGregor Diversion and Cariboo Falls	Jul/77	3,679
Lower McGregor Diversion and Hemp Creek	Jul/77	4,888
Grand Canyon and Hemp Creek	Oct/76	2,497
Lower McGregor Diversion, Cariboo Falls and Hemp Creek	Jul/77	5,370
Individual Alternative Project		
Lower McGregor Non-Diversion	Oct/76	1,778

NOTES: (1) Assumed for this analysis with construction beginning in April 1972.

(2) Based on average generation with flood control operation (Table 5-8).

TABLE 6-9

PRESENT WORTH IN 1972 OF UPSTREAM PROJECT GENERATION BENEFITS (1)

Level of Development	Installed Generating Capacity	With Flood Control Operation			With Mitigating Releases		
		Average Annual Energy Production (2)	Discounted Sum of Average Annual Energy Production (1)	Generation Benefits (3)	Average Annual Energy Production (2)	Discounted Sum of Average Annual Energy Production (1)	Generation Benefits (3)
	(MW)	(GWh)	(GWh)	($1,000)	(GWh)	(GWh)	($1,000)
Individual System E Project							
Lower McGregor Diversion	Nil (4)	3,197	33,484	233,100	3,197	33,484	233,100
Grand Canyon	144	806	8,892	61,270	631	6,962	47,970
Cariboo Falls	126.5	482	5,318	37,480	456	5,031	35,450
Hobson Lake	72	517	5,704	38,940	517	5,704	38,940
Clearwater-Azure (Upper and Lower Stations)	157	964	10,636	72,920	964	10,636	72,920
Hemp Creek	368	1,691	18,657	130,000	1,691	18,657	130,000
Granite Canyon	148.5	902	9,952	68,300	902	9,952	68,300
Clearwater	59.5	350	3,862	26,510	350	3,862	26,510
Complete System E	1,075.5	9,084	98,436	681,860	8,821	95,534	661,760
Combinations of System E Projects							
Lower McGregor Diversion and Grand Canyon	144	4,003	42,376	294,370	3,828	40,446	281,070
Lower McGregor Diversion and Cariboo Falls	126.5	3,679	38,802	270,580	3,653	38,515	268,550
Lower McGregor Diversion and Hemp Creek	368	4,888	52,141	363,100	4,888	52,141	363,100
Grand Canyon and Hemp Creek	512	2,497	27,549	191,270	2,322	25,619	177,970
Lower McGregor Diversion, Cariboo Falls and Hemp Creek	494.5	5,370	57,459	400,580	5,344	57,172	398,550
Individual Alternative Project							
Lower McGregor Non-Diversion	276	1,778	19,617	134,290	1,866	20,588	140,940

NOTES:
(1) For operating period (October 1976 through 2032) for all projects except Lower McGregor Diversion (July 1977 through 2032); discounted at seven percent per annum to 1972.
(2) Based on average generation shown in Table 5-8.
(3) Figures are to nearest $10,000 based on BCHPA cost data for provision of equivalent energy and capacity from Hat Creek; they are for the most likely growth and price change projection.
(4) At G.M. Shrum and Site One Generating Stations -- see 5.5.1.

6.5 Ecological Consequences of Upstream Projects

The following description of these consequences on local and regional resources is abridged from that contained in the Fraser River Ecology Committee Summary Report (Reference: Annex II, 3-6). Evaluation techniques utilized in computing the costs of these consequences are outlined in 3.6. Present worths quoted herein from the Summary Report are based generally on the economic criteria listed in 3.1, except for minor differences in the time horizons used in their development from that given in 3.1f. These differences were considered by the Ecology Committee to be insufficient to necessitate adjustment of the present worth figures.

Consensus was not reached by the Ecology Committee with respect to several factors basic to evaluation of the ecological consequences of project development; hence its Summary Report and this abridgment largely reflect the separate opinions of those agencies most involved with each resource. The principal factors lacking collective Ecology Committee opinion were market level choices for resource evaluation, real value escalator selection, anadromous fish loss estimates and evaluations, and water quality change forecasts. This lack of general agreement is understandable in view of the relatively new concepts used in natural resource evaluation and the problems encountered in making determinate estimates of the effects of changed conditions arising from project development.

6.5.1 Lower McGregor Diversion

6.5.1.1 The Anadromous Fish Resource

The Lower McGregor Diversion project would reduce the peak daily flow of the McGregor River at the damsite from about 40,000 cfs in an average runoff year to 1,000 cfs or less, depending on the totality of the diversion. Impoundment is not expected to lower the present high nutrient load in the river downstream from the damsite; but it would virtually eliminate the dilution effect occurring in this reach under natural flow conditions. The loss of McGregor River inflow would adversely affect the water quality of the Fraser River downstream from their confluence; but the available data are insufficient to quantify this effect. Mitigation of these effects through increased project outflows during the high water period has not been recommended, as such increases would be incompatible with the purpose of the project.

About 600 chinook salmon now spawn upstream from the proposed damsite. However, the provision of fish passage facilities through the dam is not recommended due to its height of 460 feet, and to the inundation of nearly all of the presently utilized spawning areas, as well as one-quarter of the estimated 861,000 square yards of potential spawning areas. Migrating juvenile salmon probably would be attracted to the diversion and so lost to production. The largest salmon stock existing in the reach of the McGregor River downstream from the damsite is about 200 chinook in Seebach Creek, with a 2,000 potential; this stock could face virtual elimination from project development. The major impact of the resulting reduced flows in the Fraser River system would be on salmon stocks upstream from Shelley, where the Bowron River sockeye run may be endangered; lesser effects would be anticipated on stocks further downstream, such as Nechako River chinook and sockeye. Losses to both upstream and downstream Fraser River migrants could be expected, due to lower freshet flows, poorer water quality, and lower dissolved oxygen content.

The diversion route offers possible access for parasite-carrying Arctic pike to the Fraser River system. Infestation of Fraser River salmon from this source could have a serious impact on the marketability of these salmon, and consequently on the British Columbia salmon industry as a whole. Direct losses of undetermined magnitude to Fraser salmon stocks also would be occasioned by predation and inter-species competition for food. Prevention of pike transfer might be achieved by: (a) construction of a barrier on the Parsnip River near Anzac; (b) construction of a barrier at the Arctic-Pacific divide; or (c) permanent complete closure of the McGregor River from the Fraser River system. Possibility (a) or (b) would require a barrier perhaps 25 feet or higher to block migration completely at all stages; (a) also has an element of uncertainty, as pike already may be present in the Parsnip River system upstream from Anzac. Possibility (c) carries the risk of a landslide blocking the diversion channel. No assessment has been made of the effects of possible transfer of Pacific drainage disease organisms and parasites to the Arctic drainage.

The effects of this project on Fraser River salmon production were calculated assuming the provision of no mitigating measures in project design or operation. Table 6-10 gives the estimated percentage reductions in Fraser River salmon production associated with development of this project. The estimated average annual losses of Fraser River salmon associated with development of this project total 523,000, or seven percent of the 7,400,000 present total annual catch, as shown in Table 6-11.

The geographical areas referred to in Table 6-10 and succeeding percentage reduction Tables 6-15, 6-18, 6-21, 6-22, 6-23, 6-29 and 6-32 are defined as:

North Fraser Area -- all of the Fraser River basin upstream from Prince George to the Grand Canyon project site, including the Nechako River basin but excluding the McGregor River basin;

Middle Fraser Area-- all of the Fraser River basin downstream from Prince George to just upstream from the Fraser-Thompson Rivers confluence, excluding the Nechako River and Quesnel River basins;

Lower Fraser Area -- all of the Fraser River basin downstream from the Fraser-Thompson Rivers confluence, excluding the Thompson River basin.

Realization of the potential of existing natural spawning and rearing capacities and of existing and potential artificial propagation facilities is expected to result in a 20,400,000 total annual catch of Fraser River salmon. It is anticipated that the average annual loss associated with development of this project would increase to 1,660,000 under these conditions.

The estimated annual loss to the commercial fishery is $1.81 millions, which has a present worth of $62.61 millions; and the corresponding figures for salmon-related recreation are $850,000 and $39.44 millions, respectively.

TABLE 6-10

ESTIMATED PERCENTAGE REDUCTIONS IN FRASER RIVER SALMON PRODUCTION

ASSOCIATED WITH LOWER MCGREGOR DIVERSION PROJECT DEVELOPMENT

Region	Chinook	Sockeye	Coho	Pink	Chum
Upper Fraser River Basin					
A - Grand Canyon Project Basin	15	-	-	-	-
B - McGregor River Basin	82	-	-	-	-
C - North Fraser Area	12	16	-	-	-
Central Fraser River Basin					
D - Cariboo River Basin	10	-	-	-	-
E - Quesnel River Basin (less D)	10	12	-	-	-
F - Middle Fraser Area	10	12	10	10	-
Thompson River Basin					
G - Clearwater River Basin	2	2	2	-	-
H - North Thompson River Basin (less G)	2	2	2	-	-
J - Thompson & South Thompson River Basins (less G & H)	2	2	2	2	-
Lower Fraser Area	2	2	2	2	2

TABLE 6-11

ESTIMATED AVERAGE ANNUAL LOSSES IN NUMBERS OF FRASER RIVER SALMON (1)

ASSOCIATED WITH LOWER MCGREGOR DIVERSION PROJECT DEVELOPMENT

Species	Fishery				
	Commercial	Saltwater Sport	River Sport	Indian Food (2)	Total
Chinook	13,500	1,610	277	346	15,700
Sockeye	386,000	-	-	10,900	397,000
Coho	3,920	1,250	104	362	5,640
Pink	85,600	1,200	-	395	87,200
Chum	17,000	-	-	278	17,300
Total Loss	506,000	4,060	381	12,300	523,000
Total Catch	7,090,000	100,000	21,600	182,000	7,400,000
Percentage Loss	7	4	2	7	7

NOTES: (1) Numbers to three significant integral figures.
(2) Computed on a shared-loss basis.

Food fishing is an integral element in the lifestyle of the resident Indian population, as stated in the following excerpts from the report entitled "Indian Fishing and its Cultural Importance in the Fraser River System" (Bennett - 1973), published jointly by the Fisheries and Marine Service and the Union of British Columbia Indian Chiefs:

> "In the evaluation of impacts of dams or other projects upon Indian lifestyle in the Fraser River system, three main points deserve consideration:
>
> First, the water itself is part of the traditional Indian way of life. Most reserves are located on or within one-half mile of the system's waterways. Changes in the riverine environment would disrupt the established link between the people and the river - a significant aspect of Indian existence.
>
> Second, the fishery resource provides part of the food supply for a very high proportion of Indian families. If the fishery were adversely affected, a large number of Indians

would be without sufficient food. It is doubtful whether alternative forms of sustenance would be acceptable. Most of those sampled said they would not substitute other foods in place of fish in their diet. Furthermore, because of the fact that fishing is a fundamental part of their lives, the loss of the fishery would detach the Indian people from the culture which they have developed throughout the centuries.

Third, while the fishery is a prime concern, other faunal and floral resources of the system play important roles in the continuing native subsistence effort."

Possible total and definite losses to the Indian food fishery anticipated from project development were computed and expressed only in numbers of salmon, as there is no accurate method of evaluating these losses to this fishery in monetary terms.

Possible total losses to the Indian food fishery were estimated for each project by assuming that this fishery would share proportionately in the possible total losses in numbers of salmon calculated for the entire fishery. These results are referred to as being on a "shared-loss" basis; and on this basis the possible present total annual loss to the Indian food fishery from Lower McGregor Diversion project development would be 12,300 salmon (Table 6-11), with a corresponding potential total annual loss of 19,900 salmon.

In recognition of the magnitude of these estimated losses and of the high value of food fishing to the Indian lifestyle, it was agreed that the Indian food fishery rate of catch after project development should be maintained at essentially the preproject rate. This would be accomplished by preservation of the gross escapement, thereby limiting losses to the definite one resulting from elimination of a spawning population. With present basin productivity this definite loss resulting from Lower McGregor Diversion project development is estimated to be 129 chinook salmon annually; and with potential productivity there would be an annual loss of 276 chinook.

6.5.1.2 The Sports Fish, Wildlife and Recreational Resources

In the McGregor River basin, this project would replace the existing sports fish river, stream and lake habitat with one large lake. The altered water temperature patterns and probable shoreline slumping would lower the natural excellent productive conditions to moderate or even marginal quality. The limited range of water levels in the new lake might result in reasonably productive habitat areas existing where the shores slope gently, as in the arm upstream from Herrick Creek. Excellent spawning grounds would remain in Gleason and Pass Creeks. The existing sports fishery on Arctic, Portage, Pacific and Otter Lakes would be terminated; and it is doubtful if the new lake would become a popular fishing area.

The destruction of habitat caused by creation of the new lake would displace an estimated 300 moose (95 percent loss), 70 caribou (50 percent loss), 30 grizzly bear (90 percent loss), 35 black bear (50 percent loss), 50 pairs of nesting Canada geese (100 percent loss), and an unknown number of grouse and aquatic furbearing animals. Marten, fisher, wolverine and squirrel would continue to be abundant; but beaver, muskrat, mink and otter would disappear from the area. Shoreline debris and longer swimming distances would tend to cause additional losses to migrating species. These changed conditions would result in the disappearance of the present high quality hunting resource extending generally throughout the McGregor River basin, with a corresponding reduction in guiding and trapping activities.

Wildlife populations in the McGregor River valley downstream from the proposed damsite would decline owing to the drastic reduction in river flows and consequent changes in water conditions and shore area vegetation. These changes would cause a rapid decrease in waterfowl, sports fish and aquatic furbearing animals; and a more gradual reduction in other species.

Few good camping areas would exist in the vicinity of the new lake; and the reduced river flows downstream would virtually eliminate recreational water travel in this reach. While a potential for hiking to adjacent alpine areas still would exist, few people would visit the area for photography or general recreation. The main dam would not be near the principal tourist travel routes.

The estimated net impact of the lower McGregor Diversion project on the sports fish, wildlife and other recreational resources of the McGregor River basin is -$10.41 millions, as shown in Table 6-12.

TABLE 6-12

SPORTS FISH, WILDLIFE AND RECREATIONAL RESOURCES

COMPARISON OF PRESENT WORTHS UNDER PRESERVATION AND DEVELOPMENT ALTERNATIVES

LOWER MCGREGOR DIVERSION PROJECT -- IN MCGREGOR RIVER BASIN

Alternative	Benefits From Recreational Uses		Benefits From Commercial Uses	Total Benefits
	Primary	Secondary		
	($1,000)	($1,000)	($1,000)	($1,000)
Preservation	11,643	153	98	11,894
Development	1,422	30	29	1,481
Net Impact	-10,221	-123	-69	-10,413

In the Parsnip River basin, the greatest impact of the Lower McGregor Diversion project would occur along the 35-mile reach of the Parsnip River from the diversion entry below Arctic Lake downstream to the vicinity of Anzac. In this reach the Parsnip River meanders through a very flat marshy valley from one-half to one mile wide. Entry of the diverted water would drastically increase Parsnip River flows through this reach, causing extensive channel changes and an unknown degree of marshland modification. Parsnip River sports fish would be affected significantly; and the diversion could result in an undesirable exchange of fish species between the Arctic and Pacific drainages.

In the absence of specific data, it is believed that marshland changes would result in reduction of the moose population by perhaps one-half, and in some decline in numbers of bears, wolves, coyotes and other predators. Little effect on caribou is anticipated, and none on mountain goat. Hunting, guiding and trapping would be reduced to some extent.

The loss of nesting and feeding areas would adversely affect the duck, goose and other migrant waterfowl populations. This loss of habitat would be especially significant in view of the similar losses which have occurred as a result of Columbia River system development.

The effect of the project on recreational water travel and camping cannot be forecast accurately; the route from the new lake on the McGregor River to Williston Lake on the Peace River could become popular for canoe trips. The relatively remote location of the affected reach of the Parsnip River from principal tourist travel routes makes it unlikely that many people would visit the area for photography or general recreation purposes.

The estimated net impact of the Lower McGregor Diversion project on the sports fish, wildlife and other recreational resources of the Parsnip River basin is - $4.85 millions as shown in Table 6-13.

The Parsnip River valley fish and wildlife resources provide important food supplies for the Indian population of the region, and their trapline operations are a source of cash income. The river itself forms part of their historic travel system. While approximate monetary estimates of the value of these resource used by the Indians might be derived, they would not reflect the social value to the Indians in enabling them to maintain their traditional way of life. This is of particular importance to the Indians, as integration into a non-Indian society is difficult for many of them.

The estimated total net impact of the Lower McGregor Diversion project on the sports fish, wildlife and other recreational resources of the McGregor and the Parsnip River basins is - $15.27 millions, as shown in Table 6-14, which is derived from Tables 6-12 and 6-13.

TABLE 6-13

SPORTS FISH, WILDLIFE AND RECREATIONAL RESOURCES

COMPARISON OF PRESENT WORTHS UNDER PRESERVATION AND DEVELOPMENT ALTERNATIVES

LOWER MCGREGOR DIVERSION PROJECT -- IN PARSNIP RIVER BASIN

Alternative	Benefits From Recreational Uses		Benefits From Commercial Uses	Total Benefits
	Primary	Secondary (1)		
	($1,000)	($1,000)	($1,000)	($1,000)
Preservation	5,738	-	278	6,016
Development	1,075	-	88	1,163
Net Impact	-4,663	-	-190	-4,853

NOTE: (1) Secondary benefits are considered to be insignificant.

TABLE 6-14

SPORTS FISH, WILDLIFE AND RECREATIONAL RESOURCES

COMPARISON OF PRESENT WORTHS UNDER PRESERVATION AND DEVELOPMENT ALTERNATIVES

LOWER MCGREGOR DIVERSION PROJECT -- IN MCGREGOR AND PARSNIP RIVER BASINS

Alternative	Benefits From Recreational Uses		Benefits From Commercial Uses	Total Benefits
	Primary	Secondary		
	($1,000)	($1,000)	($1,000)	($1,000)
Preservation	17,381	153	376	17,910
Development	2,497	30	117	2,644
Net Impact	-14,884	-123	-259	-15,266

6.5.1.3 The Forestry Resource

In the McGregor River basin the new lake created by the Lower McGregor Diversion project would inundate about 139.5 million cubic feet of merchantable timber, estimated to permit an annual cut of 1.345 million cubic feet on a sustained yield basis. This annual cut was valued at $867,000 in terms of sawmill-produced lumber and chips, which has a present worth of $12.17 millions. The forest industry would sustain a direct loss of 44 jobs and there would be an indirect loss of the same number. The increase in transport costs resulting from the creation of the new lake was estimated to have a present worth of $2.16 millions.

