REPORT

OF THE

ROYAL COMMISSION

ON

FLOOD COST BENEFIT

WINNIPEG, MANITOBA

December, 1958

ROYAL COMMISSION
ON FLOOD COST-BENEFIT
1958

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To the PRESIDENT of the COUNCIL,
PROVINCE of MANITOBA

Sir,

We the Commissioners, appointed as a Royal Commission on Flood Cost-Benefit by an Order in Council 1795/56, dated 18th December, 1956, were directed to make inquiry, findings and recommendations in accord with the terms of reference therein set forth,

BEG TO SUBMIT THE FOLLOWING REPORT

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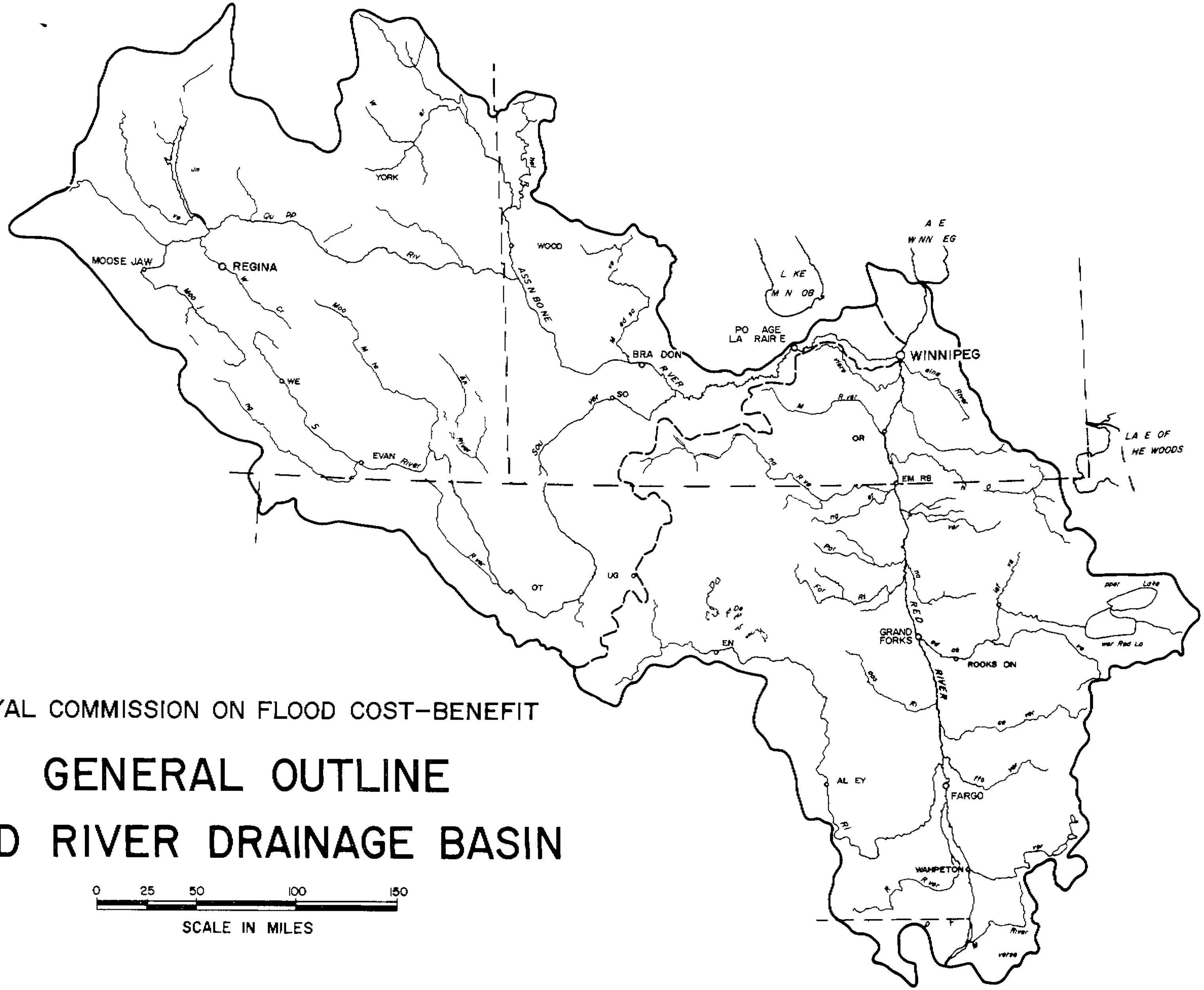
Foreword

In Chapter 1 of this report will be found set forth in brief form, the flood threat which faces Southern Manitoba, the specific recommendations of the Commission for protection of the flood-prone areas, together with a statement of the benefits which logically should flow from implementation of its recommendations

Chapter 2 outlines some of the salient features in the background of the flood problem, and gives a short statement of the measures which the Commission considered, and accepted or rejected, as a result of its studies

In Chapters 1 and 2, read together, the Commission has stated the main facts about floods and flood protection which an interested citizen should know It is the hope of the Commission that these chapters may develop informed opinion of the present flood danger to our economy, of the protective measures now recommended and of what may happen if counter-measures are not taken immediately

For those whose interest in the subject is more analytical, Chapters 3 to 11 offer further elaboration on the economic studies made by the Commission Chapter 12 is a report on Flood Insurance For those who wish to study the engineering basis of the report, attention is directed to Appendix G, in which are listed the engineering reports on which the Commission has relied



ROYAL COMMISSION ON FLOOD COST-BENEFIT

GENERAL OUTLINE
RED RIVER DRAINAGE BASIN

0 25 50 100 150
SCALE IN MILES

CHAPTER 1

RECOMMENDATIONS

The 1950 flood is still fresh in the minds of the people not only in Greater Winnipeg and in the basins of the two great rivers but also in lesser degree across Canada and in fact throughout the continent

Not as well known is the fact that disastrous floods occurred in 1826, in 1852 and in 1861 Furthermore in 1956 with adverse weather conditions during the runoff period, the flood level in that year could have been even greater than that of 1950 in fact, almost 2 feet higher If this had occurred it is probable that all the dykes including any emergency dykes built on top of the present permanent system would have been overtopped and flood waters would have covered a large section of Greater Winnipeg and much of the Red River Valley Even with favourable weather conditions severe flooding did occur on the Assiniboine in 1956

Since the 1950 flood is the only major flood in the memory of most people it is interesting to compare its magnitude with other major floods on the Red River

- 1950—peak flow of 103,600 c f s (cubic feet per second) and an elevation at the junction of the Red and Assiniboine of 758 5 feet (30 2 feet above city datum)
- 1861—peak flow of 125,000 c f s and elevation 2 feet higher than in 1950
- 1852—peak flow of 165,000 c f s and elevation 4 feet higher than in 1950
- 1826—peak flow of 225 000 c f s and elevation 6 feet higher than in 1950

There is talk of a legendary flood in 1776 which exceeded that of 1826 but there is no accurate record to support this

The Red River Basin Investigation estimated that the maximum flow that could be reached under the worst conceivable combination of circumstances would be 270,000 c f s This would produce a flood level in Winnipeg of from 7 to 8 feet higher than the 1950 flood Disastrous floods have also occurred on the Assiniboine River In fact in 1882 the peak flow at Portage la Prairie is believed to have been more than twice as large as that which occurred in 1956

FACTS AND FINDINGS

1 Given the conditions that cause flooding it is as certain as the law of mathematical probability that

(a) Greater Winnipeg and the Red River Valley will experience a flood of 1950 severity or greater on the average of once every 36 years

(b) The Assiniboine Valley in certain reaches will be flooded at much more frequent intervals Damage will be particularly severe in the Portage to Headingley reach

2 Faced with the certainty of floods, the people of Greater Winnipeg and of the Red and the Assiniboine Valleys can do one of two things (a) accept the damages from flood when they arise or (b) take engineering steps to reduce or prevent them

The problem facing this Commission was to ascertain if there were preventive measures which would be less expensive than accepting the damage from the floods themselves

It was found that

(a) There are a number of engineering projects that will substantially protect Greater Winnipeg at a cost considerably less than the anticipated flood damages

(b) There are two major projects on the Assiniboine River which in view of the benefits they give to Winnipeg and the Assiniboine Valley have an economic justification

(c) Due to the nature of the terrain and the type of floods there are no known methods of protecting the Upper Red River Valley as a whole that have an economic justification There are engineering projects which can effectively prevent flooding but the cost of these is many times the cost of the damage prevented

There are a number of towns and villages which can be protected by ring dykes to a certain flood level with an economic justification

If detailed engineering studies are made a combination of smaller projects may be found which with the Pembina Reservoir offer hope of some protection These studies will require considerable time to develop and to bring to finality

3 By computing the probable flood frequency the probable size of floods and the amount of damage likely to be done the Commission estimates that at present day costs and with the present population, the anticipated floods threat of floods and fighting of floods in the three areas studied represent an annual average economic loss to the people of the Province of Manitoba of approximately $14 million as follows

Greater Winnipeg	$12 870 600
Red River Valley	731 400
Assiniboine Valley	497 900
	$14 099 900

This means that the total cost on an average for the next fifty years with no gain in population and with no increase in price levels, would be $700 000 000 The details of these costs or damages are set forth in Chapters 6, 7 and 8

4 Floods do not occur with any regularity The frequency of flooding is important to know but it is equally important to remember that, even with a frequency expectation of once in a hundred years that once' may be next year

RECOMMENDATIONS

1 The Commission recommends the following major projects

(a) A Greater Winnipeg Floodway with a capacity of 60 000 c f s (Plan 60 768) at an estimated cost of $57 361 000

(b) A diversion of the Assiniboine River to Lake Manitoba along the High Bluff Route with a capacity of 25 000 c f s at an estimated cost of $8,672,000 (herein after referred to as the Portage Diversion)

(c) A storage reservoir near Russell, Manitoba at an estimated cost of $6 450,000

These projects as shown on Plate 2 are described briefly in Chapter 4 of this volume and are explained in more detail in the Report of the Red River Basin Investigation

Taken as a group these three projects cost about $72 5 million provide average annual benefits of $10 920 000 and have a benefit cost ratio of 2 73 (see Table 1 1) The implementation of this recommendation will ensure virtually complete flood protection to all parts of Greater Winnipeg behind the main dyking system for all floods up to 169 000 cubic feet per second This provides a margin of 65 000 c f s in excess of the 1950 peak These projects also offer a very high degree of flood protection to the farming area between Portage la Prairie and Headingley, and substantial protection to the valley flats between Millwood and Brandon In total they provide flood protection to a large portion of the Province's population and productive capacity

While the primary purpose of each of these projects is flood protection one of them the Russell Reservoir, also provides important benefits in the form of a better and more assured water supply for the towns and cities along the Assiniboine River and an improvement in the degree of sewage dilution in the same areas and in Greater Winnipeg

2 The Commission also recommends

(i) That a detailed engineering study of the potentialities of the Pembina Dam be undertaken by a competent authority so that its benefit cost characteristics in terms of water supply may be assessed in conjunction with its benefits from flood control, which latter, under present knowledge were not substantial and that thereafter the inclusion of the Dam with the major projects recommended in 1 above be reconsidered

The Commission observes that the engineering studies of the Red River Basin Investigation on which it has relied throughout were not as detailed on the Pembina Dam as those on the major projects which it now recommends

(b) The construction of ring dykes around towns and villages along the Red River south of Winnipeg if detailed studies prove them to be feasible and economic as well as acceptable to residents It is estimated that this will cost up to $1,250 000

(c) That detailed engineering studies be commenced immediately in the Upper Red River Valley to determine the effectiveness and benefits from flood control and water supply of

(i) small reservoirs on the tributaries

(ii) improving the present main channel at various locations so that a more uniform capacity may be secured

Table 1 1

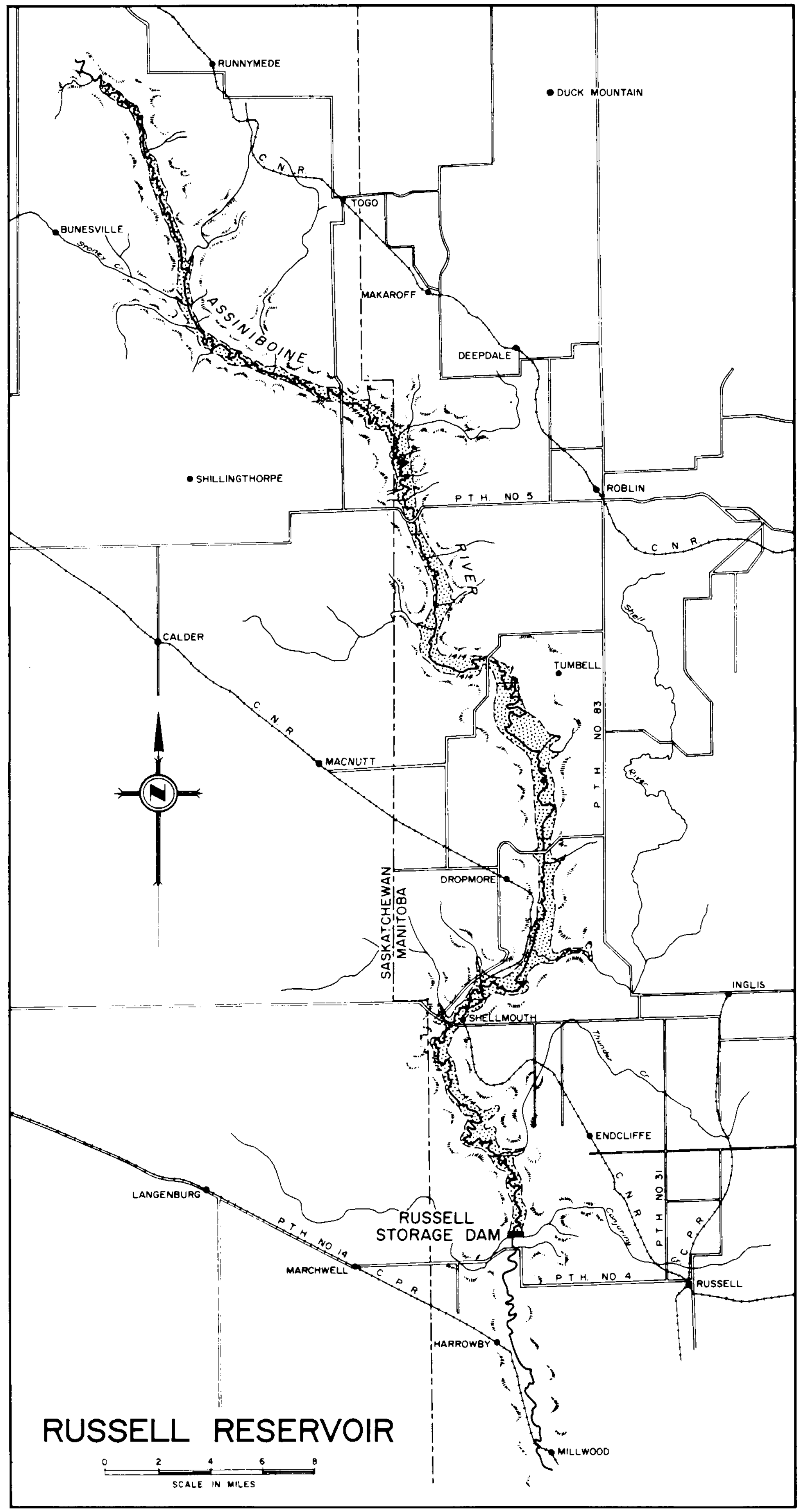
BENEFITS AND COSTS FOR THREE MAJOR PROJECTS

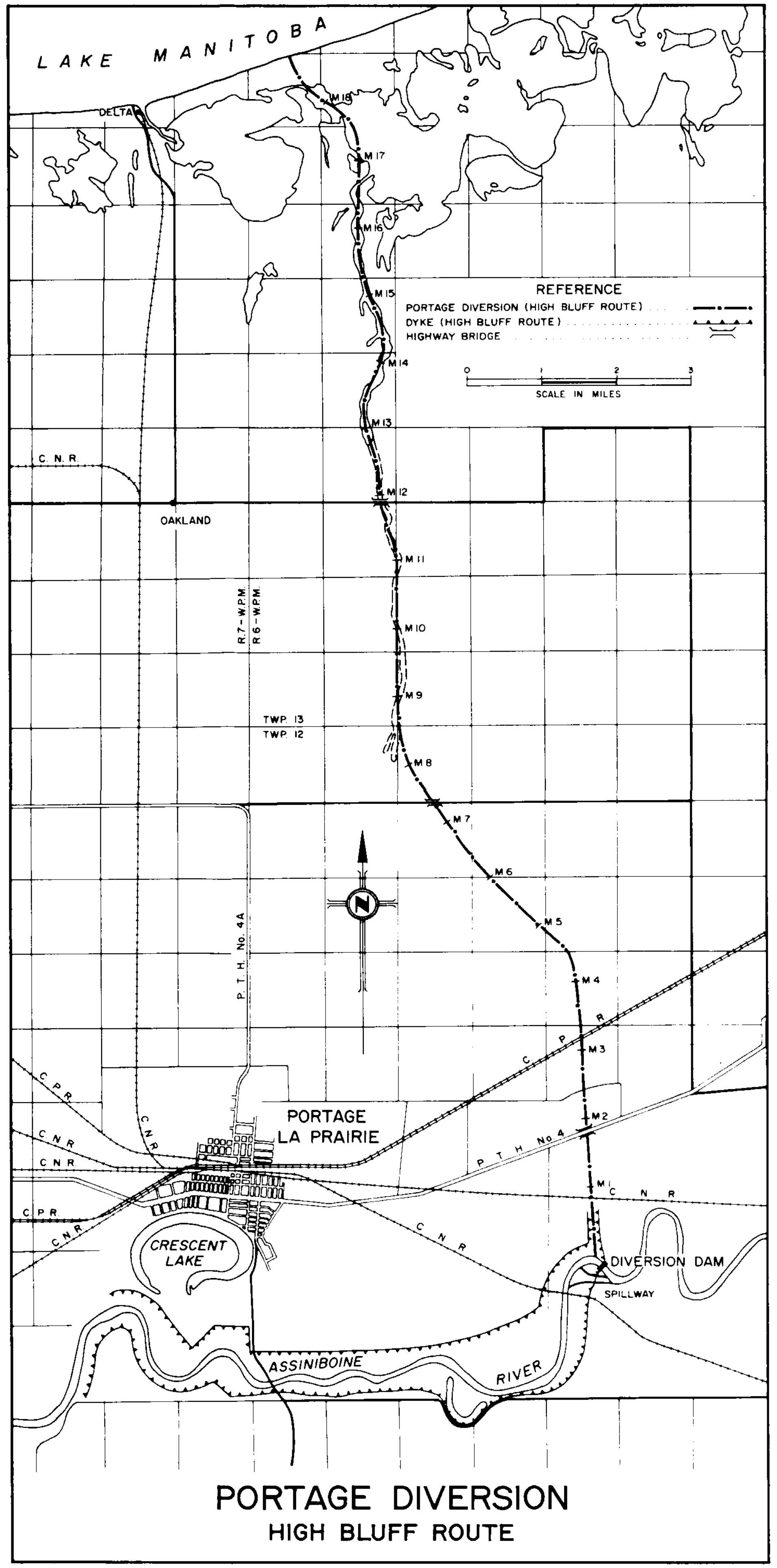
Project	Capital Cost	Annual Cost	Annual Benefit	Benefit cost Ratio
Greater Winnipeg Floodway Plan 60 768 60 000 c f s	$57 361 000	$3 161 700	$ 9 127 000	2 89
Portage Diversion High Bluff 25 000 c f s	8 672 000	506 200	4 587 000	9 06
Russell Reservoir	6 450 000	333 900	2 062 000	6 18
Combination of Three Projects	$72 483 000	$4 001 800	$10 920 000*	2 73

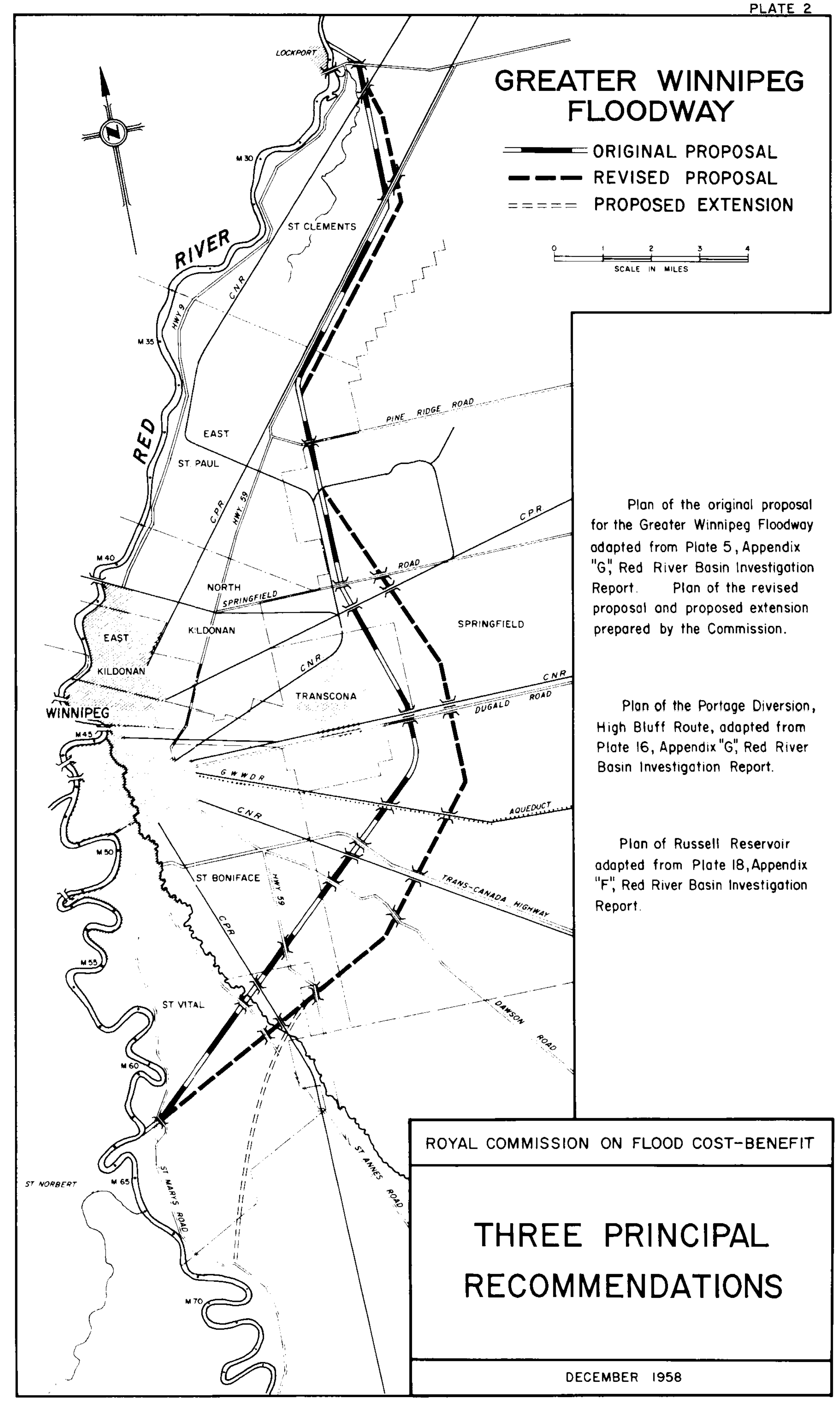
By virtue of duplication at lower flood levels this is less than the total of each project alone See Chapter 11

NOTE In this report annual interest and amortization costs have been calculated on the basis of a 4 percent rate of interest This is close to the average rate paid by the Province of Manitoba over the past ten years The Commission is aware that current interest rates are higher than this

The use of a higher rate would result in a lower benefit cost ratio it would not result in any change in the Commission s recommendations With an interest rate of 5 percent instead of 4 percent on the three major projects recommended the benefit cost ratio would be 2 30 (instead of 2 73) and the annual cost would be $4 740 400







Plan of the original proposal for the Greater Winnipeg Floodway adapted from Plate 5, Appendix "G", Red River Basin Investigation Report. Plan of the revised proposal and proposed extension prepared by the Commission.

Plan of the Portage Diversion, High Bluff Route, adapted from Plate 16, Appendix "G", Red River Basin Investigation Report.

Plan of Russell Reservoir adapted from Plate 18, Appendix "F", Red River Basin Investigation Report.

ROYAL COMMISSION ON FLOOD COST-BENEFIT

THREE PRINCIPAL RECOMMENDATIONS

DECEMBER 1958

In making this recommendation the Commission recognizes that no major project on which it has engineering information offers adequate protection to the Valley, and that a combination of smaller projects, if fully engineered and examined, may assist in meeting the need for protection

(d) The maintenance by the proper authorities of the channel of the Assiniboine River at not less than its present capacity, in the area between Portage la Prairie and Headingley In this region, silt carried down from further upstream has been gradually filling in the river channel, and the removal by dredging of any obstacles to the free flow of the river is necessary

MODIFICATION TO THE GREATER WINNIPEG FLOODWAY

The Commission recommends that the intake of the Greater Winnipeg Floodway, which, in the plan proposed by the Red River Basin Investigation, would leave the main channel of the Red River just north of St Norbert at Mile 62 7, be moved upstream to about Mile 68 (See dotted line Plate 2) providing this proves feasible from an engineering point of view The cost of this extension to the Floodway will be about $3,000,000

While this addition to the cost of the Floodway will not have an economic justification at this time, the Commission recognizes that it will have other benefits now and in the foreseeable future and recommends it for the following reasons

(a) It will bring St Norbert, now recognized as an integral part of the Greater Winnipeg Metropolitan area, and some of the area contiguous to St Norbert within the area to be protected,

(b) The increased cost of some $3 0 millions is not material in view of the fact that the Greater Winnipeg area inevitably will face a major growth in the next twenty-five years,

(c) Even with the cost increase due to this extension, the overall benefit-cost ratio is still very favourable

WHAT THESE PROJECTS WILL DO

1 For Greater Winnipeg and the Assiniboine River Valley

A combination of a 60,000 c f s Greater Winnipeg Floodway, a 25,000 c f s Portage Diversion and the Russell Reservoir will provide Greater Winnipeg and the Assiniboine River Valley with a very substantial degree of flood protection

These projects will ensure almost complete protection to all parts of Greater Winnipeg behind the main dyking system from all floods of 169,000 c f s or less A flood flow of 169,000 c f s will be reached or exceeded only about once in 165 years By building temporary dykes on top of the existing dyking system, it may be possible to carry an additional flow of some 20,000 c f s through the city Further, if the control gates of the Greater Winnipeg Floodway are operated so as to raise the natural flood levels south of St Norbert, an additional 10,000 c f s could be passed through the floodway channel around the city These emergency measures would make it possible to fight a flood of some 200,000 c f s in the Greater Winnipeg area

On the Assiniboine River between Portage la Prairie and Winnipeg, the Russell Reservoir and the 25,000 c f s Portage Diversion together will provide complete protection for all floods not exceeding 55,000 c f s Floods in excess of this amount can be expected to occur about once in every 500 years In addition, the Russell Reservoir will provide a substantial degree of protection against flooding in the valley area between Millwood and Portage la Prairie and in the City of Brandon For example, if the Russell Reservoir had been in existence 40 years ago, it would have eliminated almost all of the flooding that has occurred since then in the valley flats between Millwood and Brandon and in conjunction with the existing dyke at Brandon, it would have prevented all flooding in the area protected by the dyke

The Russell Reservoir will also make it possible to maintain a minimum monthly summer flow of 600 c f s at Portage la Prairie and Headingley instead of the present minimum of 160 c f s This will provide a more assured potable water supply for Brandon, Portage la Prairie and a number of smaller towns along the river Better sewage dilution will also be provided in the Greater Winnipeg area and in the area downstream from the reservoir This improvement in water supply will make these cities and towns more attractive to industry and should substantially assist their future growth and prosperity

2 For the Red River Valley South of Winnipeg

The ring dykes proposed by this Commission would give partial flood protection to towns and villages in the valley In some towns these dykes would cause considerable inconvenience and dislocation (*See Chapter* 4), but they appear to be the only flood project in the Red River Valley which has an economic justification at the present time

REASONS FOR SELECTING THESE PROJECTS

Most of the projects under analysis by the Commission showed favourable benefit-cost ratios when considered separately, distinct from any other project. This made it evident that a substantial degree of flood protection would be justified. But only two of these projects had sufficient capacity by themselves to give Greater Winnipeg an adequate degree of flood protection. These two projects were:

(a) An enlargement of the channel below and through Winnipeg from its present capacity of 80,000 c.f.s. to some 140,000 c.f.s.;

(b) A floodway around the city large enough so that the floodway, plus the present river channel, would carry a flood flow of 140,000 c.f.s.

The second of these two alternatives proved much more economical. Thus, to increase the capacity of the present channel by 60,000 c.f.s. would cost some $123 million whereas a floodway with a capacity of 60,000 c.f.s. would cost only $57 million.

Not only is the floodway more economical but it can also be expanded in size more easily, its construction would involve no major disturbance to industrial activity in the city such as will occur with channel improvement, and it will avoid the risk of increased erosion to bridge piers and the scouring of river banks which might occur with the increased river velocities resulting from channel improvement.

For these reasons the majority of this Commission had no hesitation in accepting and recommending the floodway as the main form of flood protection for Greater Winnipeg.

Taken by itself, the Ste. Agathe Detention Basin showed a very favourable benefit-cost ratio. Unfortunately, this project involves the periodic flooding of valuable farm lands and small towns in the Red River Valley with consequent insecurity to the farmers and home owners in the area to be flooded. Furthermore, since it could not by itself give adequate protection to Greater Winnipeg, it would have to be combined with some other project or projects. Finally, there is always the risk in operating the reservoir that some of its potential benefits may be lost through failure to predict the timing of the flood accurately. For these reasons, the Commission rejected the Ste. Agathe project early in its thinking.

During its studies the Commission gave consideration to the flood protection value of the Perimeter Highway presently under construction around Greater Winnipeg. It is understood that this highway is being constructed to a minimum elevation of one foot above the 1950 flood level and includes a Red River Bridge capable of passing the 1950 peak flow without appreciable backwater. As thus designed, the highway grade would tend to prevent overland flow on both sides of the River from reaching the City, in the same manner as McGillivray Boulevard did in 1950. However, the main river flow, at least up to that of 1950, would pass through the highway bridge unchecked and would be controlled downstream only to the extent of the capacity of the existing, or emergency, river dyking system. Flows greater than this would be somewhat restricted by the bridge, the effect of which would be to set up a head of water which would increase the discharge through the bridge into the downstream dyking system. Eventually these flows would overtop the highway grade. Control gates in the bridge structure and permanent or emergency dyking along the highway would limit, to the extent of their capacity, the flow into the downstream dyking system, but their effect would be to create artificial flooding in the upstream valley, including St. Norbert, in a manner similar to the Ste. Agathe Detention Basin. All the other disadvantages of the Ste. Agathe project would exist to the same or greater degree in this method of flood prevention and the Commission therefore gave no further consideration to the use of the perimeter highway as a major, permanent flood control work.

During the course of its study the Commission raised the question of combining into a single structure the perimeter highway bridge and the river diversion structure for the Greater Winnipeg Floodway. The Provincial Department of Public Works referred the matter to its consulting engineers who submitted a report stating that, while under certain limited circumstances, some saving in total cost could be obtained, this was too indefinite, and not sufficient to outweigh the advantages in planning and timing obtainable by the use of separate structures. The Commission found this report consistent with its recommendation that consideration be given to relocating the inlet of the floodway to a point south of St. Norbert.

Several plans for eliminating the reef at Lister's Rapids and for enlarging the channel below Winnipeg were investigated. While these plans had benefit-cost ratios on parity with those obtained on the floodway, they had the disadvantage that they did not provide a uniform amount of benefit throughout the city. Most of their benefits were in the northern and central portions of the city. Very little benefit would be provided to the south end of Metropolitan Winnipeg. Further, once a certain measure of channel improvement had been made, any additional improvement in the way of flood stage reduction became increasingly expensive. All in all, these plans were not as favourable as the floodway and were rejected.