The project would affect little merchantable timber in the Parsnip River basin, and would result only in costs to protect or alter existing forestry operations. These costs would include protection of the Pas Lumber Company sawmill, modification of a proposed bridge near Anzac, and relocation of some 15 miles of logging roads.

Other costs not directly related to the forest industry that would be incurred in the Parsnip River basin would be to raise and lengthen the British Columbia Railway Parsnip River bridge, and to relocate six miles of track; to raise the Hart Highway bridge and approaches, improve the channel and provide pier protection; and to increase the ballast over the gas and oil pipeline crossings on the bed of the river. All of these forestry and non-forestry costs were provided for in the flowage item of the project cost estimate (Table 4-7).

6.5.2 Grand Canyon

6.5.2.1 The Anadromous Fish Resource

Grand Canyon project construction and operation would have adverse effects on the anadromous fish resource. Although a fishway is provided in the project design, some reduction is anticipated in the average annual run of 5,800 chinook salmon past the dam. The project reservoir would inundate about 124,000 square yards or nearly 10 percent of the available spawning areas upstream from the damsite, and might decrease tributary chinook runs substantially.

In years of low runoff, the peak daily flow of the Fraser River at the project site is about 50,000 cfs, and the maximum monthly mean flow during such years approaches 40,000 cfs. Juvenile salmon survival could be below average with flows in this range, and almost certainly would decline if project operation lowered these flows by a substantial amount. This effect would be most noticeable in the reach of the river immediately downstream from the project, and thus would involve the important Bowron River salmon run. Such flow reductions, coupled with the release of cold water from the project, with turbine intakes more than 70 feet and spillway invert 48 feet below normal maximum headwater elevation, would degrade water quality downstream, due to less dilution, lower water temperatures, and reduced dissolved oxygen content.

Mitigation of these adverse water conditions would require adherence to the minimum project outflows listed in Table 5-7, and the installation of multi-level turbine intakes. The use of these minimum outflows would reduce average generation at the project by 20 MW, as shown in Table 5-8, or about 22 percent. The installation of additional turbine intakes at depths of 15 feet and 45 feet below normal maximum headwater elevation would add an estimated $3.63 millions to the project construction cost (Table 6-31).

The estimated percentage reductions in Fraser River salmon production associated with development of the project are given in Table 6-15, both without and with provision of the mitigating measures in project design and operation outlined above.

The estimated average annual losses of Fraser River salmon associated with development of this project total 750,000 without mitigation and 244,000 with mitigation, as shown in Table 6-16. These figures are respectively 10 and three percent of the 7,400,000 percent total annual catch. The average annual losses to the 20,400,000 potential total annual catch are estimated to be 2,470,000 without mitigation and 800,000 with mitigation.

Annual losses to the commercial fishery are estimated to be $2.65 millions without mitigation and $870,000 with mitigation, which have respective present worths of $92.49 millions and $30.59 millions. Annual losses to salmon-related recreation are estimated to be $1.28 millions without mitigation and $400,000 with mitigation; and the corresponding present worths are $65.03 millions and $20.19 millions, respectively.

On a shared-loss basis the possible total annual losses to the Indian food fishery would be 16,800 salmon without mitigation and 5,340 with mitigation (Table 6-16); the corresponding potential total annual losses would be 26,600 and 8,480 salmon respectively. There would be a definite present annual loss of 1,220 and a potential annual loss of 2,580 chinook without mitigation. No loss would occur with mitigation and maintenance of gross escapement.

6.5.2.2 The Sports Fish, Wildlife and Recreational Resources

Creation of the reservoir would reduce the available sports fish spawning areas by about 25 percent; and the littoral zone resulting from project operation and shoreline conditions would tend to cause a decline in fish food supply. Loss of an important food source for trout resident upstream from the project site would occur to the extent that the dam inhibits upstream passage and spawning of chinook salmon. These changes would reduce the existing sports fishery upstream from the project site; but their extent is uncertain, and hence they have not been evaluated in the present analysis.

The loss of winter range and destruction of habitat would reduce the resident moose and wolf populations by an estimated 80 percent, and black bear by 50 percent. The relatively few mule deer now present would disappear from the vicinity of the reservoir. Elimination of future guiding and trapping activities in the area is probable.

TABLE 6-15

ESTIMATED PERCENTAGE REDUCTIONS IN FRASER RIVER SALMON PRODUCTION

ASSOCIATED WITH GRAND CANYON PROJECT DEVELOPMENT

Region	Chinook		Sockeye		Coho		Pink		Chum	
	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation
Upper Fraser River Basin										
A - Grand Canyon Project Basin	100	40	-	-	-	-	-	-	-	-
B - McGregor River Basin	20	6	-	-	-	-	-	-	-	-
C - North Fraser Area	15	5	25	8	-	-	-	-	-	-
Central Fraser River Basin										
D - Cariboo River Basin	7	2	-	-	-	-	-	-	-	-
E - Quesnel River Basin (less D)	7	2	16	5	-	-	-	-	-	-
F - Middle Fraser Area	7	2	16	5	7	2	10	3	-	-
Thompson River Basin										
G - Clearwater River Basin	1	0.3	3	1	1	0.3	-	-	-	-
H - North Thompson River Basin (less G)	1	0.3	3	1	1	0.3	-	-	-	-
J - Thompson & South Thompson River Basins (less G & H)	1	0.3	3	1	1	0.3	3	1	-	-
Lower Fraser Area	1	0.3	3	1	1	0.3	3	1	3	1

TABLE 6-16

ESTIMATED AVERAGE ANNUAL LOSSES IN NUMBERS OF FRASER RIVER SALMON (1)

ASSOCIATED WITH GRAND CANYON PROJECT DEVELOPMENT

Species	Fishery									
	Commercial		Saltwater Sport		River Sport		Indian Food (2)		Total	
	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation
Chinook	26,500	12,100	3,160	1,450	1,200	170	198	58	31,100	13,800
Sockeye	559,000	178,000	-	-	-	-	15,400	4,910	574,000	183,000
Coho	1,980	578	631	189	52	16	182	53	2,840	836
Pink	114,000	37,100	1,600	522	-	-	553	181	116,000	37,800
Chum	25,500	8,490	-	-	-	-	422	143	25,900	8,630
Total Loss	727,000	236,000	5,390	2,160	1,250	186	16,800	5,340	750,000	244,000
Total Catch	7,090,000	7,090,000	100,000	100,000	21,600	21,600	182,000	182,000	7,400,000	7,400,000
Percentage Loss	10	3	5	2	6	1	9	3	10	3

NOTES: (1) Numbers to three significant integral figures.
(2) Computed on a shared-loss basis.

Substantial decreases in the resident waterfowl and aquatic furbearing animal populations would occur through loss of habitat, both by inundation of existing marshes and meadows in the reservoir area, and by reduction of wet lands downstream from the dam owing to elimination of the annual spring freshets. The ultimate disappearance of aquatic furbearing animals from the area is probable, as the new reservoir shoreline is unlikely to suit these species.

The reach of the Fraser River that would be inundated is of historic interest as part of one of the early travel and migration routes through this region. This loss, coupled with reduction in sports fish populations, would reduce the general recreational potential of the area. It is unlikely that this reduction would be offset by the project being a point of interest to tourists travelling the Yellowhead Highway.

The estimated net impact of the Grand Canyon project on the sports fish, wildlife and other recreational resources of the Upper Fraser region is -$11.03 millions, as shown in Table 6-17.

TABLE 6-17

SPORTS FISH, WILDLIFE AND RECREATIONAL RESOURCES

COMPARISON OF PRESENT WORTHS UNDER PRESERVATION AND DEVELOPMENT ALTERNATIVES

GRAND CANYON PROJECT

Alternative	Benefits From Recreational Uses		Benefits From Commercial Uses	Total Benefits
	Primary	Secondary		
	($1,000)	($1,000)	($1,000)	($1,000)
Preservation	11,671	180	51	11,902
Development	835	25	12	872
Net Impact	-10,836	-155	-39	-11,030

Development of the Grand Canyon project would create the first man-made barrier on the main stem of the Fraser River in its 850-mile passage from the Continental Divide to the sea. The value associated with retention of the river in its free-flowing state throughout its course would be diminished to the extent of the worth placed by society upon its preservation in this state.

6.5.2.3 The Forestry Resource

The Grand Canyon project would inundate about 97 million cubic feet of merchantable timber, estimated to permit an annual cut of 1.064 million cubic feet on a sustained yield basis. This annual cut was valued at $665,000 in terms of sawmill-produced lumber and chips, which has a present worth of $9.34 millions. The forest industry would sustain a direct loss of 35 jobs and there would be an indirect loss of the same number. The project would not affect forestry operations in the areas adjacent to the reservoir, and no forestry improvements would be lost by inundation.

6.5.3 Cariboo Falls

6.5.3.1 The Anadromous Fish Resource

The project reservoir would inundate the entire portion of the upper Cariboo River accessible to salmon, with the loss of about 85 percent of the most suitable spawning area. While fish passage facilities could be provided in the project, such provision is not recommended in view of the small numbers of salmon which presently utilize the river system upstream from the damsite, and the marginal quality of upstream spawning area that would remain after project development.

The substantial reductions in freshet flow that would occur in the Cariboo River downstream from the project could seriously affect downstream salmon populations. The Cariboo River run is fairly small and would not in itself justify the establishment of minimum outflows from the project. However, the freshet flow reductions could have a significant effect on the much larger Quesnel River salmon stocks, which are considered to warrant the application of minimum project outflows. Water quality downstream from the project may be degraded due to lower water temperatures and dissolved oxygen content resulting from the turbine intakes being about 100 feet below normal maximum headwater elevation.

Mitigation of these adverse water conditions would require adherence to the minimum project outflows listed in Table 5-7, and the installation of multi-level turbine intakes. The use of these minimum outflows would reduce average generation at the project by 3 MW as shown in Table 5-8, or about five percent. The installation of additional turbine intakes at depths of 15, 40 and 70 feet below normal maximum headwater elevation would add an estimated $7.26 millions to the project construction cost (Table 6-31).

The impact of the Cariboo Falls project would affect only the chinook and sockeye salmon species, and would be limited to the Cariboo and Quesnel River basins. The estimated percentage reductions in Fraser River salmon production associated with development of the project are given in Table 6-18, both without and with provision of the mitigating measures in project design and operation outlined above.

The estimated average annual losses of Fraser River salmon associated with development of this project total 12,600 without mitigation and 9,500 with mitigation, as shown in Table 6-19. The average annual losses to the 20,400,000 potential total annual catch are estimated to be 45,900 without mitigation and 34,400 with mitigation.

TABLE 6-18

ESTIMATED PERCENTAGE REDUCTIONS IN FRASER RIVER SALMON PRODUCTION ASSOCIATED WITH CARIBOO FALLS PROJECT DEVELOPMENT

Region	Chinook		Sockeye	
	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation
Central Fraser River Basin				
D - Cariboo River Basin	25	14	-	-
E - Quesnel River Basin (less D)	2	1.6	4	3

Annual losses to the commercial fishery are estimated to be $49,000 without mitigation and $37,000 with mitigation, which have respective present worths of $1.78 millions and $1.09 millions. Annual losses to salmon-related recreation are estimated to be $21,000 without mitigation and $15,000 with mitigation; and the corresponding present worths are $1.11 millions and $0.79 million, respectively.

The effect of the project on the Indian food fishery would be negligible.

6.5.3.2 The Sports Fish, Wildlife and Recreational Resources

The project reservoir would not support sports fish in the numbers and size presently available, as about 85 percent of the total spawning area would be inundated, while the steep shores and substantial drawdown would create a limited and unproductive littoral zone. Artificial enhancement of the sports fishery would not be justified under these conditions.

Inundation of virtually all of the 7,900 acres of winter range and accompanying loss of habitat in the Cariboo River Valley would reduce the resident moose population by an estimated 250 animals, about 90 percent of the total. Alternative winter range is not available, as it now is used to full capacity. Hunting quality in the area would decline, and guiding and trapping presumably would cease on completion of the project.

The loss of meadows and marshes through inundation would eliminate the resident waterfowl and reduce the aquatic furbearing animal populations, and would cause an estimated 80 percent decline in use of the area by migrating waterfowl.

The project would eliminate river boating, canoeing, valley bottom wildland recreation opportunities, and sites of historic interest in the

TABLE 6-19

ESTIMATED AVERAGE ANNUAL LOSSES IN NUMBERS OF FRASER RIVER SALMON (1)

ASSOCIATED WITH CARIBOO FALLS PROJECT DEVELOPMENT

Species	Fishery									
	Commercial		Saltwater Sport		River Sport		Indian Food (2)		Total	
	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation
Chinook	217	147	25	17	3	2	-	-	245	166
Sockeye	12,400	9,330	-	-	-	-	-	-	12,400	9,330
Coho	-	-	-	-	-	-	-	-	-	-
Pink	-	-	-	-	-	-	-	-	-	-
Chum	-	-	-	-	-	-	-	-	-	-
Total Loss	12,600	9,480	25	17	3	2	-	-	12,600	9,500
Total Catch	7,090,000	7,090,000	100,000	100,000	21,600	21,600	182,000	182,000	7,400,000	7,400,000
Percentage Loss	-	-	-	-	-	-	-	-	-	-

NOTES: (1) Numbers to three significant integral figures.
(2) Computed on a shared-loss basis.

Keithley Creek area. Recreational potential of the reservoir would depend on navigability and shoreline access. This potential probably is very limited, owing to the nearby location of the much larger and more interesting Quesnel Lake and numberous smaller lakes.

The estimated net impact of the Cariboo Falls project on the sports fish, wildlife and other recreational resources of the Cariboo River area is -$2.26 millions, as shown in Table 6-20.

TABLE 6-20

SPORTS FISH, WILDLIFE AND RECREATIONAL RESOURCES

COMPARISON OF PRESENT WORTHS UNDER PRESERVATION AND DEVELOPMENT ALTERNATIVES

CARIBOO FALLS PROJECT

Alternative	Benefits From Recreational Uses		Benefits From Commercial Uses	Total Benefits
	Primary	Secondary		
	($1,000)	($1,000)	($1,000)	($1,000)
Preservation	2,316	49	47	2,412
Development	143	7	5	155
Net Impact	-2,173	-42	-42	-2,257

Regardless of project development, the Cariboo River valley probably will be logged extensively in the future, resulting in removal of most of the mature timber. This would result in gradual replacement of the present wilderness activities by outdoor recreational use common to accessible forested areas, which tend to attract more people. This possible increase in recreational use of the area would be eliminated by creation of the reservoir.

6.5.3.3 The Forestry Resource

The Cariboo Falls project would inundate about 39 million cubic feet of merchantable timber, estimated to permit an annual cut of 0.354 million cubic feet on a sustained yield basis. This annual cut was valued at $220,000 in terms of sawmill-produced lumber and chips, which has a present worth of $3.10 millions. The forest industry would sustain a direct loss of 12 jobs, and there would be an indirect loss of the same number. Relocation of the existing logging road through the reservoir area, was estimated to cost $915.000, which has a present worth of $834,000. The increase in transport costs resulting from reservoir creation was estimated to have a present worth of $655,000, based on a 24-year period during which all mature timber could have been removed from the remaining area.

6.5.4 The Clearwater River Projects

Five projects are located on the Clearwater River; proceeding downstream they are Hobson Lake, Clearwater-Azure, Hemp Creek, Granite Canyon and Clearwater. The first two of these projects provide storage capacity, mostly on existing lakes; the third creates storage capacity on the river itself; and the last two develop pondage only. All five projects contain power generation facilities.

These projects have separate impacts on some of the resources of the basin, while the impacts on other resources result from project combinations. The separate impacts are noted hereunder where possible, and the project combinations are given for each group impact.

6.5.4.1 The Anadromous Fish Resource

The Hobson Lake project would not affect potential salmon production because it would inundate streams only marginally suitable for salmon propagation and considered to be inalterably inaccessible. The Clearwater-Azure project would inundate some 141,000 square yards of potential spawning area now inaccessible but blocked only by minor obstructions. The Hemp Creek project would inundate most of the presently utilized chinook spawning area and 70 percent of the potential spawning area in the Clearwater River. The Granite Canyon project would inundate about 37,000 square yards of potential spawning area now used by juvenile chinook and hence important for rearing purposes. The Clearwater project would inundate no existing or potential spawning areas. Construction of the five projects could cause an annual loss of 1,700 chinook.

The cumulative effects of the three storage projects could degrade the water quality in the Clearwater River through lowering of the dissolved oxygen content by storage operations, and reduction of reaeration owing to inundation of rapids in the river. Nitrogen supersaturation is not considered likely.

Storage operations on the Clearwater River would tend to increase the winter flows in the North Thompson River downstream from their confluence, which could be beneficial to incubating chinook, sockeye and coho eggs. However, these operations would reduce the freshet flow downstream, which could deposit silt in the North Thompson River spawning gravels and lower the dissolved oxygen content, tending to reduce juvenile salmon survival.

Mitigation of the possible adverse effects of Clearwater River regulation would require adherence to the minimum project outflows listed in Table 5-7, and preferably to minimum freshet flows of 15,000 cfs in the lower Clearwater River and 35,000 cfs in the North Thompson River downstream from their confluence, except during large freshets. Multi-level turbine intakes should be installed at the Hemp Creek project at an estimated construction cost of

$3.02 millions (Table 6-31) to provide more flexible control of release water temperatures. If the Granite Canyon and Clearwater projects are built, aeration facilities should be installed at an estimated construction cost of $1.21 million, either at Hemp Creek or at Clearwater. Adherence to the minimum project outflows listed in Table 5-7 would cause no loss of average generation at the Clearwater River projects.

The estimated percentage reductions in Fraser River salmon production associated with Clearwater River project development are given in Tables 6-21 to 6-23 for three project selections, both without and with provision of the mitigating measures in project design and operation outlined above. These three selections are: A - Hemp Creek only; B - Hobson Lake, Clearwater-Azure and Hemp Creek; and C - all five Clearwater River projects.

Tables 6-24 to 6-26 give the estimated average annual losses of Fraser River salmon associated with development of each of the three project selections listed above. Without mitigation these losses total 366,000, 367,000 and 397,000 for A, B and C respectively; with mitigation they total 270,000 in all three cases. These loss figures are respectively five percent of the present 7,400,000 total annual catch without mitigation, and four percent with mitigation. The average annual losses to the 20,400,000 potential total annual catch without mitigation are estimated to be 777,000, 780,000 and 835,000 for A, B and C respectively; with mitigation they are 560,000 in all three cases.

The estimated annual losses to the commercial fishery without mitigation are $1.26 millions, $1.26 millions and $1.37 millions for A, B and C respectively; these losses have respective present worths of $34.14 millions, $34.21 millions and $37.29 millions. The estimated annual losses with mitigation are $930,000 for all three cases, with a corresponding present worth of $24.84 millions.

The estimated annual losses to salmon-related recreation without mitigation are $607,000, $610,000 and $660,000 for A, B and C respective; these losses have respective present worths of $25.09 millions, $25.24 millions and $27.31 millions. The estimated annual losses with Mitigation are $448,000 in all three cases, with a corresponding present worth of $18.54 millions.

On a shared-loss basis the possible total annual losses to the Indian food fishery without mitigation would be 5,450, 5,460 and 5,620 salmon for A, B and C respectively; with mitigation these losses would be 4,010 salmon in all three cases (Tables 6-24 to 6-26). The corresponding potential total annual losses would be 8,680, 8,690 and 8,980 without mitigation, and 6,340 with mitigation. In all three cases without mitigation the definite present annual losses would be 381 chinook, 80 coho and 18 sockeye; and the potential annual losses of these species would be 816, 163 and 18 respectively. With mitigation the definite present annual losses would be 381 chinook and 61 coho, with potential annual losses of 807 and 125 respectively.

A value additional to those directly related to the use of a resource is associated with the preservation of the recreational opportunities it may provide, irrespective of their actual use, and is referred to as a "preservation"

TABLE 6-21

ESTIMATED PERCENTAGE REDUCTIONS IN FRASER RIVER SALMON PRODUCTION

ASSOCIATED WITH HEMP CREEK PROJECT DEVELOPMENT

Region	Chinook		Sockeye		Coho		Pink		Chum	
	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation
Upper Fraser River Basin										
A - Grand Canyon Project Basin	1	0.8	-	-	-	-	-	-	-	-
B - McGregor River Basin	1	0.8	-	-	-	-	-	-	-	-
C - North Fraser Area	1	0.8	2	1.5	-	-	-	-	-	-
Central Fraser River Basin										
D - Cariboo River Basin	1	0.8	-	-	-	-	-	-	-	-
E - Quesnel River Basin (less D)	1	0.8	2	1.5	-	-	-	-	-	-
F - Middle Fraser Area	1	0.8	2	1.5	1	0.8	2	1.5	-	-
Thompson River Basin										
G - Clearwater River Basin	100	100	100	30	100	84	-	-	-	-
H - North Thompson River Basin (less G)	15	5	20	6	7	3	-	-	-	-
J - Thompson & South Thompson River Basins (less G & H)	6	4	8	6	6	3	5	3.5	-	-
Lower Fraser Area	1	0.8	2	1.5	1	0.8	2	1.5	2	1.5

TABLE 6-22

ESTIMATED PERCENTAGE REDUCTIONS IN FRASER RIVER SALMON PRODUCTION

ASSOCIATED WITH DEVELOPMENT OF HOBSON LAKE, CLEARWATER-AZURE AND HEMP CREEK PROJECTS

Region	Chinook		Sockeye		Coho		Pink		Chum	
	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation
Upper Fraser River Basin										
A - Grand Canyon Project Basin	1	0.8	-	-	-	-	-	-	-	-
B - McGregor River Basin	1	0.8	-	-	-	-	-	-	-	-
C - North Fraser Area	1	0.8	2	1.5	-	-	-	-	-	-
Central Fraser River Basin										
D - Cariboo River Basin	1	0.8	-	-	-	-	-	-	-	-
E - Quesnel River Basin (less D)	1	0.8	2	1.5	-	-	-	-	-	-
F - Middle Fraser Area	1	0.8	2	1.5	1	0.8	2	1.5	-	-
Thompson River Basin										
G - Clearwater River Basin	100	100	100	30	100	84	-	-	-	-
H - North Thompson River Basin (less G)	17	5	21	6	7	3	-	-	-	-
J - Thompson & South Thompson River Basins (less G & H)	6	4	8	6	6	3	5	3.5	-	-
Lower Fraser Area	1	0.8	2	1.5	1	0.8	2	1.5	2	1.5

TABLE 6-23

ESTIMATED PERCENTAGE REDUCTIONS IN FRASER RIVER SALMON PRODUCTION

ASSOCIATED WITH DEVELOPMENT OF ALL FIVE CLEARWATER RIVER PROJECTS

Region	Chinook		Sockeye		Coho		Pink		Chum	
	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation
Upper Fraser River Basin										
A - Grand Canyon Project Basin	1	0.8	-	-	-	-	-	-	-	-
B - McGregor River Basin	1	0.8	-	-	-	-	-	-	-	-
C - North Fraser Area	1	0.8	2	1.5	-	-	-	-	-	-
Central Fraser River Basin										
D - Cariboo River Basin	1	0.8	-	-	-	-	-	-	-	-
E - Quesnel River Basin (less D)	1	0.8	2	1.5	-	-	-	-	-	-
F - Middle Fraser Area	1	0.8	2	1.5	1	0.8	2	1.5	-	-
Thompson River Basin										
G - Clearwater River Basin	100	100	100	30	100	84	-	-	-	-
H - North Thompson River Basin (less G)	25	5	25	6	8	3	-	-	-	-
J - Thompson & South Thompson River Basins (less G & H)	7	4	9	6	7	3	5	3.5	-	-
Lower Fraser Area	1	0.8	2	1.5	1	0.8	2	1.5	2	1.5

TABLE 6-24

ESTIMATED AVERAGE ANNUAL LOSSES IN NUMBERS OF FRASER RIVER SALMON (1)

ASSOCIATED WITH HEMP CREEK PROJECT DEVELOPMENT

Species	Fishery									
	Commercial		Saltwater Sport		River Sport		Indian Food (2)		Total	
	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation
Chinook	14,200	11,000	1,690	1,320	439	396	236	168	16,500	12,900
Sockeye	242,000	179,000	-	-	-	-	4,320	3,180	247,000	182,000
Coho	5,340	3,250	1,700	1,040	159	100	242	165	7,440	4,550
Pink	76,800	56,400	1,080	790	-	-	373	277	78,200	57,500
Chum	17,000	12,700	-	-	-	-	278	211	17,300	12,900
Total Loss	356,000	262,000	4,460	3,140	598	496	5,450	4,010	366,000	270,000
Total Catch	7,090,000	7,090,000	100,000	100,000	21,600	21,600	182,000	182,000	7,400,000	7,400,000
Percentage Loss	5	4	4	3	3	2	3	2	5	4

NOTES: (1) Numbers to three significant integral figures.
(2) Computed on a shared-loss basis.

TABLE 6-25

ESTIMATED AVERAGE ANNUAL LOSSES IN NUMBERS OF FRASER RIVER SALMON (1)

ASSOCIATED WITH DEVELOPMENT OF HOBSON LAKE, CLEARWATER-AZURE AND HEMP CREEK PROJECTS

Species	Fishery									
	Commercial		Saltwater Sport		River Sport		Indian Food (2)		Total	
	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation
Chinook	14,400	11,000	1,720	1,320	443	396	237	168	16,800	12,900
Sockeye	243,000	179,000	-	-	-	-	4,330	3,180	247,000	182,000
Coho	5,340	3,250	1,700	1,040	159	100	242	165	7,440	4,550
Pink	76,800	56,400	1,080	790	-	-	373	277	78,200	57,500
Chum	17,000	12,700	-	-	-	-	278	211	17,300	12,900
Total Loss	356,000	262,000	4,490	3,140	602	496	5,460	4,010	367,000	270,000
Total Catch	7,090,000	7,090,000	100,000	100,000	21,600	21,600	182,000	182,000	7,400,000	7,400,000
Percentage Loss	5	4	4	3	3	2	3	2	5	4

NOTES: (1) Numbers to three significant integral figures.
(2) Computed on a shared-loss basis.

TABLE 6-26

ESTIMATED AVERAGE ANNUAL LOSSES IN NUMBERS OF FRASER RIVER SALMON (1)

ASSOCIATED WITH DEVELOPMENT OF ALL FIVE CLEARWATER RIVER PROJECTS

Species	Fishery									
	Commercial		Saltwater Sport		River Sport		Indian Food (2)		Total	
	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation
Chinook	16,200	11,000	1,930	1,320	468	396	261	168	18,800	12,900
Sockeye	266,000	179,000	-	-	-	-	4,440	3,180	270,000	182,000
Coho	5,840	3,250	1,860	1,040	172	100	253	165	8,120	4,550
Pink	81,400	56,400	1,140	790	-	-	386	277	83,000	57,500
Chum	17,000	12,700	-	-	-	-	278	211	17,300	12,900
Total Loss	386,000	262,000	4,930	3,140	640	496	5,620	4,010	397,000	270,000
Total Catch	7,090,000	7,090,000	100,000	100,000	21,600	21,600	182,000	182,000	7,400,000	7,400,000
Percentage Loss	5	4	5	3	3	2	3	2	5	4

NOTES: (1) Numbers to three significant integral figures.
(2) Computed on a shared-loss basis.

value. Assignment of a tangible allowance for a preservation value is contingent on the resource being relatively unique and subject to irreversible destruction by project development. Wells Gray Provincial Park is considered to be the only area that would be affected by development of any of the projects listed in Table 4-6 which meets these preservation value criteria in relation to the anadromous fish resource. Development of project selection C without mitigation has been assigned an annual preservation value loss of $271,000, with a corresponding present worth of $6.47 millions. This loss figure also was assigned to project selections A and B without mitigation, as all three selections contain the Hemp Creek project, which is charged with almost all of the anadromous fish losses estimated for the five Clearwater River projects (Tables 6-24 to 6-26).

6.5.4.2 The Sports Fish, Wildlife and Recreational Resources

Project development in the Clearwater River system would result in the creation of generally steep-shored reservoirs that would be very unproductive for fish, owing to the loss of spawning habitat and the reduction of the existing limited littoral zones. Project operation would neither ameliorate the present low water temperatures nor improve the turbidity to any extent. The Hobson Lake reservoir would lower the existing limited fish production capability of the drainage area to this lake. None of the tributaries of the Clearwater-Azure reservoir that would be made available by the inundation of falls and rapids offers spawning habitat development potential. Hemp Creek project development would eliminate most of the present Clearwater River fishery through inundation. Stocking to enhance fish populations is considered to be impractical.

The loss of high quality habitat at the north end of Hobson Lake would reduce the resident moose and grizzly bear populations; adequate winter range for caribou would remain in areas above full reservoir level, but drawdown may affect their migration patterns. Clearwater-Azure reservoir creation would inundate about 1,500 acres of prime winter range, resulting in an estimated complete loss of the present moose and caribou populations. Hemp Creek reservoir would eliminate about half of the best winter range in the project area, thus reducing the numbers of resident moose and deer. Granite Canyon project would displace small moose, black bear and deer populations for the same reason. A marked decrease in present hunting activities would be inevitable.

Habitat loss would affect waterfowl resident in the area adjacent to the north end of Hobson Lake. Clearwater-Azure reservoir would eliminate the existing habitat areas between Clearwater and Azure Lakes and along the upper Azure River, sharply reducing the resident aquatic furbearer and waterfowl populations. Hemp Creek reservoir would have the same effect on these species; and its large range of level fluctuation would inhibit reestablishment of these populations. The stable water levels resulting from Granite Canyon project development probably would result in an increase of aquatic furbearers and waterfowl.

Development of the three Clearwater River system reservoir projects would inundate the major existing campsite at Clearwater Lake, the wilderness campsites on Clearwater and Azure Lakes, and the potential campsite areas at the Clearwater-Mahood Rivers confluence. New campsites could be built on the Clearwater-Azure and Hemp Creek reservoirs if the areas continued to attract sufficient patronage. Assuming complete reservoir clearing, all three reservoirs would be navigable, but the shorelines would offer very few wilderness campsites and would be less attractive than formerly, especially in early summer before reservoir refill was complete. Stable water levels would encourage boating on the headponds of the Granite Canyon and Clearwater projects, and campsites would be available on the adjacent benchlands. Boaters and canoeists probably would choose to use other lakes such as Mahood, as being more attractive in their continuing natural state. More campers probably would be attracted to Spahats Falls and Dawson Falls, requiring the installation of increased facilities at these locations.

The increased ease of access to much of the Clearwater River system that would result from project development may possibly maintain the number of day-visitors to the area for general sightseeing and photography. However, the intrusion on the wilderness would curtail the use of the area for camping, hiking and canoeing, and greatly reduce the overall number of recreation-days spent there.

The estimated net impact of the five Clearwater River projects on the sports fish, wildlife and other recreational resources of the Clearwater River drainage basin is -$57.08 millions, as shown in Table 6-27.

TABLE 6-27

SPORTS FISH, WILDLIFE AND RECREATIONAL RESOURCES

COMPARISON OF PRESENT WORTHS UNDER PRESERVATION AND DEVELOPMENT ALTERNATIVES

CLEARWATER RIVER PROJECTS

Alternative	Benefits From Recreational Uses		Benefits From Commercial Uses	Total Benefits
	Primary	Secondary		
	($1,000)	($1,000)	($1,000)	($1,000)
Preservation	71,550	2,720	90	74,360
Development	16,280	950	50	17,280
Net Impact	-55,270	-1,770	-40	-57,080

The foregoing net impact of -$57.08 millions has been apportioned among the three storage projects; Hobson Lake, Clearwater-Azure and Hemp Creek. The two downstream projects which develop pondage only, Granite Canyon and Clearwater, cause minor damages compared to those from the storage projects; and these minor damages have been included in the figures for Hemp Creek. This apportionment is given in Table 6-28.

TABLE 6-28

APPORTIONMENT OF NET IMPACT OF CLEARWATER RIVER STORAGE PROJECTS

Project	Net Impact	Net Impact
	($1,000)	(%)
Hobson Lake	-2,000	3.5
Clearwater-Azure	-31,000	54.3
Hemp Creek	-24,080	42.2
Total	-57,080	100.0

The severe impact of the Clearwater River storage projects on the outdoor recreational resources of the area which they would affect is illustrated by the figures in Table 6-28, and is due to the location of almost all of this area within Wells Gray Provincial Park. This is a Class A park under the British Columbia Park Act, and as such it is "dedicated to the preservation of its natural environment for the inspiration, use, and enjoyment of the public". The uses of Class A park lands and natural resources situated therein are limited by this Act to those necessary to the preservation and maintenance of the recreational values of these parks.

Wells Gray Park is the third largest park in the provincial parks system; it possesses a relatively unspoiled wilderness character, offers a diversity of outstanding recreational features, and is reasonably accessible to most British Columbia residents. Development of the Clearwater River storage projects would largely destroy the great potential capacity of this park to satisfy the growing recreational demands imposed by an increasing population in a province with generally high standards of living. The loss of this potential capacity would substantially reduce the ability of the provincial parks system to provide adequate diversified outdoor recreational opportunities for residents of the province. This park is by far the most important recreational area that would be affected by development of any of the projects listed in Table 4-6; and its retention in its natural state carries significant preservation and social values supplementary to the impact values given in Table 6-28.

6.5.4.3 The Forestry Resource

Almost all of the area that would be affected by construction of the Hobson Lake, Clearwater-Azure and Hemp Creek projects is within Wells Gray Park and therefore is not available for normal commercial forestry operations; hence it is assumed that construction of these projects would have no appreciable effect on the commercial forestry resource. Although the Granite Canyon and Clearwater projects are situated outside of this Park, their impact on the forestry resource is considered to be insignificant.

6.5.5 Lower McGregor Non-Diversion

This project is an alternative to the Lower McGregor Diversion project referred to in 6.5.1. As shown in Table 4-6, this alternative has a slightly smaller dam and reservoir, much greater drawdown, and on-site power generation facilities. Its ecological effects resemble those of the diversion project, but vary in extent and do not involve the Parsnip River basin.

6.5.5.1 The Anadromous Fish Resource

Elimination of freshet peaks through impoundment would reduce the dilution effect in the McGregor River downstream from the dam, which presently has a high nutrient load. Regulation of the McGregor River would tend to lower the water quality of the Fraser River downstream from their confluence during freshet periods when migration is in progress, through reduction of temperatures and of dissolved oxygen content.

Some 600 chinook now spawn upstream from the proposed damsite. However, the provision of fish passage facilities through the dam is not recommended due to its height of 440 feet, and to the inundation of nearly all of the presently utilized spawning areas, as well as probably one-quarter of the potential spawning areas. The largest salmon stock existing in the reach of the McGregor River downstream from the damsite is about 200 chinook in Seebach Creek, with a 2,000 potential; this stock could face drastic reduction from project operation without minimum flow releases. Reduced freshet flows in the Fraser River system could affect salmon stocks upstream from Shelley, including the Bowron River sockeye run, and also might cause losses to both upstream and downstream migrants. These effects could be offset by project operation with minimum flow releases.

Mitigation of these adverse water conditions would require adherence to the minimum project outflows listed in Table 5-7, and the installation of multi-level turbine intakes. The use of these minimum outflows would have only minor effect on the average generation at the project, as shown in Table 5-8 and explained in 5.5.9. The installation of multi-level turbine intakes at intermediate depths below normal maximum operating elevation would add possibly $6.05 millions to the project construction cost.

The estimated percentage reduction in Fraser River salmon production associated with development and operation of this project with the mitigating measures outlined above are given in Table 6-29.

TABLE 6-29

ESTIMATED PERCENTAGE REDUCTIONS IN FRASER RIVER SALMON PRODUCTION

ASSOCIATED WITH LOWER MCGREGOR NON-DIVERSION PROJECT DEVELOPMENT

Region	Chinook	Sockeye	Coho	Pink	Chum
Upper Fraser River Basin					
A - Grand Canyon Project Basin	8	-	-	-	-
B - McGregor River Basin	41	-	-	-	-
C - North Fraser Area	6	8	-	-	-
Central Fraser River Basin					
D - Cariboo River Basin	5	-	-	-	-
E - Quesnel River Basin (less D)	5	6	-	-	-
F - Middle Fraser Area	5	6	5	5	-
Thompson River Basin					
G - Clearwater River Basin	1	1	1	-	-
H - North Thompson River Basin (less G)	1	1	1	-	-
J - Thompson & South Thompson River Basins (Less G & H)	1	1	1	1	-
Lower Fraser Area	1	1	1	1	1

The estimated average annual losses of Fraser River salmon associated with development and operation of this project with the mitigating features outlined above total 261,000, or four percent of the 7,400,000 present total annual catch, as shown in Table 6-30. The average annual loss to the 20,400,000 potential total catch is estimated to be 830,000 under these conditions.