When considered by itself, the Eastern Tributaries Diversion has a benefit-cost ratio of 2 28 However, practically all the benefit provided by this project results from the prevention of flood damages in the Greater Winnipeg area And for this area, the primary stages of flood protection can be provided much more economically by other methods When the Eastern Tributaries Diversion is considered as part of a combination of a 40,000 c f s floodway and a 40,000 c f s Portage Diversion, its incremental benefit-cost ratio is only 59 In contrast, an increase in the size of the floodway from 40,000 to 60,000 c f s gives an incremental benefit-cost ratio of 88 Because of its more favourable ratio the Commission recommended the 60,000 c f s floodway in preference to a combination of the Eastern Tributaries Diversion and a 40,000 c f s floodway

Taken by itself, a diversion of the Assiniboine River to Lake Manitoba at Portage la Prairie, has a very favourable benefit-cost ratio For example, a 25,000 c f s Portage Diversion on the High Bluff route has a benefit-cost ratio of 9 06 Moreover, even on an incremental basis the benefit-cost ratio remains favourable until a diversion capacity in excess of 40,000 c f s is reached In other words, up to that point, the additional benefits obtained from increasing the size of the diversion is larger than the extra cost of such an increase in its size In combination with a Greater Winnipeg Floodway, this project retains its high benefit-cost ratio As a part of a combination, it would be particularly valuable in very large floods, when a substantial flow could be expected on the Assiniboine River A 40,000 c f s diversion would almost completely eliminate flooding between Portage la Prairie and Winnipeg and would also provide a substantial degree of flood protection for Greater Winnipeg at a moderate cost

Analysis showed that flood protection works with a capacity of up to 40,000 c f s would be justified on the Assiniboine River This amount of protection could be provided in two different ways

(1) by constructing a 40,000 c f s Portage Diversion or,

(2) by constructing a 25,000 c f s diversion and the Russell Reservoir

The Russell Reservoir would give flood protection to the upper reaches of the Assiniboine River as well as to the area between Portage la Prairie and Headingley and to Greater Winnipeg While from a benefit-cost point of view, it is not quite as favourable as an increase in diversion capacity from 25,000 to 40,000 c f s, it would give flood protection to the upper Assiniboine Valley and it provides a substantial corollary benefit in the form of improved low water flows A higher minimum flow in dry periods will give cities and towns along the Assiniboine a more assured water supply and provide better sewage dilution in Greater Winnipeg Accordingly, The Commission decided in favour of the 25,000 c f s Portage Diversion and the Russell Reservoir in preference to a 40,000 c f s Portage Diversion

One problem which called for very careful thought was the decision as to the size of the Greater Winnipeg Floodway that should be recommended Ultimately this question was narrowed down to a choice between a 40,000 c f s or a 60,000 c f s floodway capacity, each in combination with the Russell Reservoir and a 25,000 c f s Portage Diversion From a strictly benefit-cost point of view, on the basis of today's population and property values, the extra 20,000 c f s capacity in the larger floodway was not justified, since the ratio of extra benefit to extra cost was only 88 as against a desirable ratio of 1 0 In other words, for the additional 20,000 c f s floodway capacity, there is a saving of only 88c in annual benefits for every dollar of annual cost

The Commission recommended a combination involving the 60,000 c f s floodway for the following reasons

(a) The situation in Winnipeg is complicated by being at the confluence of two rivers, both of which contribute to the flood flow The major flow, of course, is on the Red River and on the average, some 80 percent of the water passing through Greater Winnipeg is from the Red and 20 percent from the Assiniboine River By its geographical location it is much cheaper to take the water out of the Assiniboine than to take care of an equivalent amount of water on the Red For this reason, in working out a combination of projects, the Commission utilized as fully as possible the cheaper projects on the Assiniboine River However, the Commission was forced to recognize that

   (1) Projects on the Assiniboine cannot reduce the flood flows on the main stem of the Red River, and

   (2) While the cost-benefit figures used by the Commission in this report are of necessity based on the average distribution of flood flows, in any given flood the contribution from south of the junction point could be much higher than average, in fact, in 1950, 93 percent of the peak flood flow in Greater Winnipeg came from the Red River itself

(b) Furthermore, with the forecast increase in size and population of Greater Winnipeg, in a very few years the incremental benefit-cost ratio will exceed 1 0

To be safe, therefore, the Commission considered it necessary to have a larger capacity on the floodway than is justified by the immediate incremental benefit-cost ratio

The engineering information developed by the Red River Basin Investigation for the Pembina Reservoir was preliminary only Its report indicates that the Dam would have reduced the flood flow at Winnipeg in 1950 by 3 inches or up to 1,500 c f c , a reduction which cannot be considered substantial

This Commission, on the basis of such engineering study as was made by the Red River Basin Investigation, determined that in terms of flood control the Dam had a benefit-cost ratio, as a single project, of 2 14, but that in combination with other and larger projects, such as the floodway, its ratio was only 32, it therefore did not compare favourably with other major projects such as are now recommended, and on which engineering information was available and more complete

However the Commission is of the opinion that further detailed engineering and economic studies of the Pembina River Reservoir would reveal not only additional local flood control benefits but substantial benefits in the form of domestic and industrial water supply, sewage dilution, future irrigation and recreational advantages

The Commission therefore recommends that, since this study could not be completed within the time available to the Commission, it should be undertaken as a separate investigation by the appropriate provincial engineering authority with a view to including it, if found advantageous, in the overall water control program for the Red River Basin

The Red River Valley otherwise poses a very difficult problem for flood protection Because of the flat terrain there are no reservoir sites large enough to control any significant portion of the runoff Flood protection could probably be provided by enlarging and/or dyking the existing channel or constructing a second channel or floodway from the intake of the Greater Winnipeg Floodway to a point near Emerson Due to the proximity to the natural river channel of many farm and village dwellings, any of these forms of protection would disturb, leave unprotected, or aggravate the flooding of much of the river valley property and thus reduce the benefits of the works Investigations made by the Commission indicate that the costs of these projects would considerably exceed the resulting benefits

The only exception to this conclusion, that the Commission was able to find, was a system of ring dykes around the main towns and villages subject to flooding It is recognized that these dykes would have disadvantages and may not be acceptable to many of the residents but preliminary study indicates that they may have favourable benefit-cost ratios

Throughout its studies of the Red River Valley above Winnipeg, the Commission was at a disadvantage due to the lack of detailed engineering information Within its time limitations it did obtain some preliminary engineering data on which the above comments are based, but this was entirely inadequate on which to make final economic appraisals and conclusions The Commission therefore recommends that the Province undertake as early as possible, detailed engineering studies, not only of the above suggested control works along the main stem of the Red River, but also of all possible minor retention basins on all tributaries These, while not providing protection from major floods, may provide some appreciable relief to the upper valley residents during minor runoffs, and additional benefits from water conservation during low flow periods

CONSTRUCTION COSTS

On many of the projects considered in this report, the original cost estimates were prepared by the Red River Basin Investigation These costs were reviewed by the Commission and were revised in accordance with the 1957-58 conditions The Commission felt that for the purpose of the benefit-cost study, estimates of construction cost should be made on a very conservative basis, because even these produce favourable benefit-cost ratios There is some reason to believe that if the works were undertaken today, the actual cost might be less than the Commission used in its calculations This would result in even more favourable benefit-cost ratios

FLOOD PLAIN ZONING

Flood plain zoning is often advocated as an alternative to flood protection Under such a plan, certain flood-prone areas would be zoned to prevent any further construction These areas would then be gradually converted into parks or other uses which are not particularly subject to flood damage

Such a plan, in the opinion of this Commission, would not be suitable for Greater Winnipeg A great deal of property has already been constructed in areas subject to flooding and our studies show that it would be profitable to construct a floodway and other works in order to protect this property The flat character of the terrain in the Greater Winnipeg area and the Red River Valley would make it necessary to zone a very large area in order to eliminate serious flooding

FLOOD INSURANCE

This Commission made a careful study of the cost and feasibility of a flood insurance program

The Commission concluded that

1 A self sustaining flood insurance plan is not practical or feasible, either on a governmental basis or by the insurance industry

2 An assistance fund could be established

(a) This assistance fund should be supported by the Federal, Provincial and Municipal governments in the same proportion as now applies in disaster relief throughout Canada

(b) For the Upper Red River Valley such a fund would require

(i) a capital sum of $16,000,000 at 4% interest, or

(ii) annual payments of $750,000 per year

3 Under the Prairie Farm Assistance Act damage to growing grain crops from many causes, including flood, is reimbursed on a fixed and limited scale, provided the damage caused by flooding is sufficient or extensive enough to qualify the area as a "crop failure area" In its present form the P F A A does not provide a satisfactory form of flood indemnification The Federal Government could amend the P F A A to cover specific losses to individual farmers for flood damages to growing grain crops and for the deterioration to farm lands caused by these floods The required spread in premiums to make such a scheme operative and self-sustaining is now provided by the of 1% levy on the sale of all grain

The foregoing are the recommendations and findings of four members of the Commission, namely Mr H W Manning, chairman, Mr W C Riley, Mr W J Macdonald and Mr A S Beaubien whose signatures appear at the conclusion of this report

A dissenting opinion of the fifth member of the Commission, Mr J McDowell, which has not been presented to the other Commissioners at this date, follows the majority report

CHAPTER 2

SCOPE AND NATURE OF STUDY

This Commission was set up to determine whether the economic benefits of various flood control works designed to reduce or prevent flooding on the Red and Assiniboine River Basins would justify the cost of these projects It was asked, in particular, to direct its attention to the proposals set forth in the Report of the Red River Basin Investigation but it was not required to confine its attention to these projects only It was also requested to make a report on the practicability and estimated cost of a flood insurance scheme for those parts of the two river basins which could not be economically protected in other ways

The Red River Basin Investigation was set up by the Government of Canada following the disastrous flood of 1950 and was instructed "To Report on Measures for the Reduction of the Flood Hazard in the Greater Winnipeg Area" This authority prepared a comprehensive engineering report on the nature and causes of periodic flooding on the Red and Assiniboine Rivers and investigated and drew up preliminary engineering plans on a wide range of possible flood control schemes on the two rivers For the Assiniboine River, these proposals were based on those reported in a parallel study of somewhat wider scope which had been undertaken by the Prairie Farm Rehabilitation Administration of the Federal Department of Agriculture

While the Report of the Red River Basin Investigation contained a detailed study of flood frequencies, it did not include a study of economic benefits and hence made no recommendations for action

The report of the investigation received wide circulation in Canada and throughout the continent, particularly among hydraulic engineers and government and municipal bodies faced with flood problems It has been generally commended as a very thorough report This Commission therefore accepted the report of the Red River Basin Investigation as an authoritative and sound base on which to develop its studies

In carrying out its task the Commission held public hearings in Winnipeg, Portage la Prairie, Brandon and Morris The consensus of the submissions made and views expressed at these hearings was that protection for the various flood-prone areas should be recommended by the Commission to the maximum extent that was considered to be economically justified The Commission agreed with this view and proceeded to examine various flood control projects on this basis Its recommendations are, in the opinion of the Commission, the logical answer to the views of the public as expressed at these hearings

THE TASK OF THE COMMISSION

The final goal of the Commission was the preparation of benefit-cost ratios on the many different flood projects under consideration To reach this goal required extensive work of both an economic and an engineering nature

On the economic side, it was necessary to make a detailed study of the flood damages and flood losses that would be caused by floods of different sizes Such estimates were prepared for three principal areas, Greater Winnipeg, the Red River Valley and the Assiniboine River Valley (*see Chapters* 6, 7 *and* 8) By relating these flood damage estimates for floods of different sizes to the frequency with which these floods can be expected to occur, it was possible to arrive at estimates of the average annual flood loss that can be attributed to all possible floods

On the engineering side, it was necessary to calculate the reduction in flood flows and river stages that would be produced by the operation of all the various flood control projects By combining this engineering information on stage reductions with economic data on the flood damages that would occur at different flood levels, it was possible to convert the reductions in flood stage into a dollar benefit, a measure of the flood damages prevented (*see Chapter* 5) This measure of average annual benefit was then compared with the annual cost of the project in question to obtain its benefit-cost ratio

Annual cost includes interest on the capital cost of the project, an amount sufficient to amortize or pay off the capital cost of the project in a 50-year period, and annual maintenance and operating costs

Up to the present benefit-cost studies for such a large and varied group of projects had not previously been carried out in Canada However, the St Paul District Office of the United States Army Corps of Engineers had long experience in studies of this kind Its staff were familiar with the problems of the Red River Basin and had been consulted by the Province previously With the consent of the United States Government, the services of the Corps of Engineers were made available to the Commission and the Corps' policies, modified to meet local conditions, assisted the Commission materially in setting up a framework for its studies

FLOOD DAMAGES AND OTHER FLOOD LOSSES

Data on the flood damages and flood losses expected to occur in Greater Winnipeg during a major flood are given in Table 2 1 It is clear that these may be very large indeed If a flood such as that which occurred in 1861 were to take place again today, our estimates show that it would cause damages and losses in the Greater Winnipeg area of some $267 million This total includes not only the heavy damages that would be caused to business, industrial, governmental and residential property but also the severe loss of income that would result from a virtual cessation of activity in a highly productive area and extra costs incurred such as the cost of evacuation

In 1861 there was a peak flow of 125,000 cubic feet per second at Redwood Bridge and the water level in the city was about two feet higher than the peak reached in 1950 It is clearly a flood level that could be reached again for, according to the forecasts made in the spring of 1956, a peak flow of 120,000 c f s could have been reached if adverse weather conditions had prevailed during the runoff period By the time such a flood level had been reached, almost the entire city would have had to be evacuated

For still larger but less frequent floods such as those which occurred in 1852 and 1826, the flood damages and flood losses that would be caused in present-day Winnipeg would be even more severe Indeed, once the 1950 level is exceeded, each additional rise of one foot in the flood level inundates a large additional area and causes a rapid increase in the total amount of damages Our estimates show that a flood of the 1852 magnitude would cause damages of about $593 million in the Greater Winnipeg area and that a flood of the 1826 magnitude would cause damages of about $852 million The flood level reached in 1852 was about 4 feet higher than that reached in 1950 and the level reached in 1826 was 2 feet higher still By the

Table 2 1

ESTIMATED FLOOD LOSSES, (1957) — GREATER WINNIPEG
SUMMARY BY TYPE OF LOSS FOR MAJOR FLOODS

Size of Flood for which Estimate is Made*	Probable Flood Frequency Once in Every	Buildings and Contents	Public Utilities, Railways Roads Bridges and Sewers	Loss of Income	Extra Costs and Flood Fighting	Total All Losses
			(Thousands of dollars)			
1948 (69 000 c f s)	12 years	$ 236	$ 54	$ 47	$ 313	$ 650
1950 (103,600 c f s)†	36 years	92 161	3,723	13 941	4,375	114 200
1861 (125 000 c f s)	64 years	166 483	8,108	81,000	10,809	266,700
1852 (165 000 c f s)	150 years	383 570	14 846	172 000	22,784	593,200
1826 (225 000 c f s)	460 years	592,598	17 353	216 000	26,549	852 500

*Flood discharges are at Redwood Bridge

†1950 flood losses are based on the assumption that flooding is general behind the main dyking system

Table 2 2

ESTIMATED FLOOD LOSSES, (1957) — RED AND ASSINIBOINE RIVER VALLEYS
SUMMARY BY TYPE OF LOSS FOR MAJOR FLOODS

Size of Flood for which Estimate is Made*	Probable Flood Frequency Once in Every	Buildings and Contents	Public Utilities Railways, Roads, Bridges and Sewers	Loss of Income	Extra Costs and Flood Fighting	Total All Losses
			(Thousands of dollars)			
		RED RIVER VALLEY				
1948 (52 000 c f s)	11 years	$ 1 221	$ 291	$ 557	$ 113	$ 2 182
1950 (94 000 c f s)	46 years	5 622	2 050	3 041	565	11 278
1852 (137,000 c f s)	150 years	9,514	4 611	5 894	948	20,967
1826 (182 000 c f s)	460 years	11,851	5 429	7 005	1,218	25,503
		ASSINIBOINE RIVER VALLEY†				
(19,000 c f s)	10 years	$ 167	$ 42	$ 446	$ 31	$ 686
(25 000 c f s)	25 years	958	373	2 247	403	3,981
(36,000 c f s)	100 years	1,987	1,088	4,519	755	8 349
(66,000 c f s)	1 000 years	4,736	5 468	11,280	1,880	23 364

*Flood discharges are at Emerson for the Red River Valley and at Portage la Prairie for the Assiniboine River Valley

†Flood losses at Brandon assume flooding is general behind the main dyking system

time an 1852 flood level had been reached virtually the entire city would have been evacuated. Some 70,000 dwellings would be in the flooded area and in some 50,000 of these the flood waters would be above the main floor. In addition, some 75 to 80 percent of all non-residential property in the area would be flooded.

The flood damages and other losses that would be caused in the Red and Assiniboine River valleys outside of Greater Winnipeg by a number of major floods, are shown in Table 2.2. In the Red River Valley above Winnipeg, the total losses caused by a flood of the 1950 magnitude have been estimated at $11.3 million. A major item in this total, some $2 million, is the loss of farm income which can be expected to occur on the average as a result of the delay in the date of seeding and the disruption caused to livestock on farms in the flooded area. Important too, are the damages that would be caused to farm and non-farm buildings, to personal property, to grain, livestock and machinery, to business inventories and fixtures and to roads, bridges, railroads and other types of property.

For still larger floods, these damages would increase to about $21 million for a flood of the 1852 magnitude and to $25.5 million for a flood of the 1826 magnitude. It is estimated that in a flood such as occurred in 1826, some 960 square miles of valley land would be flooded, almost twice the area that was flooded in 1950.

In the Assiniboine River Valley, the heaviest damages occur in the area between Portage la Prairie and Headingley. Here it is estimated that a flood of 36,000 c.f.s., a flood that can be expected to occur on the average about once in 100 years, would cause damages of $7.3 million. Though there have been no recent floods on the Assiniboine of this size, the flood that occurred in 1882 is believed to have been larger than this. Damages in the valley area between Millwood and Portage la Prairie are significant but much smaller in magnitude than those in the Portage plains.

As the city grows, the benefits that will be derived from any flood protection scheme that is constructed today will gradually increase in size as the city's population and income level increases. In providing flood protection for the Greater Winnipeg area, some attention must also be paid to the growth that is in prospect for this area over the next 25 or 50 years. Our estimates indicate that, when account is taken of growth, the benefit-cost ratios, which are based on present property values and incomes only, will be increased by a factor of 50 percent. Thus, when allowance is made for the city's prospective growth, the benefit-cost ratio for the combination of projects recommended above, 2.73, will be increased to 4.09. An allowance for growth has been made only in respect to the Greater Winnipeg area. While growth will undoubtedly be of significance in other areas, no firm basis was available for such estimates.

FLOOD PROTECTION MEASURES CONSIDERED

There are four basic types of projects available to prevent floods: floodways or diversions, reservoirs or detention basins, improvements to the river channels, and dykes, levees or river walls. The Red River Basin Investigation studied and prepared preliminary engineering plans for a number of projects of each of these types. This Commission examined in some detail all of the projects suggested by the Red River Basin Investigation. In addition, a number of projects which the latter body considered outside its terms of reference or examined only briefly, were given preliminary consideration. The following is an outline of the principal projects examined in this report.

A. Floodways and Diversions

1. The Greater Winnipeg Floodway

A diversion of the Red River around and east of Greater Winnipeg. Preliminary plans were made for ten different designs ranging in size from 20,000 c.f.s. to 145,000 c.f.s.

2. The Portage Diversion

A diversion of the Assiniboine River into Lake Manitoba at Portage la Prairie. Proposals were made for two alternative routes and for three sizes of diversion, that is, diversions with capacities of 10,000 c.f.s., 25,000 c.f.s. and 40,000 c.f.s.

3. The Eastern Tributaries Diversion

A diversion in the eastern half of the Red River Basin which would divert the Roseau, Rat and Seine Rivers through Cook's Creek into the Red River near Selkirk.

B. Reservoirs and Detention Basins

1. The Russell Reservoir — a reservoir with a capacity of 450,000 acre feet on the Assiniboine River near Russell, Manitoba.
2. The Ste. Agathe Detention Basin
3. The Pembina River Reservoir

A dam on the Pembina River some miles south west of Morden.

4. Small dams

Small local dams, much smaller than the Russell or Pembina River Reservoir.

C. Channel Improvement

1. Channel widening and deepening on the Red River downstream from Winnipeg, especially in the area known as Lister's Rapids. The Red River Basin Investigation considered 22 different proposals for

channel improvement in this area and recommended three for further study

2 Channel Improvement through Greater Winnipeg

A proposal to widen and deepen the channel through the city was dismissed as impractical by the Red River Basin Investigation This Commission gave this project further study and prepared preliminary plans for improved channels of three different magnitudes

3 Channel Improvement from St Norbert to Emerson

Preliminary plans were prepared for two different sizes of channel enlargement in this area

D Dykes

1 Dyking in the Greater Winnipeg Area

A proposal to increase the height of the present main dyking system by an additional five feet

2 Dyking in the Red River Valley

Two proposals were examined One of these was a proposed system of dykes on either side of the Red River from Winnipeg south to a point near Letellier The other was a proposal to build ring dykes around the principal villages and towns in the valley

3 Dyking on the Assiniboine

Dyking in three areas was considered (a) a system of dykes on either side of the Assiniboine from Headingley to Portage la Prairie, (b) a dyke in the Brandon flats, (c) dykes along the Assiniboine between Millwood and Brandon

These projects are described in some detail in Chapter 4

GENERAL CONSIDERATIONS

In seeking appropriate recommendations, the Commission was guided by the following general or basic principles

(a) The benefit-cost ratio, i e, a comparison of the amount of damage prevented with the cost of the engineering project,

(b) Safety of the areas which require protection,

(c) Evenness of protection and number of people, of homes, of structures, of business operations, and of public works and buildings protected,

(d) Consistent with economic justification therefore, covering the widest area possible,

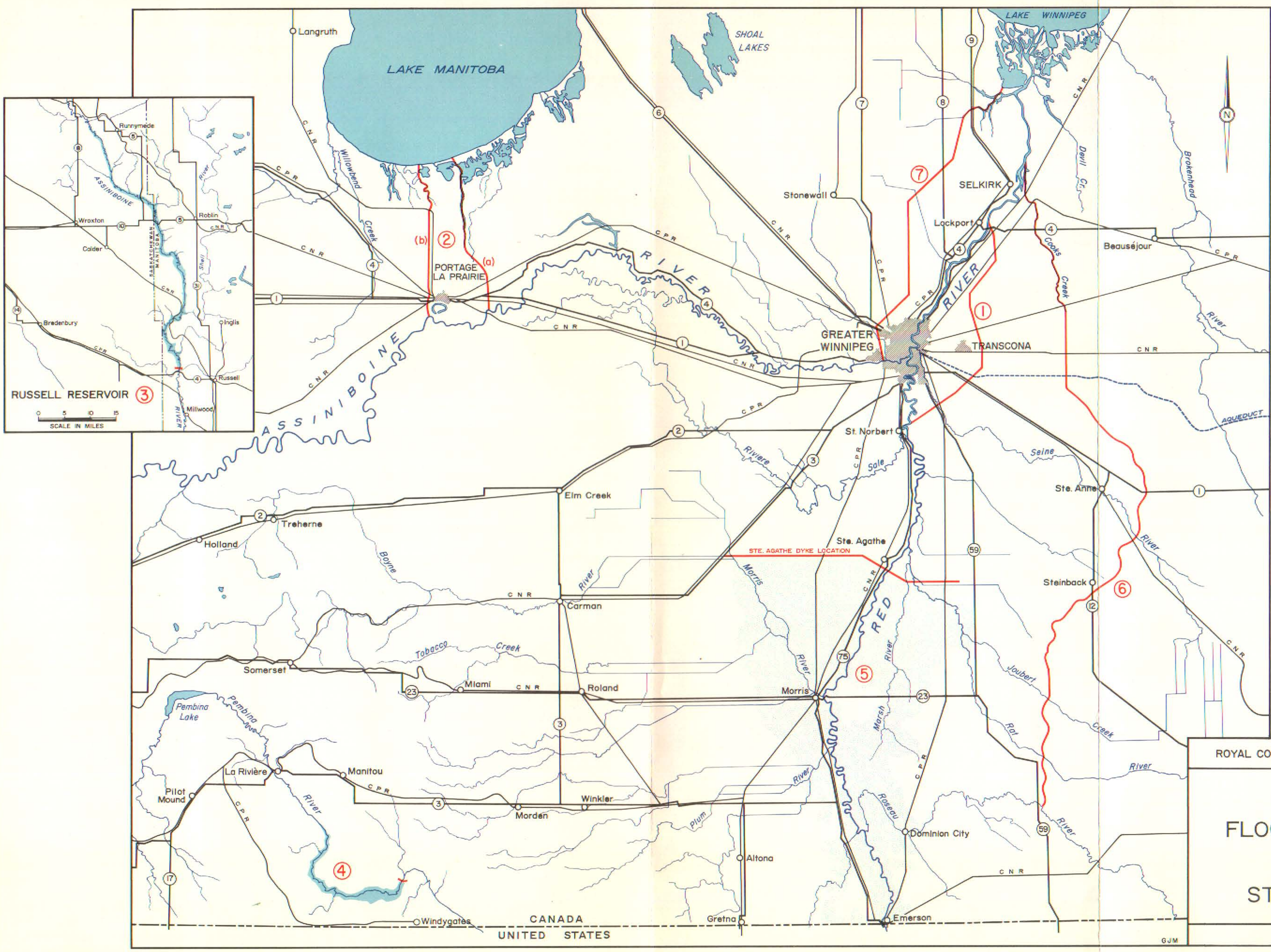
(e) Corollary benefits, such as increased river flow, irrigation, water supply, scenic and recreational values

(f) Unfavourable corollary factors, such as increased erosion, inconvenience, dislocation,

(g) Expectation of expansion

While under its terms of reference the Commission was governed generally by dollar considerations, that is, costs compared with benefits, it was aware that no dollar value could ever be attributed to the intangible benefits which will arise from removal of the threat of flood from the minds of those who live constantly with that threat and are faced every year with the possible recurrence of a major flood Nor can a dollar value be placed on the benefit that may occur in the form of increased confidence in the minds of industrialists who may be considering the location of new business premises in any flood-prone area

The plan of this study is as follows Chapter 3 gives a general description of the nature and frequency of floods in the Red and Assiniboine River Valleys In Chapter 4, a general description is presented of the many flood control projects that were analyzed by the Commission After this, in Chapter 5, an explanation of the basic theory underlying a benefit-cost analysis is presented Chapters 6, 7 and 8 present basic damage estimates for Greater Winnipeg, the Red and the Assiniboine River Valleys and explains in general terms how these estimates were made Chapter 9 provides an explanation of the way prospective growth can be incorporated into a benefit-cost analysis Then, in Chapter 10, each of the projects under consideration is analyzed from a benefit-cost point of view In Chapter 11, a similar analysis is applied to various combinations of projects and the reasoning underlying the final conclusions is explained A chapter on Flood Insurance completes the body of the report



LEGEND

1. Greater Winnipeg Floodway *
2. Portage Diversion
   - (a) High Bluff Route
   - (b) Fort La Reine Route
3. Russell Reservoir
4. Pembina Reservoir
5. Ste. Agathe Detention Basin
6. Eastern Tributaries Diversion
7. Omand's Creek Diversion

Area inundated by 1950 flood when controlled by the Ste. Agathe Detention Basin.

Note: Adapted from Plate I, Appendix G; and Plates 7, 11 and 18, Appendix F; Red River Basin Investigation Report.

* Revised location.

0 5 10 15
SCALE IN MILES

ROYAL COMMISSION ON FLOOD COST-BENEFIT

LOCATION OF FLOOD DIVERSIONS AND STORAGE DAMS

DECEMBER 1958

CHAPTER 3

THE NATURE AND FREQUENCY OF FLOODING IN THE RED AND ASSINIBOINE RIVER BASINS

The Red River originates in the North-Central United States some 350 miles almost due south of its outlet in Lake Winnipeg In the City of Winnipeg it is joined by its major tributary, the Assiniboine River, which drains an area of 63,000 square miles to the west Despite the fact that the area drained by the Red River to the south of Winnipeg is smaller than this, being just 48,000 square miles, the maximum flows on the Red are much higher than those on the Assiniboine During the period of record from 1913 to 1957, some 80 per cent of the peak flows at Redwood Bridge in Winnipeg came down the main stem of the Red Further, a very large portion of these peak flows, some 80 per cent or more, originated in the United States Of this total drainage area on the Red alone, some 39,360 square miles are in the United States and 8,640 square miles are in Canada (See Plate 1)

The drainage area of the Red River has two basic types of topography The central portion of the area extending east and west of the river is the bed of the former glacial Lake Agassiz This region is a broad, flat plain with very gentle slopes As a result, once the river leaves its banks, very extensive areas are subject to flooding In 1950, for example, an area of 530 square miles was flooded between Winnipeg and the international boundary at Emerson Surrounding the plain is a rougher and higher upland region

Because of the gentle slopes that characterize this former lake bed, the Red River and the lower end of its tributaries have never developed sufficient velocity to cut channels adequate to carry the higher flows From Wahpeton, North Dakota, to Lake Winnipeg, the river makes a gradual continuous descent averaging about one-half foot per mile Between Emerson and Winnipeg the slope is especially flat, averaging only about one-quarter of a foot per mile

The soil covering the Red River plains consists of a highly plastic clay which is able to hold large quantities of water and possesses high swelling and shrinking characteristics with changes in moisture content These qualities make it a very poor foundation material and make the river banks in many areas unstable and subject to slides, a characteristic which Sir Sandford Fleming noted in his report of 1879 Underlying these clays, at depths of from 4 to 60 feet, is the glacial drift or hardpan, a heterogeneous mass of rock flour, clay, sand, gravel and boulders which, in contrast to the overburden, makes excellent foundation material

The characteristics of the Assiniboine River drainage basin contrast sharply with those of the Red In the area west of Brandon, the Assiniboine and the Qu'Appelle Rivers flow through broad, deep valleys that are in many places depressed from one to three hundred feet below the general prairie level In glacial times, the South Saskatchewan River drained into the Assiniboine via the Qu'Appelle and eventually flowed into Lake Agassiz At one stage, the shores of Lake Agassiz reached to Brandon but the large volume of sand and gravel carried into the lake by these rivers built up a large delta which gradually moved eastward towards the present location of Portage la Prairie

At the end of glacial times the South Saskatchewan took a northward course and the flow through the Assiniboine and its tributaries was greatly reduced At the present time, the Assiniboine River above Brandon flows through a small channel in the relatively flat valley bottom In this area, the valley bottom falls very slowly, about one-half to one foot per mile, and as a result, the river has little erosive power Because the river banks are usually higher than the adjacent valley land, as soon as these banks are overtopped, almost the entire valley flats are flooded From Brandon to Portage la Prairie the river gradient is steeper and the river is still actively eroding its channel

Between Portage la Prairie and Winnipeg the river now flows along what is virtually a narrow ridge Over the course of time the river has gradually built up its channel until the water level in the river is often higher than the land a few miles from the river As a result, when the river overflows its banks, the water either flows south and east to enter the Red via the Sale River or flows to the north, going into overland storage or returning to the Assiniboine via Sayer's Creek In years of very high water, there is also some flow north from Portage la Prairie into Lake Manitoba

There is evidence that at one time the Assiniboine River flowed north from Portage la Prairie into Lake Manitoba Aerial photographs also indicate at least six old river channels south of the present channel through which the river used to flow to reach the Red

The natural channel capacity of the river in the region from Portage la Prairie to Winnipeg had been increased by dykes along the edges of the river bank These dykes were first begun by the Federal Department of Public Works in 1922 and have more recently been extended and improved by the Prairie Farm Rehabilitation Branch of the Federal Department of Agriculture

Because of the many sharp turns in the river and the still limited channel capacity, flood troubles in this area are severe and are accentuated by frequent ice jams during the spring runoff

Anyone who views the Red River in Winnipeg at its normal summer level may have difficulty believing that it could cause disastrous floods, for at such times the Red is a placid stream flowing between well-defined banks from 20 to 30 feet high Yet there are authentic records of a number of very extreme flows The 1950 flood, the largest within the memory of anyone now alive, reached a flow of 103,600 c f s and an elevation some 30 feet above the normal summer water level

Though this has been viewed by many as an extreme flood, and it was the largest flood since Winnipeg became a city of substantial size, there are clear records of three floods since the area was first settled, all of which were larger than the 1950 flood Indeed, two of these, the floods of 1826 and 1852, were very much larger as the following data clearly indicate (See also Table 3 1)

	Estimated Peak Flow at Redwood Bridge	Level of Water above 1950 Flood Peak at Main Street Bridge
1826	225,000 c f s	6 feet
1852	165,000 c f s	4 feet
1861	125,000 c f s	2 feet

Thus, in 1826, the voluume of water flowing through Winnipeg was more than twice as large as the amount recorded in 1950 and the water reached levels in the city that were 6 feet higher than in 1950

There are also historic references to a major flood on the Red in 1776 In addition, there may have been other major floods in this period for which there is no record The Red River Basin Investigation estimated that a flood as large as 270,000 c f s could occur