TABLE 6-30

ESTIMATED AVERAGE ANNUAL LOSSES IN NUMBERS OF FRASER RIVER SALMON (1)

ASSOCIATED WITH LOWER MCGREGOR NON-DIVERSION PROJECT DEVELOPMENT

Species	Fishery				
	Commercial	Saltwater Sport	River Sport	Indian Food (2)	Total
Chinook	7,160	853	147	183	8,340
Sockeye	193,000	-	-	5,450	198,000
Coho	1,960	625	52	181	2,820
Pink	42,800	600	-	198	43,600
Chum	8,500	-	-	139	8,640
Total Loss	253,000	2,080	199	6,150	261,000
Total Catch	7,090,000	100,000	21,600	182,000	7,400,000
Percentage Loss	4	2	1	3	4

NOTES: (1) Numbers to three significant integral figures.
(2) Computed on a shared loss basis.

The estimated annual loss to the commercial fishery with mitigation is $910,000, which has a present worth of $31.30 millions; and the corresponding figures for salmon-related recreation are $430,000 and $19.72 millions respectively.

On a shared-loss basis the possible total annual loss to the Indian food fishery would be 6,150 salmon (Table 6-30), with a corresponding potential total annual loss of 9,950 salmon. There would be a definite present annual loss of 70 and a potential annual loss of 150 chinook.

6.5.5.2 The Sports Fish, Wildlife and Recreational Resources

The Lower McGregor Non-Diversion project would have a somewhat greater impact on these resources in the McGregor River basin than would the diversion project discussed in 6.5.1.2, because of the much greater fluctuation in its reservoir water levels. This increase in impact may be offset to some extent by the slightly lower dam and consequent smaller reservoir area of the non-diversion project. For analysis purposes it has been assumed that these impacts would not differ substantially; therefore the estimated net impact of the non-diversion project on the sports fish, wildlife and recreational resources has been taken as -$10.41 millions, as shown in Table 6-12.

6.5.5.3 The Forestry Resource

The impact of the non-diversion project on the forestry resource of the McGregor River basin is considered to be almost identical to that of the diversion project discussed in 6.5.1.3, an annual loss of $867,000 in terms of sawmill-produced lumber and chips for a present worth of $12.17 millions. The increase in transport costs resulting from reservoir creation would have an estimated present worth of $2.16 millions. There would be no costs to protect or alter existing forestry operations or related facilities in the Parsnip River basin, as the non-diversion project does not affect the Parsnip River.

6.5.6 System E

The ecological consequences of the upstream projects comprising System E have been described briefly in 6.5.1 to 6.5.4; the consequences of complete System E development are essentially combinations of these separate project impacts.

6.5.6.1 The Anadromous Fish Resource

All of the effects detrimental to this resource ascribed to the respective projects would occur with complete System E development. Mitigation of adverse water conditions would require adherence to the minimum project water releases itemized in Table 5-7, and provision of the mitigating project features outlined in 6.5.1 to 6.5.4 and listed in Table 6-31.

The estimated percentage reductions in Fraser River salmon production associated with complete System E development, both without and with provision of the mitigating measures referred to above, are given in Table 6-32.

The estimated average annual losses of Fraser River salmon associated with complete System E development total 1,830,000 without mitigation and 920,000 with mitigation, as shown in Table 6-33. These figures are respectively 25 and 12 percent of the 7,400,000 present total annual catch. The average annual losses to the 20,400,000 potential annual catch are estimated to be 5,840,000 without mitigation and 2,720,000 with mitigation.

TABLE 6-31

MITIGATING FEATURES FOR SYSTEM E AND ALTERNATIVE PROJECTS (1)

Project(s)	Feature	Estimated Costs (2)		
		Feature		Project
		Direct (3)	Construction (4)	Construction
		($1,000)	($1,000)	($1,000)
Grand Canyon	Fishway	1,905 (5)	2,305	
	MLTI (6)	3,000	3,630	5,935
Cariboo Falls	MLTI (6)	6,000	7,260	7,260
Hemp Creek - in combination (7)	MLTI (6)	2,500	3,025	
	Aeration facilities	1,000	1,210	4,235
Complete System E		14,405		17,430
Hemp Creek only	MLTI (6)	2,500	3,025	3,025
Lower McGregor	MLTI (6)	5,000 (8)	6,050	6,050

NOTES:
(1) As proposed by Fisheries and Marine Service, Environment Canada.
(2) At 1972 price levels.
(3) Fisheries and Marine Service estimates except where noted otherwise.
(4) Direct cost plus 10 percent for engineering and administration, plus 10 percent for contingencies.
(5) From Table 4-8.
(6) Multi-level turbine intakes.
(7) With any other Clearwater River project.
(8) Derived from estimated costs of similar installations at other projects.

TABLE 6-32

ESTIMATED PERCENTAGE REDUCTIONS IN FRASER RIVER SALMON PRODUCTION

ASSOCIATED WITH COMPLETE SYSTEM E DEVELOPMENT

Region	Chinook		Sockeye		Coho		Pink		Chum	
	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation
Upper Fraser River Basin										
A - Grand Canyon Project Basin	100	67	-	-	-	-	-	-	-	-
B - McGregor River Basin	99	81	-	-	-	-	-	-	-	-
C - North Fraser Area	38	18	55	23	-	-	-	-	-	-
Central Fraser River Basin										
D - Cariboo River Basin	36	28	-	-	-	-	-	-	-	-
E - Quesnel River Basin (less D)	16	13	35	17	-	-	-	-	-	-
F - Middle Fraser Area	16	12	30	15	16	12	17	13	-	-
Thompson River Basin										
G - Clearwater River Basin	100	100	100	35	100	85	-	-	-	-
H - North Thompson River Basin (less G)	29	7	30	9	12	7	-	-	-	-
J - Thompson & South Thompson River Basins (less G & H)	11	6	14	8	11	6	11	6	-	-
Lower Fraser Area	6	3	8	4	6	3	8	4	8	4

TABLE 6-33

ESTIMATED AVERAGE ANNUAL LOSSES IN NUMBERS OF FRASER RIVER SALMON (1)

ASSOCIATED WITH COMPLETE SYSTEM E DEVELOPMENT

Species	Fishery									
	Commercial		Saltwater Sport		River Sport		Indian Food (2)		Total	
	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation	Without Mitigation	With Mitigation
Chinook	54,200	38,700	6,470	4,620	1,920	872	1,010	550	63,600	44,700
Sockeye	1,350,000	649,000	-	-	-	-	33,300	16,200	1,380,000	665,000
Coho	14,900	8,150	4,760	2,530	414	224	1,140	289	21,200	11,200
Pink	291,000	161,000	4,090	2,260	-	-	1,440	761	297,000	164,000
Chum	67,900	34,000	-	-	-	-	1,120	565	69,000	35,000
Total Loss	1,780,000	891,000	15,300	9,400	2,330	1,100	38,000	18,400	1,830,000	920,000
Total Catch	7,090,000	7,090,000	100,000	100,000	21,600	21,600	182,000	182,000	7,400,000	7,400,000
Percentage Loss	25	13	15	9	11	5	21	10	25	12

NOTES: (1) Numbers to three significant integral figures.
(2) Computed on a shared-loss basis.

Annual losses to the commercial fishery are estimated to be $6.40 millions without mitigation and $3.22 millions with mitigation, which have respective present worths of $220.90 millions and $106.08 millions. Annual losses to salmon-related recreation are estimated to be $3.14 millions without mitigation and $1.53 millions with mitigation; and the corresponding present worths are $156.57 millions and $76.20 millions respectively. A further loss without mitigation is the preservation value loss in Wells Gray Provincial Park associated with Clearwater River project development referred to in 6.5.4.1. This loss has been assigned an annual value of $271,000, with a corresponding present worth of $6.47 millions.

On a shared-loss basis the possible total annual losses to the Indian food fishery would be 38,000 salmon without mitigation and 18,400 with mitigation (Table 6-33); the corresponding potential total annual losses would be 61,100 and 29,700 salmon respectively. Without mitigation the definite present annual losses would be 1,720 chinook, 80 coho and 18 sockeye; and the potential annual losses of these species would be 3,670, 163 and 18 respectively. With mitigation the definite present annual losses would be 510 chinook and 61 coho, with potential annual losses of 1,080 and 125 respectively.

Adherence to the minimum project water releases (Table 5-7) and provision of the mitigating project features (Table 6-31) would reduce the anadromous fish losses associated with complete System E development by $185.70 millions or nearly one-half, as shown in Table 6-34.

TABLE 6-34

PRESENT WORTH IN 1972 OF ANADROMOUS FISH LOSSES WITHOUT AND WITH MITIGATION

ASSOCIATED WITH COMPLETE SYSTEM E DEVELOPMENT

Loss or Cost	Without Mitigation	With Mitigation	Reduction With Mitigation
	($1,000)	($1,000)	($1,000)
Commercial Loss	220,900	106,080	114,820
Recreation Loss	156,570	76,200	80,370
Preservation Value Loss	6,470	-	6,470
Mitigating Features Cost	-	15,960	(-15,960)
Total	383,940	198,240	185,700

Evidence indicates that some salmon populations affected by project development may be maintained by providing compensatory artificial production facilities downstream. Hatcheries are considered to be the most suitable production facilities for chinook and coho, and spawning channels for sockeye, pink and chum salmon. The estimated construction costs of compensatory facilities to offset losses to present salmon production associated with complete System E development are $41.48 millions without and $25.57 millions with the provision of the mitigating measures referred to above. The corresponding cost estimates to offset losses to potential production are $106.21 millions and $57.77 millions respectively. The provision of such compensatory facilities would not offer absolute assurance against salmon losses from project development, owing to species and race differences and to possible genetic and disease problems.

Fraser River sockeye and pink salmon fisheries are regulated by the International Pacific Salmon Fisheries Commission in accordance with a Convention and Protocol between the United States of America and Canada. Any decrease in the numbers of these salmon available for harvest that could be ascribed to System E development would affect the total allowable catch available to fishermen of each country.

6.5.6.2 The Sports Fish, Wildlife and Recreational Resources

Complete System E development would alter existing river, lake and adjacent shore areas, affect water temperatures and quality, lower natural productive conditions, and reduce feeding and habitat areas. These changes would decrease the sports fish population, displace game animals and birds, and adversely affect waterfowl and aquatic furbearing species. The overall result would be a decline in sports fishing, hunting, guiding and trapping activities. Camping, recreational water travel, visits for photography and general recreation would be lessened; and few people would be likely to visit the projects as points of interest, as none of them are immediately adjacent to the main provincial highways. A river reach of historic interest would be inundated on the Fraser River upstream from the Grand Canyon project.

The estimated net impact of complete System E development on the sports fish, wildlife and other recreational resources of the regions affected by the various projects is -$85.63 millions, as shown in Table 6-35 (the summation of Tables 6-14, 6-17, 6-20 and 6-27).

TABLE 6-35

SPORTS FISH, WILDLIFE AND RECREATIONAL RESOURCES

COMPARISON OF PRESENT WORTHS UNDER PRESERVATION AND DEVELOPMENT ALTERNATIVES

COMPLETE SYSTEM E

Alternative	Benefits From Recreational Uses		Benefits From Commercial Uses	Total Benefits
	Primary	Secondary		
	($1,000)	($1,000)	($1,000)	($1,000)
Preservation	102,918	3,102	564	106,584
Development	19,755	1,012	184	20,951
Net Impact	-83,163	-2,090	-380	-85,633

6.5.6.3 The Forestry Resource

Complete System E development impact on the forestry resource would be the sum of the respective impacts of the Lower McGregor Diversion, Grand Canyon and Cariboo Falls projects on this resource. Almost all of the area that would be affected by the three Clearwater River storage projects is within Wells Gray Park and hence not available for normal commercial forestry operations; and the impact on forestry of the two projects with pondage only is considered to be insignificant. Thus System E development would inundate about 275.5 million cubic feet of merchantable timber, estimated to permit an annual cut of 2.763 million cubic feet on a sustained yield basis. This annual cut was valued at $1.752 millions in terms of sawmill-produced lumber and chips, which has a present worth of $24.61 millions. The forest industry would sustain a loss of 91 jobs and there would be an indirect loss of the same number. The increase in transport costs resulting from lake and reservoir creation on the McGregor and Cariboo Rivers was estimated to have a present worth of $2.815 millions. Relocation of the existing logging road through the Cariboo Falls reservoir area was estimated to have a present worth of $834,000.

6.5.7 Total Ecological Costs of Upstream Projects

Cost estimates of the ecological consequences associated with development of the System E and alternative projects are contained in the brief descriptions of these consequences given in 6.5.1 to 6.5.6 for those losses susceptible to monetary evaluation. These cost estimates, both without and with the provision of mitigating measures to reduce anadromous fish losses, are incorporated in Tables 6-36 and 6-37 respectively.

These tables also include estimated costs of the ecological consequences for several project combinations. Anadromous fish loss figures for these project combinations were extracted from the report entitled "An Assessment of the Effects of the System E Flood Control Proposal on the Salmon Resource of the Fraser River System," dated January 1974 and prepared by the Fisheries and Marine Service of Environment Canada. The sports fish, wildlife and recreational net impacts and the forestry costs are summations of the project figures given in 6.5.1 to 6.5.4.

These tables do not include Indian food fishery losses nor the estimated costs of compensatory artificial salmon production facilities. Indian food fishery losses were computed and expressed in numbers of salmon, but were not evaluated in monetary terms, as explained in 6.5.1.1. The costs of compensatory facilities were estimated as referred to in 6.5.6.1, but their effectiveness is somewhat uncertain.

Substantial reductions in total ecological costs would result in most instances from the provision of mitigating measures to lessen anadromous fish losses, as illustrated by comparison of these costs in Tables 6-36 and 6-37. These mitigating measures include provision of the project mitigating features listed in Table 6-31, and project operation with the minimum water releases for mitigation purposes itemized in Table 5-7. These cost reductions are about 57 percent for the Grand Canyon project and about 37 percent for the complete System E, allowing in each case for the cost of project mitigating features.

TABLE 6-36

PRESENT WORTH IN 1972 OF UPSTREAM PROJECT ECOLOGICAL COSTS--WITHOUT MITIGATION (1)

Level of Development	Anadromous Fish Losses				Net Impacts--Sports Fish, Wildlife and Recreational				Forestry Losses and Costs			Total Ecological Costs
	Commercial Losses	Sports Losses	Preservation Value Loss	Total Losses	Recreational Uses Primary	Recreational Uses Secondary	Commercial Uses	Total	Timber Losses	Transport Costs	Total	
	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)
System E Project(s)												
Lower McGregor Diversion	62,610	39,440	-	102,050	14,880	120	260	15,260	12,170	2,160	14,330	131,640
Grand Canyon	92,490	65,030	-	157,520	10,840	160	40	11,040	9,340	-	9,340	177,900
Cariboo Falls	1,780	1,110	-	2,890	2,170	40	40	2,250	3,100	1,490(2)	4,590	9,730
Hemp Creek	34,140	25,090	6,470	65,700	23,320	740	20	24,080	-	-	-(3)	89,780
Hobson Lake, Clearwater-Azure and Hemp Creek	34,210	25,240	6,470	65,920	55,270	1,770	40	57,080	-	-	-(3)	123,000
Hobson Lake, Clearwater-Azure, Hemp Creek, Granite Canyon, and Clearwater	37,290	27,310	6,470	71,070	55,270	1,770	40	57,080	-	-	-(3)(4)	128,150
Complete System E	220,900	156,570	6,470	383,940	83,160	2,090	380	85,630	24,610	3,650(2)	28,260	497,830
Lower McGregor Diversion and Grand Canyon	142,450	98,710	-	241,160	25,720	280	300	26,300	21,510	2,160	23,670	291,130
Lower McGregor Diversion and Cariboo Falls	65,070	40,750	-	105,820	17,050	160	300	17,510	15,270	3,650(2)	18,920	142,250
Lower McGregor Diversion and Hemp Creek	96,070	68,320	6,470	170,860	38,200	860	280	39,340	12,170	2,160	14,330	224,530
Grand Canyon & Hemp Creek	152,940	98,460	6,470	257,870	34,160	900	60	35,120	9,340	-	9,340	302,330
Lower McGregor Diversion, Cariboo Falls & Hemp Creek	99,220	69,480	6,470	175,170	40,370	900	320	41,590	15,270	3,650(2)	18,920	235,680
Alternative Project												
Lower McGregor Non-Diversion	(5)	(5)	-		10,220	120	70	10,410	12,170	2,160	14,330	

NOTES:
(1) For most likely growth and price change projection for the periods outlined in 6.5, discounted at seven percent per annum to 1972; all figures are to nearest $10,000.
(2) Includes existing Cariboo Falls logging road relocation cost.
(3) Affected area is within Wells Gray Provincial Park, hence not available for commercial forestry operations.
(4) Impact of Granite Canyon and Clearwater projects on forestry is insignificant.
(5) Not estimated.

TABLE 6-37

PRESENT WORTH IN 1972 OF UPSTREAM PROJECT ECOLOGICAL COSTS--WITH MITIGATION (1)

Level of Development	Anadromous Fish Losses				Net Impacts--Sports Fish, Wildlife and Recreational				Forestry Losses and Costs			Total Ecological Costs (2)
	Commercial Losses	Sports Losses	Total Losses	Mitigating Feature Costs	Recreational Uses Primary	Recreational Uses Secondary	Commercial Uses	Total	Timber Losses	Transport Costs	Total	
	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)
System E Project(s)												
Lower McGregor Diversion(3)	62,610	39,440	102,050	-	14,880	120	260	15,260	12,170	2,160	14,330	131,640
Grand Canyon	30,550	20,190	50,740	5,410	10,840	160	40	11,040	9,340	-	9,340	71,120
Cariboo Falls	1,090	790	1,880	6,620	2,170	40	40	2,250	3,100	1,490(4)	4,590	8,720
Hemp Creek	24,840	18,540	43,380	2,760	23,320	740	20	24,080	-	-	-(5)	67,460
Hobson Lake, Clearwater-Azure and Hemp Creek	24,840	18,540	43,380	3,860	55,270	1,770	40	57,080	-	-	-(5)	100,460
Hobson Lake, Clearwater-Azure, Hemp Creek, Granite Canyon and Clearwater	24,840	18,540	43,380	3,860	55,270	1,770	40	57,080	-	-	-(5)(6)	100,460
Complete System E	106,080	76,200	182,280	15,960	83,160	2,090	380	85,630	24,610	3,650(4)	28,260	296,170
Lower McGregor Diversion and Grand Canyon	64,880	44,680	109,560	5,410	25,720	280	300	26,300	21,510	2,160	23,670	159,530
Lower McGregor Diversion and Cariboo Falls	63,390	39,440	102,830	6,620	17,050	160	300	17,510	15,270	3,650(4)	18,920	139,260
Lower McGregor Diversion and Hemp Creek	85,360	61,000	146,360	2,760	38,200	860	280	39,340	12,170	2,160	14,330	200,030
Grand Canyon and Hemp Creek	66,550	44,580	111,130	8,170	34,160	900	60	35,120	9,340	-	9,340	155,590
Lower McGregor Diversion, Cariboo Falls and Hemp Creek	86,920	61,010	147,930	9,380	40,370	900	320	41,590	15,270	3,650(4)	18,920	208,440
Alternative Project												
Lower McGregor Non-Diversion	31,300	19,720	51,020	5,520	10,220	120	70	10,410	12,170	2,160	14,330	75,760

NOTES:
(1) For most likely growth and price change projection for the periods outlined in 6.5, discounted at seven percent per annum to 1972; all figures are to nearest $10,000.
(2) Not including mitigating feature costs.
(3) Figures are those for without mitigation, as diversion would be essentially total.
(4) Includes existing Cariboo Falls logging road relocation cost.
(5) Affected area is within Wells Gray Provincial Park, hence not available for commercial forestry operations.
(6) Impact of Granite Canyon and Clearwater projects on forestry is insignificant.

6.6 Other Effects of Upstream Projects

6.6.1 Navigation

The only navigable reach of commercial importance in the Fraser River system is the main stem of the river downstream from Hope through the Lower Fraser Valley to its mouths at the Strait of Georgia. Tidal effect begins near Chilliwack, is appreciable at Mission, and increases downstream to the river mouths. Many industries are located along the reach from Mission downstream to utilize low cost shallow draft river transportation, consisting chiefly of tow boats, log booms, barges and fishing vessels.

Flow regulation by upstream projects would be generally beneficial to shallow draft navigation through increase of minimum depths during winter periods, decrease of current velocities during freshet periods, and reduction of sediment deposition in navigable channels with consequent savings in dredging costs. Less debris would be carried downstream into navigable channels; but the resultant saving in debris collection and disposal costs is expected to be offset to some extent by the more expensive disposal methods needed to meet more stringent air pollution abatement requirements.

Port Mann is the upstream limit of deep-sea navigation, which also would benefit to some extent from flow regulation. Most of the deep-sea navigation benefits arise from less collision damage to vessels during the freshet period and reduced draft restrictions in the post-freshet period. These benefits accrue primarily to foreign shipowners and therefore are outside the referent area for this review. Lesser benefits occur from ship berthing and departures being facilitated by reduction in freshet currents; these benefits are considered to be within the referent area, and are contained in the upstream project navigation benefits given in Table 6-38. Evaluation of upstream project impact was made as outlined in 3.4.1, based on the data contained in the background document on this subject (Reference: Annex 11, 3-4), which provides a detailed description of the effects of flow regulation on navigation.

6.6.2 Agriculture

The benefits to agriculture from flood control provided by upstream projects would far outweigh the losses due to reservoir inundation. Most of these benefits would occur in the Lower Fraser Valley, which is the major agricultural production area in the Fraser River basin; they would consist primarily of reduction in crop loss from flooding and of higher land use for agriculture (increased yields per acre, higher value crops and improved pasture land productivity). These benefits have been included in the flood control benefit figures contained in Table 6-4.

Most of the farmland subject to inundation by upstream project development is of marginal quality; fertility and climatic limitations make it more suitable for forestry than for agriculture, and its timber loss due to inundation has been included in the forestry costs contained in Tables 6-36 and

6-37. The only improved farmland that would be affected by project development is some 2,000 acres in the Grand Canyon reservoir area, valued at $150 per acre. This $300,000 agricultural loss is less than 0.3 percent of the estimated project cost and therefore has been considered as absorbed therein.

Sub-irrigation is an important source of water supply for perennial crops on Lower Fraser Valley farmland. Minor alteration of the seasonal water table in the Valley resulting from upstream project operation is not expected to have a material effect on this source of supply.

Irrigation in the Fraser River basin is confined primarily to benchlands where suitable soil and climatic conditions prevail and water is available. None of the upstream projects under review are located where they might improve the availability of water for this purpose.

6.6.3 Miscellaneous

The impact of upstream project development on the mining industry would be negligible; the resulting inundation would affect no existing mines, potential mining properties or mineral resources of significance.

Archaeological resources consist primarily of the sites of previous cultural development and the artifacts contained therein. Their loss due to inundation can be largely overcome by site excavation and artifact salvage prior to project development. Site search of all project areas except that of Lower McGregor disclosed sites of importance only in the Clearwater-Azure and Hemp Creek project areas. The estimated costs of excavation, artifact retrieval and research in these two areas are $100,000 and $114,000 respectively; and these relatively minor costs could readily be absorbed in the respective project cost estimates.

6.7 Upstream Project and Transmission Cost Data

In its analysis to determine upstream project generation benefits, BCHPA developed transmission construction cost estimates for connecting each project to the BCHPA integrated transmission system. These transmission construction cost estimates are shown in Table 6-39, together with the project construction cost estimates from Tables 4-7 to 4-15 inclusive and the mitigating feature construction cost estimates from Table 6-31. The present worth in 1972 of the construction cost estimates contained in Table 6-39, and of the operating costs derived as described in 3.9, is shown for each project and project combination, without and with mitigation, in Tables 6-40 and 6-41 respectively.

6.8 Upstream Project Benefits and Costs

The quantifiable benefits and costs attributed to each upstream project and project combination, both without and with the inclusion of mitigating measures, are recapitulated in Tables 6-42 and 6-43, respectively. The net benefits and the benefit-cost ratio derived for each project and project combination also are contained in these tables, which thus provide a measure of relative economic worth.

TABLE 6-38

PRESENT WORTH IN 1972 OF UPSTREAM PROJECT NAVIGATION BENEFITS (1)

Level of Development	Activity				Total
	Shallow Draft Navigation	Deep-Sea Shipping	Debris Disposal	Dredging	
	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)
Individual System E Project					
Lower McGregor Diversion	412	47	118	358	935
Grand Canyon	721	83	206	626	1,636
Cariboo Falls	177	20	51	153	401
Hobson Lake	74	8	21	64	167
Clearwater-Azure (Upper and Lower Stations)	294	34	84	256	668
Hemp Creek	294	34	84	256	668
Granite Canyon	-	-	-	-	-
Clearwater	-	-	-	-	-
Complete System E	1,472	169	422	1,278	3,341
Combinations of System E Projects					
Lower McGregor Diversion and Grand Canyon	1,045	120	300	907	2,372
Lower McGregor Diversion and Cariboo Falls	648	74	186	562	1,470
Lower McGregor Diversion and Hemp Creek	662	76	190	575	1,503
Grand Canyon and Hemp Creek	839	96	241	728	1,904
Lower McGregor Diversion, Cariboo Falls and Hemp Creek	897	103	257	780	2,037
Individual Alternative Project					
Lower McGregor Non-Diversion	412	47	118	358	935

NOTE: (1) For period from 1977 through 2032 and for most likely growth and price change projection; discounted at seven percent per annum to 1972.

TABLE 6-39

UPSTREAM PROJECT AND TRANSMISSION CONSTRUCTION COST ESTIMATES (1)

Level of Development	Transmission (2)	Without Mitigating Features (3)		With Mitigating Features (3)		
		Project (4)	Total (5)	Feature (6)	Project (7)	Total (5)
	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)
Individual System E Project						
Lower McGregor Diversion	-(8)	117,370	117,370	Nil	117,370	117,370
Grand Canyon	5,120	106,330 (9)	111,450	5,935	112,265	117,385
Cariboo Falls	5,960	50,420	56,380	7,260	57,680	63,640
Hobson Lake	8,485	43,720	52,205	Nil	43,720	52,205
Clearwater-Azure (Upper and Lower Stations)	8,485	81,050	89,535	Nil	81,050	89,535
Hemp Creek	18,065	132,665	150,730	3,025	135,690	153,755
Granite Canyon	7,650	56,515	64,165	Nil	56,515	64,165
Clearwater	7,220	25,825	33,045	Nil	25,825	33,045
Complete System E	60,985	613,895	674,880	17,430	631,325	692,310
Combinations of System E Projects						
Lower McGregor Diversion and Grand Canyon	5,120	223,700	228,820	5,935	229,635	234,755
Lower McGregor Diversion and Cariboo Falls	5,960	167,790	173,750	7,260	175,050	181,010
Lower McGregor Diversion and Hemp Creek	18,065	250,035	268,100	3,025	253,060	271,125
Grand Canyon and Hemp Creek	23,185	238,995	262,180	8,960	247,955	271,140
Lower McGregor Diversion, Cariboo Falls and Hemp Creek	24,025	300,455	324,480	10,285	310,740	334,765
Individual Alternative Project						
Lower McGregor Non-Diversion	5,960	155,185	161,145	6,050	161,235	167,195

NOTES:
(1) At 1972 price levels.
(2) BCHPA data for individual projects; others by summation.
(3) As listed in Table 6-31.
(4) From Tables 4-7 to 4-15 for individual projects; others by summation.
(5) Sum of project and transmission construction costs.
(6) From Table 6-31.
(7) As for (4) plus mitigating feature costs.
(8) Transmission system from G.M. Shrum and Site One Generating Stations is adequate to carry the added energy produced from this diversion.
(9) Without fishway and barrier dam.

TABLE 6-40

PRESENT WORTH IN 1972 OF UPSTREAM PROJECT AND TRANSMISSION

CONSTRUCTION AND OPERATION COSTS -- WITHOUT MITIGATION (1)

Level of Development	Project Construction	Project Operation	Project Construction and Operation	Transmission Construction and Operation	Total Construction and Operation
	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)
Individual System E Project					
Lower McGregor Diversion	108,940	7,430	116,370	-	116,370
Grand Canyon	96,960	7,050	104,010	5,290	109,300
Cariboo Falls	45,970	3,230	49,200	6,140	55,340
Hobson Lake	39,860	2,830	42,690	8,790	51,480
Clearwater-Azure (Upper and Lower Stations)	73,900	5,430	79,330	8,790	88,120
Hemp Creek	120,970	8,790	129,760	18,840	148,600
Granite Canyon	51,530	3,730	55,260	7,930	63,190
Clearwater	23,550	1.640	25,190	7,450	32,640
Complete System E	561,680	40,130	601,810	63,230	665,040
Combinations of System E Projects					
Lower McGregor Diversion and Grand Canyon	205,900	14,480	220,380	5,290	225,670
Lower McGregor Diversion and Cariboo Falls	154,910	10,660	165,570	6,140	171,710
Lower McGregor Diversion and Hemp Creek	229,910	16,220	246,130	18,840	264,970
Grand Canyon and Hemp Creek	217,930	15,840	233,770	24,130	257,900
Lower McGregor Diversion, Cariboo Falls and Hemp Creek	275,880	19,450	295,330	24,980	320,310
Individual Alternative Project					
Lower McGregor Non-Diversion	141,530	10,320	151,850	6,140	157,990

NOTE: (1) For Period from commencement of construction in 1972 through 2032, discounted at seven percent per annum to 1972. Figures are to nearest $10,000 and are based on cost estimates contained in Table 6-39; they are for the most likely growth and price change projection, and include interest during construction at seven percent per annum.

TABLE 6-41

PRESENT WORTH IN 1972 OF UPSTREAM PROJECT AND TRANSMISSION

CONSTRUCTION AND OPERATION COSTS -- WITH MITIGATION (1)

Level of Development	Project Construction	Project Operation	Project Construction and Operation	Transmission Construction and Operation	Total Construction and Operation
	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)
Individual System E Project					
Lower McGregor Diversion (2)	108,940	7,430	116,370	-	116,370
Grand Canyon	102,370	7,440	109,810	5,290	115,100
Cariboo Falls	52,590	3,690	56,280	6,140	62,420
Hobson Lake	39,860	2,830	42,690	8,790	51,480
Clearwater-Azure (Upper and Lower Stations)	73,900	5,430	79,330	8,790	88,120
Hemp Creek	123,730	8,990	132,720	18,840	151,560
Granite Canyon	51,530	3,730	55,260	7,930	63,190
Clearwater	23,550	1,640	25,190	7,450	32,640
Complete System E	577,640	41,270	618,910	63,230	682,140
Combinations of System E Projects					
Lower McGregor Diversion and Grand Canyon	211,310	14,870	226,180	5,290	231,470
Lower McGregor Diversion and Cariboo Falls	161,530	11,120	172,650	6,140	178,790
Lower McGregor Diversion and Hemp Creek	232,670	16,420	249,090	18,840	267,930
Grand Canyon and Hemp Creek	226,100	16,430	242,530	24,130	266,660
Lower McGregor Diversion, Cariboo Falls and Hemp Creek	285,260	20,110	305,370	24,980	330,350
Individual Alternative Project					
Lower McGregor Non-Diversion	147,050	10,720	157,770	6,140	163,910

NOTES: (1) For period from commencement of construction in April 1972 through 2032, discounted at seven percent per annum to 1972. Figures are to nearest $10,000 and are based on cost estimates contained in Table 6-39; they are for the most likely growth and price change projection, and include interest during construction at seven percent per annum.

(2) Figures are those for without mitigation, as diversion would be essentially total.

TABLE 6-42

PRESENT WORTH IN 1972 OF UPSTREAM PROJECT BENEFITS AND COSTS -- WITHOUT MITIGATION

Level of Development	Benefits				Costs			Benefits	Benefit/ Cost Ratio
	Flood Control (1)	Generation (2)	Navigation (3)	Total	Ecological (4)	Construction and Operation (5)	Total		
	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)
Individual System E Project									
Lower McGregor Diversion	42,400	233,100	940	276,440	131,640	116,370	248,010	28,430	1.11
Grand Canyon	60,250	61,270	1,640	123,160	177,900	109,300	287,200	-164,040	0.43
Cariboo Falls	20,520	37,480	400	58,400	9,730	55,340	65,070	- 6,670	0.90
Hobson Lake	11,170	38,940	170	50,280	2,000(6)	51,480	53,480	- 3,200	0.94
Clearwater-Azure (Upper and Lower Stations)	36,810	72,920	670	110,400	(7)	88,120			
Hemp Creek	33,350	130,000	670	164,020	89,780	148,600	238,380	- 74,360	0.69
Granite Canyon	-	68,300(8)	-	68,300	(9)	63,190	63,190	5,110	(11)
Clearwater	-	26,510(8)	-	26,510	(9)	32,640	32,640	- 6,130	(11)
Complete System E	87,410	681,860	3,340	772,610	497,830	665,040	1,162,870	-390,260	0.66
Combinations of System E Projects									
Lower McGregor Diversion and Grand Canyon	73,050	294,370	2,370	369,790	291,130	225,670	516,800	-147,010	0.72
Lower McGregor Diversion and Cariboo Falls	57,050	270,580	1,470	329,100	142,250	171,710	313,960	15,140	1.05
Lower McGregor Diversion and Hemp Creek	62,760	363,100	1,500	427,360	224,530	264,970	489,500	- 62,140	0.87
Grand Canyon and Hemp Creek	70,500	191,270	1,900	263,670	302,330	257,900	560,230	-296,560	0.47
Lower McGregor Diversion, Cariboo Falls and Hemp Creek	73,530	400,580	2,040	476,150	235,680	320,310	555,990	- 79,840	0.86
Individual Alternative Project									
Lower McGregor Non-Diversion	42,250	134,290	940	177,480	(10)	157,990			

NOTES:
(1) From Table 6-4.
(2) From Table 6-9.
(3) From Table 6-38.
(4) From Table 6-36.
(5) From Table 6-40.
(6) From Table 6-28; individual project has no significant effect on anadromous fish and forestry.
(7) Individual project ecological cost not available.
(8) Only if upstream storage available for flow regulation -- see 5.5.7 and 5.5.8.
(9) Ecological impact insignificant.
(10) Anadromous fish losses without mitigation not estimated.
(11) Not available as individual project due to upstream storage requirement -- see Note 8.

TABLE 6-43

PRESENT WORTH IN 1972 OF UPSTREAM PROJECT BENEFITS AND COSTS -- WITH MITIGATION (1)

Level of Development	Benefits				Costs			Net Benefits	Benefit/Cost Ratio
	Flood Control (1)	Generation (2)	Navigation (3)	Total	Ecological (4)	Construction and Operation (5)	Total	Benefits	Benefit/ Cost Ratio
	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)
Individual System E Project									
Lower McGregor Diversion (6)	42,400	233,100	940	276,440	131,640	116,370	248,010	28,430	1.11
Grand Canyon	60,250	47,970	1,640	109,860	71,120	115,100	186,220	- 76,360	0.59
Cariboo Falls	20,520	35,450	400	56,370	8,720	62,420	71,140	- 14,770	0.79
Hobson Lake	11,170	38,940	170	50,280	2,000(7)	51,480	53,480	- 3,200	0.94
Clearwater-Azure (Upper and Lower Stations)	36,810	72,920	670	110,400	(8)	88,120			
Hemp Creek	33,350	130,000	670	164,020	67,460	151,560	219,020	- 55,000	0.75
Granite Canyon	-	68,300(9)	-	68,300	(10)	63,190	63,190	5,110	(11)
Clearwater	-	26,510(9)	-	26,510	(10)	32,640	32,640	- 6,130	(11)
Complete System E	87,410	661,760	3,340	752,510	296,170	682,140	978,310	-225,800	0.77
Combinations of System E Projects									
Lower McGregor Diversion and Grand Canyon	73,050	281,070	2,370	356,490	159,530	231,470	391,000	- 34,510	0.91
Lower McGregor Diversion and Cariboo Falls	57,050	268,550	1,470	327,070	139,260	178,790	318,050	9,020	1.03
Lower McGregor Diversion and Hemp Creek	62,760	363,100	1,500	427,360	200,030	267,930	467,960	- 40,600	0.91
Grand Canyon and Hemp Creek	70,500	177,970	1,900	250,370	155,590	266,660	422,250	-171,880	0.59
Lower McGregor Diversion, Cariboo Falls and Hemp Creek	73,530	398,550	2,040	474,120	208,440	330,350	538,790	- 64,670	0.88
Individual Alternative Project									
Lower McGregor Non-Diversion	42,250	140,940	940	184,130	75,760	163,910	239,670	- 55,540	0.77

NOTES:
(1) From Table 6-4.
(2) From Table 6-9.
(3) From Table 6-38.
(4) From Table 6-37.
(5) From Table 6-41.
(6) Figures are those for without mitigation, as diversion would be essentially total.
(7) From Table 6-28; individual project has no significant effect on fisheries and forestry.
(8) Individual project ecological cost not available.
(9) Only if upstream storage available for flow regulation -- see 5.5.7 and 5.5.8.
(10) Ecological impact insignificant.
(11) Not available as individual project due to upstream storage requirement -- see Note 9.