That our records of the flood elevations reached in 1826, 1852 and 1861 are as good as they are is in large measure due to the careful records made by Sir Sandford Fleming in 1879 In examining the river in the area from Winnipeg to Selkirk with a view to choosing a suitable location for a crossing by the C P R , Sir Sandford questioned local inhabitants who had witnessed the earlier floods and on the basis of their evidence and the high water marks they pointed out, drew up a set of elevations for these three historic floods at various points between the mouth of the Assiniboine and Selkirk After a thorough examination of all the historical records of this period, the Red River Basin Investigation confirmed the general accuracy of these findings On the basis of these elevations and after examining the cross-sectional area of the river below Winnipeg, the Red River Basin Investigation then estimated the volume of flow for each of these historic floods

As far as can be determined, there is no evidence of any increase in the size of the channel in this area of sufficient importance to affect the accuracy of the historic flow estimates prepared by the Red River Basin Investigation This conclusion is supported by engineering data on the cross-sectional area of the Red River, both above and below Greater Winnipeg, and in the city itself These data show that no significant change in the carrying capacity of the channel occurred between 1912 and 1951 Further, at a point opposite Old St Andrew's Church, a cross-section taken in 1886 shows very little change in the river's carrying capacity since that date The above data also disprove the charge that the channel of the Red River has been silting up and cannot now carry as much water as, at one time, it was able to

This latter conclusion is supported by a diver's report on the condition of the river bed in Greater Winnipeg A diver engaged by the Commission examined the bed of the Red River at four different points He found the river channel for the most part clear of silt or obstruction According to his report, in twelve years of diving at various points between Morris and the Manitoba Yacht Club, he has always found the river bottom "very clear of debris or any sunken obstacles "

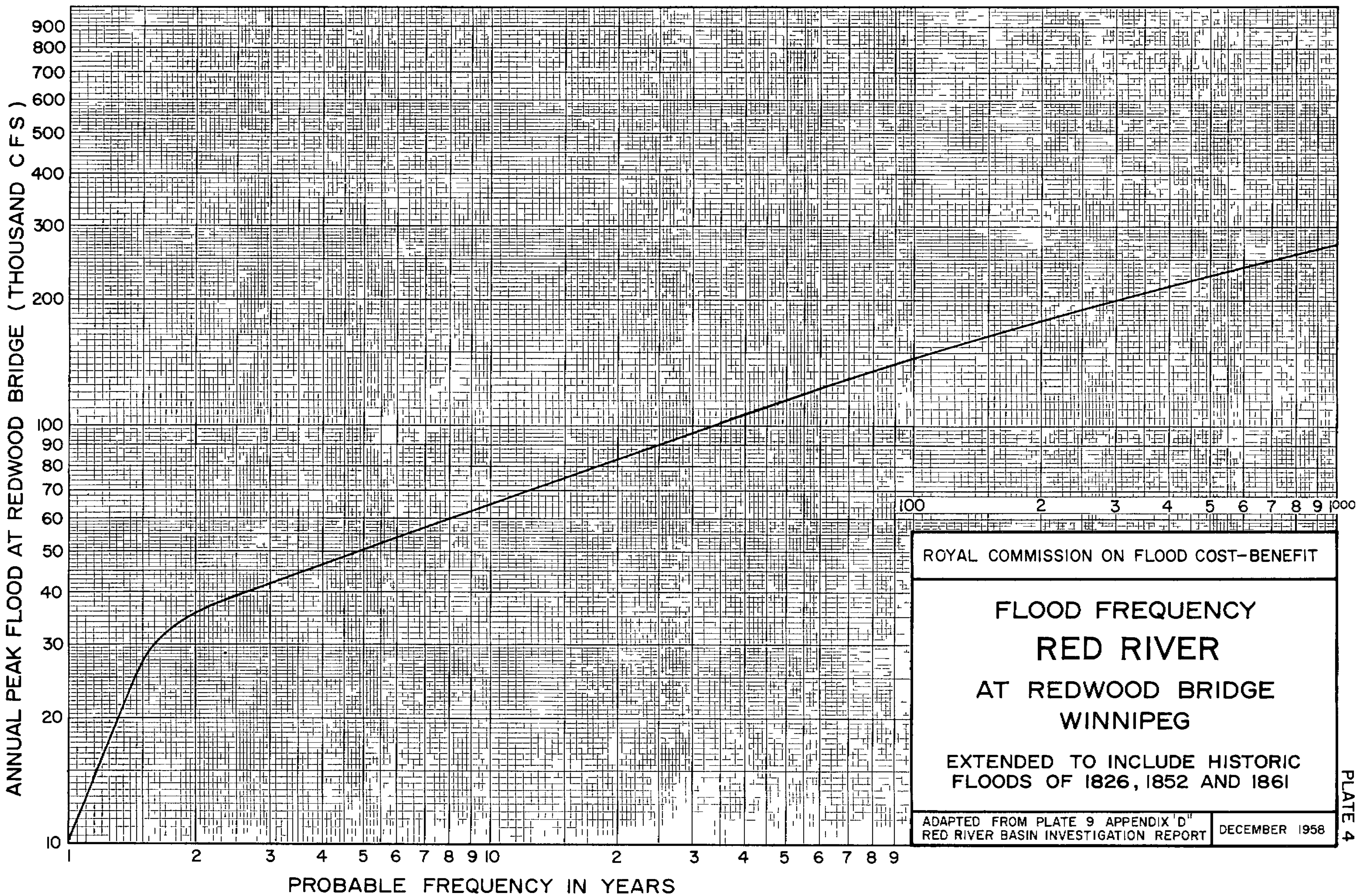
Floods on the Red River have invariably occurred during the spring runoff period Although there have been heavy rain storms over large parts of the drainage area on a few occasions, these have never produced enough runoff to cause flood levels on the Red Data on each of the three major early floods, taken together with information obtained from the 1950 flood experience, suggest a similar causal pattern The climatic conditions which lead to the likelihood of an extreme flood are as follows

(1) A wet summer or fall in the preceding year which thoroughly saturates the ground before freeze-up
(2) Cold weather with little snow during the early winter, allowing a deep penetration of frost
(3) A cold winter with heavy snowfall over the entire drainage basin,
(4) A late spring followed by a sudden rise in temperature, producing a rapid runoff,
(5) Heavy rains during the runoff period

Many or all of these conditions were present in each of the flood years 1826, 1852, 1861 and 1950

After a careful study of all the available flood records, the Red River Basin Investigation estimated that there was reason to expect the 1950 flood level to be equalled or exceeded on the average of once every 36 years This checks roughly with the known fact that there have

PLATE 4


ANNUAL PEAK FLOOD AT REDWOOD BRIDGE (THOUSAND C F S)
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
2
3
4
5
6
7
8
9
100
2
3
4
5
6
7
8
9
1000
PROBABLE FREQUENCY IN YEARS
ROYAL COMMISSION ON FLOOD COST-BENEFIT
FLOOD FREQUENCY
RED RIVER
AT REDWOOD BRIDGE
WINNIPEG
EXTENDED TO INCLUDE HISTORIC
FLOODS OF 1826, 1852 AND 1861
ADAPTED FROM PLATE 9 APPENDIX "D"
RED RIVER BASIN INVESTIGATION REPORT
DECEMBER 1958

been four floods as large as or larger than the 1950 flood since 1826, an average of one in every 33 years It is, of course, quite consistent with such a flood frequency that there may be periods much longer than 36 years during which no flood of this size occurs Thus, there was no flood equal to, or in excess of, the 1950 level between 1861 and 1950, a period of 89 years On the other hand, at times, more than one flood of this magnitude may occur within a 36-year period In fact, there were three known floods larger than the 1950 flood in the 35year period from 1826 to 1861

This same study estimated that a flood which would exceed the existing dyked channel capacity in Winnipeg could be expected on the average of once every 18 years For this estimate the present channel capacity was taken at 80,000 c f s , this assumes a freeboard allowance on the dyke of one foot, that is, a flood level one foot below the top of the existing dyking system Data on the peak discharges, stages, and frequencies of the ten major floods of record in Winnipeg are given in Table 3 1

According to these data, a flood of the 1826 magnitude may be expected to be equalled or exceeded on the average of once every 460 years For the 1852 and 1861 floods the corresponding frequencies are 150 and 64 years The frequency discharge curve from which these data were taken appears in Plate 4

Continuous records of flood flows on the Assiniboine River are available only since 1912 Information about earlier historic floods is sketchy and incomplete The largest flood for which there is any authentic information occurred in 1882 Engineers of the Prairie Farm Rehabilitation Administration estimate that the peak discharge in that year was about 40,000 second-feet at Brandon and 32,000 second-feet at Headingley At Brandon the river reached a level 5 5 feet higher than any flood stage reached since that time At Portage la Prairie the river is said to have overflowed to the north flowing into Lake Manitoba through an old river channel The water in this channel was reported to have reached a depth of 7 feet and to have enabled a steamboat to travel overland from Portage la Prairie to Lake Manitoba

There is also one historical reference to an overflow from the Assiniboine to Lake Manitoba at Portage la Prairie in 1861 Except for this isolated reference, there is no information as to the levels of flow on the Assiniboine in 1861, 1852, and 1826, years of major floods on the Red However, it seems probable that the flow on the Assiniboine was substantial in each of these years In more recent years major floods on the Assiniboine occurred in 1922, 1923, 1927, 1955 and 1956 In each of these years the flow at Portage la Prairie was in the range of 20,000 to 23,000 cubic feet per second In some sections of the valley there was also significant flooding in 1948 and 1954

After a frequency study of the historical records, the P F R A estimated that floods on the Assiniboine River could be expected to occur with the frequency shown in Table 3 2 These data indicate that at Portage la Prairie a flow of 25,000 c f s can be expected to be reached or exceeded on the average of once every 25 years, and a flow of 36,000 c f s or larger can be expected once in 100 years Flows as large as 70,000 c f s are possible, though such a flood

Table 3 1

MAXIMUM DISCHARGES, STAGES AND FREQUENCIES FOR THE TEN GREATEST FLOODS OF RECORD ON THE RED RIVER AT WINNIPEG

Date of Maximum Discharge Year	Month	Day	Estimated Maximum Discharge at Redwood Bridge second-feet	Maximum Elevation at Junction of Red and Assiniboine Rivers G S of C Datum	Elevation in Feet above City Datum James Ave	Probable Frequency Years
1826	May	21	225 000	764 5	37 3	460
1852	May	21	165 000	762 5	35 2	150
1861	May	8	125 000	760 5	32 3	64
1950	May	19	103 600	758 5	30 3	36
1882	May	3	79 700	753 6	25 5	18
1916	April	22	71,200	751 6	23 5	13
1948	April	30	69,000	751 2	23 1	12
1956	April	27	68,850	750 3	22 3	12
1904	April	24	66,000	752 2*	24 2*	11
1897	April	27	64,500	750 0	22 0	10

*Probably affected by ice

SOURCE *Report of the Red River Basin Investigation* Main Report, p 25 and Appendix D', Plate 3 would be a very rare occurrence However, in 1956, it was predicted that if adverse weather occurred during the spring breakup, a peak of 60,000 c f s would be reached at Portage la Prairie Frequency-discharge curves for Brandon and Portage la Prairie appear in Chapter 8 (See Plates 18 and 19)

In the area from Portage la Prairie to Winnipeg there is reason to believe that the Assiniboine River has been gradually building up its bed through deposition of silt and sand carried down from further upstream In flood periods this material is deposited on the river banks, thus raising the level of the land on either side of the river At other times deposits in the river channel appear to have gradually raised the river bed Thus, over a period of hundreds of years, the river bed has gradually risen so that now the river flows along the top of a natural ridge which is higher than the land a few miles from the river

On both the Red and Assiniboine Rivers it is clear that there have been historic floods of a much larger size than those which have occurred during the past few decades According to estimates made by the P F R A, the flood peak on the Assiniboine River in 1882 was more than twice as large as the peak that occurred in 1956 And in the record flood that occurred on the Red River in 1826, the peak flow at Winnipeg was more than twice that of 1950 Moreover, there is no reason to expect that such record floods could not occur again Indeed, the official forecast made in the spring of 1956 anticipated, under adverse weather conditions, a peak of 60,000 c f s at Portage la Prairie and a peak of 120,000 c f s at Redwood Bridge This would have produced a flood peak in Winnipeg about 2 feet higher than occurred in 1950 It is clear that any adequate flood protection system must be capable of handling much larger floods than those Manitoba has experienced in recent years

Table 3 2

PEAK DISCHARGES FOR SELECTED FREQUENCIES ASSINIBOINE RIVER, BY REACHES

Frequency		Peak Discharges in c f s		
In Years	In Percent	Millwood to Virden	Brandon	Portage la Prairie
10	10	10 000	16 000	19,000
25	4	15 000	23,500	25 000
100	1	32 000	36,000	36 000

SOURCE Plates 18 and 19

CHAPTER 4

FLOOD PROTECTION MEASURES CONSIDERED

This Commission was asked to evaluate the various measures that could be taken to prevent or lessen flooding on the Red and Assiniboine Rivers In pursuing this task it has had as a guide the excellent engineering reports provided by the Red River Basin Investigation and by the Prairie Farm Rehabilitation Branch of the Federal Department of Agriculture

After the disastrous flood of the Red River in 1950 the Canadian Government appointed the Red River Basin Investigation and asked it to make a survey of the problem of flood control for the Greater Winnipeg area The report of this body, entitled "Report on Investigation into Measures for the Reduction of the Flood Hazard in the Greater Winnipeg Area" and consisting of a main report and eight separate appendices, gives a detailed picture of the flood problem and outlines a number of measures that could be taken to reduce or eliminate flooding

Before the appointment of this body the P F R A had begun a study on Conservation and Flood Control on the Assiniboine River This detailed engineering study was coordinated with that undertaken by the Red River Basin Investigation and its final report was included as Appendix H of the latter's report The main report of the former, which is entitled "Report on Conservation and Flood Control on the Assiniboine River," is supplemented by five appendices

By its terms of reference the Red River Basin Investigation was limited to a study of measures which might reduce the flood hazard in the Greater Winnipeg area In view of the somewhat wider terms of reference of this Commission it has been necessary to supplement and extend the investigations of that report The "Report on Conservation and Flood Control on the Assiniboine River," on the other hand, was wider in scope and included an investigation into measures that could be taken to lessen flooding in various reaches of the Assiniboine as well as in Winnipeg

Both reports were limited to an engineering appraisal of the flood control problem and were not concerned with benefit analysis Since it has had to rely extensively on the report of the Red River Basin Investigation this Commission has been reassured to learn that this report is very highly regarded in engineering circles It has been reviewed by a number of eminent hydraulic engineers and they are in general agreement that it is a very competent and detailed engineering report

The discussion in this chapter is confined to the general character and nature of the various flood protection measures considered The results of our benefit-cost analysis of these projects is given in Chapter 10

There are four basic methods of preventing or reducing floods

1 Diversion channels or floodways can be constructed to divert part of the flow out of the main channel,
2 Storage reservoirs on the river can be used to limit or reduce the flood flows,
3 The capacity of the river channel can be increased to allow it to carry a larger volume of water,
4 The water can be retained within the river channel by building dykes, levees or retaining walls in areas where the channel capacity will not carry the volume of water that must be accommodated in flood years

Each of these methods may be used separately or in combination with one or more of the other methods The reports cited above studied a number of measures in each of these fields and their findings are summarized here

Diversions

Diverting part of the river's flow through a diversion channel or a floodway provides one of the most effective means of flood control available The diversion channel removes completely some or all of the excess water from the flood threatened area It can be effective against floods of any size or duration Diversion channels may be constructed to transfer part of the flood flow into another river or lake, or, they may simply by-pass the area to be protected and re-enter the river sufficiently far downstream to avoid backwater effects Diversions are particularly suited for controlling floods on rivers such as the Red and Assiniboine Rivers where the flood flow remains at a high level over a period of several weeks

The Red River Basin Investigation considered four possible diversion schemes, namely (a) a by-pass channel around Winnipeg called the Greater Winnipeg Floodway, (b) a diversion channel from the Assiniboine River to Lake Manitoba in the vicinity of Portage la Prairie referred to as the Portage Diversion, (c) a channel from the Assiniboine River in St James via Omand's Creek to Lake Winnipeg called the Omand's Creek Diversion, and (d) a plan to divert a number of the eastern tributaries of the Red River in Manitoba northward into Cook's Creek which enters the Red River just below Selkirk This last plan is known as the Eastern Tributaries Diversion The location of these four diversions is shown on Plate 3

(a) The Greater Winnipeg Floodway

The Greater Winnipeg Floodway plan involves a by-pass channel that would divert part of the flood flows on the Red River around the east side of the Greater Winnipeg area The proposed floodway route would leave the Red River near St Norbert, pass to the east of Transcona, proceed through a natural depression in Bird's Hill and return to the river about one-half mile below St Andrew's Dam The overall length would be about 26 miles Plans were made for channels of a number of different sizes with design capacities ranging from 20,000 c f s up to 145,000 c f s

The channel would vary in depth from a minimum of about 24 feet near the south end to a maximum of 67 feet through its highest point at Bird's Hill, with an average depth over most of its course of about 35 feet The top width of the channel would vary from 350 to 1,600 feet depending on the size of the floodway The plans call for acquisition of sufficient land to permit the excavated material to be deposited in a spoil bank on either side of the floodway

The floodway plan calls for a control structure on the Red River just below the floodway inlet and an adjoining dyke running in a westerly direction The deposition of excavated material would provide a similar dyke east of the river on the side of the floodway nearer the city This dyke and control structure would make it possible to raise the floodwater elevations upstream from the floodway, and thus increase the amount of flow through the floodway It would also prevent increased erosion in the river bed which otherwise would be created by the drawdown produced by the floodway channel In addition, the control structure would make it possible to provide a proper distribution of flows between the natural channel and the floodway in accordance with the volume of flow on the Assiniboine

A dyke is necessary to prevent the floodwaters by-passing the floodway inlet on the west side of the river The proposed dyke would be 20 feet wide at the top, have 4 to 1 slopes and vary in height from 17 feet near the river to near zero at its western end This height allows for from 3 0 to 7 5 feet of freeboard to protect against wave action The downstream slope of the dyke would be seeded to grass and the upstream slope would be protected with a layer of gravel overlaid with at least one foot of rock rip-rap On the east side of the river the dyke would follow the inside rim of the floodway channel, would have a minimum top width of 100 feet and would be provided with a minimum of three feet of freeboard

At the floodway's outlet a drop structure is provided to discharge the flow in the floodway to the lower river elevation without causing erosion The Seine River would be diverted permanently into the Floodway

According to the estimates prepared by the Red River Basin Investigation in 1952 the cost of a floodway would range from $23 4 million for a 20,000 c f s size up to $75 8 million for the 145,000 c f s design

Revised costs on this project were prepared by the Commission According to these revisions, the 1957 cost of this project would range from $30 million for the 20,000 c f s design up to $94 million for the 145,000 c f s design

The Greater Winnipeg Floodway has the major advantage that it can be designed to a size that will give any desired degree of flood protection to the Greater Winnipeg area Situated, as it would be, on the main stem of the Red River, the source of the major part of any flood flow, it gives positive and dependable protection for any combination of flows from the Red and Assiniboine Rivers Even a small floodway would substantially reduce the amount of flooding that would occur in the event of a major flood and would almost completely eliminate the damages caused in minor floods Although the project has a few disadvantages, these are of a minor nature

(b) The Portage Diversion

This project calls for diversion of all or part of the flood flows on the Assiniboine River into Lake Manitoba It would reduce or eliminate flooding in the area between Portage la Prairie and Winnipeg and would reduce flood levels in Greater Winnipeg Plans have been prepared for diversions with capacities of 10,000 c f s, 25,000 c f s and 40,000 c f s respectively

After examination of a number of alternative routes, the "Report on Conservation and Flood Control, Assiniboine River" recommended two general routes, one west and one east of the city of Portage la Prairie The former, the Fort la Reine Diversion, would leave the Assiniboine about two miles west of Portage la Prairie, run almost due north to Oakland and from there would follow an old natural channel to Lake Manitoba The latter, the High Bluff Diversion, would leave the Assiniboine about 5 miles east of Portage la Prairie, would follow a generally northwest course until it reached Portage Creek and would follow the Creek to the Lake The Fort la Reine Diversion is about 18 miles long and the High Bluff Diversion about 19 miles long The locations of these two diversions are shown on Plate 3

For both diversions the channels are formed by a combination of dykes and channel excavation and are designed in such a way as to provide the necessary capacity at a minimum cost The dykes would be 10 feet across at the top, would have 4 to 1 side slopes and provide for 2 feet of freeboard Since the gradient of the channel has been designed to allow velocities as high as 5 feet per second, provision was made for covering the channel with one foot of top soil and seeding it with a thick cover of grass to prevent erosion Because of the sharp drop in elevation between Portage la Prairie and Lake Manitoba, about 48 feet on the Fort la

Reine Route and 30 feet on the High Bluff Route, drop structures would be located on the channel to reduce the gradient of the channel and prevent excessive excavation. Since operation of the diversion works would increase the water level in the Assiniboine, dykes would also be necessary to connect the diversion channel and dam to high ground west of Portage la Prairie. These dykes would be located so as to provide a wide flood plain and leave room for future changes in the river course (See Plate 2). They would also have a ten foot top width and 4 to 1 side slopes. For the 10,000 c.f.s., 25,000 c.f.s. and 40,000 c.f.s. Diversions, the dykes would be designed to provide protection upstream of the diversion structures for flows of 30,000 c.f.s., 45,000 c.f.s. and 60,000 c.f.s. respectively.

At the entrance to the diversion channel a weir would be constructed that would make it possible to keep water out of the channel when the natural flow on the river was less than 10,000 c.f.s. However, when flood conditions existed in Greater Winnipeg a control dam across the river would make it possible to divert the complete flow on the Assiniboine into the diversion channel until the capacity of the diversion was reached. Beyond that point, the gates on the dam would be lowered sufficiently to maintain a constant capacity flow in the diversion channel. Any excess water would flow over the spillway down the river channel.

Diversion of additional water into Lake Manitoba would raise the Lake level and unless steps were taken to offset this, would cause occasional flooding to low-lying lands along the lake shore. It was estimated that the use of the diversion would have increased the level of Lake Manitoba by .8 feet in 1923 and .7 feet in 1950. The outlet of Lake Manitoba through the Fairford River is now controlled by a small dam. However, even when the dam is open, the flow is limited by a rock ledge about 250 feet upstream of the dam. Provision was made in the cost estimates of the Portage Diversion for removal of this ledge and improvements to the channel sufficient to increase the capacity of the Fairford River by 2,000 second-feet at normal lake levels. For the larger diversions some allowance was also included for possible increased flood damages along the lake shore since it was not expected that these improvements would eliminate all damages. Proposals for controlling the level of the water in Lake Manitoba have received further study in the "Report of the Lakes Winnipeg and Manitoba Board" (1958).

Original and revised costs for each of the diversions are given in Table 4.3.

In the rural area between Portage la Prairie and Winnipeg the Portage Diversion would eliminate flooding completely for floods up to a 4 per cent flood (once in 25 years) in the case of a 10,000 c.f.s. diversion, up to a 1 per cent flood (once in 100 years) for a 25,000 c.f.s. diversion and up to a .2 per cent flood (once in 500 years) for a 40,000 c.f.s. diversion.

In the Greater Winnipeg area the effects of the Portage Diversion are complicated by the overflow to the south that normally occurs when the Assiniboine River exceeds a bankfull stage and by the question of the size of flow on the Assiniboine that can be expected when the Red River is in flood. This problem is analyzed in some detail in Chapter 10.

The Assiniboine Report whose findings were adopted by the Red River Basin Investigation indicated a preference for the Fort la Reine route rather than the High Bluff route for the Portage Diversion, on the grounds that the latter put Portage la Prairie behind a system of dykes. In reaching this conclusion they may have been thinking primarily of the 10,000 c.f.s. capacity diversion since they also tentatively recommended a combination of the Russell Reservoir and the 10,000 c.f.s. diversion. However, for the two larger diversions, construction costs are relatively much lower on the High Bluff route. Thus the High Bluff route is lower in cost than the Fort la Reine route by the following amounts for each of the three diversions:

10,000 c.f.s.	—	$ 875,000
25,000 c.f.s.	—	$2,338,000
40,000 c.f.s.	—	$3,236,000

It would seem likely that with only a moderate additional expenditure on the High Bluff route the dykes protecting Portage la Prairie could be made completely safe.

(c) Eastern Tributaries Diversion

This project provides for the diversion of part of the flood flows on the tributaries that enter the Red River from Eastern Manitoba into a floodway which would run parallel and about 20 miles east of the Red River, bypassing Greater Winnipeg and emptying into the Red River below Selkirk. The floodway would start at the Roseau River about three miles west of Stuartburn, would run north, passing about two miles south-east of Steinbach and four miles east of Ste. Anne, and would enter Cook's Creek some four miles east of Oakbank. Thereafter it would follow Cook's Creek to the Red River. (See Plate 3.)

The Floodway would consist of an excavated channel with a single dyke on the west side of the channel in the region south of Ste. Anne and double dykes in the area further north where land is more valuable. The dyke on the west side of the channel would have a 20 foot top width and a gravel-surfaced roadway. The second dyke where needed would have a 10 foot top width. All dykes would have three to one side slopes. The channel would be designed to carry 5,000 second-feet from the Roseau to the Rat River, 7,000 second-feet from the Rat River to Joubert Creek, 8,000 second-feet from Joubert Creek to the Seine River, 9,000 second-feet from the Seine River to Cook's Creek and 10,000 second-feet from there to the Red River

Concrete diversion dams would be constructed on the Roseau, Rat and Seine Rivers and on Joubert Creek to allow the diversion of these waters during periods of threatened flood, on either the Red River or the lower reaches of these streams Low flows would be passed through slide gates in the dam

The diversion dams would be operated in the following way In the winter the dams would be open and the entire flow would be passed In the spring, with the return of open water, the flow on these streams would be diverted completely up to the floodway's capacity whenever a flood on the Red River was forecast In other years the dams could be operated to prevent flooding on the lower reaches of the tributaries The diversion could also be operated to prevent summer and autumn floods on the tributaries

It was estimated by the Red River Basin Investigation that if the Eastern Tributaries Diversion had been in operation in 1950 it would have reduced the flood flow through Greater Winnipeg by 4,700 c f s and would have given a stage reduction of 77 feet For the 1948 flood the equivalent stage reduction would have been 95 feet For larger floods the stage reduction effected would be a little smaller Some stage reduction would also be effected in the Red River Valley between Emerson and Winnipeg The estimated cost of the project in terms of 1957 prices is $11,330,000

(d) Omand's Creek Diversion

The Red River Basin Investigation gave very preliminary consideration to a project which would involve pumping the water from the Assiniboine River at Omand's Creek near the western boundary of Winnipeg through a diversion channel that would proceed north and east to discharge into either the Red River below Selkirk or Netley Creek Because this project would tend to duplicate the effects of the Greater Winnipeg Floodway and because it appeared considerably more expensive for the benefits obtained, the R R B I did not investigate it in any detail They concluded that it did not merit any further consideration This Commission has found no reason for revising this opinion

Storage Reservoirs

The Red River Basin Investigation surveyed possible storage reservoir sites in both the Red and Assiniboine River Valleys In general, it found that reservoir storage on the tributaries would not have appreciable effects on the flood situation in Greater Winnipeg for floods of the 1950 magnitude or greater However, it did survey in some detail two projects of this kind a proposal to build a dam on the Pembina River in Manitoba just north of the International Border and a proposal for the construction of a reservoir in the upper Assiniboine near Russell, Manitoba In addition, it explored fully the possibility of building a dam on the main stem of the Red River near Ste Agathe, Manitoba These three projects will be referred to as the Pembina Reservoir, the Russell Reservoir and the Ste Agathe Detention Basin A canvass was also made of the possibility of building storage reservoirs in the United States section of the Red River drainage area, but United States flood control authorities informed us that the only storage sites of sufficient capacity to significantly affect flows on the main stem of the Red River in Canada have been developed to such an extent as to make their use for that purpose impractical

Possibilities of flood storage on the main stem of the Red are severely limited because the major portion of the effective drainage area consists of the old bed of Lake Agassiz which, because of its gentle slopes, offers very little possibility of flood storage

Moreover, the amount of storage needed to prevent flooding in Greater Winnipeg is very large It has been estimated that when the flood was at its peak there was about 700,000 acre-feet in channel and valley storage between Emerson and Winnipeg alone To reduce the 1950 flood level to a flow of 80,000 c f s would have required an additional storage capacity of 600,000 acre-feet on the main stem of the river above Winnipeg Since storage reservoirs on tributary streams may not all be effective in any one flood, a combined capacity of a still larger amount would have been required on tributary streams to achieve this same result Storage possibilities of these magnitudes are simply not available

In the United States portion of the Red River drainage area a number of reservoirs have already been constructed However, the flood-control benefit attributable to these streams is mainly local in effect and has very little significance either for Winnipeg or for the Red River Valley area from Emerson to Winnipeg Some portion of such benefits as do exist have been offset by channel improvements in other areas Further, the U S Army Corps of Engineers have made a thorough survey of the entire drainage basin south of the Canadian-U S border and have been unable to find any suitable sites for major storage reservoirs Some smaller reservoir projects are still under consideration Of these, the most important for Canada is the proposal to construct a dam on the Pembina River near Walhalla, North Dakota Further reference will be made below to this project, the Pembelier Dam

The topography of the Assiniboine River is more suitable for the location of storage reservoirs and the P F R A has already constructed a number of small dams on tributary streams such as Birdtail Creek and the Minnedosa River as well as on the Souris River On the Souris River there is now a developed storage of about 270,000 acre-feet, most of it located in the United States

Of the sites investigated on the Assiniboine, the most feasible site was judged to be the one near Russell, Manitoba, just upstream of Millwood A reservoir at this site would affect about half of the flood runoff on the Assiniboine River although the area which contributes this runoff forms only about 12 percent of the drainage area of the Assiniboine Basin Its long distance from Winnipeg, 530 river miles, reduces its effectiveness for flood control purposes in the Greater Winnipeg area

(a) The Pembina River Dam and Reservoir

The Pembina River has its source in Canada, flows partially through the United States and is joined by the little Pembina to enter the Red River at Pembina, North Dakota

In 1950, the Pembina River contributed to flooding in Canada by cresting twice It reached a peak of 20,500 c f s on April 18 and a second peak of 12,000 c f s on May 9 The channel capacity of the Pembina River below Walhalla could not contain these excessive flows and as a result the river broke out of its banks and flowed in a north-easterly direction across the land to enter the Buffalo floodway and the Plum and Marais Rivers, in Canada This overtaxed a drainage system known as D M D -"F" in the Rural Municipalities of Rhineland and Montcalm Bridges were washed away, the residents had to be evacuated, their livestock also, personal belongings were destroyed or damaged and agricultural undertakings were severely disrupted Although the Pembina River contributed directly only some six inches of flooding at Emerson, the flooding in that area would have been greater except for this overflow to the northeast, in consequence other areas and villages assumed extra flood damages

In addition, even in years when there is no flood on the Red, the Pembina River may cause flooding in this area as a result of the spring runoff or heavy summer rains

The reservoir on the Pembina River proposed by the Red River Basin Investigation would have a storage capacity of 175,000 acre-feet and would extend upstream for about 16 miles when the water level was at the top of the gates Though it was designed primarily from the viewpoint of flood control, its effects in the Greater Winnipeg area would be small It has been estimated that, if it had been in operation, the Pembina River reservoir could have reduced the 1950 flood peak in Winnipeg by about 1,500 c f s, giving a stage reduction of about three inches In the 1948 flood it would have given a discharge reduction of 1,100 c f s However, this dam would eliminate local flooding from the Pembina below the dam site, in particular it would prevent the overflow to the Plum and Marais Rivers which now occurs

This reservoir would also produce a substantial increase in the low water flow on the Pembina and Red Rivers By using about 120,000 acre-feet of the storage capacity for water conservation, a dependable flow of 40 second-feet could have been provided throughout the driest period on record, 1936-1942 During this period the flow on the Pembina River was zero for extended periods and the flow on the Red River at Emerson reached a low of 9 second-feet during February, 1937 Its effect in this regard is particularly important because additional water in the Pembina triangle is badly needed

Maintenance of a higher minimum flow on the Pembina River during dry periods would provide

(a) Improved sewage dilution for towns and villages on the Pembina and Red rivers
(b) A permanent supply of potable water for the Pembina Triangle from a source that would be under Canadian control
(c) Water for irrigation purposes thereby increasing the agricultural productivity of the area
(d) An attraction for new industries for the towns and villages in the area

Joint use of the reservoir for flood control and water conservation purposes is feasible because floods on the Red River in Canada occur only during the spring runoff period During the balance of the year the reservoir can be used entirely for water conservation The reservoir would need to be emptied for flood control purposes only in the spring and only when the flood forecast indicated some risk of flooding was present When a possible flood is forecast the reservoir would be drawn down until sufficient capacity was available to store the anticipated runoff An accurate forecast of spring runoff would be required for proper operation of the reservoir