CHAPTER 7

AN INTEGRATED PLAN FOR FURTHER FLOOD PROTECTION

7.1 Results of the Benefit-Cost Analysis

Review of the System E and alternative upstream diversion and storage projects in accordance with Clause 26 of the May 24, 1968 Agreement (1.3 and Annex I) was completed in Chapter 6 to the stage of determining the net benefits and the benefit-cost ratios for the projects and for selected project combinations, with the results shown in Tables 6-42 and 6-43.

It is evident from examination of Tables 6-42 and 6-43 that on the basis of this benefit-cost analysis the only economically viable individual project is the Lower McGregor Diversion. It also is clear that none of the selected project combinations, including the complete System E, is economically viable except that of Lower McGregor Diversion and Cariboo Falls. This exception is due to the relatively small negative net benefits of the Cariboo Falls project being more than offset by the larger positive net benefits of the Lower McGregor Diversion project.

Although the incorporation of the anadromous fish loss mitigating measures proposed for the Grand Canyon, Cariboo Falls, Hemp Creek and Lower McGregor Non-Diversion projects changes their generation benefit, ecological cost, and construction and operation cost figures, comparison of Tables 6-42 and 6-43 shows that these changes are not sufficient to make any of these projects economically viable. Incorporation of these measures in the Cariboo Falls project actually lowers its benefit-cost ratio to some extent, as the reduction in ecological costs is more than offset by the decline in generation benefits and the increase in construction and operation costs.

The project combinations shown in Tables 6-42 and 6-43 were selected for evaluation primarily on the basis that each of them would offer 65 percent or more of the total flood control benefits attributed to the complete System E. A combination of Lower McGregor Diversion and Hobson Lake projects probably would be economically viable; but the flood control benefits that would be obtained from Hobson Lake are far the least of those available from any of the individual projects, particularly in the Lower Fraser Valley (Table 6-4). Evaluation of such a combination thus was not warranted for the purpose of this review.

7.2 Observations Respecting the Benefit-Cost Analysis

The upstream project benefit and cost figures contained in Tables 6-42 and 6-43 represent the evaluation of these benefits and costs based on available information. The supply of basic data available for the various elements investigated ranged from adequate to minimal, necessitating much broader assumptions for the determination of some factors than for others. The lack of data in some instances may have resulted in estimates containing overly generous or overly conservative allowances for unknowns.

In addition, the techniques utilized for the derivation of these figures are in widely different stages of development; for example, the methods of estimating project construction costs are well established, while many concepts used in natural resource evaluation are relatively new.

This situation was most apparent in the evaluation of the ecological consequences of project development, as referred to in 6.5. However, the use of these ecological cost figures was essential to the completion of the benefit-cost analysis of the projects under review; and this use of these figures was made without their collective acceptance by the Board. Because of this lack of agreement, a sensitivity analysis was carried out utilizing the ecological cost figures provided (Tables 7-1 and 7-2). This analysis showed that ecological cost methodologies were not a critical factor in determining the economic viability of any of the projects remaining after the Lower McGregor Diversion had been built.

7.3 Conditions Governing Formation of a Plan for Further Flood Protection

7.3.1 Review Objective

The objective of this review was to develop an integrated plan for further flood protection, utilization and control of the water resources of the Fraser River basin, with particular emphasis on flood protection for the Lower Fraser Valley, through utilization of dykes, upstream storage reservoirs and diversions (1.4).

7.3.2 Dykes

Completion of the extensive dyking program now in progress as outlined in 4.1 will provide 85 percent of the Lower Fraser Valley flood plain lands with substantial protection from spring snowmelt floods up to the 1894 level. This will approach the practical maximum degree of protection that can be provided in this manner. The Lower Fraser Valley flood plain requires protection from inundation whenever the water elevation at Mission exceeds 18 feet, which usually prevails for a month or more during high freshets (Table 1-2). This prolonged duration of high water levels with accompanying increased river velocities introduces uncertainties in the protection offered by dykes. These include the effects of bank erosion, and particularly the tendency for dykes to deteriorate under prolonged submergence, and the changing stability of dyke materials and soil foundations with varying degrees of saturation and seepage. Flood levels higher than that of 1894 can and will occur; only their time of occurrence is unknown.

7.3.3 Upstream Developments and Projects

7.3.3.1 Existing Upstream Developments

Existing upstream storage reservoirs on the Nechako and Bridge Rivers, although created primarily for hydroelectric power generation, are of considerable value for flood control when operated on an emergency basis as in 1972 (2.2.5 and 2.2.6). The flood control capability of these reservoirs has been estimated as capable of reducing a peak flood level of 1894 proportions by 0.7

feet at Mission, or about one-fourth of the total reduction that could be accomplished by the complete System E (Table 5-6). The British Columbia Ministry of the Environment has called upon the owners of these reservoirs (Aluminum Company of Canada and British Columbia Hydro and Power Authority) for their emergency use for flood control in those any years when forecast conditions indicated that this function would be desirable.

The existing Stave Lake Reservoir, which was created primarily for hydroelectric power generation downstream on the Stave River, is not an upstream storage reservoir in terms of its location in the Fraser River system. However, it provides useful emergency storage adjacent to the Lower Fraser Valley flood plain area for effecting last-minute flood peak reduction on the Fraser River downstream from Mission. It was utilized for this purpose in 1972 (2.2.5 and 2.2.6), under the arrangement noted above.

7.3.3.2 Upstream Storage and Diversion Projects - Results of Review

With the exception of the Lower McGregor Diversion, none of the upstream projects included in this review proved to be economically viable as an individual project. The benefit-cost ratio for the Clearwater-Azure project on an individual basis was not derived owing to the lack of anadromous fish loss figures on this basis. However, the estimated net impact of a $31.0 millions loss attributed to its effects on sports fish, wildlife and recreational resources (Table 6-28) would give this project a benefit-cost ratio of less than unity, even if it caused no anadromous fish loss.

The only combination of upstream projects determined as economically viable was that of Cariboo Falls with Lower McGregor Diversion (Tables 6-42 and 6-43); and the economic viability of this combination was dependent on the Lower McGregor Diversion project, as mentioned in 7.1.

7.3.3.3 Allocation of Benefits and Costs to Upstream Projects in Combination

The flood control accomplishment of a combination of the projects under review is less than the sum of the individual project accomplishments, as can be seen in Table 5-6. Consequently, the flood control benefits attributed to a combination of projects are less than the sum of the individual project flood control benefits (Table 6-4). The same condition applies to the project navigation benefits (Table 6-38).

The sequence of project development thus affects the flood control and navigation benefits credited to each project in a combination. The first project built would receive full credit for these benefits, while the second one would receive only the difference between the credit for the project combination and that for the first project alone. Similarly a third project would receive only the difference between the credit for the combination of three and that for the combination of the first two.

In contrast, the generation accomplishment of a combination of the projects under review is equal to the sum of the individual project accomplishments, except where flow regulation at one project affects generation at others downstream. Only the projects located on the Clearwater River are so affected; and the only project combination under review which contains more than one Clearwater River project is the complete System E (Table 5-8). The generation benefits shown in Table 6-9 reflect this condition.

The ecological costs attributed to upstream project combinations differ from the sum of the individual project ecological costs owing to the differences in anadromous fish losses ascribed to project combinations from those ascribed to individual projects (Tables 6-36 and 6-37). Analysis of projects in a sequence of development would require that these costs be allocated in the same manner as described above for flood control and navigation benefits.

Since the Lower McGregor Diversion is the only economically viable individual upstream project, it is reasonable to assume that this project would be the first to be built, either alone or as part of a project combination. In either case, Lower McGregor Diversion would be credited with the benefits attributed to it as an individual project in Tables 6-42 and 6-43. The flood control benefits credited to this project would be slightly more than one-half of the total of such benefits in the Lower Fraser Valley credited to the complete System E, and nearly one-half of those benefits in all areas (Table 6-4), although the project provides no flood control for the Kamloops area.

The effects of prior construction of the Lower McGregor Diversion project on the benefits and costs attributed to the remaining projects in those combinations which include this project are shown in Tables 7-1 and 7-2, without and with mitigation respectively. The benefit-cost ratios in these tables clearly indicate that the remaining projects are far from being economically viable after the Lower McGregor Diversion has been built.

Further examination of Tables 7-1 and 7-2 reveals that in only one instance (Hemp Creek without mitigation -- Table 7-1) do the total benefits of the remaining projects exceed their construction and operation costs; and in this instance the excess benefits are very small ($2.32 millions). Hence, as noted in 7.2, ecological costs are not a critical factor in determination of the economic viability of the projects remaining after the Lower McGregor Diversion has been built.

TABLE 7-1

PRESENT WORTH IN 1972 OF BENEFITS AND COSTS FOR THOSE UPSTREAM PROJECTS FORMING SELECTED PROJECT COMBINATIONS

WITH LOWER McGREGOR DIVERSION PROJECT ASSUMING THE LATTER ALREADY BUILT - - WITHOUT MITIGATION

Project Combination: Lower McGregor Diversion Plus	Benefits				Costs			Net Benefits	Benefit/ Cost Ratio
	Flood Control (1)	Generation (2)	Navigation (1)	Total	Ecological (1)	Construction and Operation (2)	Total		
	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	
Grand Canyon	30,650	61,270	1,430	93,350	159,490	109,300	268,790	- 175,440	0.35
Cariboo Falls	14,650	37,480	530	52,660	10,610	55,340	65,950	- 13,290	0.79
Hemp Creek	20,360	130,000	560	150,920	92,890	148,600	241,490	- 90,570	0.62
Cariboo Falls and Hemp Creek	31,130	167,480	1,100	199,710	104,040	203,940	307,980	- 108,270	0.65
Remainder of Complete System E	45,010	448,760	2,400	496,170	366,190	548,670	914,860	- 418,690	0.54

NOTES: (1) Derived from Table 6-42.
(2) From Table 6-42.

TABLE 7-2

PRESENT WORTH IN 1972 OF BENEFITS AND COSTS FOR THOSE UPSTREAM PROJECTS FORMING SELECTED PROJECT COMBINATIONS

WITH LOWER McGREGOR DIVERSION PROJECT ASSUMING THE LATTER ALREADY BUILT - - WITH MITIGATION

Project Combination: Lower McGregor Diversion Plus	Benefits				Costs			Net Benefits	Benefit/ Cost Ratio
	Flood Control (1)	Generation (2)	Navigation (1)	Total	Ecological (1)	Construction and Operation (2)	Total		
	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	($1,000)	
Grand Canyon	30,650	47,970	1,430	80,050	27,890	115,100	142,990	- 62,940	0.56
Cariboo Falls	14,650	35,450	530	50,630	7,620	62,420	70,040	- 19,410	0.72
Hemp Creek	20,360	130,000	560	150,920	68,390	151,560	219,950	- 69,030	0.69
Cariboo Falls and Hemp Creek	31,130	165,450	1,100	197,680	76,800	213,980	290,780	- 93,100	0.68
Remainder of Complete System E	45,010	428,660	2,400	476,070	164,530	565,770	730,300	- 254,230	0.65

NOTES: (1) Derived from Table 6-43.
(2) From Table 6-43.

7.3.3.4 Upstream Storage Reservoirs Located in Wells Gray Park

The reservoirs of the three storage projects on the Clearwater River are located almost entirely within the boundaries of Wells Gray Provincial Park. Hobson Lake and Clearwater-Azure dams and reservoirs are situated entirely within the Park; the Hemp Creek dam is just downstream from the southern Park boundary with the project reservoir extending about 24 miles upstream into the Park. This now is a Class A park under the British Columbia Park Act, and as such it is "dedicated to the preservation of its natural environment for the inspiration, use and enjoyment of the public". The uses of Class A park lands and natural resources situated therein are limited by this Act to those necessary to the preservation and maintenance of the recreational values of these parks.

The inevitable effects on park lands and natural resources that would occur as a result of construction and operation of these projects makes it exceedingly doubtful that development of any of them would be permitted in the foreseeable future. Although the Granite Canyon and Clearwater run-of-river projects are located further downstream on the Clearwater River, they have no effect on the Park. However, they are dependent on the upstream storage that would be in the Park, and hence their development would not take place unless some or all of the upstream storage projects were built.

The three Clearwater River storage projects are the only ones included in the review which would provide flood control downstream that would give protection to the Kamloops area.

7.3.3.5 Prediction of High Water Occurrence

While not mentioned specifically in the objective of this review, prediction of the occurrence of high water conditions on rivers is an essential element in the effective operation of flood protection plans. The British Columbia Ministry of the Environment maintains a high water prediction program in the Fraser River system, providing both high water volume forecasts and high water level warnings. This information is used by the Ministry for the following purposes:

(a) The intensification of dyke patrols and the performance of urgent dyke repairs;

(b) The activation of arrangements with the respective owners of existing reservoirs on the Nechako, Bridge and Stave Rivers for flood control use, and the subsequent operation of the reservoirs;

(c) The notification of other agencies, such as civil, military and transportation authorities, regarding possible emergency requirements; and

(d) The placing of other emergency measures, such as evacuation of residents and animals and their accommodation elsewhere, on an "alert" basis for rapid implementation if necessary.

7.4 Plan for Further Flood Protection

The only economically viable source of further flood protection for the Lower Fraser Valley in addition to that provided by dykes (7.3.2) and existing upstream reservoirs (7.3.3.1) is the Lower McGregor Diversion project, which also would give substantial flood protection to Prince George and Quesnel. These three elements - dykes, existing reservoirs, and the Lower McGregor Diversion project - therefore constitute the major structural components of an integrated plan for further flood protection. The incorporation of improved flood forecasting procedures and the continuation of flood plain management policies would complete an integrated plan in accordance with the review objective.

7.5 Lower McGregor Diversion Project -- Consequences of Development

Development of the Lower McGregor Diversion project would result in the following favourable and unfavourable consequences:

(a) Favourable

i. The substantial degree of flood protection provided for the Lower Fraser Valley, Prince George and Quesnel.

Under natural conditions there would have been an estimated one-in-three probability that the 1894 flood will be equalled or exceeded at Mission during the 60-year period from 1973 to 2032.

Under present conditions the use of existing reservoirs on the Nechako and Bridge Rivers lessens this risk to an estimated one-in-five probability.

Diversion of the McGregor River would further lessen this risk to an estimated one-in-eleven probability, thus reducing by more than one-half the likelihood of such a flood in the Lower Fraser Valley under present conditions.

Diversion of the McGregor River also would virtually eliminate the threat of damaging Fraser River floods at Prince George and Quesnel.

ii. The dependable nature of flood control provided by removal of flow from a river system.

The most dependable flood control downstream is provided by total diversion of a river from its natural system. The positive nature of flood control by upstream diversion is free from the uncertainties associated with the protection offered by dykes in areas such as the Lower Fraser Valley (7.3.2).

The McGregor River drainage basin is one of the higher water yield regions of the Fraser River drainage basin upstream from Hope. The mean flow of the McGregor River near the diversion project site is nearly 10 percent of that of the Fraser River at Hope during freshet periods, and has reached 15 percent at freshet peaks. The respective freshet periods at the diversion project site and at Hope essentially coincide. Diversion of the McGregor River would lower freshet peak water levels at Mission by as much as one foot; and would shorten substantially the periods when Mission water levels exceed 18 feet, with corresponding relief to the Lower Fraser Valley dyking system.

iii. The large increase in hydroelectric energy generated at the Peace River stations without installation of additional generating facilities.

Diversion of the McGregor River to the Peace River would produce additional average annual energy of 3,197 GWh at G.M. Shrum and Site One generating stations without installation of additional facilities at either station. This is almost twice the energy that would be provided by the largest of the other System E projects (Hemp Creek).

iv. The benefits to navigation on the Lower Fraser River.

Navigation would benefit by the reduction in freshet magnitude and duration resulting from McGregor River diversion, through the consequent decrease in current velocities and sediment deposition in navigable channels. Deep-sea navigation would be facilitated, as the decrease in current velocities during freshet periods would reduce berthing and departure problems and lessen the likelihood of collisions. The diversion would achieve nearly 30 percent of the total navigation benefits attributed to the complete System E.

(b) Unfavourable

i. The loss of anadromous fish.

There would be loss of chinook salmon resident in the McGregor River, but the major impact of the diversion would be on the Bowron River sockeye run; lesser effects would be anticipated on stocks further downstream, such as Nechako River chinook and sockeye. The diversion route also offers possible access for parasite-carrying Arctic pike to the Fraser River system, unless adequate preventive measures are incorporated in the diversion project. Anadromous fish losses are nearly 78 percent of the total estimated project ecological costs.

ii. The impact on sports fish, wildlife and recreation.

The diversion project would create a large lake, destroying much of the existing sports fish and wildlife habitat. Fishing, hunting and trapping would decline significantly, as would recreational water travel and camping. Neither the main dam nor the diversion would be near the principal tourist travel routes. These losses are more than 11 percent of the total estimated project ecological costs.

iii. The loss of timber and increase in future transport costs.

The new lake that would be created by the diversion accounts for nearly all of these costs through the inundation of merchantable timber and the increase in transport costs to harvest remaining timber stands. Losses would be confined almost entirely to the McGregor River basin, as little merchantable timber in the Parsnip River basin would be affected by the diversion. These losses and costs are nearly 11 percent of the total estimated project ecological costs.

iv. The physical changes in the Parsnip River and adjacent valleys caused by the diverted flow.