The relatively small contribution of the Pembina River Reservoir to flood control on the Red is due to the fact that the proposed dam controls only about 2 per cent of the effective drainage area of the Red River Although the dam controls a total drainage area of some 2,600 square miles, it has been estimated that only about 475 square miles of this would produce a runoff rapid enough to contribute to peak discharges on the Pembina and the Red In much of the area controlled by the dam, the land is flat and the drainage is undeveloped

In addition, the Pelican, Rock and Swan Lakes provide some regulations on the river flow Thus for some 80 percent or more of the Pembina River's drainage area, the runoff would reach the dam site after the peak of the river's hydrograph had passed

The effectiveness of the dam, as a flood control measure, would also be reduced if the peaks on the Red and Pembina failed to synchronize However, flood flows on the two rivers have coincided to a considerable extent during past flood years

The estimated cost of this reservoir (in terms of 1957 prices) is $5,140,000

(b) The Pembelier Dam

The Commission has also been aware that U S authorities have under consideration a dam on the Pembina River near Walhalla, North Dakota, commonly known as the Pembelier dam The proposed dam would have a storage capacity at spillway crest of about 146,000 acre-feet and at normal summer pool elevations of about 120,000 acre-feet It is proposed to operate the dam primarily for flood control purposes However, the dam would also provide sufficient water to meet all foreseeable potable water supply requirements in the United States even during dry periods In addition, there would be a substantial surplus of water that could be made available to Canada The cost of the proposed dam is estimated at well over $10,000,000

(c) The Ste Agathe Detention Basin

One of the storage projects studied by the Red River Basin Investigation was a detention basin in the Red River Valley near Ste Agathe The detention basin would be created by building an earth dyke about 25 miles long across the valley just south of Ste Agathe A control structure on the river would make it possible to pass all ordinary river flows without undue restrictions Under flood conditions the gates on this structure would be operated to limit the volume of flow passing through Winnipeg by storing water temporarily in the valley lands upstream of the dam

In constructing the dam, provision is made for compacted earth fill dams across the Marsh and Rat Rivers and for the diversion of these rivers into the Red River at a point about 1,000 feet upstream of the control structure Openings would be left in the dyke where it is crossed by railroads and highways These would be blocked by sandbags or by other means during a flood Since by the time the dam's operation became necessary, rail and highway traffic would have been interrupted anyway, no additional interference with traffic would be involved

The height of the dyke would vary from 18 feet above natural ground level in the central portion to about two feet above natural ground level at its western end The maximum water height against the dyke would be 12 feet, the remainder of the dyke being freeboard for protection against wave action The dyke would be 20 feet wide at the top, would have 4 to 1 side slopes and would be seeded to grass or protected with rip-rap The total cost of the project was estimated in 1957 at $9,234,000

If the Ste Agathe Detention Basin had been in operation in 1950 it is estimated that it could have reduced the peak flow in Greater Winnipeg by about 24,000 c f s This would have given a stage reduction of some 4 5 feet at Redwood Bridge in Winnipeg In a flood of the size that occurred in 1852 it would reduce the flow through Winnipeg by 30,000 c f s which is the equivalent of about 2 5 feet in terms of stage reduction At still larger flows the discharge reduction obtained would be smaller but still substantial

The effectiveness of the dam arises partly out of the fact that it controls the major portion, some 95 percent or more, of the drainage area on the main stem of the Red River It also reflects the fact that its operation involves the enhancement of a natural storage situation Because of a natural depression south of Ste Agathe a large storage reservoir develops naturally in years of major floods Construction of the dam would increase the size and capacity of this natural storage reservoir

(d) Russell Reservoir

After investigating a number of different potential sites for storage reservoirs on the Assiniboine River, the "Report on Conservation and Flood Control" recommended a site on the Assiniboine River just west of Russell, Manitoba, as the most suitable location Tentative plans on this project call for a reservoir with a storage capacity at spillway crest of 450,000 acre-feet and a length of 56 miles Some 350,000 acre-feet of this capacity would be reserved for water conservation purposes leaving 100,000 acre-feet of storage available for the control of summer floods For spring floods, a flood forecasting system would be required which could predict, at least three weeks in advance, whether or not the total runoff above the dam would be more or less than the total available storage capacity In the light of this data the reservoir could be emptied in advance to whatever extent was deemed necessary to contain the runoff Three weeks would be required to empty the reservoir completely

Based on 1957 prices, the cost of this project was estimated at $6,450,000

The data for flood years on Table 4 1 indicate the contribution made to the flow on the Assiniboine River by a number of its major tributaries The years selected were those in which the flow either exceeded 15,000 c f s at Headingley or exceeded 10,000 c f s at Brandon

(1936 was excluded because no data was available at the three tributary points in that year)

These data indicate that in flood years, flows on the Assiniboine River at Millwood that would be subject to control by the Russell Reservoir have accounted for about 60 percent of the flow reaching Brandon and about one-half of the total flow reaching Portage la Prairie At Brandon the remaining 40 percent of the total flow has been divided about equally between flows from the Qu'Appelle which enter the Assiniboine just above St Lazare and flows from a variety of smaller streams, such as the Oak, Arrow and Minnedosa Rivers and Birdtail Creek Almost all the runoff from the Riding Mountains that reaches the Assiniboine enters through these streams below Millwood At Portage la Prairie the remaining 50 percent of the total flow—flow other than that coming from above Millwood—comes from the Souris (20 to 25 percent), from the Qu'Appelle (some 15 percent) and from a variety of smaller streams (10 to 15 percent)

It is clear that under favourable conditions a reservoir as large as this one could provide an important flood control weapon A storage capacity of 450,000 acre-feet would make it possible to cutoff completely a flow of 15,000 c f s for a 15-day period, or a flow of 10,700 for 21 days Moreover, in an emergency the total storage capacity can be raised to 600,000 acre-feet with some overflow

In addition to its flood control benefits, the Russell Reservoir would also greatly improve the water supply on the Assiniboine River in dry years By reserving 350,000 acre-feet for water conservation purposes it is estimated that a minimum dependable summer discharge of 350 second-feet could be maintained just below the reservoir Based on the experience from 1928-1948, this would give a minimum open water flow of 600 second-feet at Headingley as compared with 160 second-feet under present conditions

(e) Small Dams

The Assiniboine Report gave some consideration to the construction of a number of small dams as an alternative to one major storage project It is reported that to provide storage in small dams is much more expensive per acre-foot of storage provided According to their estimate, storage provided by small dams costs about $100 per acre-foot of water compared with a cost of about $15 per acre-foot for large reservoirs Thus, from the point of view of flood control, large storage reservoirs are much more economical

At the Commission's Public Hearings in Morris, a number of different groups who appeared before the Commission suggested that the construction of small dams in the escarpment which runs along the western edge of the Red River Valley might have a valuable flood

Table 4 1

SOURCE OF ASSINIBOINE RIVER FLOWS

	Assiniboine River* at			Qu'Appelle River at Tantallon	Souris River at Wawanesa
	Headingley	Brandon	Millwood		
			(c f s)		
1913	14,000	14 800	12 700	N A †	1 500
1916	21,700	9,100	2 900	N A	6 100
1922	19,300	21,300	17 800	2 000	2 000
1923	21,000	23,000	14 500	2 000	5,900
1927	18,300	17,100	12,600	2 100	3 000
1947	11,300	11,100	4,100	1 400	2,000
1948	16,700	15,900	7,800	2 200	4,100
1949	15,200	4 900	900	200	8 300
1954	13,500	12 700	9 300	3,200	1 900
1955	16,900	18,900	9 600	8 400	4 200
1956	19 900	15,200	8,000	5 600	7,300
Average of above	17 100	14,900	9,100	3 000	4,200

FLOWS AS PERCENT OF TOTAL FLOW, ELEVEN FLOODS 1913-56

Source of Flow	Percent of Total at Headingley	Percent of Total at Brandon
Assiniboine at Millwood	53 2%	61 1%
Qu'Appelle at Tantallon	17 5%	20 1%
Souris at Wawanesa	24 6%	

*Flows at Portage la Prairie are available only for the following years 1923 22 100 c f s 1927 20 400 c f s 1955 22 900 c f s and 1956 19 900 c f s

†Not available

control effect as well as providing important conservation and water supply benefits The Commission was also aware that a substantial flow is contributed to the Red River from tributaries such as the Morris, Plum and Roseau Rivers In addition, it was pointed out that the Soil Conservation Service of the United States Department of Agriculture had undertaken an extensive program for the construction of small dams and some of the officials had suggested that these dams would have important flood control effects

In order to investigate this matter further the Commission subsequently met in Fargo, North Dakota, with representatives of the U S Soil Conservation Service, the U S Department of the Interior and the North Dakota State Water Conservation Commission These representatives confirmed the fact that an extensive program of small dam construction was under way as part of a watershed control program For example, 18 dams, ranging in size from 100 to 5,000 acre-feet are being constructed in the upper reaches of the Tongue River However, it was their opinion that, in the control of major floods, these small dams would have only a slight effect Moreover, since many of them have not yet been completed, they can not be given any credit for the fact that the 1956 flood threat did not materialize These officials also confirmed the finding of the Assiniboine Report that the cost per acre-foot of water stored in small dams is relatively high as compared with its cost in a large dam

Channel Improvements

A river channel may be improved by widening and deepening, by eliminating sharp bends thus reducing the length of the stream and increasing its velocity, and by reducing the friction losses that result from irregularities in the river banks or from trees and other obstructions in the channel

Where the channel is improved the maximum benefit in the form of stage reduction occurs immediately upstream from the improvement and this benefit decreases progressively as one moves further upstream

(a) Below Greater Winnipeg

The Red River Basin Investigation explored in some detail the improvements that would result from channel deepening and widening in the area downstream of Winnipeg This area includes the section referred to as Lister's Rapids, some seven or eight miles in which an outcrop of bedrock has prevented erosion of the river bed After giving preliminary study to some 22 different designs for channel enlargement in this region, it selected eleven for detailed analysis and the three of these which appeared most favourable were discussed in some detail These three, Trials 12, B and C, involved the following channel changes

i) Trial 12—This trial provided for moderate widening of the natural channel from Mile 32 6 (about 2½ miles upstream from Old St Andrew's Church) to Mile 40 2 (just below Bergen Cutoff) For a cost (in 1957) of $5,674,000 it was estimated that, under 1950 flood conditions, this improvement would have provided a stage reduction of 1 5 feet at Redwood Bridge Upstream of this point the stage reduction declines, reaching zero near Elm Park Bridge

ii) Trial B—Trial B provides for a deeper channel from Mile 27 3 (near Lockport) to Mile 40 9 (near Bergen Cutoff) with some minor widening designed to eliminate abrupt changes in channel width For a cost, in 1957, of $14,925,000 this trial would provide, under 1950 flood conditions, a stage reduction of 2 8 feet at Redwood Bridge, and a reduction of 5 feet at the southern limits of Greater Winnipeg

iii) Trial C—Trial C, the largest of these three projects, includes both widening and deepening in the same area as in Trial B, namely, from Mile 27 3 to Mile 40 9, with the aim of producing a more efficient, uniform channel It calls for 3 to 1 side slopes, a bottom width of from 500 to 600 feet, and a rockcut to the average depth of ten feet For an expenditure in 1957 of $29,326,000 it was estimated that this would give a stage reduction of 4 5 feet at Redwood Bridge under 1950 flow conditions, decreasing to 0 5 feet at the southern limits of Greater Winnipeg

In designing each of these plans for channel enlargement, the shape of the natural channel was studied and an effort was made to secure the maximum benefit in relation to cost Wherever possible, an attempt was made to straighten the channel and make it more uniform in shape

Since the above three trials appeared the most favourable on the basis of preliminary analysis in that they provided the largest stage reduction at Redwood Bridge in relation to their cost, and since they included examples of a small, a medium size and a large project, the Commission decided to use these trials as the basis for its benefit-cost analysis of Lister's Rapids removal

(b) The Greater Winnipeg Area

Though the removal of Lister's Rapids provides substantial stage reductions in the north end of Greater Winnipeg, the size of these stage reductions declines rapidly as you move upstream through the city The Red River Basin Investigation considered the possibility of extending these benefits further upstream by means of channel improvement in the heart of the city but concluded that such an undertaking would not be economically feasible "due to the high cost of the work and the uncertainty as to the effect it would have on the stability and erosion of the river banks"

In order to canvass thoroughly all possible approaches to the problem of flood protection in Greater Winnipeg, the Commission felt it was desirable to explore the possibility of channel improvement through the city in more detail In this view they were supported by Dr L G Straub, Director of the St Anthony Falls Research Laboratory, University of Minnesota, who suggested that a moderate degree of channel improvement through the Greater Winnipeg area might provide substantial reductions in frictional losses and significant increases in channel capacity as a result of a more rapid rate of flow Accordingly the Commission decided to have some further investigations carried out in this field The Water Resources Branch of the Provincial Government made an office study of this problem, using available field data The investigation was carried out in consultation with Dr Straub and the results were reviewed with him when it was completed

Three different proposals for channel improvement were studied These proposals were designed to provide a channel that would carry flows of 110,000 c f s , 130,000 c f s and 140,000 c f s through the city at river levels one foot below the existing dyking system In each case the proposed channel improvement extended throughout Greater Winnipeg and to a point below Lister's Rapids

In the area below Greater Winnipeg each of these three proposals incorporate in a modified form one of the designs for the removal of Lister's Rapids originally investigated by the Red River Basin Investigation Thus, Plan No 1 (110,000 c f s) is based on Trial C but with a smaller depth of excavation Plan No 2 (130,000 c f s) is based on Trial I but with the amount of channel deepening reduced by from 1 to 4 feet throughout the entire length of the original proposal As originally designed, Trial I called for a fairly deep excavation and considerable widening from Mile 40 9 (at Bergen cutoff) to Mile 27 7 (just above St Andrew's Dam) Plan No 3 (140,000 c f s) incorporates Trial I without any changes In each instance a variety of proposals were investigated and these three were selected as being the most economical

Some consideration was given to lining the channel in the area below Winnipeg, with asphalt or concrete Lining the channel would reduce frictional losses and by increasing the river velocity, provide greater carrying capacity in the channel However, it was found that this would be impractical in many areas because of the unstable character of the soil and that, although it would be practical in the areas where there is an outcrop of rock, the depth of the lining needed over rock would make it uneconomic

Costs of the above three channel improvements were based on the estimates prepared by the Red River Basin Investigation Their cost estimates were revised to take account of the different amounts of excavation involved and to allow for the rise in labour costs since 1952 In addition, an allowance was included for a modification to the St Andrew's Dam which would make possible the maintenance of water levels in the City of Winnipeg throughout the winter

The increase in channel capacity obtained in the area below Greater Winnipeg was extended throughout the Metropolitan area by a combination of channel enlargement, an improvement in channel alignment and a reduction of roughness in the channel Roughness would be reduced by the removal of trees, shrubs and other obstructions to the river's flow Both the improvement in channel alignment and the roughness reduction would increase the river's velocity and thus add to its carrying capacity

For each proposal a channel was designed which would provide the required carrying capacities (110,000, 130,000 and 140,000 c f s) with a water level throughout the city at about one foot below the top of the main dyking system In each instance, provision was made for a smooth uniform channel throughout the entire metropolitan area This channel would have a 200 foot bottom width, 10 to 1 side slopes up to elevation 735 (one foot above normal summer water level in Winnipeg) and 5 to 1 side slopes above that elevation The side slopes above elevation 735 would be seeded to grass Thus, the shape of the channel would be uniform in all three proposals, the increased capacity in the larger channels being obtained by increasing the depth and width of the channel

In a few areas this plan was modified In three areas in the central part of Winnipeg, excavation was confined to one side of the river because of the large amount of expensive property in this area Provision was also made for a cutoff in the Elm Park area, the abandoned river channel to be filled with excavated material

As a result of these improvements to the channel, it was estimated that the average value of the roughness coefficient "n" (in Manning's formula) would be reduced from 034 to 029 While a slightly larger reduction than this might be obtained immediately upon completion of the improvements, some of this would disappear in a few years The above reduction is the amount that should be capable of continuous maintenance

The cost of these three projects is shown in Table 4 2

(c) St Norbert to Emerson

The Commission gave careful consideration to the possibility of providing flood protection to the valley area between St Norbert and Emerson by means of widening and/or deepening the Red River channel Preliminary engineering study was given to two plans for channel improvement

1 A plan to increase the size of the existing river channel to such an extent that it would be capable of carrying a flood flow of 130,500 c f s and

2 A similar plan, capable of carrying a flood flow of 95,000 c f s

In both plans, separate cost estimates were prepared for channel improvements throughout the entire length of the river from St Norbert to Emerson and for channel improvements confined to the area from St Norbert to Ste Agathe

Improvements to the channel south of Winnipeg would reduce the natural storage of floodwater that now occurs in this area and would result in higher flood stages in Winnipeg It has been estimated that valley storage during the 1950 flood reduced the flood peak in Winnipeg by 2½ feet An increase in the capacity of the Greater Winnipeg Floodway of the size needed to reduce the flood peak by this amount would cost $9,800,000

(d) On the Assiniboine

On the Assiniboine River, channel improvement in the past has been confined to a few cut-offs where particularly sharp bends or loops were causing frequent ice jams No general scheme for improving the channel was included in the report on this river made by P F R A It would be possible to enlarge and straighten the Assiniboine River channel between Portage la Prairie and Winnipeg and this would undoubtedly reduce flooding in the farming region on both sides of the river However, such an improvement would have the major disadvantage that it would worsen the flood situation in Greater Winnipeg in years when high flows on the Assiniboine coincided with floods on the Red River This would result from the loss of some of the natural storage now provided by the overflow from the Assiniboine that occurs in flood years

Because the Assiniboine River is a heavy silt-carrying stream, some maintenance of the river channel is required if the present carrying capacity of the river is to be maintained

Table 4 2

THE COST OF CHANNEL IMPROVEMENTS, RED RIVER, BELOW AND THROUGH GREATER WINNIPEG

	Plan No 1 (110 000 c f s)	Plan No 2 (130 000 c f s)	Plan No 3 (140 000 c f s)
I BELOW GREATER WINNIPEG		(Thousands of Dollars)	
Excavation	$16 943	$ 23,474	$ 30,249
Dewatering	3 082	3 194	3,306
Disposal Grounds	100	145	185
Modification, St Andrew's Dam	350	350	350
Engineering and Miscellaneous	2,457	3 260	4 091
Sub-Total	$22,932	$ 30 423	$ 38,181
II GREATER WINNIPEG			
Excavation	$12 353	$ 23 194	$ 25,270
Disposal Grounds	137	201	253
Reconstruction Haul Routes	2 130	2,130	2,130
Pipeline Crossings and Bridge Prot	5 000	6,000	7,000
Reconstruction of Streets	486	873	999
Relocation, Pumping Stations	825	1 125	1,200
Bridges	1,231	1 851	2,454
Engineering and Miscellaneous	2 827	4 413	4,885
Property Acquisition	18 626	36 726	40,577
Sub-Total	$43 615	$ 76 513	$ 84 768
III TOTAL COST	$66 547	$106,936	$122,949

In preparing cost estimates for each of these plans, the river was divided into twenty-one reaches and estimates were prepared of the amount of excavation required in each reach For example, at Ste Agathe it was estimated that the river would have to be widened by 300 feet to provide the 130,500 c f s flow and by 150 feet to provide the 95,000 c f s flow

The cost of these proposals was estimated to be as follows

	St. Norbert to Emerson	St Norbert to Ste Agathe
Channel 1 (130,500 cfs)	$67,000,000	$24,520 000
Channel 2 (95,000 cfs)	50,360,000	14,230,000

Dykes

Although the construction of dykes is widely used as a method of flood protection, they contain inherent dangers that sharply limit their usefulness Once the dykes have been constructed, people living in the protected area are likely to become over confident and build expensive property in low-lying areas If in a subsequent flood the dykes are overtopped, the total damage to property will be greatly increased In addition, people may remain in their homes too long so that the danger of loss of life becomes much higher If the dykes fail, water will come in with a rush and people may find themselves trapped by the rapidly rising waters Flood control authorities have attempted to avoid this risk by building dykes high enough to withhold the highest known flood But this does not eliminate the risk of dyke failure or the chance that a flood may occur which exceeds any previously recorded These risks are explained in more detail in Chapter 10

(a) Dykes in the Greater Winnipeg Area

Following the 1950 flood, the Federal Government entered into an agreement with the Province of Manitoba which provided for the construction of a system of dykes in the Greater Winnipeg area These dykes were intended to provide a partial degree of flood protection and reduce the flood hazard in the area until the overall flood protection problem could be studied The dyking scheme provided a main line of flood defence at a height of about two feet above the 1948 flood level and about four feet below the 1950 flood level

In general these dykes were built to a standard width of 26 to 50 feet and in most instances the dyke is used as a permanent roadway This width will make it possible to build temporary dykes on the river edge of the permanent dyke and still leave room for two traffic arteries The broad width also makes for easier access during periods of emergency dyke construction It has been suggested by the Greater Winnipeg Dyking Board that emergency dykes could be built up to the 1950 flood elevation

The dykes are confined to areas where the natural land elevation is below 26 5 feet (City datum, James Avenue) and are tied into higher land elevations to form a primary line of defence throughout the Greater Winnipeg area In areas where the land elevation exceeds 26 5 feet the line of defence has been chosen so as to permit ready traffic access It continues out into the country until it ties in with high land

The project also provided for the erection of 21 separate pumping stations adjacent to main sewer outfalls These sewer outlets have been provided with sluice gates so that in flood periods the river water can be closed off and the sewage and rain water can be pumped over the banks and into the river Six further pumping stations have been built and equipped since the dykes were first constructed

While in periods of emergency it would be possible to add to the present dyking elevations and at least to fight a flood up to the 1950 flood elevation, there are, however, serious risks inherent in this process

Because of these various risks the Red River Basin Investigation concluded that emergency dyking should not be relied on as a positive method of flood protection Accordingly, they suggested that the safe carrying capacity of the river channel should be taken as the flow between the existing dykes with an adequate allowance for freeboard However, the Red River Basin Investigation did make two proposals for permanent additions to the present dyking system One of these proposals was designed to provide permanent flood protection against a flow of 28 5 feet at James Avenue The other called for a set of dykes which, together with channel enlargement, Trial C, would be capable of confining the 1950 flood within the dykes

The dyking system involved in the first proposal was designed wherever practicable to provide a freeboard of three feet above the 28 5 feet design flow

The plan calls for ten foot top dykes in areas where the dyke is located on other than a street or road Where the proposed location is along a road or street, the plan calls for the raising of the road to the required height with a 26 foot top width If this is impractical, provision is made for a 10 foot shoulder dyke on the river side of the road

It was estimated that such a dyking system would create a safe channel capacity of 95,000 cubic feet per second as compared with the capacity of about 80,000 c f s provided by the present dyking system

The second dyking proposal of the Red River Basin Investigation was for the construction of a set of dykes which would extend the benefits obtained from channel enlargement, Trial C, uniformly through the city Under 1950 flood conditions Trial C provides stage reductions of 4 5 feet at Redwood Bridge, 3 1 feet at the mouth of the Assiniboine and 5 feet at the University of Manitoba

In the main, the additional dyke construction required by this second proposal lies in the south end of the city where dykes can be constructed more cheaply and borrow material is more accessible Much of the costly dyke construction in the centre of the city that would be required for the 28 5 foot dyke design is eliminated or greatly reduced under this proposal Implementation of this plan would provide a safe carrying capacity of 103,600 c f s, the 1950 flood flow

(b) Dyking between Emerson and St Norbert

Preliminary investigations were made of two proposals for dyke construction in the area from St Norbert to Emerson

1 A preliminary study was made to see what would be the possibility of providing a ring dyke to encircle the Town of Morris and a reconnaisance was made of similar dykes for other towns along the Red River

2 The feasibility of providing dykes along each side of the Red River from Winnipeg to Letellier was investigated These dykes would give protection to a height of somewhat less than that of the 1950 flood Any higher protection would raise the water level at the International Boundary

Indications are that the ring dykes around the towns would vary in height from about 3 feet around Letellier to from 7 to 15 feet high around Morris For some towns, such as St Norbert, Ste Agathe, St Jean Baptiste and Emerson, the towns are so close to the river that the proposed dyke would have to be located back on the nearest roadway and, in some instances, such as Emerson, it would have to be located on the main street of the town This would undoubtedly create many difficulties and probably would not be acceptable to the residents This will be particularly true where the dyke is of substantial height All the proposed dykes are 26 or more feet wide on top and are expected to be used as streets or roads

It is not usual to construct dykes to an elevation below that of the highest known flood because dykes give people a false sense of security If the dyke fails or is overtopped it could lead to serious loss of life However, in the case of ring dykes in the Valley, the surrounding area would be flooded in any case and it is therefore reasonable to assume that evacuation would occur well in advance of the flood peak

Regarding the suggestion for parallel dykes on either side of the Red River, it was assumed that Highway 75 would serve as a dyke on the west side of the river and St Mary's Road or River Road would be used on the east side Highway 75 is higher than the 1950 flood level throughout its length from Emerson to St Norbert except for ten miles north St Jean Baptiste It was assumed that this latter area could be raised by means of temporary dyking in a flood emergency Provision was made for raising St Mary's Road to one foot above the 1950 flood level, with a 30 foot roadway top and 4 to 1 side slopes Culverts through Highway 75 and the St Mary's Road dyke would be gated and the water these culverts normally drain would be pumped over the dyke in flood periods

A number of the larger tributary streams such as the Morris, Plum and Roseau rivers and some of the larger drainage ditches are dyked back to higher ground elevation since it was anticipated that temporary pumps would not be able to handle the flow

Excepting the St Mary's Road dyke, all the dykes would have a 26 foot top width and 3 to 1 side slopes They would be surfaced with 6 inches of gravel to permit easy access to and inspection of the dykes in a flood period

Because many houses and buildings are built close to the Red River or to tributary streams, a substantial amount of property would not be protected by these dykes Indeed, property located between the dykes and the river would be subject to more frequent and more severe flooding than under natural conditions

According to preliminary indications, dykes around the towns along the Red River south of Winnipeg would cost about $1,400,000 and the system of dykes from Emerson to St Norbert would cost about $8,400,000

(c) Dyking on the Assiniboine

The Report on Conservation and Flood Control on the Assiniboine River considered the possibility of dyke construction in several reaches of the Assiniboine River Two dyking schemes were considered in the Portage la Prairie to Winnipeg Reach, a dyking scheme in the Brandon area was discussed and some evaluation was made of a dyking plan for the Millwood to Brandon Reach of the river

For the Portage la Prairie to Winnipeg area, the report decided that it was impractical to build a dyking system that would protect against the highest known flood Instead, a plan to provide protection against a one percent flood was studied

Two alternative plans were considered The first provided for a system of dykes at a cost of $7 million (in 1952) about one mile apart on either side of the river This plan would avoid the dyke erosion problem that occurs when dykes are placed on the banks of the river A few cut-offs were provided in order to protect the old No 1 Highway The alternate plan provided for dykes on the river bank at a cost of $6,700,000 (in 1952)

Both plans would provide protection up to an elevation of 36,000 c f s Although the cost of the second plan is slightly lower, the maintenance costs of such a dyking system would be much higher Further, some revenue might be obtained from the first scheme through leasing hayland between the dykes

Since the report was completed, the P F R A has improved the old dyking system on the banks of the river that was begun by the Department of Public Works after the floods of 1922 and 1923 Present plans call for raising these dykes to a level which would contain a flow of from 21,000 to 22,000 cubic feet per second, with no allowance for freeboard

Dyking along the Assiniboine below Portage la Prairie has the major disadvantage that it tends to increase the flood levels in Greater Winnipeg It has been estimated that the two dyking schemes outlined above would increase the flood flow at the mouth of the Assiniboine in Greater Winnipeg by 1,500 c f s

In the Brandon area the Assiniboine Report developed a proposal for a dyking scheme in the Brandon Flats together with a cut-off for one major loop at a total cost of $500,000 The dyke was designed to provide protection for a one percent flood or a flow of 36,000 cubic feet per second

Between 1954 and 1956 at a cost of $50,000 a dyke was constructed on the south side of the river in approximately the location suggested in the P F R A report This dyke is some 9,500 feet long, has an average crown width of 21 feet and has an elevation of 1,179 5 feet above sea level (1,180 W — 1,179 E) It successfully withheld the spring floods of 1954, 1955 and 1956 The highest flow at Brandon during this period was 18,900 c f s in 1955 The top of the present dyking system corresponds to a flow of about 29,000 c f s Allowing for 1½ feet of freeboard, the dykes might withstand a flood of about 21,000 c f s

In the reach from Millwood to Brandon, the Report concluded that it was not feasible to construct continuous dykes However it would be possible to construct dykes that would protect a number of major areas This analysis indicated that the cost of this proposal would amount to $100 per acre of agricultural land protected for dykes that would protect against a 4 percent flood (once in 25 years) and $75 per acre for dykes that would protect against a 10 percent flood (once in 10 years)

Revision of Costs

Where cost estimates were originally prepared by the Red River Basin Investigation in 1952, it was necessary to revise them to take account of the increase in labour and material costs since that date Account was also taken of new structures or roads that had been located along the routes of the various projects

In revising the costs of the Greater Winnipeg Floodway it was necessary to alter the floodway's route because of the new railway yard the C N R is developing across the original location The original and revised routes are shown on Plate 2 Some changes were also made to accommodate the floodway's location to the proposed route for the perimeter road and to take account of the extension that has been made in Highway 59 This revised route is somewhat longer than the original route proposed by the Red River Basin Investigation

In the original cost estimates it was assumed that the average cost of excavation would be 30 cents per cubic yard for ordinary material and $1 00 per cubic yard for hardpan These costs were reviewed with a number of engineering authorities and with a group of construction contractors After careful consideration it was decided that the original cost estimates for this item should not be changed However, two of the members of this Commission feel that there is a good possibility that if the project is carried out, a significantly lower price for this portion of the project may be obtained On a 60,000 c f s floodway, a difference of 5 cents per cubic yard on excavation would amount to about $6 million

In revising the costs of acquiring right-of-way along the floodway's route, two local land appraisers were consulted and land prices were revised in the light of their advice

A detailed breakdown of the revised costs for the Greater Winnipeg Floodway is given in Table 4 4 The original and revised costs for other projects are shown in Table 4 3 The revised costs on the High Bluff route for the Portage Diversion include an allowance for a new bridge that will be required where the project crosses the Trans-Canada Highway For the channel improvements in the Lister's Rapids area, provision was made in the costs for a modification to the dam at Lockport which would enable the maintenance of water levels in the City of Winnipeg throughout the winter months

Table 4 3

ORIGINAL AND REVISED COSTS, VARIOUS FLOOD PROTECTION WORKS

	Original 1952	Revised 1957-58
	(Thousand	Dollars)
Portage Diversion		
Fort La Reine Route		
10,000 c f s	$ 5,995	$ 6,584
25,000 c f s	10,117	11,010
40,000 c f s	12,935	14,097
High Bluff Route		
10,000 c f s	5,118	5,709
25,000 c f s	7,758	8,672
40,000 c f s	9,654	10,861
Russell Reservoir	6,000	6,450
Ste Agathe Detention Basin	8,750	9,234
Pembina River Reservoir	4,700	5,140
Eastern Tributaries Diversion	10,300	11,330
Lister's Rapids Removal		
Trial 12	5,236	5,674
Trial B	13,119	14,925
Trial C	24,826	29,326

Table 4 4

REVISED GREATER WINNIPEG FLOODWAY COST ESTIMATES
(In Thousands of Dollars)

Floodway Design	Control Structure	Dykes	Right of Way	Excavation	Highway Bridges	Railroad Bridges	Aqueduct	Seine R Diversion	Outlet Structure	Misc	Total Cost	Increase Over 1952 Estimate
20-766	3,417	951	2 400	15 671	2 815	3 779	215	70	337	565	30,220	6 840
40-766	3,417	951	3 370	26 177	3 680	5 072	226	70	553	565	44 081	8 041
60-766	3 417	951	3 750	38 865	5 823	6 892	260	70	691	565	61 284	1 124
40-768	3 417	1 120	3,140	23 514	3 989	5 102	226	70	581	565	41,724	7 954
60-768	3 417	1,120	3 520	35 246	5 639	6 762	260	70	762	565	57,361	10 527
80-768	3 417	1,120	3,900	45 769	6 844	8 461	294	70	906	565	71 436	12 723
60 770	3 417	1,434	3 650	31 602	5 462	6,889	260	70	846	565	54,195	11,225
80-770	3 417	1,434	4 100	41 674	6 968	8 547	294	70	1 058	565	68,127	12 817
100 770	3,417	1,134	4 570	48 281	7,882	9,625	317	70	1,324	565	77,485	14 255
145 773	3 417	1,979	5 100	57,552	10,475	12 259	396	70	2 152	565	93 965	18 165

CHAPTER 5

THE BENEFIT-COST ANALYSIS OF FLOOD CONTROL PROJECTS

The primary purpose of a benefit-cost analysis is to compare the benefits of a particular project with its costs. Where there are several ways of preventing flood damages, such an analysis will show which of these is the most favourable, that is, which provides the greatest benefit for a given cost. It is usual to express this comparison of costs and benefits in the form of a benefit-cost ratio.

The benefit-cost ratio for a project is determined by dividing the annual benefits of a project by its annual costs. If this ratio exceeds 1.0, the project will be considered favourable since the annual benefits exceed the annual costs. The higher this ratio, the more favourable is the project. Thus, where the benefit-cost ratio is 3.0, the annual benefits in the form of flood damages prevented will be three times as large as the annual costs of the project. In other words, by constructing the project, the community concerned can save themselves three dollars in the form of flood damages prevented for every dollar spent in building the project. Benefit-cost ratios can be calculated for a combination of projects as well as for individual projects.

In addition to overall benefit-cost ratios, incremental or marginal benefit-cost ratios have been calculated. Such a ratio compares the additional benefit obtained from a given increase in the size of the project with the added cost of obtaining that benefit. At some stage in most projects it will be found that the incremental benefit-cost ratio falls below 1.0. This indicates that the additional benefit from a given increase in the size of the project is less than the cost of this addition. In these circumstances, for those benefits which can be reduced to a dollar value, the community would be further ahead if they were to absorb the additional damage when it occurs rather than incur the added cost required to prevent it. This will be true even where the overall benefit-cost ratio still exceeds 1.0. Both overall and incremental benefit-cost ratios have been used in this study.

Annual costs normally include the annual interest charges on the capital cost of the project, an annual amortization charge which will accumulate a fund sufficient to repay the capital cost of the project over its useful life, and the cost of maintaining and operating the project.

Interest charges will vary with the interest rate that has to be paid by the borrowing authority which is financing the project. In this study, an interest rate of four percent has been selected as a basis of evaluation. This corresponds closely to the average rate paid by the Province of Manitoba since the end of the war. It is higher than the corresponding Federal rate but somewhat lower than the rates paid by municipalities in the Greater Winnipeg area.

Amortization charges on all projects have been calculated on the basis of a 50-year life. While there is no doubt that some projects will have a useful life of more than 50 years, any increase in the length of the amortization period beyond 50 years does not have any very material effect on annual costs. Use of a 50-year period means that, in effect, the project will have been fully paid for within 50 years, and benefits obtained beyond that point will involve no interest or amortization cost.

Thus, as the data in Table 5.1 illustrate, an extension of the amortization period from 50 to 100 years only reduces the combined interest and amortization charge by 12 percent. Accordingly, since use of a longer evaluation period than 50 years would not significantly affect the size of the benefit-cost ratios, a standard 50-year period was adopted for the evaluation of all projects. A similar period is used by the United States Army Corps of Engineers and other authorities in the United States.

Table 5.1

ANNUAL INTEREST AND AMORTIZATION COSTS ON A $10 MILLION PROJECT

Life of Project	Interest (at 4 Percent)	Amortization	Total
20 years	$400,000	$335,817	$735,817
40 years	400,000	105,235	505,235
50 years	400,000	65,502	465,502
60 years	400,000	42,018	442,018
100 years	400,000	8,080	408,080

Interest and amortization charges are calculated on a capital cost for each project which includes not only the cost of constructing the project but also the interest which will have to be paid on borrowed funds during the construction period.

The benefits of a flood-control project consist of the flood damages and flood losses which the project will prevent.

In practice, floods occur at irregular intervals and often cause very high damages when they do occur. The benefit derived from the flood-control scheme consists of the elimination of all or part of these irregularly occurring damages. To reduce the benefits obtained from the elimination of serious damages at irregular intervals to an equivalent average annual benefit which can be compared with the annual cost of a flood control project requires a special analysis The procedure followed is to make a frequency-damage analysis of all possible floods

The frequency of a flood refers to how often on the average it can be expected to occur and is estimated on the basis of past experience It can be expressed either in terms of years or percent For example, according to the frequency study carried out by the Red River Basin Investigation, a flow of 115,000 cubic feet per second or higher on the Red River at Redwood Bridge can be expected to occur once in every 50 years (The 1950 flood flow was 103,600 c f s) This is known as a two percent flood Over a long period of time it is a flood level that can be expected to be reached or exceeded on the average twice in every one hundred years or two percent of the time Similarly, a flow of 95,000 c f s at Redwood has an estimated frequency of once in 29 years or 3 4 percent

A comparison of the frequencies of these two flows indicates that a flood somewhere in the range from 95,000 to 115,000 c f s can be expected to occur on the average with a frequency of 1 4 percent (3 4-2 0), or about once in every 71 years Thus, in a period of 150 years, about five floods of 95,000 c f s or higher could be expected and of these five, some three would exceed 115,000 c f s The remaining two would fall in the range from 95,000 c f s to 115,000 c f s The damages that would be caused in Greater Winnipeg by a flood of this size, a flood of from 95,000 to 115,000 c f s , would amount on the average to $127 million dollars The equivalent in annual terms of these damages can be estimated as the total damages caused by such a flood multiplied by the chance of its occurrence, in this case 1 4% x $127 million, or $1 778,000

Applying a similar analysis to floods of all other sizes, the annual equivalent of the total damages that might be caused by floods of all possible sizes can be estimated This total is the sum of the damages that would be caused by floods of all possible magnitudes multiplied in each case by the percentage frequency with which such a flood can be expected to occur

Such an analysis is illustrated in tabular form for the Greater Winnipeg area in Tables 5 2 and 5 3 The basis of these damage estimates is explained in Chapter 6

Table 5 2 gives the frequency of occurrence and the estimated total damages that would be caused in the Greater Winnipeg area by a series of flood flows taken at 20,000 c f s intervals ranging from 55,000 c f s at Redwood Bridge up to 195,000 c f s Table 5 3 which has been adapted from the material in Table 5 2 shows for all possible sizes of flow at Redwood Bridge, the probability or chance that a flood of a given size will occur and an estimate of the average damages that would be caused by such a flood if it did occur

Table 5 2

FREQUENCY OF OCCURRENCE AND ESTIMATED FLOOD DAMAGES IN GREATER WINNIPEG FOR SELECTED FLOWS AT REDWOOD BRIDGE

Flow at Redwood Bridge (c f s)	Frequency of Occurrence* (in years)	(in percent)	Flood Damages In Greater Winnipeg† (Million Dollars)
(1)	(2)	(3)	(4)
55,000	6 4	15 6	0
75,000	15	6 7	7 4
95,000	29	3 4	63 0
115,000	49	2 0	191 0
135,000	78	1 28	351 0
155,000	120	83	520 0
175,000	185	54	672 0
195,000	265	38	759 0

*See Plate 4

†Damages that would occur in the absence of all dykes. Estimates have also been prepared showing the damages that would occur if all flooding behind the dyking system were prevented The dykes are not 100 percent safe and as the flood level rises, an increasing amount of flooding behind the dyking system can be expected

Equivalent annual damages are obtained by multiplying these estimated average total damages by the chance of their occurence (column 2 multiplied by column 3) These data show that the annual damages for floods of all sizes (assuming no dykes) in the Greater Winnipeg area amount to $13,294,000 The annual damages (column 4) shown in any given row of Table 5 3 give the equivalent in annual terms of the damages caused by floods in that particular size range For example, a flood in the size range from 115,000 to 135,000 c f s would, on the average, cause total damages of $271 million and, since such a flood can be expected to occur with a frequency of 72 percent (once in 139 years), in annual terms this gives a damage of $1,951,000 (72% x $271 million)

A rough check on the above estimate of annual damages can be obtained by asking the following question suppose the same floods were to occur during the next 150 years as Winnipeg actually experienced during the past 150 years? On the basis of this set of floods, what would be the average annual amount of flood damages incurred, assuming throughout this period the same amount of property and income in existence as exists today? (The effects

Table 5 3

FREQUENCY DAMAGE ANALYSIS, GREATER WINNIPEG AREA

Flow at Redwood Bridge (c f s)	Frequency of Occurrence (Percent)	Average Damages ($ Million)	Equivalent Annual Damages ($ thousand)
(1)	(2)	(3)	(4)
Below 55,000	84 4%	$ 0 0	$ 0
55 - 75,000	8 9	3 7	329
75 - 95,000	3 3	35 2	1,162
95 - 115,000	1 4	127 0	1,778
115 - 135,000	72	271 0	1,951
135 - 155,000	45	435 5	1 960
155 - 175,000	29	596 0	1,728
175 - 195,000	16	715 0	1,145
195,000 and over	38	853 0	3,241
Total	100 0%		$13,294

of growth on benefit-cost analysis is discussed in Chapter 9) The answer to this question is provided by the data in Table 5 4 which show estimated damages for each of the seven largest floods recorded in the past 150 years

A period of 150 years has been used rather than the 125 years from 1826 to 1950 because it is reasonable to allow for a number of flood-free years at both the beginning and end of this period Before 1875, records are available only for the three major floods that occurred in 1861, 1852 and 1826 It is possible, therefore, that our list is incomplete and omits some floods of substantial size of which no record is available Nevertheless, even with this possible omission, the estimate of annual damages obtained in this way, $12,283,000, is very close to the estimated total of $13,294,000 obtained in Table 5 3 Thus, the record of actual experience provides a rough check on the method of analysis used in this benefit-cost study

Table 5 4

ESTIMATED FLOOD DAMAGES AND OTHER LOSSES, GREATER WINNIPEG AREA FOR SEVEN MAJOR FLOODS

Year of Occurrence	Size of Flood Discharge in c f s at Redwood Bridge	Flood Damages for such a flood in Greater Winnipeg in 1957 ($ Million)
1826	225,000	$ 852 5
1852	165,000	593 2
1861	125,000	266 7
1950	103,600	114 2
1882	79,700	13 5
1916	71,200	1 8
1948	69,000	6
Total for Seven Floods		$ 1,842 5
Annual Average Basis 150 years		$12,283,000

Although the flood damages in Table 5 4 are those which would occur in the absence of the present dyking system, these totals would not be reduced very much by our present dykes Thus, even if it were possible by emergency dyking to make our present dyking system safe for all floods of less than 100,000 c f s, the above damage total for these seven major floods would only be reduced by about $16 million

In practice, annual damages are estimated by the use of graphs rather than tables, since this permits a more accurate evaluation The procedure used in this volume is as follows

1 A stage (elevation)-discharge curve is prepared This shows for some central reference point (e g Redwood Bridge) the flood water elevations corresponding to different discharges (i e volume of flow measured in cubic feet per second) Such a curve, in engineering parlance a rating curve, is shown in Plate 5, Figure 5A (the upper curve labelled "natural conditions")

2 A stage-damage curve is prepared showing the total flood damages and flood losses that would occur at different floodwater elevations (See Plate 5, Figure 5B) In preparing such a curve, flood damages are estimated for a number of selected elevations and these points are then joined together with a smooth curve

3 A frequency-discharge curve is prepared which shows the frequency with which floods of different sizes can be expected Such a curve had already been prepared for Greater Winnipeg by the Red River Basin Investigation and this is shown in Plate 5, Figure 5C To take a particular flow, say 100,000 c f s, this curve shows that such a flow at Redwood Bridge can be expected to occur on the average 3 percent of the time, or once in every 33 years This means that over a very long period of time a flood flow equal to or exceeding 100,000 c f s at Redwood Bridge can be expected to occur, on the average, once for every 33 years in this period It does not mean that there will be one flood of this magnitude in every 33 years It is perhaps worth noting that since 1826 there have been four floods in Greater Winnipeg which exceeded 100,000 c f s

4 A frequency-damage curve is then constructed with the data given in the above three curves (See Plate 5, Figure 5D) Thus, if we take a given discharge, say 135,000 c f s, we can obtain the corresponding flood elevation at Redwood Bridge from Figure 5A, namely 760 feet above mean sea level At this elevation

we can find the total flood damages in this reach, $112,000,000 from Figure 5 B (follow the line of arrows to the right). Using Figure 5 C we find that 135,000 c.f.s. occurs with a frequency of 1.3 percent or once in 77 years. Accordingly, we plot this point, $112 million and 1.3 percent in Figure 5D. Similarly, the frequencies and damages for other flood discharges can be plotted. Joining up these plotted points gives us the smooth curve in Figure 5D.

The total area under this curve which can be measured with an instrument called a planimeter is a measure of the annual damages caused by all floods in this particular reach of Greater Winnipeg. Any one square under the curve in Figure 5B is equal in terms of Average Annual damages to $200,000 (1% x $20 million).

A similar analysis can be carried out for other segments of the Greater Winnipeg area. The average annual damages obtained for each reach can then be added together to obtain the total equivalent annual damage for the entire Greater Winnipeg area. When this is carried out, a total of $12,870,600 is obtained, somewhat less than the rough estimate given in Table 5.3 above but somewhat more than the amount obtained in Table 5.4. Thus, these three different estimates give results which are of the same general size.

This set of curves may then be used to evaluate the flood protection benefits arising from any particular project. This has been illustrated by showing the effects on each of the figures in Plate 5, of a hypothetical project which would reduce the flow at Redwood Bridge by 30,000 cubic feet per second.

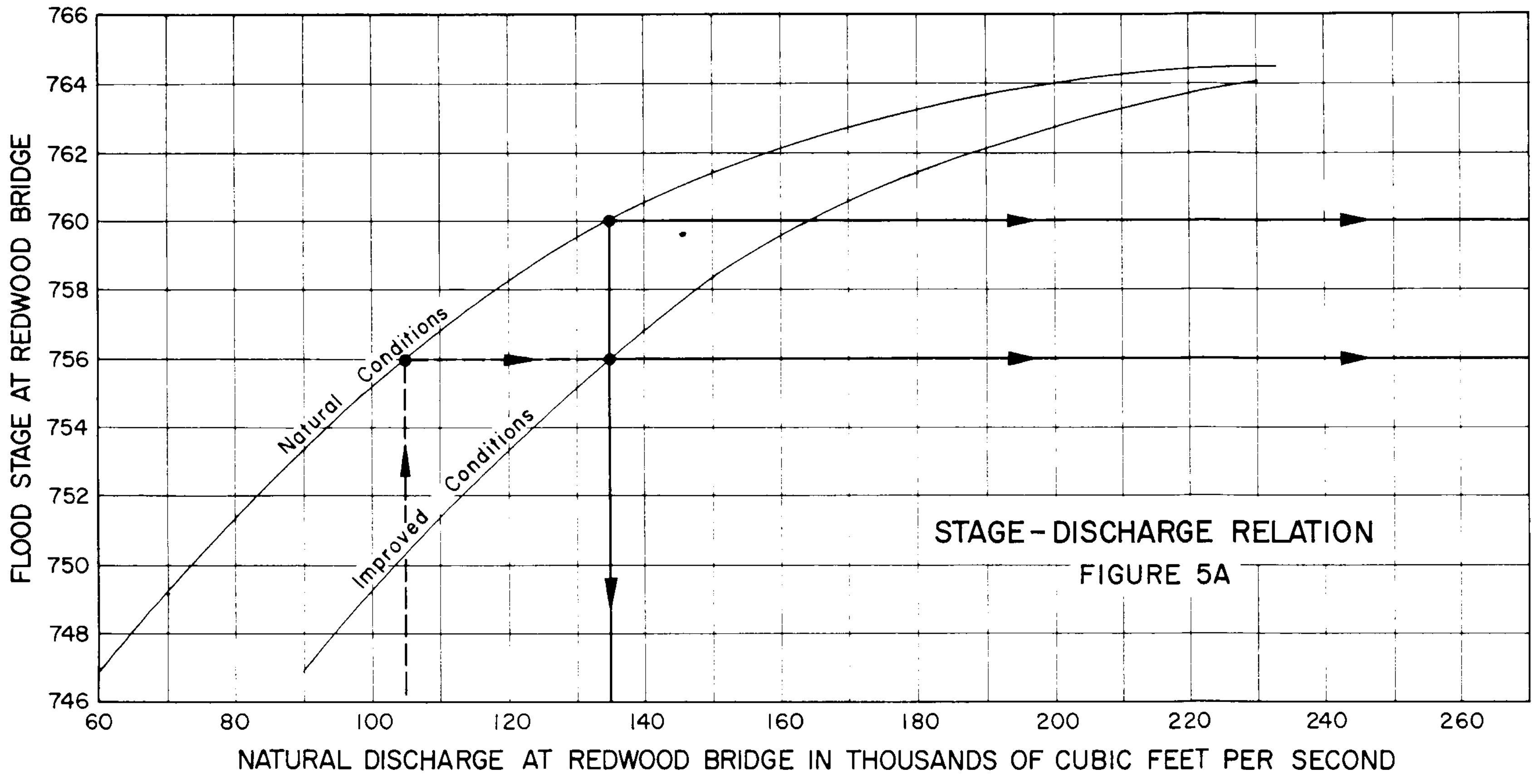
In the analysis used here it is assumed that the horizontal axis on Figures 5A and 5C, labelled *Natural Discharge at Redwood Bridge*, measures at all times the total flow in the River System. In other words, it measures the flow that would have reached Redwood Bridge in the absence of any improvements. On this assumption, the effects of the removal of 30,000 c.f.s. are to produce a lower elevation at Redwood Bridge for the same total flow in the river system (See Figure 5A). Thus, a total discharge of 135,000 c.f.s. will be reduced to 105,000 c.f.s. at Redwood Bridge and this will give an elevation of 756 feet, four feet below the flood elevation produced by 135,000. The new elevations with the improvement, which removes 30,000 c.f.s. in effect, are shown by the curve labelled "improved conditions" in Figure 5A. (It should be noted that this curve is not a rating curve in the ordinary sense, that is, a curve showing elevations plotted against actual discharges at that point.)

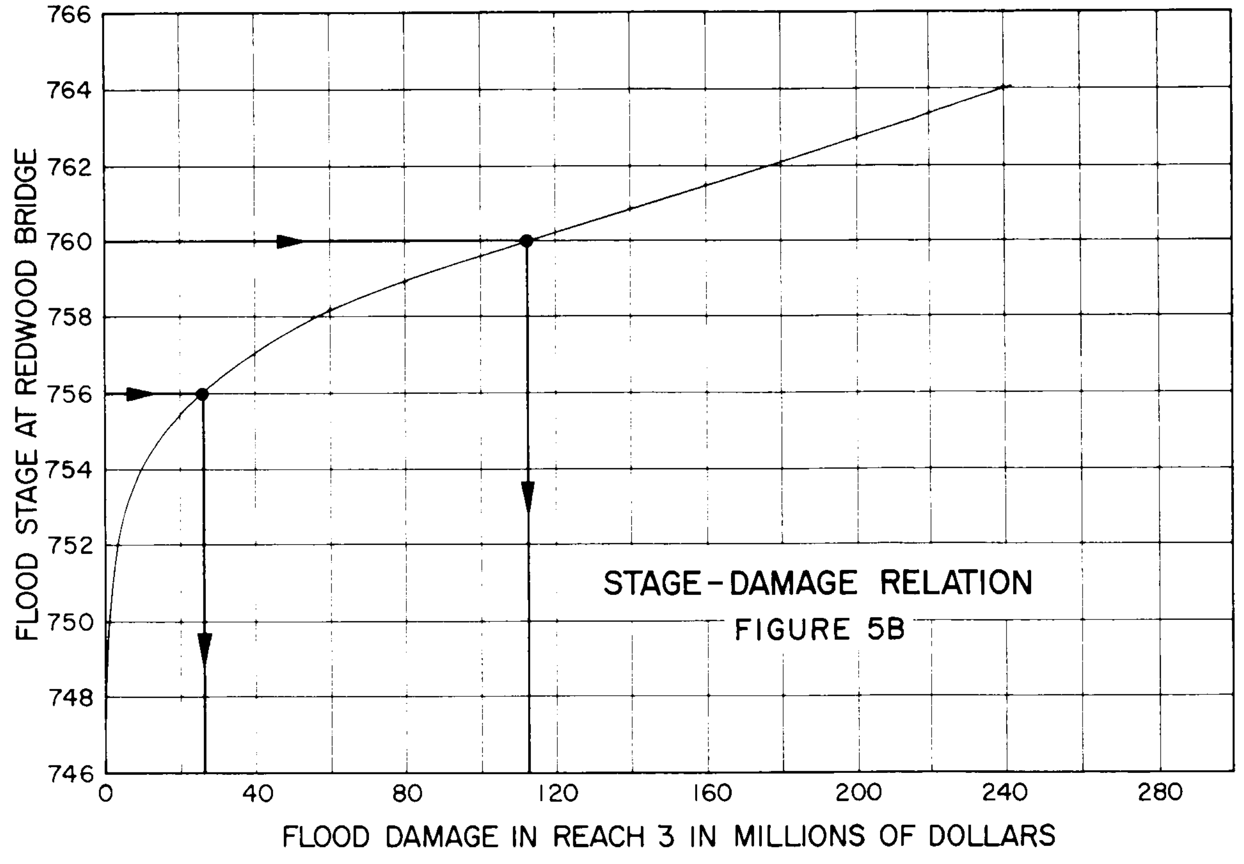
These new lower elevations result in smaller flood damages. Thus, at a total natural discharge of 135,000 c.f.s., the removal of 30,000 c.f.s. produces an elevation of 756 feet at Redwood Bridge, some four feet lower than under unimproved conditions and the damages at this elevation are only $26 million, substantially less than the $112 million of flood damages that would have been caused by a total flow on the river system of 135,000 c.f.s. under unimproved conditions (See Figure 5B). This new lower damage total is now plotted on Figure 5D opposite the frequency for a flow of 135,000 c.f.s., that is, 1.3 percent (follow the line of arrows across and down).

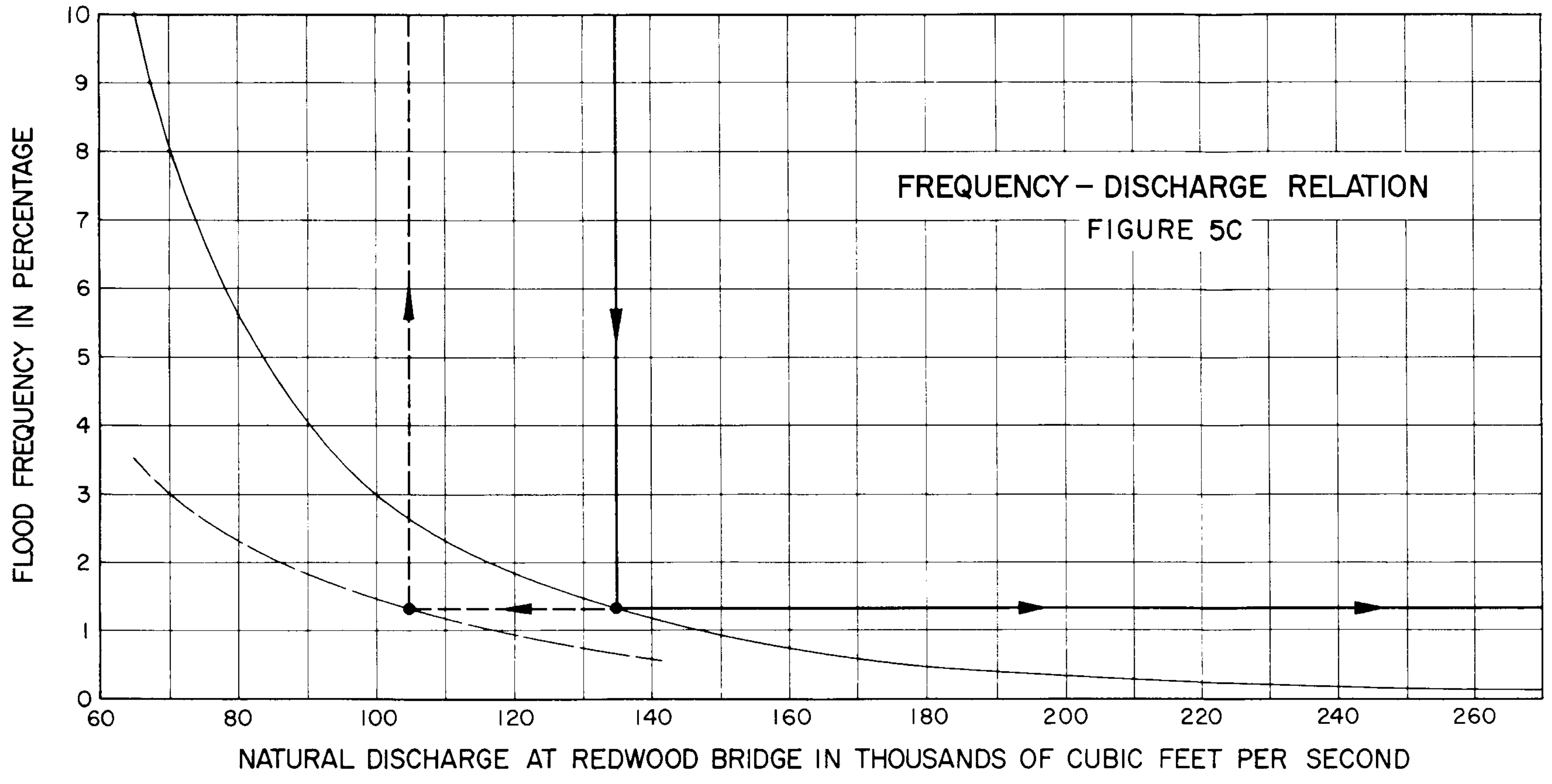
In a similar way, the new lower damages can be plotted for other flood flows. When these points are joined up, the new frequency damage relation shown by the line labelled "improved conditions" in Figure 5D is obtained. The benefit to Greater Winnipeg is then measured by the area enclosed by the original line (labelled "natural conditions") and the line below it (labelled "improved conditions"). This measures the difference between the average annual damages caused by floods of all sizes in Greater Winnipeg under natural conditions and the damages that would occur with such an improvement in effect. This difference, in this case $1,865,500, is the annual benefit that will be derived from this particular project in Reach 3 of the Greater Winnipeg area. A similar analysis can be applied to Reaches 1 and 2. The sum of the annual benefits for the 3 reaches gives the total benefit of this particular project. The benefit-cost ratio for the project is then obtained by dividing this annual benefit by the annual cost of the project.[1]

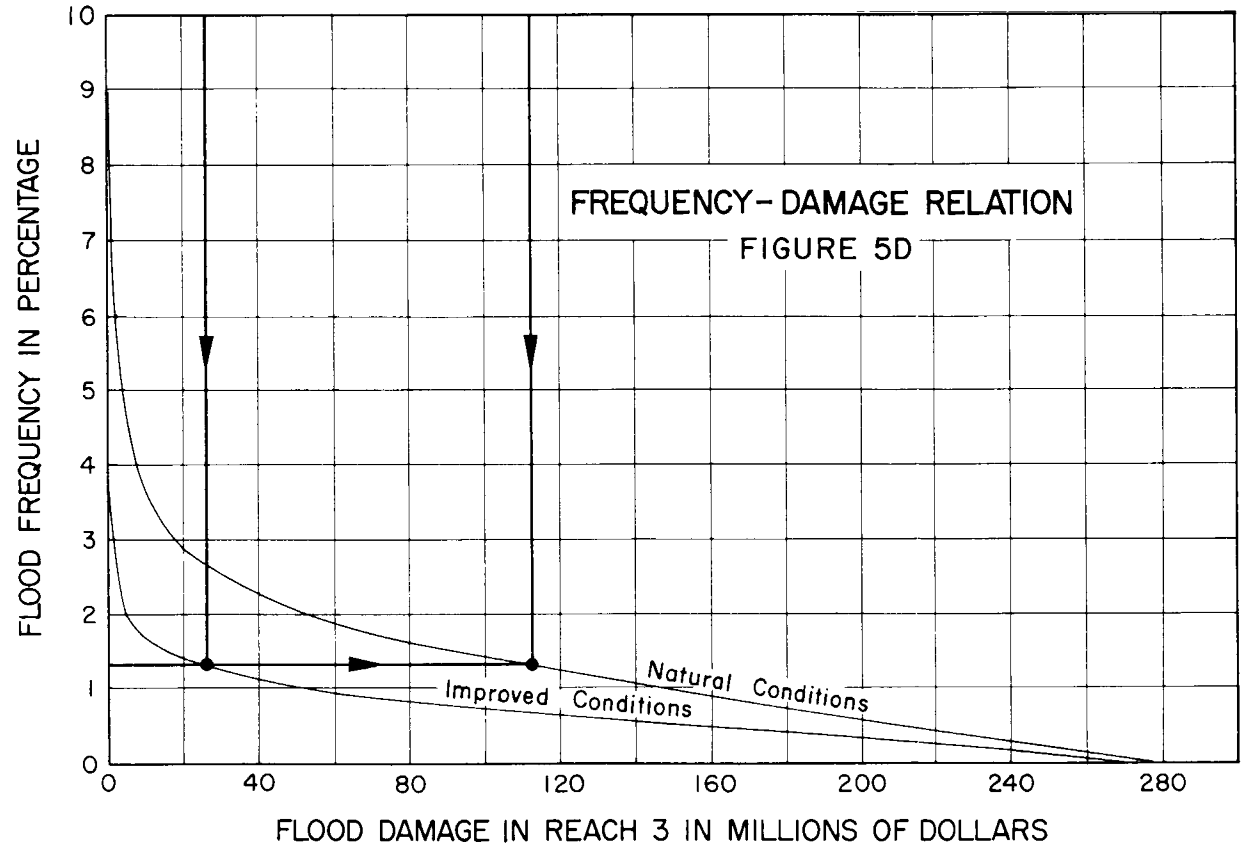
The annual benefit calculated with either of these two approaches takes account of the reduction in flood damages achieved for floods of all possible sizes. The area enclosed by the "natural conditions" and "improved conditions" curves in Figure 5D is a measure of the annual damages eliminated by the project in question.

1 In an alternative method of presenting this same result, the horizontal axis in Figures 5A and 5C refers to the actual discharge at Redwood Bridge rather than the total flow that would have reached that point in the absence of any improvements. In this type of presentation, the effects of diverting 30,000 c.f.s. out of the river are shown in Figure 5C (see dotted line), rather than on Figure 5A. Thus, with 30,000 c.f.s. diverted out of the river at all discharges a total flow of 135,000 in the river system will now give a flow of only 105,000 c.f.s. at Redwood Bridge. Hence, a flow of 105,000 c.f.s. at Redwood Bridge will now occur at the same frequency as formerly applied to a flow of 135,000 c.f.s., that is 1.3 percent. In a similar way, other points on this new discharge frequency curve can be established. Then for each point on the new discharge frequency curve (see dotted curve Figure 5C) a new elevation can be read off Figure 5A. Thus, for a flow of 105,000 c.f.s. at Redwood Bridge the elevation on the natural conditions curve in Figure 5A is 756 which is the same elevation obtained in the approach explained above. Following the line of arrows to Figure 5B gives the same damages of $26 million and this can then be plotted on Figure 5D opposite the new frequency for 105,000 c.f.s. (1.3 percent), which gives the same point as obtained in the original analysis. Thus, each of these approaches gives identical results.









NOTE:

This plate shows the derivation of average annual flood damages for one section of Greater Winnipeg: (1) under assumed natural conditions (no dyking system in existence) and (2) after construction of a hypothetical control project which would have the effect of reducing all natural discharges at Redwood Bridge by 30,000 cubic feet per second.

The area of graph located below the natural frequency-damage curve measures average annual damages under natural conditions. The area of graph located below the improved frequency-damage curve measures average annual damages remaining after the hypothetical control project is in effect. The area of graph located between these two curves measures the average annual benefits-the reduction in average annual damages-which may be attributable to the project.

The stage-damage and frequency-damage relations shown in this plate cover the following areas of Greater Winnipeg: Ward III of the City of Winnipeg, the City of East Kildonan, the R.M. of West Kildonan, the R.M. of North Kildonan, the R.M. of Old Kildonan, the R.M. of East St. Paul, the R.M. of West St. Paul and the Town of Transcona. These municipalities together constitute Reach 3.