Entry of the diverted McGregor River water would drastically increase Parsnip River flow, especially through the 35-mile reach downstream from the Arctic Lake outflow confluence to the vicinity of Anzac. These increased river flows would cause channel and marshland changes; but it was not possible to predict with any degree of accuracy the nature and extent of these changes, and the duration of the transition period covering their occurrence. However, an endeavour was made to recognize the effects of these changes in determining the impact of the project on sports fish, wildlife and outdoor recreation in the Parsnip Valley, as given in Table 6-13.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

In accordance with the requirements set out in Clause 26 of the May 24, 1968 Agreement (Annex I), the Advisory Board initiated studies including a review of the System E program of upstream diversion and storage. This program, contained in the 1963 Report of the Fraser River Board (Reference: Annex II, 1-2), proposed a system of upstream reservoirs on the Fraser River and its tributaries to provide flood protection for the Lower Fraser Valley and communities on the other river flood plains. All studies for this review were based on mid-1972 price levels.

Full consideration was given to site selection as proposed in the 1963 report, to design, to benefits likely to accrue, and to costs which could be incurred from project development. In regard to these costs the Advisory Board assigned to its Ecology Committee the task of evaluating the expected impact of the proposed reservoirs on the ecology of the affected areas. This particular evaluation developed into an exceedingly complex study, the results of which were neither completely conclusive nor collectively accepted by either the Ecology Committee or the Advisory Board. Nevertheless, the Advisory Board took cognizance of the implications set out in the Ecology Committee Report (Reference: Annex II, 3-6).

The overall review of System E, supported by the Ecology Committee Report, showed that with one exception, the Lower McGregor Diversion, the benefits accruing to each project would not exceed the costs.

In addition to the review of System E, the Advisory Board examined the flood risk to the developed areas of the Fraser River Valley. In the light of the recognized flood danger, the Advisory Board evaluated the effectiveness of dyking, flood forecasting, flood plain management, and the utilization of existing reservoirs for flood control. As a result the Advisory Board has reached the following conclusions:

(a) The Lower Fraser Valley faces a continuing and serious flood threat. Greater floods than that of 1894 can and will occur, but the specific year or years of their occurrence cannot be predicted. There is a 1-in-3 probability that the 1894 flood will be equalled or exceeded during the 60-year period from 1973 to 2032.

(b) Floods greater than that of 1894 will result in damages in the Lower Fraser Valley in the order of $500 millions, always with the attendant risk to human life. Residential damage involving thousands of homes would constitute the major part of this loss. In addition, tens of thousands of people would have to be evacuated from affected Valley areas.

(c) The current Lower Fraser Valley dyking program, which does not encompass all of the developed areas, will only increase the reliability of protection against floods up to the 1894 level. Raising dykes above this level is essentially impractical, and in some cases not considered to be engineeringly sound. In addition, such raising would generate a false feeling of security.

(d) Additional flood protection is essential and could only be achieved through development of upstream storage reservoirs or diversion of major tributary rivers. The Lower McGregor Diversion was found to be the only economically viable project that would provide such protection.

(e) Substantial benefits can be achieved through operation of existing reservoirs for flood control purposes whenever necessary.

(f) Non-structural measures, including flood forecasting and flood plain management practices can contribute significantly to the reduction of potential flood damages.

8.2 Recommendations

The Advisory Board recommends that:

(1) the Lower McGregor Diversion project be constructed as soon as possible;

(2) the dyking program now in progress be completed as rapidly as possible;

(3) the British Columbia Ministry of the Environment formalize arrangements with the Aluminum Company of Canada and the British Columbia Hydro and Power Authority for use of the existing reservoirs on the Nechako, Bridge and Stave Rivers for flood control operation whenever necessary;

(4) the appropriate agencies continue and intensify their efforts toward the development of improved short term and long term forecasting techniques to facilitate flood warning and flood control operations;

(5) the responsible authorities continue to implement the existing system of flood plain management policies in the Lower Fraser Valley; and

(6) an environmental assessment and a monitoring program be included as part of the Lower McGregor Diversion project.

Implementation of the foregoing recommendations, especially (1) and (2), would provide very substantial relief from flooding and associated problems in the Lower Fraser Valley, and at Prince George and Quesnel. This significant improvement in present conditions would be achieved at some ecological cost, but with appreciable generation benefits and with virtually no dislocation of resident population and established settlement.

ANNEX I

"COPY"

AGREEMENT

covering a plan for flood control in the Fraser Valley, British Columbia

THIS AGREEMENT made the 24th day of May, 1968.

BETWEEN

THE GOVERNMENT OF CANADA
(hereinafter referred to as "Canada"), represented by the Honourable Jean-Luc Pepin, Minister of Energy, Mines and Resources of Canada

OF THE FIRST PART,

AND

THE GOVERNMENT OF THE
PROVINCE OF BRITISH COLUMBIA
(hereinafter referred to as "the Province"), represented by the Honourable Ray Williston, Minister of Lands, Forests and Water Resources

OF THE SECOND PART.

WHEREAS the Fraser River Valley and other areas adjacent to the Lower Fraser Valley of British Columbia have in the past experienced widespread losses and damages from flooding;

AND WHEREAS such flood loss and damage can be reduced by a program of works;

AND WHEREAS Canada and the Province have agreed that it is in the national and the provincial interest to undertake jointly a comprehensive program of flood control for the area;

AND WHEREAS Canada and the Province have agreed on a general flood control program, hereinafter referred to as "the Program" for the area and on a plan for its implementation as described herein;

AND WHEREAS HIS EXCELLENCY, the Governor-in-Council by Order-in-Council P.C. 1968-3/1018 of May 29, 1968 has authorized the Minister of Energy, Mines and Resources to execute this Agreement on behalf of Canada;

AND WHEREAS HIS HONOUR, the Lieutenant Governor-in-Council by Order-in-Council No. 1629, 1968 has authorized the Minister of Lands, Forests and Water Resources to execute this Agreement on behalf of the Province;

NOW THEREFORE, it is agreed by and between the parties hereto as follows:

1. The purpose of this Agreement is the joint undertaking of a program of studies and works for flood control aimed at substantially reducing the flood threat to this area.

2. All projects undertaken under the Program shall be approved by the parties hereto and shall be substantially consistent with the Program Guide, attached hereto as Schedule "A", which describes and defines the basic outline of the Program and the objectives sought to be attained thereby.

3. Subject to the terms and conditions of this Agreement and subject to the funds being voted by Parliament, the aggregate sum which Canada shall be liable to contribute in respect of the Program and projects hereunder, as more particularly described and defined in the Agreement and Schedule "A" hereof, shall not exceed $18,000,000.

4. Subject to the terms and conditions of this Agreement and subject to the funds being appropriated by the provincial legislature of British Columbia, the Province shall contribute, in respect of the Program and projects hereunder, the sum of $18,000,000 exclusive of the cost of operating and maintaining said projects after an agreed completion date.

5. Canada and the Province from time to time during the life of this Agreement may approve proposed development projects of the Program which are practical, engineeringly sound, economically justified, and substantially consistent with the Program Guide, but in no circumstances shall funds be contributed in respect of any project or part of the Agreement unless approval thereof by Canada and the Province has been given.

6. Canada and the Province upon request shall give to the other any information about the Program or any project thereof.

7. Canada and the Province in a mutually agreed form shall approve annually, on or before the first of September of each year, estimates of the cost of the Program and projects hereunder to Canada and to the Province for the fiscal year beginning the first of April next following. Canada and the Province on the first of May of each year shall approve a forecast of estimated expenditures during the five fiscal years subsequent thereto, or over the period of time remaining in the Agreement, whichever is the lesser.

8. Canada and the Province shall keep complete records of all expenditures made pursuant to the Agreement and shall support such expenditures with proper documentation. Canada and the Province upon request shall make these records and documents available to auditors appointed by the other.

9. Subject to the cost sharing provisions of this Agreement, Canada shall pay to the Province expenditures made by the Province pursuant to this Agreement upon the submission of a claim in a mutually agreed manner and form by the Province, certified by a senior official of the Province, and bearing a Provincial audit certificate.

10. Each development project agreed to by Canada and the Province shall specify each party's respective share of the cost of the undertaking.

11. In the event the Canada and the Province agree that further studies or information with respect to the Program demonstrate that the objectives and basic guidelines provided for by paragraphs 2,3 and 4 and described in Schedule "A" hereof require alteration and amendment, the Agreement may from time to time be reviewed by the parties hereto and, with the approval of the Governor-in-Council and Lieutenant Governor-in-Council, may be revised.

12. The following conditions with respect to employment and the awarding of contracts under this Agreement shall apply to all projects carried out under this Agreement and, in the case of sub-paragraph (b) hereof, shall be made a condition of all contracts entered into as a result of this Agreement.

(a) Where practicable, the recruiting of labour shall be conducted through the Canada Manpower Division of the Department of Manpower and Immigration.

(b) In the employment of persons on any project there shall be no discrimination by reason of race, national origin, colour, religion or political affiliation.

13. (a) This Agreement shall not be construed as to vest in Canada any proprietary interest in the projects constructed hereunder.

(b) Except for acts of God, the Province shall save harmless and indemnify Canada for and against any and all liability, loss, damages or expenses, which may be suffered or created as a result of implementing the Program or projects hereunder and for the implementation of which Canada is not directly responsible hereunder.

14. This Agreement shall commence on, and take effect from, the date on which it becomes signed by both Canada and the Province and no costs incurred more than 60 days prior to that date shall be eligible or considered for payment under this Agreement except those specifically provided for in paragraph 21. The Agreement shall terminate 10 years from the date of signing, and no project or program shall be approved after that date, and no claim for contribution made in respect of any project or program under this Agreement or part of the program under this Agreement shall be paid unless it is received by Canada within one year following the agreed completion date of the approved project. This agreement may be renewed for any further period agreed upon by the parties hereto, but such renewal shall be subject to the approval of the Governor-in-Council and the Lieutenant Governor-in-Council.

15. (a) No Member of Parliament or member of the Legislature of the Province shall hold, enjoy or be admitted to any share or part of any contract, agreement, commission or benefit arising out of any project under the Agreement.

(b) Canada and the Province agree that in carrying out the Program or any project under this Agreement they shall observe and abide by the conditions respecting fair wages and hours of work under the Fair Wages and Hours of Labour Act, R.S.C., 1952, c. 108.

Administration

16. The purpose and intent of this section is to establish managerial machinery to implement effectively the Program described in this Agreement; to provide for adequate co-ordination among Canada, the Province and their agencies herein affected; to ensure that by placing management of that portion of the Program which is assigned by the Joint Program Committee as defined in paragraph 18 (b) to the Province in the hands of one provincial agency there is co-ordinated and comprehensive execution of the whole Program; and to arrange for continued joint involvement and participation by Canada and the Province in the planning and operation of the Program.

17. (a) The Province, through its agency the Department of Lands, Forests and Water Resources, shall be responsible for constructing approved projects, for operation and maintenance of the projects and for implementing all other portions of the Program assigned to the Province by the Joint Program Committee.

(b) Local authorities may, pursuant to an undertaking between the Province and the local authority, carry out all or part of the project on behalf of the Province and share in paying the cost thereof, as shall be provided under paragraph 21, but any such delegation of responsibility undertaken by the Province under the Agreement shall not release the Province from its obligations under this Agreement.

18. Canada and the Province shall participate in a process of joint planning. To facilitate this process there shall be established:

(a) A Joint Advisory Board consisting of six members at a senior level, three of whom will be appointed by Canada and three by the Province. This Board shall meet at least once each year and shall report to the Minister of Energy, Mines and Resources of Canada and to the Minister of Lands, Forests and Water Resources of the Province on its evaluation of the progress of the Program, its views and recommendations with respect to its implementation, the annual budget set aside for the program and its plan for the forthcoming year.

(b) A Joint Program Committee consisting of three members appointed by Canada and three by the Province. This Committee shall be responsible for carrying out the joint planning and studies, the recommendation of projects for approval by Canada and the Province, and the co-ordination of the implementation of approved projects. The Committee may recommend to the Provincial Civil Service Commission appointment of a Program Director and such other staff as may be needed from time to time to assist it in the performance of its duties; the Program Director and such other staff shall be responsible, functionally, to the Joint Program Committee. The Committee shall report to the Joint Advisory Board.

19. The Province shall provide the staff including any field staff and administrative facilities necessary to implement the construction phase of the Program and any portion of the Program assigned to the Province by the Joint Program Committee.

Cost sharing

20. In respect of costs directly related to the administration of this Program, including staff and consultant costs, Canada shall contribute 50 per cent of the total cost.

21. (a) Canada shall contribute 50 per cent of the costs incurred by the Province in the planning, design, and construction of projects under this Agreement, after deducting that portion to be paid by local interests benefiting.

(b) In the case of all projects constructed, local interests benefiting shall pay an equitable proportion of the cost of the project. This proportion shall be established for each project approval.

(c) The costs incurred by the Province with respect to this paragraph shall include those costs incurred prior to the signing of the Agreement with respect to improvements of the dykes done under emergency conditions, particularly following the highwater period of 1964, which are in conformity with guidelines established under this Agreement and its Schedule "A". The total of such expenditures by the Province was $90,297.03 of which the Federal Government share under this clause is $45,148.51.

22. As provided in the Program Guide, projects may be constructed to serve Indian lands and Indian interests. In the event and to the extent that Indian lands or Indian interests are served in a project, special cost-sharing arrangements may be negotiated.

23. The Province shall be responsible for operating and maintaining projects completed under this Agreement in proper order at all times, and for all operation and maintenance costs associated therewith. Where dyking is undertaken on Indian Reserves, Canada will arrange, in consultation with the Indians, to provide access to the lands for this purpose.

Land use zoning and flood proofing

24. The Province undertakes to continue to encourage a program of land use zoning and flood proofing to diminish potential flood losses in the area covered by this Agreement.

Research and further planning

25. Canada and the Province may jointly undertake further planning, social, economic or engineering studies and feasibility studies and assessments of this Program or any project under this Agreement.

26. In any event, Canada and the Province, no more than two years after the date of this Agreement, shall jointly initiate a review of the program of upstream storage set out in the "Final Report of the Fraser River Board on Flood Control and Hydro-Electric Power in the Fraser River Basin", dated September 1963, including any additional measures, with a view to recommending further flood protection, utilization and control of the water resources of the basin.

27. The cost of studies under paragraphs 25 and 26 shall be shared jointly by Canada and the Province, but the total cost of studies under paragraph 26 shall not exceed $1,000,000, and shall comprise part of the total funding under this Agreement as described under paragraphs 3 and 4.

IN WITNESS WHEREOF The Honourable Jean-Luc Pepin, Minister of Energy, Mines and Resources has hereunto set his hand on behalf of Canada and The Honourable Ray Williston, Minister of Lands, Forests and Water Resources for the Province, has hereunto set his hand on behalf of the Province of British Columbia.

In the Presence of	Signed on behalf of the Government of Canada
(A.T. DAVIDSON)	(JEAN-LUC PEPIN)
____________________	____________________
In the Presence of	Signed on behalf of British Columbia
(A.F. PAGET)	(RAY WILLISTON)
____________________	____________________

"COPY"

THIS AMENDING AGREEMENT MADE, IN DUPLICATE, THIS 11th DAY OF APRIL 1969.

BETWEEN

THE GOVERNMENT OF CANADA (hereinafter called "Canada"), represented by the Honourable Otto E. Lang, Acting Minister of Energy, Mines and Resources,

OF THE FIRST PART,

AND

THE GOVERNMENT OF THE PROVINCE OF BRITISH COLUMBIA (hereinafter called "the Province"), represented by the Honourable Ray Williston, Minister of Lands, Forests and Water Resources,

OF THE SECOND PART

WHEREAS Canada and the Province, on May 24, 1968, entered into an Agreement (hereinafter called "the 1968 Agreement") for the joint undertaking of a programme of studies and works for flood control aimed at substantially reducing the flood threat in the Fraser River Valley and other areas adjacent to the Lower Fraser River Valley of British Columbia;

AND WHEREAS it is a condition of the 1968 Agreement that expenditures totalling $90,297.03 (hereinafter called "the prior costs"), made by the Province prior to the signing of the 1968 Agreement, with respect to improvements of the dykes under emergency conditions, shall be shared, equally, by Canada and the Province;

AND WHEREAS the Hammersley Flood Box was replaced prior to the signing of the 1968 Agreement at a cost of $89,695.58, of which $8,296.65 was assumed by the Corporation of the District of Kent, leaving a balance of $81,398.93, which amount Canada and the Province consider should be added to the prior costs and shared equally by Canada and the Province;

NOW, THEREFORE THIS AGREEMENT (hereinafter called "Amending Agreement No. 1") WITNESSETH that Canada and the Province covenant and agree, each with the other, as follows:

1. Sub-paragraph (c) of paragraph 21 of the 1968 Agreement is deleted and the following sub-paragraph substituted therefor:

"(c) The costs incurred by the Province with respect to this paragraph shall include those costs incurred prior to the signing of the Agreement with respect to improvements of the dykes done under emergency conditions, particularly following the highwater period of 1964, which are in conformity with guidelines established under this Agreement and its Schedule "A". The total of such expenditures by the Province was $171,695.96 of which the Federal Government share under this clause is $85,847.98."

2. This Amending Agreement No. 1 is to be read and construed with the 1968 Agreement which remains in full force and effect.

IN WITNESS WHEREOF the Honourable Otto E. Lang, Acting Minister of Energy, Mines and Resources has hereunto set his hand on behalf of Canada and the Honourable Ray Williston, Minister of Lands, Forests and Water Resources has hereunto set his hand on behalf of the Province.