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ANALYSIS OF BENEFITS

30,000 C.F.S. DISCHARGE REDUCTION

GREATER WINNIPEG - 1957
REACH 3

DECEMBER 1958

If, in Figure 5D, we were to draw horizontal lines though the 1 percent frequency, the 2 percent frequency, the 3 percent frequency and so on, the areas enclosed by the "natural conditions" frequency-damage curve above and below each of these lines can be interpreted in the following way The area above a horizontal line through the 1 percent frequency and enclosed by the "natural conditions" frequency damage curve and the vertical axis is a measure of the annual damages caused by all floods with a frequency of 1 percent or greater, or in terms of discharge, by all floods of the magnitude of 147,000 c f s or smaller The corresponding area below a horizontal line through the 1 percent frequency in Figure 5D is a measure of the annual damages caused by all floods that occur with a frequency of 1 percent or less, or, in terms of discharge, all floods of the magnitude of 147,000 c f s or larger An inspection of the area enclosed by the "improved conditions" and "natural conditions" curves in Figure 5D indicates that the particular project being analyzed would eliminate most of the damage caused by floods with a frequency greater than 1 percent, a substantial part of the damages caused by floods that occur with a frequency of between 1 percent and 5 percent, but only a relatively small part of the damages caused by the rare floods with a frequency of 5 percent or less

Separation of the flood damages in a particular area into a number of reaches is necessary for benefit-cost analysis wherever the project being analyzed causes different changes in floodwater elevation at different points along the river Thus, channel improvement below Winnipeg would reduce flood stages by progressively smaller amounts for points further upstream from the improvement The procedure followed in these circumstances is to divide the total flooded area into a number of reaches Each reach runs out to the edge of the potentially flooded area on either side of the river and more or less at right angles to it A central reference point is selected for each reach and a stage-discharge and stage-damage curve is prepared for this point It is assumed that the change in flood elevations at this central point resulting from any improvement is representative on the average of the change that occurs throughout that entire reach of the river

Thus, in the calculation of benefits for any area, three basic relationships are necessary a frequency-discharge curve, a stage-discharge curve, and a stage-damage curve From these three relations, it is possible to obtain the damage-frequency curve on which the calculation of benefits is based Frequency-discharge curves on both the Red and Assiniboine Rivers and rating curves for a number of points were available from the earlier engineering reports In this study, one of our major tasks has been the construction of stage or discharge-damage relations for Greater Winnipeg and for various reaches of the Red and Assiniboine River Valleys These damage estimates are presented in the following three chapters

STAGE-DAMAGE RELATIONS GREATER WINNIPEG

Before any benefit-cost ratios can be calculated, it is necessary to prepare estimates of the flood damages that will occur at different flood stages or elevations. From these, a stage-damage curve is prepared showing the relationship between floodwater elevations and flood damages. In preparing this curve, the procedure followed is to select a number of flood elevations and calculate the flood damages and other flood losses that would occur if each of these elevations were reached. These estimated damages are then plotted against their corresponding flood elevations and a smooth curve is drawn through them such as that shown in Plate 5, Figure 5B (See Chapter 5). In some circumstances, flood damages may be more conveniently related directly to the volume of flow or discharge rather than to the flood elevation and a discharge-damage curve prepared. This latter approach was used in the Red and Assiniboine River Valleys.

For the studies undertaken by this Commission, flood damage estimates were prepared for each of three main regions, the Greater Winnipeg area, the Red River Valley between Emerson and Winnipeg and the Assiniboine River Valley from Millwood to Winnipeg. In each instance, these areas were broken up into a number of reaches and separate stage or discharge-damage curves were prepared for each reach. Each of these areas will be considered in turn.

In this study the term "flood damages" is used to cover not only damages to property caused by floods but a broad range of other losses occasioned by floods, such as loss of income and extra costs incurred by flood-fighting, evacuation or clean-up after the flood. Damage estimates are based on the property and incomes in existence in 1957. Estimates of the larger flood damages that would be incurred some 25 years from now have also been prepared for the Greater Winnipeg area. These are described in Chapter 9.

GREATER WINNIPEG AREA

In preparing stage-damage relations for the Greater Winnipeg area, the entire area was divided into three reaches. For some purposes, such as the evaluation of the removal of Lister's Rapids, two of these reaches were in turn broken down into two sub-reaches. The areas included in each of these three reaches and the central reference points selected for each were as follows:

	Areas Included	Reference Point
Reach 1	Municipalities of St. Vital and Fort Garry north of proposed Greater Winnipeg Floodway and its adjoining dyke	Mile 53 (located near the eastward extension of Oakenwald Avenue)
Reach 2	Wards I and II in Winnipeg, and St. Boniface, St. James, Tuxedo, Brooklands and Rosser	Main Street Bridge
Reach 3	Ward III in Winnipeg and East Kildonan, West Kildonan, North Kildonan, Old Kildonan, Transcona, East St. Paul and West St. Paul	Redwood Bridge

Reaches 2 and 3 were broken down into 2 sub-reaches for the analysis of projects which produced a sharply altered water profile through the Greater Winnipeg area. These sub-reaches and their reference points are as follows:

	Area Included	Reference Point
Reach 2 (a)	Ward I in Winnipeg and St. Boniface	Mile 48 (located near the eastward extension of McMillan Ave.)
Reach 2 (b)	Ward II in Winnipeg and St. James, Tuxedo, Brooklands and Rosser	James Avenue
Reach 3 (a)	Ward III in Winnipeg	Redwood Bridge
Reach 3 (b)	The four Kildonans, East and West St. Paul and Transcona	Mile 42 (located near the eastward extension of Seven Oaks Ave.)

For each of these reaches, estimates were prepared of the flood damages that would be incurred if floods of some seven different sizes were to occur. In addition, for two of these floods, estimates were prepared both for the flood damages that would occur if the floodwaters were successfully contained behind the main dyking system at all points throughout the Greater Winnipeg area and for the damages that would occur if the dykes were overtopped at all points. The magnitude of each of these floods in terms of its discharge at Redwood Bridge and the elevation that would be reached in each of the three reaches of the city are given in Table 6.1. The total flood damages that could be anticipated in each reach and in the Greater Winnipeg area as a whole if these floods were to occur today are shown in Table 6.2.

On the basis of the data in these two tables, stage-damage curves were prepared for each of these reaches and for sub-reaches in Reaches 2 and 3 These curves are shown in Plates 6, 7 and 8 The lower curve on each diagram shows the flood damages that would occur in the absence of all dyking The upper curve shows the much smaller damages that would be incurred if the floodwaters were confined entirely by the main dyking system The intermediate curve is an estimate of the damages that would probably be incurred It assumes that as the floodwaters rose, an effort would be made to confine them by the construction of temporary dykes on top of the existing permanent dykes However, it has been assumed that these flood-fighting efforts would not be entirely successful Thus, as higher and higher elevations were reached, there would be a progressive increase in the risk of failure until at about a level of 32 feet in terms of city datum, the entire dyking system would have been overtopped From this point forward, the intermediate line merges with the lower curve

It is clear from an examination of Table 6 2 that the flood damages and other flood losses that would be caused by a major flood in the Greater Winnipeg area are extremely large For example, if a flood of the size that occurred in 1852 were to recur today, it is estimated that the total loss would amount to $593 million Even a flood of the 1950 magnitude would impose a loss of $114 million on the city if the temporary dyking failed entirely and flooding was general behind the main dyking system Though these figures are very large, they are based on a very thorough analysis and we are convinced that they represent a fair and honest evaluation of the flood losses that would occur Indeed, if they err in any respect, it is that they are too low since, as will be pointed out below, they deliberately omit a variety of damages that either proved difficult to evaluate accurately or were omitted because they were of secondary importance and they make no direct allowance for many intangible considerations such as the possible loss of life and the disruption, anxiety and heartbreak caused by a major flood

Table 6 1

DISCHARGE AT REDWOOD BRIDGE AND ELEVATIONS AT 3 REFERENCE POINTS FOR SEVEN MAJOR FLOODS, GREATER WINNIPEG AREA

Flood Designation	Discharge at Redwood Bridge c f s	Elevation in Feet Above Sea Level			
		Reach 1 Mile 53	Reach 2 Main St Bridge	Reach 3 Redwood Bridge	Elevation in Feet above City Datum at James Ave
1948 Flood	69 000	753 4	751 3	749 0	23 2
26′ above City Datum	81,000	756 3	754 0	751 7	26 0
1950 Flood	103,600	760 7	758 3	755 9	30 2
1861 Flood	125,000	762 9	760 5	759 0	32 3
1852 Flood	165 000	765 3	763 0	762 6	35 2
1826 Flood	225 000	767 7	765 2	764 5	37 3
Max Probable Flood	270,000	769 0	766 5	764 8	39 0

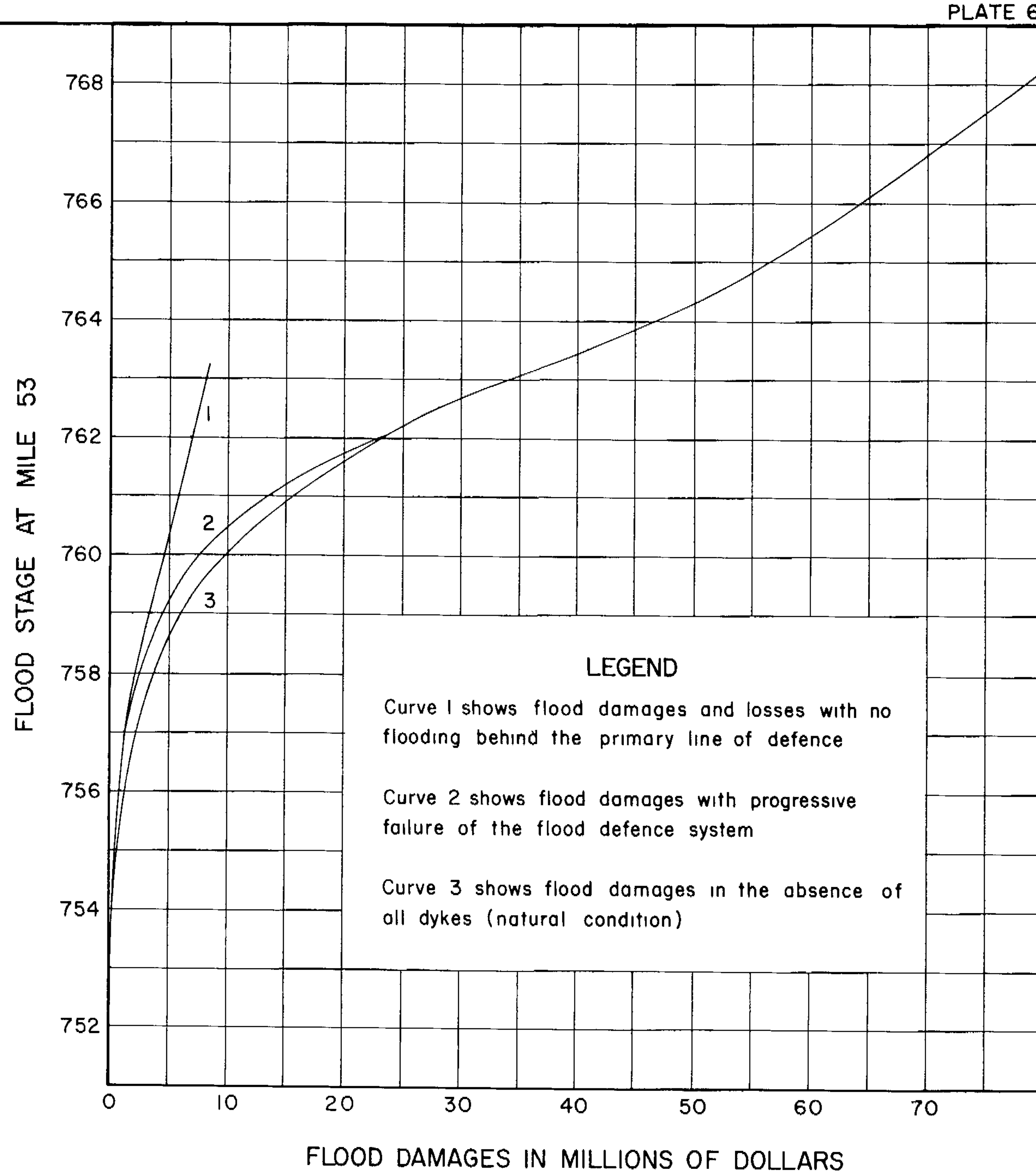
Table 6 2

ESTIMATED FLOOD DAMAGES, 1957, GREATER WINNIPEG AREA, BY REACHES FOR SEVEN MAJOR FLOOD MAGNITUDES

Flood Designation	Discharge at Redwood Bridge c f s	Total Flood Damages Reach 1	Reach 2	Reach 3	Total for All Reaches
		(Thousands of Dollars)			
1948 Flood	69,000	$ 270	$ 230	$ 150	$ 650
26′ above City Datum (Condition 1)	81,000	1,500	13,300	2,800	17,600
26′ above City Datum (Condition 2)	81,000	1,000	1,600	400	3,000
1950 Flood (Condition 1)	103,600	13,900	76 500	23,800	114,200
1950 Flood (Condition 2)	103,600	5,400	14 600	4 800	24,800
1861 Flood	125,000	33 500	154 000	79,200	266,700
1852 Flood	165,000	59 700	340,000	193,500	593,200
1826 Flood	225 000	76,500	523,500	252,500	852 500
Max Probable Flood	270 000	84,700	602 000	261,000	947,700

NOTE Condition 1 gives the damages that would occur if flooding were general behind the main dyking system Such a possibility is extremely remote for a flood level of 26 feet above city datum but it is a definite risk at the 1950 flood level

Condition 2 gives the damages that would occur if all flooding behind the main dyking system were prevented by emergency flood-fighting measures (temporary dyking, etc)



OUTLINE OF REACH I
GREATER WINNIPEG

Reach I, with Mile 53* as its central reference point, represents the following areas of Greater Winnipeg the R M of Fort Garry and the R M of St Vital

*Mile 53 is located approximately at the eastward extension of Oakenwald Avenue

ROYAL COMMISSION ON FLOOD COST-BENEFIT

STAGE - DAMAGE RELATIONS

GREATER WINNIPEG - 1957
REACH I

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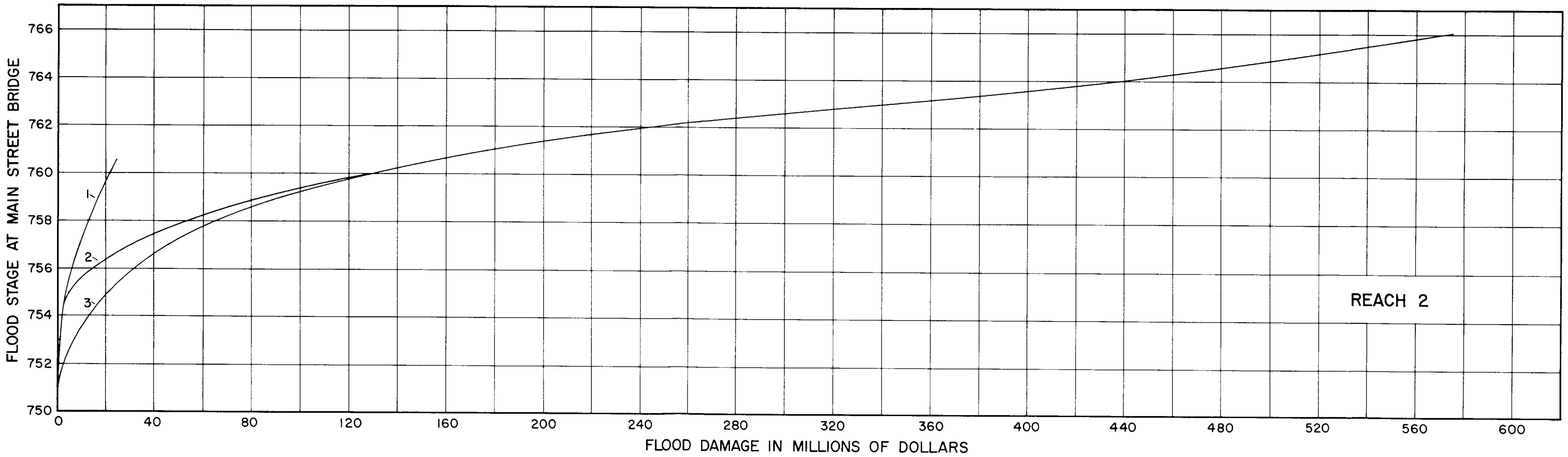
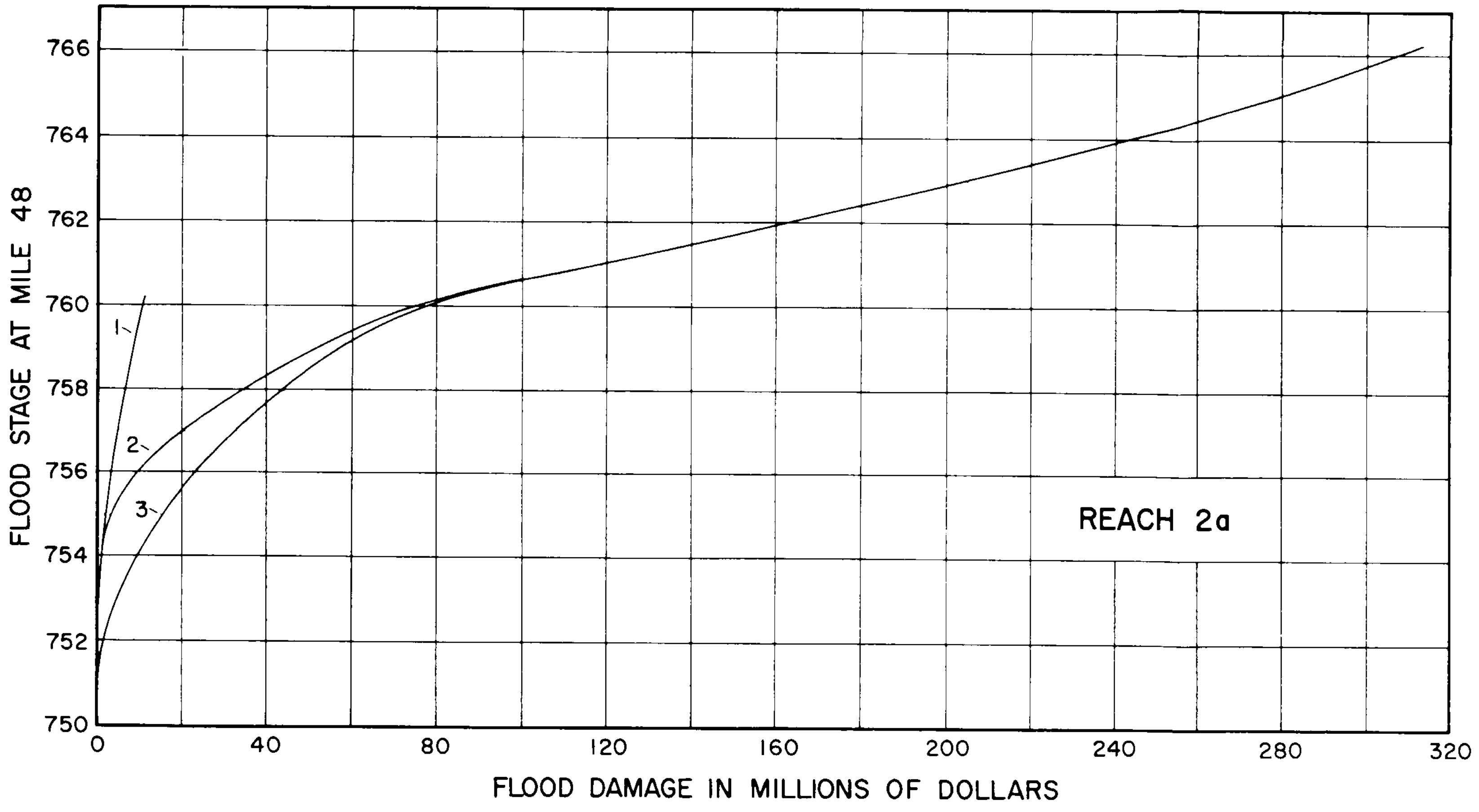
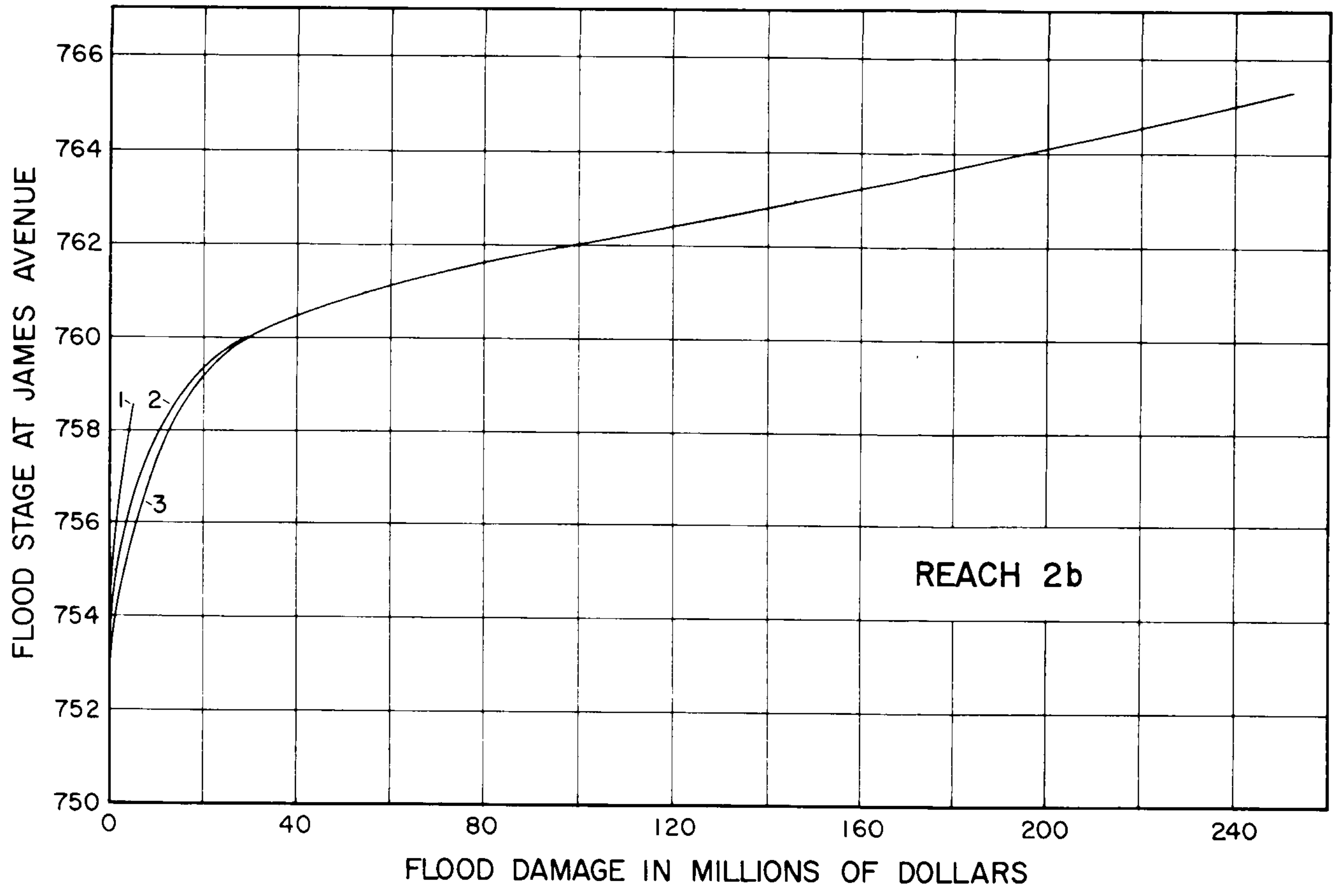






OUTLINE OF REACHES 2, 2a and 2b GREATER WINNIPEG

Reach 2, with Main Street Bridge as its central reference point, represents the following areas of Greater Winnipeg: the City of St. Boniface, Ward I of the City of Winnipeg, Ward II of the City of Winnipeg, the City of St. James, the Town of Tuxedo, the Village of Brooklands and the R.M. of Rosser.

Two smaller reaches, which together comprise the total area of Reach 2, are constituted as follows:

Reach 2a, with Mile 48* as its central reference point, represents the City of St. Boniface and Ward I of the City of Winnipeg.

Reach 2b, with James Avenue as its central reference point, represents Ward II of the City of Winnipeg, the City of St. James, the Town of Tuxedo, the Village of Brooklands and the R. M. of Rosser.

*Mile 48 is located approximately at the eastward extension of McMillan Avenue.

LEGEND

Curve 1. shows flood damages and losses with no flooding behind the primary line of defence.

Curve 2. shows flood damages with progressive failure of the flood defence system.

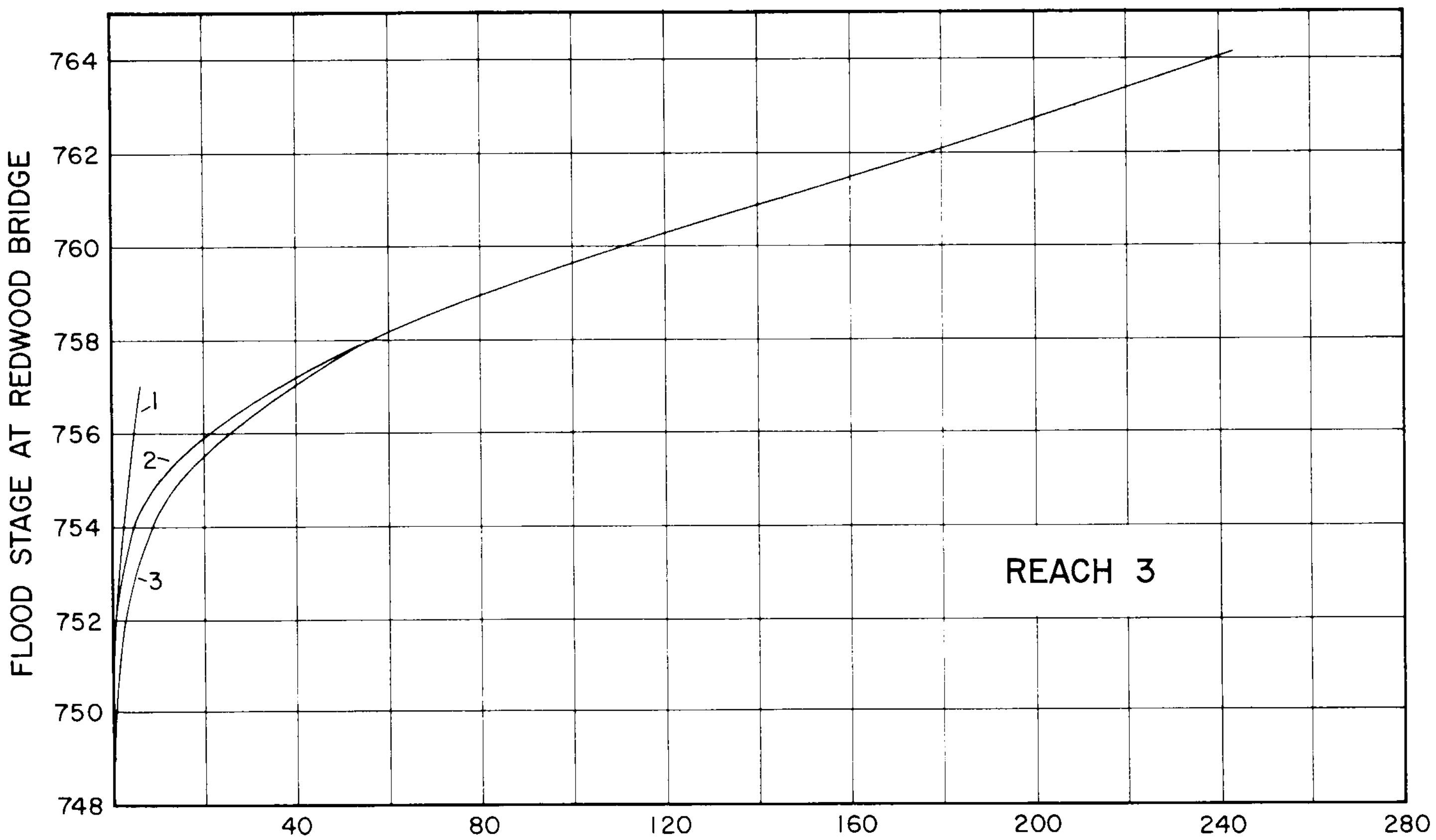
Curve 3. shows flood damages in the absence of all dykes (natural condition).

ROYAL COMMISSION ON FLOOD COST-BENEFIT

STAGE - DAMAGE RELATIONS

GREATER WINNIPEG - 1957 REACHES 2, 2a and 2b

DECEMBER 1958



OUTLINE OF REACHES 3, 3a, and 3b
GREATER WINNIPEG

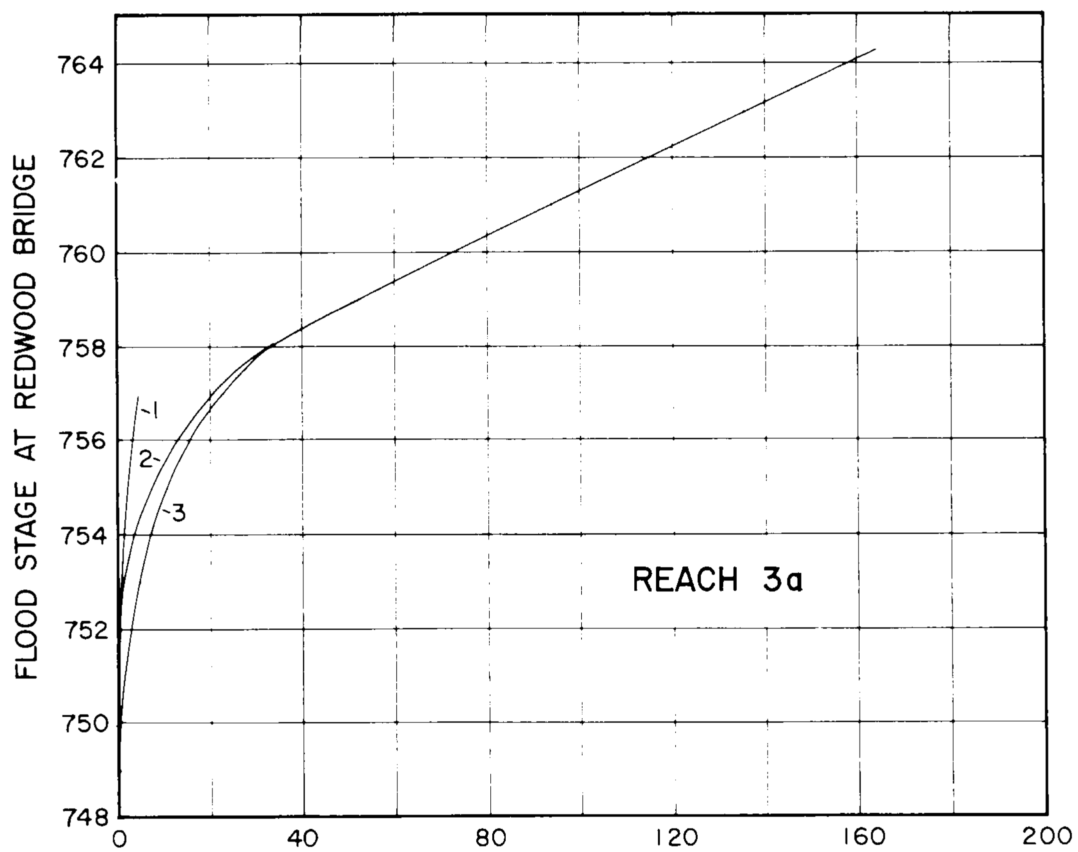
Reach 3, with Redwood Bridge as its central reference point, represents the following areas of Greater Winnipeg: Ward III of the City of Winnipeg, the City of East Kildonan, the R. M. of West Kildonan, the R. M. of North Kildonan, the R. M. of Old Kildonan, the R. M. of East St. Paul, the R. M. of West St. Paul and the Town of Transcona.

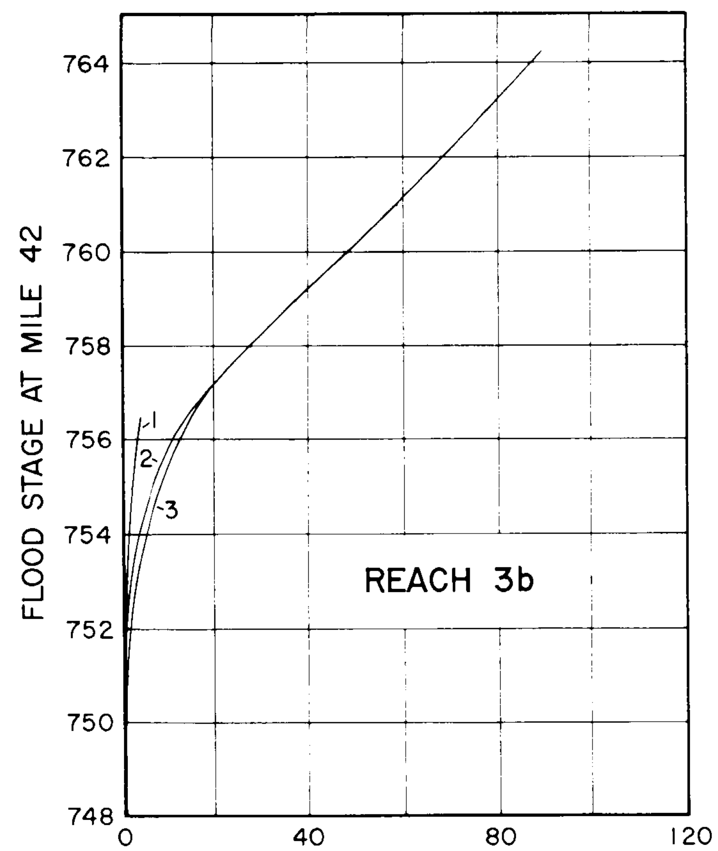
Two smaller reaches, which together comprise the total area of Reach 3, are constituted as follows:

Reach 3a, with Redwood Bridge as its central reference point, represents Ward III of the City of Winnipeg.