In the Presence of	Signed on behalf of the Government of Canada
(C. M. ISBISTER)	(O. E. LANG)
Witness	Acting Minister of Energy, Mines and Resources
In the Presence of	Signed on behalf of the Government of the Province of British Columbia
(D. M. ROWLEY)	(RAY WILLISTON)
Witness	Minister of Lands, Forests and Water Resources

"COPY"

THIS AMENDING AGREEMENT NO. 2 MADE THIS 29th DAY OF APRIL 1974

BETWEEN

THE GOVERNMENT OF CANADA (hereinafter called "Canada"), represented by the Minister of the Environment,

OF THE FIRST PART,

AND

THE GOVERNMENT OF THE PROVINCE OF BRITISH COLUMBIA (hereinafter called "the Province"), represented by the Minister of Lands, Forests, and Water Resources,

OF THE SECOND PART

WHEREAS Canada and the Province, on May 24, 1968, entered into an Agreement (hereinafter called the "1968 Agreement") for the joint undertaking of a program of studies and works for flood control aimed at substantially reducing the flood threat in the Fraser River Valley and other areas adjacent to the Lower Fraser River Valley of British Columbia;

AND WHEREAS the 1968 Agreement was amended the 11th day of April 1969 by "Amending Agreement No. 1";

AND WHEREAS Canada and the Province consider that the funds which each government should contribute under the 1968 Agreement should be increased from $18,000,000 to $30,500,000;

AND WHEREAS it is considered desirable to revise the organizational arrangements set out in the 1968 Agreement in respect to the managerial machinery considered necessary to implement the program of studies and works;

AND WHEREAS Canada and the Province consider that the extent of work covered in the Program Guide of the 1968 Agreement should be extended to other similar areas subject to flooding on the Fraser River and its tributaries;

AND WHEREAS studies being carried out under the Program in accordance with Section 26 of the 1968 agreement have not yet been completed;

AND WHEREAS it has been considered necessary and desirable to provide certain flood control works in the vicinity of Kamloops and these works are being constructed by the Province in accordance with specifications for the improvement of similar works in the Lower Fraser Valley under the 1968 Agreement;

AND WHEREAS His Excellency, the Governor-in-Council, by Order-in-Council P.C. 1974-5/602, dated March 19, 1974, has authorized the Minister of the Environment to execute this Agreement on behalf of Canada;

AND WHEREAS His Honour, the Lieutenant-Governor-in-Council, by Order-in-Council No. 1321 dated April 23rd, 1974, has authorized the Minister of Lands, Forests, and Water Resources, to execute this Agreement on behalf of the Province;

NOW THEREFORE THIS AGREEMENT (hereinafter called "Amending Agreement No. 2") WITNESSETH that Canada and the Province in consideration of the covenants and agreements herein contained, covenant and agree, each with the other, as follows:

1. Paragraph 3 of the 1968 Agreement is deleted and the following paragraph substituted therefor;

> "3. Subject to the terms and conditions of this Agreement and subject to the funds being voted by Parliament, the aggregate sum which Canada shall be liable to contribute in respect of the Program and projects hereunder, as more particularly described and defined in the Agreement and Schedule "A" hereof, shall not exceed $30,500,000."

2. Paragraph 4 of the 1968 Agreement is deleted and the following paragraph substituted therefor;

> "4. Subject to the terms and conditions of this Agreement and subject to the funds being appropriated by the provincial legislature of British Columbia, the Province shall contribute, in respect of the Program and projects hereunder, the sum of $30,500,000 exclusive of the cost of operating and maintaining said projects after an agreed completion date."

3. Paragraph 16 of the 1968 Agreement is deleted and the followng paragraph substituted therefor;

> "16. The purpose and intent of this Section is to establish managerial machinery to implement effectively the Program described in this Agreement; to provide for

adequate co-ordination among Canada, the Province and their agencies herein affected; to ensure that by placing management of that portion of the Program which is assigned by the Joint Advisory Board as defined in paragraph 18 to the Province in the hands of one provincial agency there is co-ordinated and comprehensive execution of the whole Program; and to arrange for continued joint involvement and participation by Canada and the Province in the planning and operation of the Program."

4. Paragraph 17 (a) of the 1968 Agreement is deleted and the following paragraph substituted therefor;

"17(a). The Province, through its agency, the Department of Lands, Forests, and Water Resources, shall be responsible for the design and construction of approved projects, for operation and maintenance of the projects and for implementing all other portions of the Program assigned to the Province by the Joint Advisory Board."

5. Paragraph 18 of the 1968 Agreement is deleted and the following paragraph substituted therefor;

"18. Canada and the Province shall participate in a process of joint planning. To facilitate this process, there shall be established a Joint Advisory Board consisting of six members at a senior level, three of whom will be appointed by Canada and three by the Province. This Board shall meet at least once each year and shall report to the Minister of the Environment of Canada and to the Minister of Lands, Forests, and Water Resources of the Province on its evaluation of the progress of the Program, its views and recommendations with respect to its implementation, the annual budget set aside for the Program and its plan for the forthcoming year. This Board shall be responsible for providing general direction to overall Program scheduling and studies and recommending projects for approval by Canada and the Province."

6. Paragraph 19 of the 1968 Agreement is deleted and the following paragraph substituted therefor;

"19. The Province shall provide the staff including any field staff and administrative facilities necessary to implement the design and construction phases of the Program and any portion of the Program assigned to the Province by the Joint Advisory Board."

7. The final paragraph of the Program Guide, attached to the 1968 Agreement as Schedule A, is deleted and the following paragraph substituted therefor;

> "The Agreement which the two governments have entered into has a termination date of March 31, 1978. During the term of the Agreement, the Program outlined by the Agreement and this Program Guide will be advanced by the joint federal-provincial Joint Advisory Board. This Board will be responsible for the overall implementation of the Program in order to maximize the protection and benefits to be derived from the control of the waters of the Fraser River. Recommendations for construction of specific works will originate from the Board following a full review of the soundness of the projects from an engineering viewpoint as well as their economic justification in the light of both the direct and indirect benefits which will be realized by the Province and by Canada as a whole from full implementation of this Program."

8. The following paragraph is added to the Program Guide, attached to the 1968 Agreement as Schedule "A".

> "In addition to providing the flood protection for the Lower Fraser Valley the scope of the 1968 Agreement and Program Guide attached as Schedule "A" is extended to include the Kamloops area."

9. This Amending Agreement No. 2 is to be read and construed with the 1968 Agreement as amended by Amending Agreement No. 1, which remains in full force and effect.

10. Any reference in the 1968 Agreement, Amending Agreement No. 1, or this Agreement to "the Province" shall be deemed to be a reference to "British Columbia."

11. The members of the Joint Advisory Board appointed under the 1968 Agreement shall be deemed to have been appointed under this Agreement.

IN WITNESS WHEREOF the Honourable Jack Davis, Minister of the Environment has hereunto set his hand on behalf of Canada, and the Honourable Robert A. Williams, Minister of Lands, Forests, and Water Resources, has hereunto set his hand on behalf of British Columbia.

In the Presence of	Signed on behalf of the Government of Canada
(L. SPRATLEY)	(JACK DAVIS)
Witness	Minister of the Environment
In the Presence of	Signed on behalf of the Government of the Province of British Columbia
(B. E. MARR)	(R. A. WILLIAMS)
Witness	Minister of Lands, Forests, and Water Resources

"COPY"

THIS AMENDING AGREEMENT NO. 3 made this 5th day of October 1976

BETWEEN

THE GOVERNMENT OF CANADA (hereinafter called "Canada"), represented by the Minister of the Environment,

OF THE FIRST PART,

AND

THE GOVERNMENT OF THE PROVINCE OF BRITISH COLUMBIA (hereinafter called "the Province"), represented by the Minister of Environment,

OF THE SECOND PART

WHEREAS Canada and the Province, on May 24, 1968, entered into an Agreement (hereinafter called the "1968 Agreement") for the joint undertaking of a program of studies and works for flood control aimed at substantially reducing the flood threat in the Fraser River Valley and other areas adjacent to the Lower Fraser River Valley of British Columbia;

AND WHEREAS the 1968 Agreement was amended the 11th day of April, 1969, by "Amending Agreement No. 1" and was further amended the 29th day of April, 1974, by "Amending Agreement No. 2";

AND WHEREAS Canada and the Province consider that the funds which each government should contribute under the 1968 Agreement should be increased from $30,500,000 to $60,000,000;

AND WHEREAS Canada and the Province consider that the period for the program under the 1968 Agreement should be extended until March 31, 1984;

AND WHEREAS Canada and the Province consider that the funds authorized in Section 27 of the 1968 Agreement should be increased from $1,000,000 to $1,150,000;

AND WHEREAS His Excellency, the Governor-in-Council, by Order-in-Council P.C. 1976-1714, dated July 6, 1976, has authorized the Acting Minister of the Environment to execute this Agreement on behalf of Canada;

AND WHEREAS His Honour, the Lieutenant Governor-in-Council, by Order-in-Council No. 2631, dated September 3, 1976, has authorized the Minister of Environment, to execute this Agreement on behalf of the Province;

NOW THEREFORE THIS AGREEMENT (hereinafter called "Amending Agreement No. 3") WITNESSETH that Canada and the Province in consideration of the covenants and agreements herein contained, covenant and agree, each with the other, as follows:

1. Paragraph 3 of the 1968 Agreement, as amended by Amending Agreement No. 2, is deleted and the following paragraph substituted therefor:

> "3. Subject to the terms and conditions of this Agreement and subject to the funds being voted by Parliament, the aggregate sum which Canada shall be liable to contribute in respect of the Program and projects hereunder, as more particularly described and defined in the Agreement and Schedule "A" hereof, shall not exceed $60,000,000."

2. Paragraph 4 of the 1968 Agreement, as amended by Amending Agreement No. 2, is deleted and the following paragraph substituted therefor:

> "4. Subject to the terms and conditions of this Agreement and subject to the funds being appropriated by the provincial legislature of British Columbia, the Province shall contribute, in respect of the Program and projects hereunder, the sum of $60,000,000 exclusive of the cost of operating and maintaining said projects after an agreed completion date."

3. Paragraph 14 of the 1968 Agreement is deleted and the following paragraph substituted therefor:

> "14. This Agreement shall commence on, and take effect from, the date on which it becomes signed by both Canada and the Province and no costs incurred more than 60 days prior to that date shall be eligible or considered for payment under this Agreement except those specifically provided for in paragraph 21. The Agreement shall terminate on March 31, 1984, and no project or program shall be approved after that date, and no claim for contribution made in respect of any project or program under this Agreement or part of the program under this Agreement shall be paid unless it is received by

Canada within one year following the agreed completion date of the approved project. This agreement may be renewed for any further period agreed upon by the parties hereto, but such renewal shall be subject to the approval of the Governor-in-Council and the Lieutenant Governor-in-Council."

4. Paragraph 27 of the 1968 Agreement is deleted and the following paragraph substituted therefor:

"27. The cost of studies under paragraphs 25 and 26 shall be shared jointly by Canada and the Province, but the total cost of studies under paragraph 26 shall not exceed $1,150,000, and shall comprise part of the total funding under this Agreement as described under paragraphs 3 and 4."

5. The final paragraph of the Program Guide, attached to the 1968 Agreement as Schedule A, as amended by Amending Agreement No. 2, is deleted and the following paragraph substituted therefor:

"The Agreement which the two governments have entered into has a termination date of March 31, 1984. During the term of the Agreement, the Program outlined by the Agreement and this Program Guide will be advanced by the federal-provincial Joint Advisory Board. This Board will be responsible for the overall implementation of the Program in order to maximize the protection and benefits to be derived from the control of the waters of the Fraser River. Recommendations for construction of specific works will originate from the Board following a full review of the soundness of the projects from an engineering viewpoint as well as their economic justification in the light of both the direct and indirect benefits which will be realized by the Province and by Canada as a whole from full implementation of this Program."

6. This Amending Agreement No. 3 is to be read and construed with the 1968 Agreement as amended by Amending Agreement No. 1 and Amending Agreement No. 2, both of which remain in full force and effect except as modified by this Amending Agreement No. 3.

IN WITNESS WHEREOF the Honourable Roméo LeBlanc, Acting Minister of the Environment has hereunto set his hand on behalf of Canada, and the Honourable James Arthur Nielsen, Minister of Environment, has hereunto set his hand on behalf of British Columbia.

In the Presence of	Signed on behalf of the Government of Canada
(J. BLAIR SEABORN)	(ROMEO LEBLANC)
Witness	A/Minister of the Environment
In the Presence of	Signed on behalf of the Government of the Province of British Columbia
(B.E. MARR)	(J.A. NIELSEN)
Witness	Minister of Environment

ANNEX II

BACKGROUND DOCUMENTS

Documents furnishing background information for this review of System E and alternative projects and for their ecological assessment are listed hereunder. Part A covers those documents to which reference is made in the text of the Review Report, while Part B consists of documents used in the preparation of the Ecology Committee Summary Report (Reference: 3-6).

Copies of all documents listed hereunder are available in the following agency offices and libraries for examination, but not for distribution:

Victoria - Provincial Library
Ottawa - National Library

Agency Offices

Victoria - Ministry of the Environment
Victoria - Water Investigations Branch

Ottawa - Department of Fisheries and the Environment
Ottawa - Inland Waters Directorate
Ottawa - Fisheries and Marine Service

Vancouver - Inland Waters Directorate
Vancouver - Fisheries and Marine Service

Public Libraries

Victoria
Vancouver
New Westminster
Chilliwack
Kamloops
Prince George

University Libraries

University of Victoria
University of British Columbia
Simon Fraser University

PART A -- REVIEW REPORT

Reference

1-1 Inland Waters Directorate, Environment Canada: Probable Maximum Floods for the Fraser River at Hope and Mission; Vancouver, December 1973.

1-2 Fraser River Board: Final Report on Flood Control and Hydro-Electric Power in the Fraser River Basin (2 volumes); Victoria, September 1963.

3-1 Inland Waters Directorate, Environment Canada: Compile and Extend Flow Data; Vancouver, December 1973.

3-2 Inland Waters Directorate, Environment Canada: Define and Develop Mathematical Simulation Models for Flood Regulation Studies; Vancouver, March 1974.

3-3 Inland Waters Directorate, Environment Canada: River Regime and Sediment Studies; Vancouver, July 1974.

3-4 Department of Public Works, Canada: Fraser River Upstream Storage Review - Navigation Studies; Vancouver, November 1973.

3-5 Inland Waters Directorate, Environment Canada: Estimating Flood Damages in the Fraser River Basin; Vancouver, December 1975.

3-6 Fraser River Ecology Committee: Summary Report on the Ecological Consequences of the Proposed System E Development in the Fraser River Basin; Victoria, November 1976.

3-7 International Power and Engineering Consultants Limited: Fraser River System E Power Studies; Vancouver, October 1974.

4-1 Water Resources Service, Department of Lands, Forests and Water Resources, British Columbia: The City of Kamloops - Outline Report on Flood Control Works; Victoria, January 1975.

4-2 Water Resources Service, Department of Lands, Forests and Water Resources, British Columbia: Fraser River Agreement Studies - Prince George Dyking Costs; Victoria, April 1974.

4-3 Water Resources Service, Department of Lands, Forests and Water Resources, British Columbia: Fraser River Agreement Studies - Quesnel Dyking Costs; Victoria, April 1974.

Reference

4-4 G.E. Crippen and Associates Limited: Project 1137 - Report on Fraser River Investigations - Volume I - Lower McGregor Project; North Vancouver, February 1972.

4-5 G.E. Crippen and Associates Limited: Project 1137 - Report on Fraser River Investigations - Volume II - Hemp Creek Project; North Vancouver, February 1972.

4-6 G.E. Crippen and Associates Limited: Project 1161 - 1972 Fraser River Investigations - Lower McGregor Project (2 volumes); North Vancouver, February 1973.

4-7 International Power and Engineering Consultants Limited: McGregor River Diversion Project - Feasibility Study; Vancouver, February 1973.

4-8 Crippen Engineering Limited: Project A 1212 - Revised Estimates of Capital Cost - Fraser River Storage - System 'E' Projects; North Vancouver, July 1974.

4-9 G.E. Crippen and Associates Limited: Project 1128 - Estimate of Capital Costs - Fraser River Storage - System 'E' Projects; North Vancouver, May 1971.

4-10 Inland Waters Directorate, Environment Canada: Spillway Design Floods for System E Reservoirs; Vancouver, February 1974 (Revised January 1975).

4-11 E.M. Clark and J.D. Watts: Alternative Upper Fraser Projects in the Review of Upstream Storage; Vancouver, March 1971.

4-12 Crippen Engineering Limited: Project C1212 - Fraser River Upstream Storage Study - Clearwater River Basin - Negative Storage Sites; North Vancouver, September 1974 (Revised January 1975).

PART B -- ECOLOGY COMMITTEE SUMMARY REPORT (Reference: 3-6)

Fisheries and Marine Service, Environment Canada: An Assessment of the Effects of the System E Flood Control Proposal on the Salmon Resource of the Fraser River System - (2 volumes); Vancouver, January 1974.

Howard Paish & Associates Limited: An Assessment of the Environmental Impact on Fish, Wildlife, and Outdoor Recreation of the Proposed System E Development - Summary and Conclusions; Burnaby, August 1973.

Howard Paish & Associates Limited: An Assessment of the Environmental Impact on Fish, Wildlife and Outdoor Recreation of the Proposed Lower McGregor Reservoir (System E Development) - (2 volumes); Burnaby, April 1973.

Howard Paish & Associates Limited: An Assessment of the Environmental Impact on Fish, Wildlife, and Outdoor Recreation of the Proposed Grand Canyon Reservoir (System E Development) - (2 volumes); Burnaby, April 1973.

Howard Paish & Associates Limited: An Assessment of the Environmental Impact on Fish, Wildlife, and Outdoor Recreation of the Proposed Cariboo Falls Reservoir (System E Development) - (2 volumes); Burnaby, April 1973.

Howard Paish & Associates Limited: An Assessment of the Environmental Impact on Fish, Wildlife, and Outdoor Recreation of the Proposed Clearwater River Reservoirs - Hobson Lake Project, Clearwater - Azure Project, Hemp Creek Project, Granite Canyon Project, Clearwater Project (System E Development) - (2 volumes); Burnaby, April 1973.

Pearse Bowden Economic Consultants Limited: Evaluation of the Impact of the Proposed System E Dams on Fish, Wildlife, Parks and Outdoor Recreation: Vancouver, June 1973.

Pearse Bowden Economic Consultants Limited: The McGregor River Diversion - Evaluation of its Impact on the Parsnip River Valley; Vancouver, May 1973.

Fish and Wildlife Branch, British Columbia Department of Recreation and Conservation; The McGregor River Diversion - Assessment of its Impact on the Parsnip River Valley; Victoria, March 1973.

Environment Research Consultants Limited: A Preliminary Environmental Impact Assessment of the Effects of the McGregor River Diversion on the Parsnip River Valley (2 volumes); West Vancouver, July 1975.

British Columbia Forest Service: Report on the Effect of the Proposed System E Storage Dams on Forestry; Victoria, March 1973.

British Columbia Department of Mines and Petroleum Resources: Impact of Proposed System E Development on Mining; Victoria, December 1971.

British Columbia Department of Agriculture: Benefits and Disbenefits to Agriculture in Relation to the System E Flood Control Plan - Fraser River Basin; Victoria, March 1973 - Amended January 1974.

British Columbia Archaeological Sites Advisory Board: Final Report of the System 'E' Archaeological Resources Evaluation Project 1971-72; Victoria, October 1972.