Reach 3b, with Mile 42* as its central reference point, represents the City of East Kildonan, the R. M. of West Kildonan, the R. M. of North Kildonan, the R. M. of Old Kildonan, the R. M. of East St Paul, the R. M. of West St. Paul and the Town of Transcona.

*Mile 42 is located approximately at the eastward extension of Seven Oaks Avenue.





FLOOD DAMAGE IN MILLIONS OF DOLLARS

LEGEND

Curve 1 shows flood damages and losses with no flooding behind the primary line of defence.

Curve 2 shows flood damages with progressive failure of the flood defence system.

Curve 3 shows flood damages in the absence of all dykes (natural conditions).

ROYAL COMMISSION ON FLOOD COST-BENEFIT

STAGE - DAMAGE RELATIONS

GREATER WINNIPEG - 1957
REACHES 3, 3a and 3b

DECEMBER 1958

Table 6 3

ESTIMATED FLOOD DAMAGES, 1957, GREATER WINNIPEG AREA BY TYPE OF DAMAGE FOR SIX MAJOR FLOODS

Type of Damage	1948 (69,000 c f s)	26′ above City Datum (81,000 c f s)		1950 (103,600 c f s)		1861 (125,000 c f s)	1852 (165,000 c f s)	1826 (225,000 c f s)
		Condition 1	Condition 2	Condition 1	Condition 2			
				(Thousands of dollars)				
Buildings and Contents								
Dwellings	$221	$ 6,581	$1,018	$ 39,827	$ 7,687	$ 78 557	$186,435	$309,336
Apartments		799	25	5 410	991	9,596	16 960	22,311
Business and Institutional	15	5,934	843	44,372	9,302	72,216	166 319	239,772
Public Schools and Government		480	11	2,552	205	6 114	13 853	21 179
Sub-Total	$236	$13 791	$1 897	$ 92,161	$18 185	$166,483	$383,570	$592,598
Public Utilities and Railways	54	360	130	2 070	549	4 566	7,555	9,553
Loss of Income	47	2,111	346	13,941	3,155	81,000	172,000	216,000
Extra Costs	13	280	27	3 375	1,911	9,809	21,784	25 549
Streets, Roads Bridges and Sewers		455		1,653		3 842	7,291	7,800
Flood Fighting	300	600	600	1,000	1 000	1,000	1,000	1,000
	$650	$17 600	$3 000	$114 200	$24 800	$266 700	$593 200	$852 500

Note Condition 1 gives the damages that would occur if flooding were general behind the main dyking system
Condition 2 gives the damages that would occur if all flooding behind the main dyking system were prevented by emergency flood fighting measures

Our estimate of the damages that would be caused in Greater Winnipeg if a flood of the 1950 magnitude were to recur today is much higher than the total amount of damages paid by the Red River Valley Board and the Manitoba Flood Relief Fund In very considerable measure this is due to the fact that the major part of St Boniface was protected by the Lyndale dyke in 1950 whereas our estimates are for the damages that would occur if flooding became general behind the main dyking system Almost one-third of our estimated damages and other losses, for a 1950 flood, are those that would occur in the City of St Boniface In addition, the damage payments made in 1950 did not include damages and loss of income suffered by many business firms Then, too, there has been a very considerable growth since 1950 in many flood-prone areas Further, the rise in prices and incomes since that date, increases the dollar value of any damages that occur

Estimates of flood damages and losses were prepared under the following major headings buildings and contents, with a breakdown for dwellings, apartments, business and institutional buildings, public schools and government buildings, public utilities and railways, loss of income, extra costs, streets, roads, bridges and sewers, and flood fighting costs Estimates for major floods under each of these headings are presented in Table 6 3 A general discussion of the methods followed in preparing these estimates is presented in this chapter Further details are given in Appendix E

To estimate damages in each of the designated floods it was first necessary to prepare a map showing flood levels throughout the Greater Winnipeg area Such a map, showing flooded areas for floods of the 1950, 1852 and 1826 magnitudes, is enclosed in an envelope on the back cover of this volume With this map, a related map showing lines of equal water elevation and a contour map of the area, it was possible to establish average flood levels on a block by block basis throughout the Greater Winnipeg area for each of the 26 foot, 1950 and 1852 flood levels For the other floods considered, flood levels were established by adding or subtracting a given amount to one of the three initially established flood levels, or in the case of the 1948 flood, to the flood levels recorded on individual houses by the Red River Valley Board in 1950 This information on flood levels provided the basis for estimating flood damages under each of the following categories

1 Residential Dwellings

For each block in the Greater Winnipeg area, the average and total assessed value of residential dwellings was estimated on a sample basis Flood damages were then estimated by applying a damage to assessed value relationship obtained from our analysis of the files of the Red River Valley Board and the Manitoba Flood Relief Fund The former provided a measure of the damages that the 1950 flood had caused to residential dwellings The latter provided similar information for damages to personal property in these dwellings

A detailed statement of the way in which these damages to assessed value ratios were prepared, together with a series of charts and tables showing these relations, has been included in Appendix E Since these data were expressed in terms of 1950 prices, it was necessary to adjust them for the rise in prices that had occurred since that time After an examination of price and wage rate indices it was decided to increase the real property damages by 25 percent and the personal property damages by 15 percent to put them on a 1957 price basis Both these increases are believed to be conservative

Because flood damages increase rapidly whenever flood waters rise above the floor level of the house, a small difference in the average level assumed for the floor level of residential property could significantly affect the size of the damage estimates In this study, it was assumed, after consultation with a number of

Table 6 4

FLOOD DAMAGES TO DWELLINGS* AND CONTENTS AND NUMBER OF DWELLINGS AFFECTED, MAJOR FLOODS, GREATER WINNIPEG AREA

Flood Magnitudes	Flood Damages§	Av Damage per Dwelling	Number of Dwellings Flooded: Total Number	Number of Dwellings Flooded: Number Flooded Over 1st Floor
	(Thousands)			
26 above City Datum†	$ 6,581	$1 803	3,650	1,640
1950†	39,827	2,037	19,550	8 430
1861	78,557	1 956	40,170	21,730
1852	186,438	2 647	70,440	48,740
1826	309,336	4,025	76,850	69,730

*Excludes apartments

§Includes damages to houses affected by seepage

†Assumes flooding is general behind the main dyking system

informed individuals, that on the average dwelling, floor levels in the Greater Winnipeg area are about 2 ½ feet above the contour level shown for their location A study of a special sample of the houses flooded in 1950 confirmed the general validity of this assumption

Total damages to dwellings and their contents for each of the floods considered and the number of dwellings flooded are shown in Table 6 4

Thus, in a flood of the 1852 magnitude it has been estimated that about 70,440 dwellings would be flooded in the Greater Winnipeg area and of these, some 48,740 would be flooded over the first floor The total damages to dwellings and contents would amount to $186 4 million or an average of $2,647 per dwelling flooded Of this total, some $50 3 million, or about 27% of the total, represents damages to the personal property of the owner or tenant

It is evident from the above table that our estimate of the flood damages to residential dwellings and their contents that would be caused by a flood of the 1950 magnitude are substantially higher than the payments actually made in 1950 by the Red River Valley Board and the Manitoba Flood Relief Fund for losses of this type Our estimates show that as of 1957, a flood of the 1950 magnitude would inundate some 19,550 houses and of this total, 8,430 would be flooded over the first floor and an additional 6,600 would be affected by seepage Total damages to dwellings and their contents would amount to $39 8 million These estimates are for the damages that would occur if the entire dyking system were overtopped In contrast, the Red River Valley Board paid damage claims on only about 8,500 houses in the Greater Winnipeg area Of these, only about 4 000 were flooded over the main floor No exact figure is available for the claim payments made to home owners or tenants in the Greater Winnipeg area in 1950 but we have estimated the amount at close to $10 million, about 7 5 million by the Red River Valley Board and the balance by the Manitoba Flood Relief Fund In addition, very substantial damage payments were made by private insurance companies

The difference between these two figures is accounted for by a number of factors first, the rise in prices since 1950, some 25 percent for houses and 15 percent for their contents, would increase the 1950 damage payments by about $2,250,000, second, a large number of homes in low-lying areas were protected by successful dyking in 1950 This was particularly true of St Boniface where the Lyndale Dyke held throughout the flood Our estimates for St Boniface show that, with all dykes overtopped, a 1950 magnitude flood would inundate some 5,720 dwellings in this area whereas in 1950 damage payments were made on about 500 A still further difference between the 1950 actual damage payments and our present estimates is due to the large number of homes that have been built since 1950 in areas that would be flooded if the floodwaters reached that level again *and if the dykes failed to hold*

Since our estimates of flood damages to personal property are based on the records of the Manitoba Flood Relief Fund, they necessarily assume that in future floods and for any given level of flooding within a house, the same proportion of personal property would be rescued as was in fact rescued in 1950 In that year, many people were able to save their personal belongings by moving them upstairs, by placing them on special supports or by moving them out in advance of the flood The flood damage prevented in this way reduced the damage to assessed value ratios recorded in our base sample of properties flooded in 1950 and thus reduced our overall estimates of damages to personal property correspondingly

Several considerations suggest that our estimates of flood damages to dwellings and personal property may be on the conservative side Thus, the awards made by the Red River Valley Board did not cover damage to concrete walks, driveways, fences, shrubs or lawns No special allowance has been made in our estimates for damage of this type although a significant amount of damages to property of this type undoubtedly did occur in 1950 Again, the damage payments made by the Manitoba Flood Relief Fund, upon which our estimates are based, included only a 50 percent allowance for items classed as non-essential, such as books, toys, sporting equipment, etc In addition, since in general, payments were made only where the damaged article was available for inspection, it is possible that many items were lost or overlooked and hence were excluded from the total damage payment Again, payment for loss of foodstuffs was limited to $50 00 although in many instances the losses may easily have exceeded this amount On the other hand, replacement values were allowed on all essential items even though many of these items may have already been used for a number of years

On balance, it seems likely that our estimates of damages to dwellings and personal property err on the conservative side

2 Apartments

Damages to apartments were estimated on a square footage basis Analysis of our basic sample of houses flooded in 1950 provided an estimate of the damages incurred by flood level per square foot of floor area In applying these data to apartments it was assumed that, on the average, the main floor of the apartment building would be five feet above ground level It was further assumed that in an average apartment building two-thirds of the basement floor area would be given over to apartments and for this area the main floor damage rates for dwellings would apply The rates applied included damages to both real and personal property Data on the ground floor area of apartment buildings were available from municipal assessment offices

3 Business and Institutional

In estimating flood damages to the property of business firms of all types and to churches, hospitals and other institutions, separate estimates were made for real property and for fixtures and stocks In both instances, estimates were prepared by applying an estimate of flood damages per square foot of property by flood level to the square footage of each type of property recorded in assessment rolls For buildings, flood damages were estimated by applying the flood damages rates obtained from our sample of residential dwellings flooded in 1950 This basis was suggested by officials who were instrumental in setting up the damage rates applied by the Red River Valley Board in assessing damages in 1950 In the view of these officials, damages to buildings would vary widely depending upon the type of building and the amount and location of special installations such as elevators but they felt that the rates applicable to residential dwellings would provide a fair basis of estimation

This opinion was checked with officials of the U S Army Corps of Engineers, St Paul District They expressed the view that cost on a square foot basis of repairing and rehabilitating residential buildings affected by floods was usually greater than the similar costs for industrial buildings because of the generally better construction of the latter and the more elaborate interior decorations in residential buildings However, this was offset by the fact that floods often result in settlement and other structural damages which are much more serious and costly to the better industrial and business buildings Thus, they concluded that the use of residential damage rates should give a satisfactory average approximation of the flood damages suffered by business and industrial buildings

Since analysis of the sample data taken from the records of the Red River Valley Board indicated an appreciable difference in the per square foot damage rates for new and old houses, it was decided to apply a different set of rates to property according to whether it had been constructed before or after 1920

To estimate flood damages to fixtures, machinery and equipment, inventories and supplies and other contents of buildings, a questionnaire was sent to a selected sample of business firms in the Greater Winnipeg area This questionnaire asked for an estimate of the flood damages that would occur at different levels of flooding in the firm's premises Some 30 percent of all the firms included in the sample returned the questionnaire The data from this survey was tabulated by flood level on a square footage basis to give estimates of flood damages by flood level per square foot of floor area

These damage rates per square foot of floor area for buildings and their contents were then applied to estimates of the floor area of buildings flooded that were obtained from city and municipal assessment offices Further details as to the methods followed in the preparation of these estimates, together with information on the damage rates used, are given in Appendix E

4 Public Schools

Real property damages to public schools were estimated in the same manner as real property damages to business and institutional buildings

Information on the contents of schools was obtained from records kept for fire insurance purposes and these indicated that the average value of school fixtures and movable supplies on the basement and ground floors of public schools was only about 10 to 15 percent of the comparable average value of the contents of business buildings For this reason, a damage rate of one-eighth of the business fixtures rate was applied

5 General Government Buildings

The real property damage rates applied to government buildings were the same as those applied to business and institutional property Further, insofar as fixtures were concerned, it was also assumed that the damage rate applicable to business fixtures would be applied However, since it was assumed that inventories in government buildings would be negligible, no estimate was made for damages of this category in government buildings

6 Public Utilities and Railroads

Estimates of the flood damages that would be incurred by various public utilities and the two railroads were prepared by these organizations themselves on the basis of information about flood levels supplied by the Commission's staff In addition to the two railroads, the following utilities provided information Greater Winnipeg Sanitary and Water District, Manitoba Telephone System, Manitoba Hydro-electric Board, Manitoba Power Commission, City of Winnipeg Hydro Electric System, Winnipeg and Central Gas Company, Canadian National Telegraphs, Canadian Pacific Telegraphs, and Winnipeg Central Heating Co

7 Loss of Income

One of the most serious losses that would occur in the Greater Winnipeg area in the event of a major flood would be the loss of income With business premises flooded and a major portion of the area evacuated, a large proportion of the people who normally work in this region would be completely prevented from carrying on their normal activity Of those who were still able to work at all, many would be forced to work with inadequate equipment or under difficult circumstances so that their productivity would be far below normal levels

Nor would labor income be the only type of income to suffer Many types of income from business investment originating in the area or dependent for sales on the Winnipeg area would suffer heavily Business and industrial premises would not be able to produce their normal return Railroad, power and telephone facilities in the area would be idle for an extended period The true measure of the income lost during the flood period is the loss of the net output that would otherwise have been produced Income of all types normally earned in producing this output provides a measure of its magnitude And, even though some employers may continue to make salary or wage payments to their idle workers, it will not eliminate the loss of output caused by their idleness and the idle facilities with which they are normally employed

In estimating the loss of income that would be caused by floods in excess of the 1950 level in the Greater Winnipeg area, the procedure followed was first to estimate the level of income currently produced in the region and then to evaluate the proportion of this that would be lost at different levels of flooding For floods of the 1950 magnitude and smaller, a more direct approach to income loss was used

In 1957, the gross income produced in the Greater Winnipeg area amounted to about $60 million per month or about $4,500 per employed person per year (*See Appendix E*) As defined here, gross income includes all returns to land and capital as well as labor, as well as some provision for the depreciation of productive facilities that would continue during the flood period Income is estimated before deduction of personal income tax and corporate income tax The estimated loss of income is restricted to income lost by permanent residents of the area and to the loss of returns to capital facilities and land located in the area Additional income earned by temporary workers attracted to the area is not counted as an offset to the losses suffered by permanent residents Nor has any allowance been made for the losses imposed on outside areas as a result of the disruption of normal activity in the Greater Winnipeg area during the flood period

An estimate of the loss of income that would occur today in floods of the 1861, 1852 and 1826 magnitudes is shown in Table 6 5 For each flood, losses have been estimated for three phases, phase 1, a period of inundation and initial reconstruction, phase 2, the major reconstruction period, and phase 3, a subsequent period in which activity gradually returns to 100 percent of its normal level It is clear from these estimates that income losses would be very large It is important, therefore, to consider carefully the basis on which these estimates were made

In arriving at these estimates, use was made of information provided by various utilities as to the flood stage at which their service would be interrupted According to this information, interruptions would likely occur in the following sequence

Table 6 5

ESTIMATED LOSS OF INCOME AS OF 1957, GREATER WINNIPEG AREA FLOODS OF 1861, 1852 and 1826 MAGNITUDES

Flood Magnitude	Phase 1	Phase 2	Phase 3	Total
1861				
Percent of total income lost	50%	30%	5%	
Duration of loss	1½ Months	1½ Months	3 Months	6 Months
Amount of loss	$ 45 Million	$ 27 Million	$ 9 Million	$ 81 Million
1852				
Percent of total income lost	80%	33%	10%	
Duration of loss	2 Months	2 Months	6 Months	10 Months
Amount of loss	$ 96 Million	$ 40 Million	$36 Million	$172 Million
1826				
Percent of total income lost	85%	35%	10%	
Duration of loss	2½ Months	2½ Months	6 Months	11 Months
Amount of loss	$127 5 Million	$52 5 Million	$36 Million	$216 Million

Feet above Datum James Avenue	
30′	Greater Winnipeg Water District booster station would become inoperative thus decreasing the water supply to the City of Winnipeg.
31′	Water supply would be drastically reduced due to inability to control mains in flooded areas.
31′	All bridges across the Red and Assiniboine except the Main, Midtown and St. James become inoperative.
32	C.P.R. Station facilities and Main Street Bridge become inoperative.
33′	East, west and south traffic on the C.P.R. ceases. Damage to almost all bridges becomes very serious. Midtown Bridge becomes inoperative.
34′	Water supply limited to restricted special service to key points.

In evaluating this information, it is useful to recall that the flood levels reached in each of the three largest floods of record were as follows: 1861, 32.3 feet above datum, 1852, 35.2 feet above city datum and 1826, 37.3 feet above city datum.

The general reasoning on which the income loss estimates given in Table 6.5 were based are set forth below.

(a) Loss of Income as of 1957 in Greater Winnipeg for a Flood of the 1852 Magnitude

Phase 1. Period of Inundation and Initial Reconstruction, 2 Months.

With a flood level of 35.2 feet above datum (basis James Avenue), the Greater Winnipeg area would be almost completely evacuated. Some people would still be living in St. James, Tuxedo, Charleswood, Transcona and other outlying areas but many of these would be unable to work because their normal place of employment would be under water. Some groups such as doctors, nurses, railroad workers and taxi drivers might be at least partially employed in evacuated areas but lack of equipment and office or other space would seriously limit the amount of continued employment that could take place and would greatly reduce the productivity of those so employed.

It can be assumed that evacuation would begin at about the 28 foot level and would be virtually complete by the time water had reached the 32 foot level.

An examination of flood hydrographs indicates that about 40 days would elapse between the time floodwaters exceeded the 1950 level and the date at which the river returned to below flood level (18 feet above datum). During this period there would be an almost complete cessation of normal activity within the city.

As the flood waters receded, key restoration personnel would move back into the area and begin the job of restoring essential services such as power and light, cleaning up the debris and pumping out the basements. In general, the task of these picked crews would be to make the area safe for a more general return of reconstruction workers. This work would commence as soon as there was any appreciable reduction in flood levels, perhaps 10 days before flood stage was passed, and within a month should have proceeded far enough to allow a fairly large return of reconstruction workers.

The City of Winnipeg Engineering Department has estimated that water service would be restored to the area north of the Assiniboine and west of the Red within two weeks of the time that water receded below 31.0 feet and to the entire Winnipeg area within 30 to 60 days after the river drops below flood stage. The two distributors of power, City Hydro and the Manitoba Power Commission, estimate that electric power could be restored to 50 percent of capacity within one week to one month after the water receded below flood stage. Thus, for about two months, normal activity in the area would be virtually at a standstill. It is estimated that 80 percent of the income that would normally be produced in the Greater Winnipeg area during these two months would be lost.

Phase 2. Reconstruction Period, 2 Months.

In the following period the city would gradually move back towards more normal activity. Most businesses that operate from a second or higher floor would be able to recommence operations on these levels almost immediately. In addition, many other business firms would recommence operations in flooded premises with improvised facilities and would continue to operate while reconstruction proceeded. Activity would perhaps resume more slowly in manufacturing plants where plant and equipment had to be repaired before production could start again.

Normal activity would be seriously handicapped by the absence of bridges across the Red River and by the temporary closure of the Main Street, Osborne and Maryland Street bridges across the Assiniboine.

In the initial stages of this period at least, only productive workers would return to the city But given the crowding of facilities that the wholesale evacuation of Greater Winnipeg would cause in many places, it seems reasonable to suppose that before long many families would return and live in the upstairs part of their home while the flooded portion was being repaired Homes that were subject to basement flooding only would be reoccupied within a few weeks Nevertheless a substantial part of the population of the area would remain away for several months During this period business firms in the retail trade and service industry would find their sales well below normal levels However, this would be partially compensated for by the extraordinary amount of activity in repair shops in the construction trades and in other related activities such as transportation and sale of construction materials

While it is impossible to estimate precisely the loss of income that would occur during this period, it is estimated here that one-third of the area's normal income would be lost The proportion would be much higher than this in the earlier part of this period but would fall below this level towards the end of the period

Phase 3 Gradual Return to 100 percent of Normal, 6 Months

The destruction of production facilities and the disruption of normal transport facilities resulting from the damage to roads, streets and bridges would keep income levels in the Greater Winnipeg area below normal levels for some period of time Some of the major bridges across the Red would take from two to three years to reconstruct In the meantime, sufficient temporary wooden trestle bridges would be built to allow all essential traffic to cross the river These bridges might easily be carried away by high water in the following spring and have to be replaced Thus, a further disruption of normal communication facilities across the Red River might occur in the first and second years following the flood, and until all bridges were completely restored—a period of three years—there would be a continuing loss to the community in the form of time lost through traffic congestion and the additional mileage that would have to be travelled because of the unavailability of bridges in many areas

It has been estimated that it would take from four to six months to restore completely all electric power facilities It is probable that an equal length of time would be required for the restoration of productive facilities in many private business firms

It is of course, not possible to make a precise estimate of all of these losses It has been assumed here that a loss equal to 10 percent of the area's normal income would continue for a period of six months beyond Phase 2, the major reconstruction period This figure is believed to be conservative The actual loss might be substantially higher than this

(b) Loss of Income in Greater Winnipeg for a Flood of the 1826 Magnitude

Phase 1 Period of Inundation and Initial Reconstruction, 2½ Months

During this period the problem faced by the Greater Winnipeg area would be the same in kind but more severe than those described above for an 1852 flood Evacuation would be almost complete and normal activity would be at a virtual standstill The principal difference is that the area of the city affected would be a little larger, especially on the west side of the city and the period of inundation and initial restoration would be longer As a result, the loss of income would be larger Our maps indicate that an additional 5 to 10 percent of the settled portion of the Metropolitan area would be inundated Though records on the time of the 1826 flood are very sketchy, the daily journal kept by Francis Heron of the Hudson's Bay Company shows that the period of inundation lasted about 60 days beginning about May 5th and ending about July 4th Adding to this a two to three week period of initial restoration, gives an estimate of 2½ months as the period of very serious loss of income

Phase 2 Reconstruction Period 2½ Months

Again, the problems that would be encountered in this period are similar in kind to those of an 1852 flood A large number of business firms would be faced with a restoration problem and since the depth of flooding would be about 2 feet greater, those firms who would also be affected by an 1852 flood would face a more serious and prolonged reconstruction problem No precise estimate of the magnitude of this difference can be made But it seems safe to assume that the reconstruction period would be at least two weeks longer and that the average loss of income during this period would be slightly higher Accordingly, it has been estimated that the reconstruction period would last 2½ months and that the income loss during this period would amount to 35 percent

Phase 3 Gradual Return to 100 percent of Normal, 6 Months

No difference is anticipated here between the 1826 and 1852 situation The damage to bridges across the Red and Assiniboine would be almost equally serious in either flood and the period required to restore them equally long Similarly the length of time required to restore electric power and water to the area would be about the same for both floods

(c) Loss of Income Greater Winnipeg Area, Flood of the 1861 Magnitude

Phase 1 *Period of Inundation and Initial Reconstruction,* 1½ *Months*

In a flood of the 1861 magnitude with water reaching a level 32 3 feet above datum, the period of inundation would be considerably shorter than for the two larger floods but there would still be a very major interruption of business activity and an almost complete evacuation of a large area of the city A survey of hydrograph data indicates that flood waters would remain above a flow of 80,000 c f s in Greater Winnipeg for about 30 days and that an additional 5 to 10 days would elapse before the river receded from 80,000 to 60,000 c f s As the flood water recedes, the dykes will prevent the water from returning to the river until openings are made through the dykes At the peak of the flood all bridges across the Red and Assiniboine Rivers, with the exception of the St James bridge, would be inoperative In addition, the sewer distribution system would become inoperative, and water supply would be cut off to a large part of the city

It has been estimated that this period of inundation and initial reconstruction would last 1½ months and that during this period 50 percent of normal income in the area would be lost

Phase 2 *Reconstruction Period,* 1½ *Months*

Since the total area of Greater Winnipeg flooded by and 1861 flood is somewhat smaller than in the case of an 1852 flood, it is reasonable to expect that the reconstruction period would be shorter and the loss of income during this period less severe However, in view of the extensive amount of business property that would be flooded and the major disruption that would be caused to bridges and other transport facilities, the loss would be severe Our estimates indicate that in an 1861 flood about 40 percent of all residential dwellings, about one-half of all commercial, government and institutional establishments and about 18 percent of all industrial establishments in the Winnipeg area would be flooded In addition, many of the remaining business firms would be affected by seepage Accordingly, it was estimated that the major reconstruction period would last 1½ months and that, during it, 30 percent of the area's normal income would be lost

Phase 3 *Gradual Return to* 100 *percent of Normal*

It was assumed that because the overall dislocation caused in the Greater Winnipeg area was less severe than for the two larger floods, the loss during this period would be smaller and would amount to the equivalent of 5 percent of the area's total income over a period of three months

All of the above estimates of income loss are necessarily approximate and because of this, an attempt was made to be as conservative as was consistent with a realistic appraisal of the situation These estimates were reached only after a careful discussion with numerous people and, in the judgment of this Commission, they give as accurate an evaluation of the income as can be made The data given in Table 6 6 provides some additional evidence that can be used in evaluating these results

(d) Loss of Income, Greater Winnipeg Area for Floods of the 1950 Magnitude and Smaller

In estimating the loss of income that would occur in the event of another flood of the 1950 magnitude, an attempt was first made to evaluate the loss of income that actually occurred in 1950 During the 1950 flood there was no widespread or complete shut-down of business activity Some businesses in the flooded areas suffered severe losses of income Others, even

Table 6 6

VALUE OF EQUALIZED BUILDING ASSESSMENT IN FLOOD AREAS FLOODS OF 1861 and 1852 MAGNITUDE

	1861 Flood		1852 Flood	
	Equalized Building Assessment	% of* Total	Equalized Building Assessment	% of* Total
	(000)		(000)	
Residential	$157 348	52 1	$229,276	75 9
Commercial	30,613	47 7	55,824	87 1
Industrial	11 048	18 4	43,369	72 3
Institutional and Government	36 060	44 5	62 905	77 6
	$235,069	46 4	$391,374	77 2

*Percent of total Greater Winnipeg excluding North Kildonan Old Kildonan Transcona, Tuxedo, Charleswood and Assiniboia though not flooded, suffered serious losses because of the disruption occasioned by the flood and because of the absence from the city of about 100,000 people for a period of several weeks Some of the most serious losses were incurred by firms in the service field such as the Medical Clinics and by some branches of retail trade All theatres, for example, were closed down for a week On the other hand, many firms suffered little or no loss of income at all In a questionnaire sent to a selected sample of business firms, firms such as banks, trust and insurance companies and investment dealers reported that they suffered no loss of income at all The same was true of many manufacturers For still others firms, the increased income earned during the reconstruction period more than compensated for any losses suffered during the flood This was notably true of construction companies, building material suppliers and stores engaged in selling furniture and home furnishings

An examination of general statistical indicators showed evidence of loss of income in a limited number of fields only When employment and retail sales indices for the Greater Winnipeg area were compared with similar indices for other Western cities, no clear evidence could be found of a loss to Winnipeg in 1950 On the other hand, incomes of professional people, and of people working on commission, as reported in *Taxation Statistics*, showed definite evidence of losses in 1950

In the light of this statistical evidence and the information obtained from our survey of a sample of business firms, it was decided to estimate the loss of income caused by the 1950 flood in the Greater Winnipeg area on the following basis that employees suffered no net loss of income, that all firms engaged in retail commodity trade, taken as a whole, suffered no net loss of income, the losses in some trades being offset by exceptional gains made in others, that the principal losses were incurred by professional people, by small business working in the service field, and by salesmen working on commission, that the loss of the use of flooded homes was a loss of income equal to the rental value of the property affected for the period during which its use was denied to its owner or tenant, that the loss of income reported by utilities be included

In order to arrive at an estimate of the loss that would have been incurred in 1950 if flooding had become general behind the main dyking system, it was necessary to add to our estimate of the loss actually incurred, an allowance for the heavy loss that would have been suffered in St Boniface and other areas that were protected by hazardous, emergency dykes in 1950

The loss of utility income was reported to us by the utilities concerned Loss of rental value was estimated on the basis that the rental value of a furnished house for one month was equal to 1 per cent of the house's market value or to 2 5 per cent of the equalized building assessment

Loss of Income, Greater Winnipeg, Flood of 1950 Magnitude with Flooding behind Main Dyking System

Loss of Utility Income	$ 460,000
Loss of the Rental Value of Flooded Homes	3,481,000
Other Loss of Income — Business, Professional, etc	10,000,000
	$13 941,000

It was assumed that the length of time the use of a house would be lost would vary with the level of flooding Loss of business and other income was based on a tabulation of questionnaire data together with an estimate of the loss that would have been suffered if all of St Boniface had been flooded

For floods of the 1948 magnitude, and floods at a level of 26 feet above city datum, it was assumed that loss of income would be restricted to the loss of the rental value of flooded homes and an associated loss of utility income For a flood of the 1950 magnitude, under the assumption that all flooding behind the main dyking system is prevented, it was assumed that in addition to the loss of rental value of homes and the loss of utility income, there would be a substantial loss of business income in the service field due to the major evacuation of the city that would take place Even though emergency flood fighting proved successful, it would still be necessary to ask many people to leave the city because of the severe risks involved in such high flood levels

8 Extra Costs Occasioned by the Flood

Estimates were made for four different types of extra cost that would result from a major flood (a) evacuation costs for people forced to leave the city, (b) extra food costs incurred by people forced to leave their homes because of the flood, (c) extra labor costs in flooded homes, and (d) extra transportation costs occasioned by the disruption of normal traffic routes The bases of these estimates are described below

(a) Evacuation Costs

Costs of evacuation were estimated on the basis of information obtained from an analysis of a sample of the records of the Manitoba Flood Relief Fund These records provided information on the average distance travelled and the mode of transport used by people who left the city in 1950 It was assumed that a similar pattern of evacuation would be followed in the event of future floods of the 1950 magnitude or larger This assumption was modified to the extent that in the larger floods it would be reasonable to expect that people would have to travel further to secure accommodation In addition, it was assumed that in a flood of the 1852 magnitude or larger, all motor vehicles would be taken out of the city An estimate of total evacuation costs, costs per person and the total number of people evacuating is given in Table 6 7

Table 6 7

ESTIMATED EVACUATION COSTS, GREATER WINNIPEG MAJOR FLOODS

	Total Cost	Cost Per Person	Number Evacuating
	(Thousands)		
1950, all dykes hold	$1,237	$17 67	70,000
1950, all dykes overtopped	1,767	17 67	100,000
1861	3,990	19 00	210,000
1852	7,420	21 20	350,000
1826	8,056	21 20	380,000

(b) Extra Food Costs

People who are forced to leave their homes during a flood can be expected to incur extra costs for food either because they are forced to eat in restaurants or other public eating places or because they must buy their food in out-of-the-way places or in smaller than usual quantities Statistical data indicate that on the average, Canadians spend about $22 50 per person per month on food It was assumed that all people who were forced to leave their homes during a flood would incur an extra cost for food equal to one-third of their normal expenditure, that is $7 50 per month

(c) Extra Labor Costs

All houses that are flooded will incur extra costs in the form of the labor required to clean up the house and grounds after the flood In addition, many will incur a cost in the form of the labor required to move their furniture and personal belongings to higher flood levels or to some area beyond the reach of the flood Since it was not possible to assess these costs exactly, it was decided to include in our flood loss estimates only a relatively nominal amount for this type of loss Accordingly, it was assumed that the extra labor cost would amount to $10 per dwelling for houses affected by seepage, $20 per dwelling for houses that suffer basement flooding, and $40 per dwelling for houses flooded over the main floor

(d) Extra Car Mileage

Because many of the bridges over the Red and Assiniboine Rivers are closed to traffic during major floods, motorists are forced to use more distant bridges and incur an extra cost in the form of the additional car mileage travelled The total extra mileage that would be occasioned in each flood was based on traffic count information for sub-ways and bridges in the Greater Winnipeg area and an estimate of the length of time that would be required to repair or rebuild the bridges The additional mileage travelled was valued at 8 cents per vehicle mile

9 Streets, Roads, Sewers, Waterworks and Bridges

Flood damages to this class of property were estimated on the basis of information supplied by the engineering departments of municipalities in the Greater Winnipeg area, and related data

(a) Sewers and Waterworks

It was estimated that the cost of sterilizing and repairing the water mains system would amount to $600 per square mile or about $ 94 per acre In the light of the City of Winnipeg's 1950 flood experience, damages to sewer systems were estimated on the following basis

	Systems 40 to 70 Years Old	*Systems Less Than 40 Years Old*
1950 Flood	$3 00 per Acre	$1 50 per Acre
1852 Flood	6 00 per Acre	3 00 per Acre

Since the pressure created by sewer back-up would affect all parts of the sewer system, the above damage rates were applied to the entire area served by the system

(b) Public Sidewalks

Because very few actual sidewalk repair costs resulting from the 1950 flood are available, it was difficult to obtain a unit cost for the estimation of damages The Municipality of St Vital was almost completely flooded after the flood They are now finding it necessary to repair or renew many of their sidewalks and it is believed that a good percentage of this work is directly attributable to the effects of the 1950 flood

It was finally decided to estimate flood damages to sidewalks at $500 per mile of sidewalk flooded This represents about 6 percent of the cost of renewal

(c) Streets and Lanes

In 1950 the City of Winnipeg spent an average of $6,570 per mile for cleaning up and repairing streets that had been under water In floods of a larger magnitude than the 1950 flood it is believed that damages would be greater than this because the period of inundation would be longer, more silt would be deposited, some streets would be undermined and the damage resulting from the swelling action of the clay would be much greater For these reasons, flood damages to concrete paved streets have been estimated at a rate of $10,000 per mile for floods of the 1861, 1852 and 1826 magnitudes This would be the approximate cost of placing a 2½ inch layer of asphalt over 50 percent of the street mileage flooded It can be expected that flood damages to asphalt streets would be much more extensive than to concrete streets, particularly if loads are allowed on them too soon after the water recedes It was assumed, therefore, that 75 percent of the asphalt streets would require resurfacing and damages were estimated at $15,000 per mile Since the basic unit cost used in estimating damages to concrete streets also included some allowance for the cost of repairing lanes, no separate estimate was made for damages to paved lanes

After the 1950 flood the Municipality of St Vital found it necessary to place three inches of gravel on all gravel streets This was taken as representative of the damages a flood would cause to gravel streets and damages were estimated on the basis of $2,500 per mile of gravel street, assuming a cost for gravel in place of $2 50 per cubic yard The restoration of gravelled lanes was estimated to cost $2,000 per mile

(d) Bridges

The damages that would be caused to bridges over the Red and Assiniboine Rivers by major floods on the Red River were carefully assessed by the City of Winnipeg's Engineering Department In their view, a flood as large as that which occurred in 1852 would cause serious damage to the approaches of all but a few bridges and in many instances would dislodge bridge spans and maul or partially destroy the piers For all the bridges on the Red River and for the Main Street and Osborne Street bridges on the Assiniboine River, it was estimated that from one to three years would be necessary for the completion of the repairs and rebuilding required During this period, temporary wooden bridges would have to be built to carry essential traffic These might be carried out by high water in the following year and require replacement Our estimate of bridge damage includes an allowance for the cost of these temporary bridges

10 Flood Fighting Costs

In the 1950 flood, rather large expenditures were made in fighting the flood However, since that time, a major dyking system has been built in the Greater Winnipeg area and many permanent flood pumping stations have been constructed As a result, the situation that would face flood-fighting authorities in the event of a future flood would differ fundamentally from the situation that existed in 1950 Accordingly, flood-fighting costs were estimated on the basis of what it would cost to raise the existing dyking system to the 1950 level This estimate was used as a measure of the flood-fighting cost that would be incurred in the event of a flood of the 1950 magnitude or larger For smaller floods it was assumed that the cost incurred would be proportionally smaller

In 1950 many individual firms and householders incurred substantial flood-fighting costs in building dykes and pumping water out of their basements In substantial part, these costs were made necessary because of the absence of a co-ordinated overall system of dykes and flood pumping stations Since such a system is now in existence, many of these costs would not be incurred in future floods There would still be some flood-fighting costs incurred, particularly on the part of individuals or business firms outside of the primary line of defence However, since it was difficult to find any accurate basis for assessing the extent of these costs, it was decided to omit them entirely To this extent our damage estimates are understated and our conclusions lean to the conservative side

CHAPTER 7

FLOOD DAMAGES IN THE RED RIVER VALLEY EMERSON TO ST NORBERT

Estimates of flood losses were prepared for the Red River Valley south of the dyke and control structure at the floodway inlet for floods of the magnitudes and frequency shown in Table 7 1

Table 7 1

FLOOD FREQUENCIES AND ACREAGES FLOODED MAJOR FLOODS RED RIVER VALLEY

	Acreage Flooded	Frequency of Occurrence Years	Percent	Flow at Emerson
1948 Flood	67 400	Once in 11 Years	9 10	52,000 c f s
1950 Flood	316,500	Once in 46 Years	2 20	94,000 c f s
1852 Flood	523,000	Once in 150 Years	67	137,000 c f s
1826 Flood	616,000	Once in 460 Years	22	182,000 c f s

SOURCE Acreage data based on map of flooded area (see Plate 9) Frequency of occurrence for the 1948 and 1950 floods and discharges for the 1852 and 1826 floods taken from Plate 10

is due mainly to the decline in yield which occurs when the date of seeding is delayed When this delay is too long it may not be profitable to seed at all and the loss of crop income for that year will be complete Further, the farmer will incur some additional expense in summer-fallowing his land for the balance of the season If seeding or some seed-bed preparation has already taken place at the time flooding occurs, the farmer may suffer an additional loss since some or all of this expense may have to be duplicated

These damage estimates include flood damages and losses in both rural and urban areas in the Valley and were prepared under the following headings

1 Loss of Income
2 Extra Costs Occasioned by the Flood
3 Damages to Personal, Farm and Business Property
4 Losses to Utilities and Railroads
5 Damages to Government Property

Separate estimates were made for each of the following three reaches in the Valley area

Reach 1 Municipalities of Montcalm Rhineland and Franklin and the Town of Emerson

Reach 2 Municipalities of Morris and DeSalaberry and the Town of Morris

Reach 3 Municipalities of Ritchot and Macdonald and that part of Fort Garry and St Vital south of the floodway dyke and inlet control structure

Detailed estimates of damages for the valley area as a whole are given in Table 7 2 Data on each major type of damage or loss for each of the three reaches appear in Table 7 4 Plate 9 shows the probable extent of the flooded area in each of the four major floods

Discharge-damage relations for each of the three reaches and for the Red River Valley as a whole are shown in Plate 11 The methods used in preparing these damage estimates are discussed below

1 Loss of Income

(a) Farm Income Field Crops

With spring flooding such as occurs on the Red River, the income loss suffered by farmers

Estimates were prepared of the loss of field crop income that could be expected to occur in the Red River Valley as a result of the recurrence of floods of the 1948, 1950, 1852 and 1826 magnitudes The methods used in estimating these losses are similar to those used by the U S Army Corps of Engineers and are described below

It was assumed that the pattern of cropping in the flooded areas would be the same as that reported in the 1951 census for the Municipalities in which the flooded areas are located Normal yields for each crop were estimated from data for a number of Canadian Wheat Board delivery points in the flooded area

For each crop, the loss of income per acre was calculated as the difference between the yield that would have occurred in the absence of any flooding and the yield that could be expected with flooding multiplied by the price per bushel of the particular crop Some allowance was also made for a decline in the quality of the crop At a maximum, the loss would not exceed the normal net operating income per acre from the crop plus half the cost of summer-fallowing (it was assumed that the remaining one-half the cost of summerfallowing would be offset by a higher yield in the following year), for in that circumstance, it would not be economical to seed the land at all Net operating income is defined here as gross income less direct operating expenses

Yields for both flooded and flood-free land were based on relationships between the date of seeding and crop yields Experimental data showing the effect of delays in the date of seeding on crop yields were examined and average relationships for these two variables were developed for wheat, oats, barley and flax (*See Plates* 12 *to* 16) Since barley requires a shorter growing season than wheat or oats, it was assumed that land normally seeded to wheat or oats would be shifted to barley when the delay in the date of seeding made it profitable to do so Flax is also a good crop for late seeding but since it is not seeded extensively in practice, it was not assumed that there would be any general shift into flax The seeding pattern followed in the Red River Valley in 1950 after the flood would tend to support this assumption

To estimate the yield that would have occurred in the absence of flooding, use was made of a relationship between the peak discharge on the Red River and the date when wheat seeding became general in the province (*see Plate* 16) This relationship is based on the assumption that the climatic conditions, such as heavy snowfall, late break-up and heavy rain during the runoff period, which tend to produce serious flooding, also tend to delay the date of seeding on land that is not subject to flooding Use of this relationship indicated that seeding would not occur on flood-free land until late May in years that produced floods of the 1950, 1852 and 1826 magnitudes

In the year of a major flood, seeding can only occur in the flooded area after the flood waters recede and the land becomes dry enough to work Land on the edge of the flooded area will begin to dry out as soon as the flood peak is passed At the other extreme, land in the lowest areas will not begin to dry until the river returns to its banks On the average, it can be assumed that the flooded land will begin to dry out at a date midway between these two extremes

For the Red River, there is evidence that the date of the flood peak is related to the volume of the peak discharge In general, the larger the peak flow, the later the date of the peak Plate 17 shows the general relation that exists between these two variables In estimating the effects of floods of various sizes, the *trend line* rather than the *actual* date of the flood peak was used Thus, for a flood of the 1950 magnitude, the date of the peak was taken as May 12 even though in that year the peak was not reached until May 19 This line of average relation gives, for any size of flood, the date a flood peak could be expected *on the average* and hence may differ from the date of the peak in any particular flood

The length of time required for flood waters to recede to a bank-full stage also varies directly with the size of the flood Estimates of the length of this period for each of the major floods of record were based on an examination of hydrographs or other historical records of these floods After the water recedes from the land, at least two weeks are required for the land to dry out and a further period of perhaps two weeks will elapse before the land has been cultivated, harrowed and seeded It was assumed that on the average, seeding would have taken place about four weeks after the flood waters receded

Following these procedures, the loss of crop income in the Red River Valley for floods of the 1948, 1950, 1852 and 1826 magnitude was estimated to be as follows

	Total Loss of Crop Income	Loss per Seeded Acre
1948	$ 275,000	$ 5 95
1950	1,852,000	8 67
1852	3,525 000	9 93
1826	4,191,000	10 06

A detailed statement of the basis on which these estimates were reached is given in Appendix E

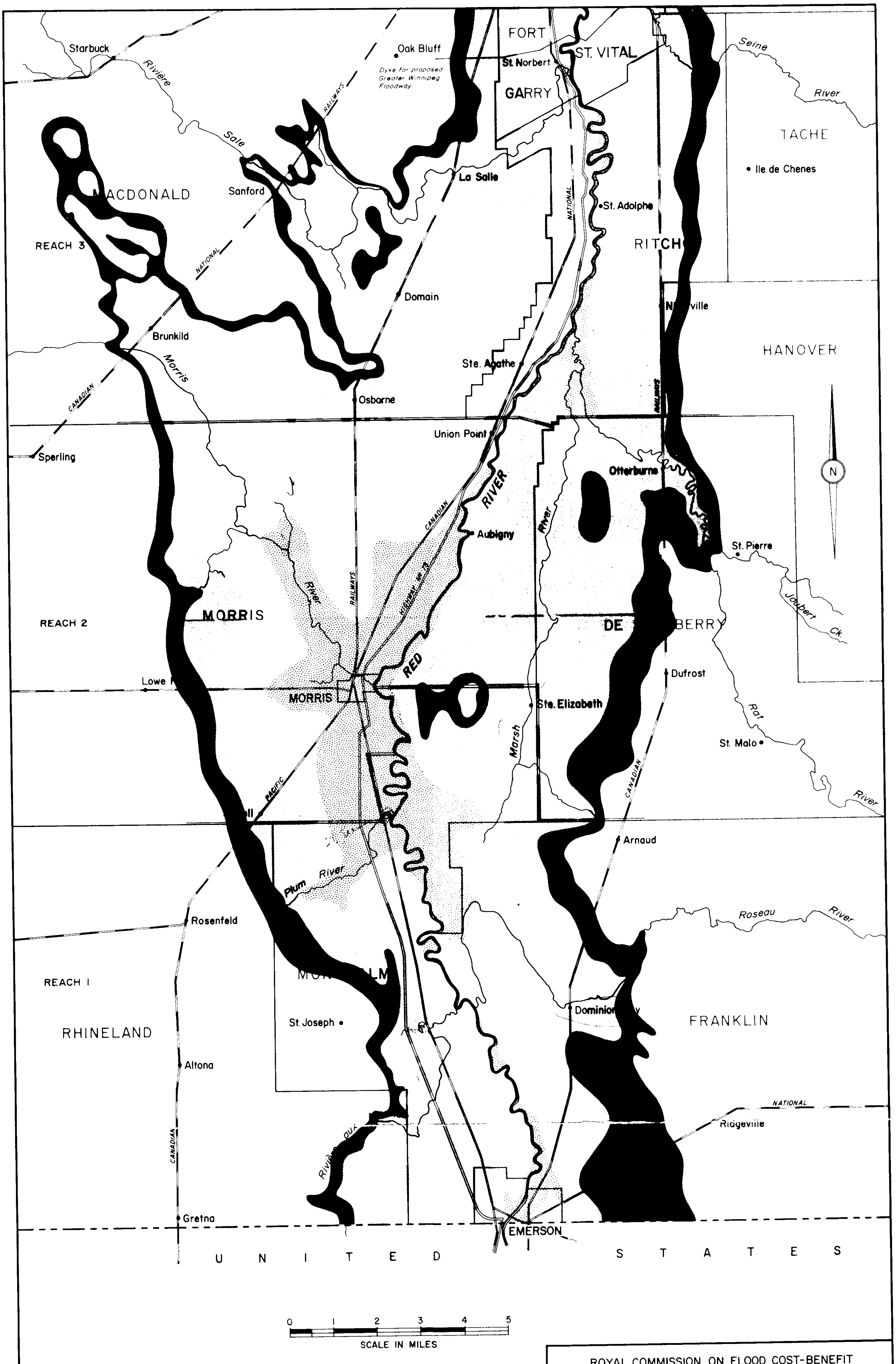
(b) Farm Income Livestock

The principal income loss suffered here would be due to the decline in the milk yield of dairy cows and a loss of weight for beef cattle and hogs

Farm income data indicate that the average value of dairy products per cow in Manitoba is about $9 00 per month Because of the prevalence of dairy farming in this area it was estimated that losses per cow would be above the provincial average Accordingly, a figure of $15 00 per cow per month was used It was assumed that (on the average) loss of output for all cows in the flooded area would amount to a complete loss for one month in a flood of the 1948 magnitude, two months for a flood of the 1950 magnitude two and a half months for a flood of the 1852 magnitude and three months for a flood of the 1826 magnitude This makes allowance for the fact that in the larger floods, the cattle would have to be moved further, the flood period would be longer, and as a consequence, a larger proportion of the cows would dry up completely

For beef cattle, it was decided on the basis of consultation with experts in this field, to assume a weight loss for all cattle in the flooded area, of 50 lbs per animal plus 1½ pounds for each day of the flood period It was estimated that the length of the flood period would be 15 days for a 1948 flood, 30 days for a 1950 flood, 40 days for an 1852 flood, and 50 days for an 1826 flood The loss of weight represents both the actual reduction in weight and the failure to gain weight at a normal rate

For hogs it was assumed that each hog would suffer a loss of actual and potential weight at the rate of 1 5 pounds per day, the natural rate



NOTE

Areas flooded in 1948 and 1950 are as shown in Appendix "F" of the Red River Basin Investigation Report.

Areas flooded in 1852 and 1826 are as estimated for the Royal Commission on Flood Cost-Benefit.

ROYAL COMMISSION ON FLOOD COST-BENEFIT

AREAS FLOODED IN 1948, 1950, 1852 AND 1826 RED RIVER VALLEY

FROM EMERSON TO WINNIPEG

DECEMBER 1958

PLATE 9

PLATE 10

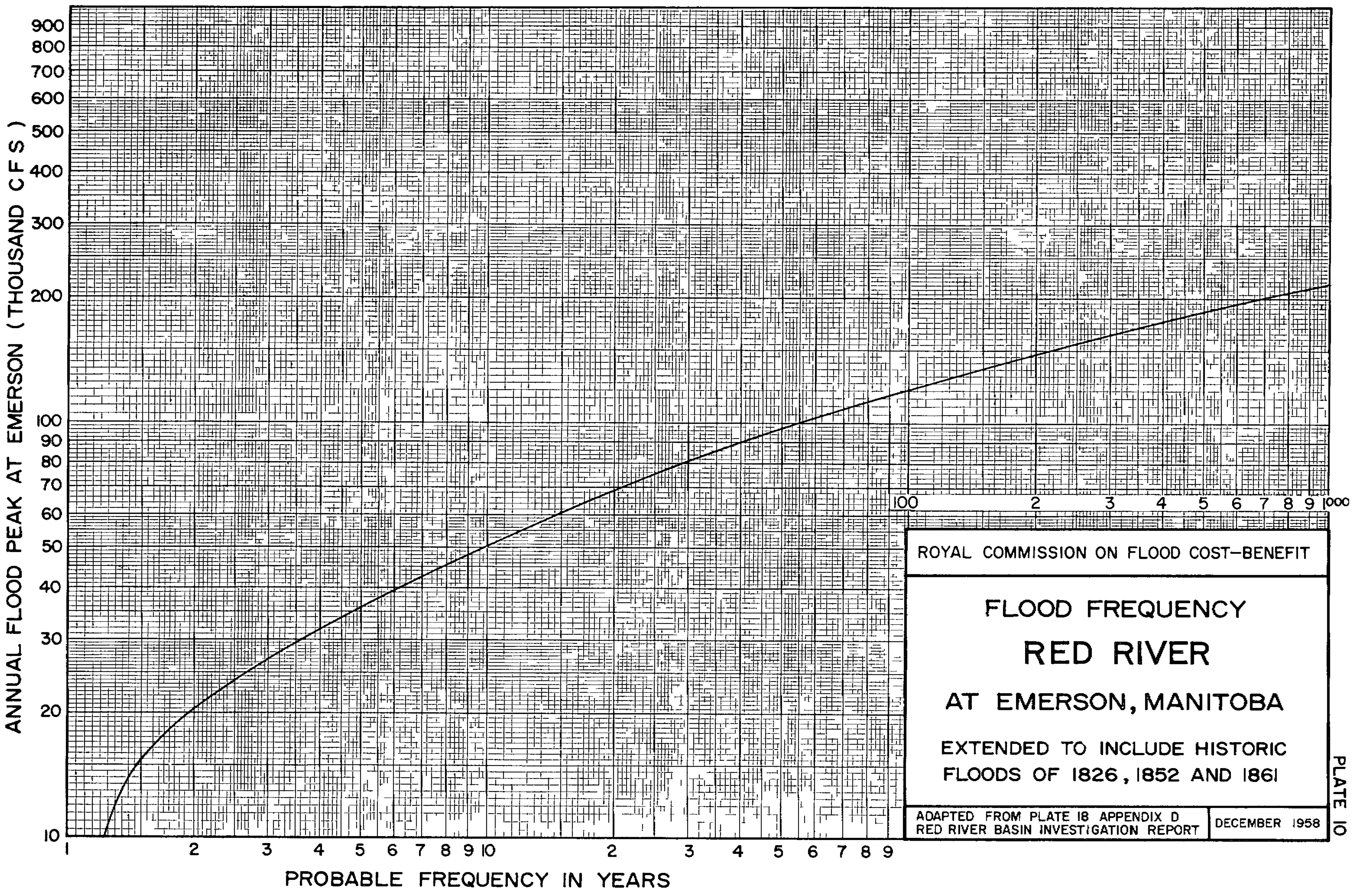

ANNUAL FLOOD PEAK AT EMERSON (THOUSAND C F S)
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
2
3
4
5
6
7
8
9
100
2
3
4
5
6
7
8
9
1000
PROBABLE FREQUENCY IN YEARS
ROYAL COMMISSION ON FLOOD COST-BENEFIT
FLOOD FREQUENCY
RED RIVER
AT EMERSON, MANITOBA
EXTENDED TO INCLUDE HISTORIC FLOODS OF 1826, 1852 AND 1861
ADAPTED FROM PLATE 18 APPENDIX D RED RIVER BASIN INVESTIGATION REPORT
DECEMBER 1958

PLATE 12

ROYAL COMMISSION ON FLOOD COST-BENEFIT

DATE OF SEEDING AND YIELD
WHEAT
MELITA, MANITOBA
1944-47

DECEMBER 1958

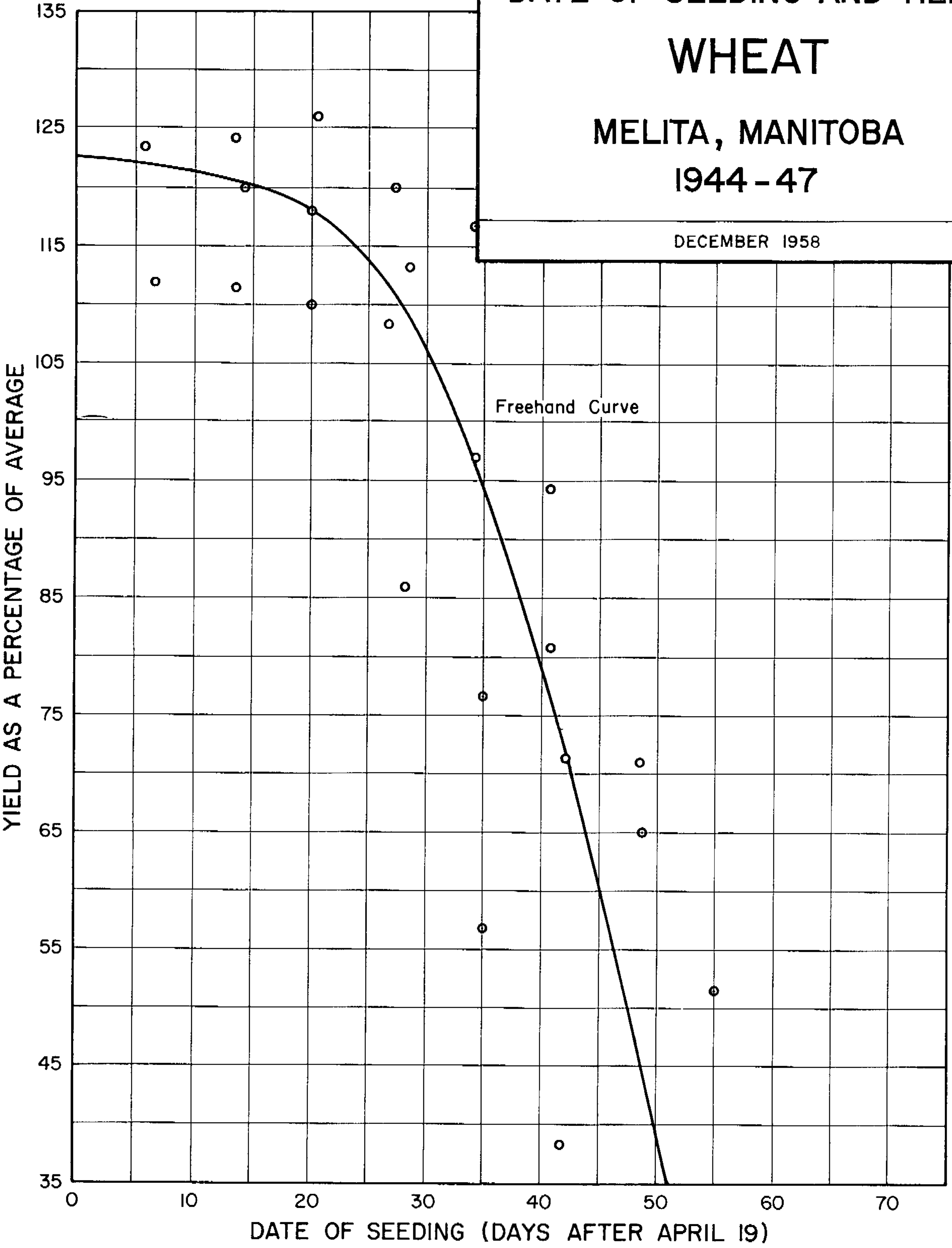
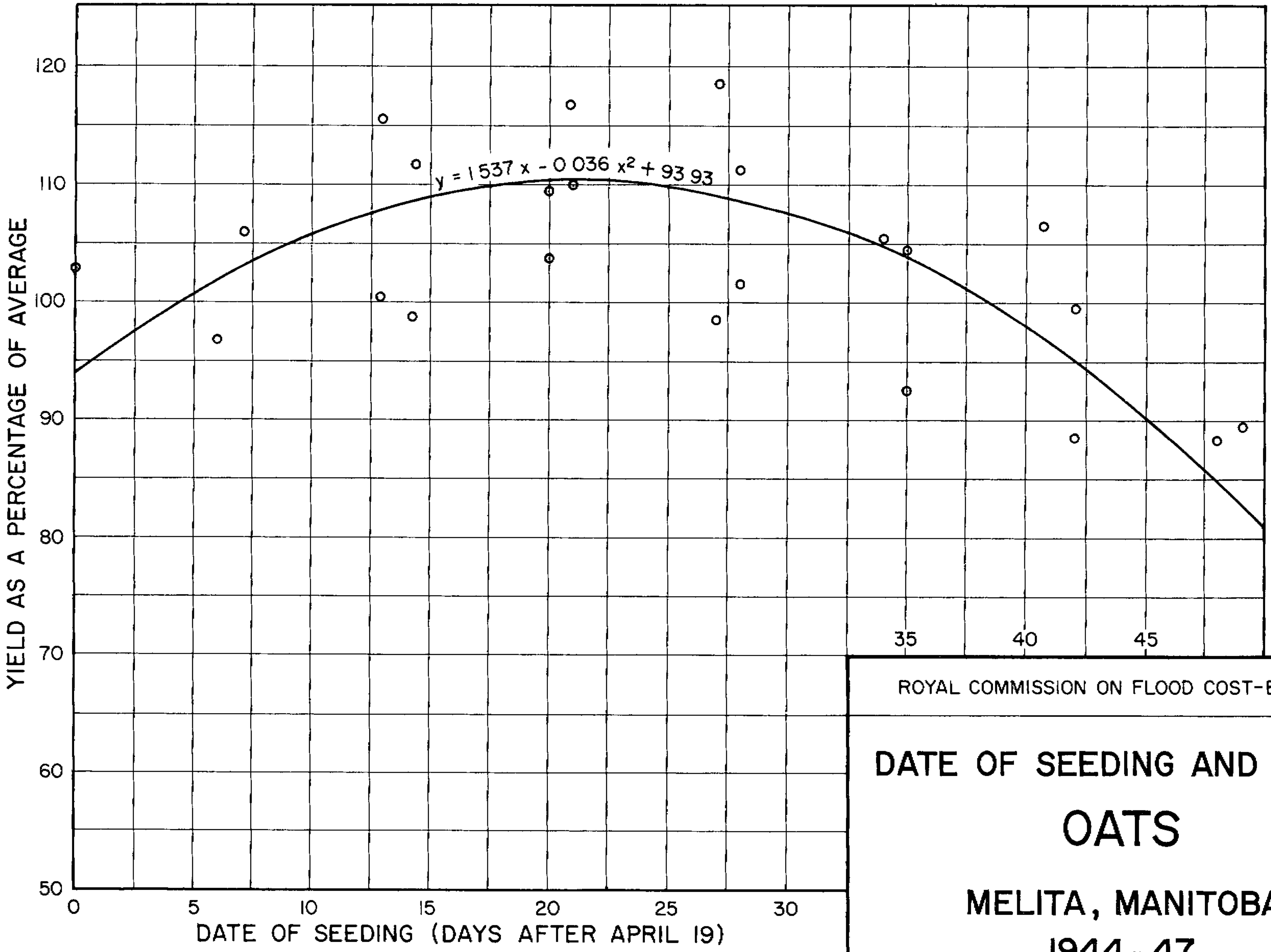


PLATE 13



ROYAL COMMISSION ON FLOOD COST-BENEFIT

DATE OF SEEDING AND YIELD

OATS

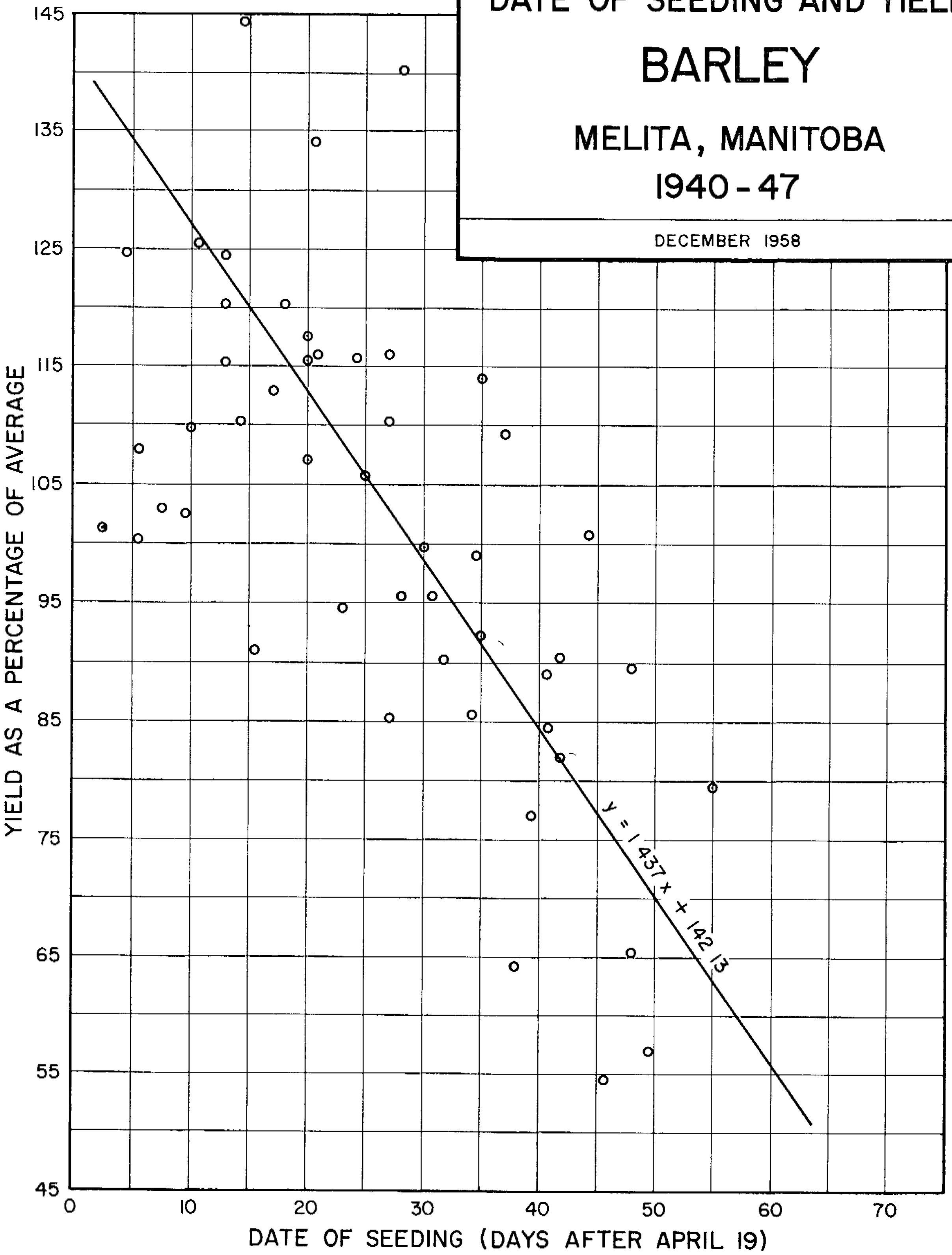
MELITA, MANITOBA
1944 - 47

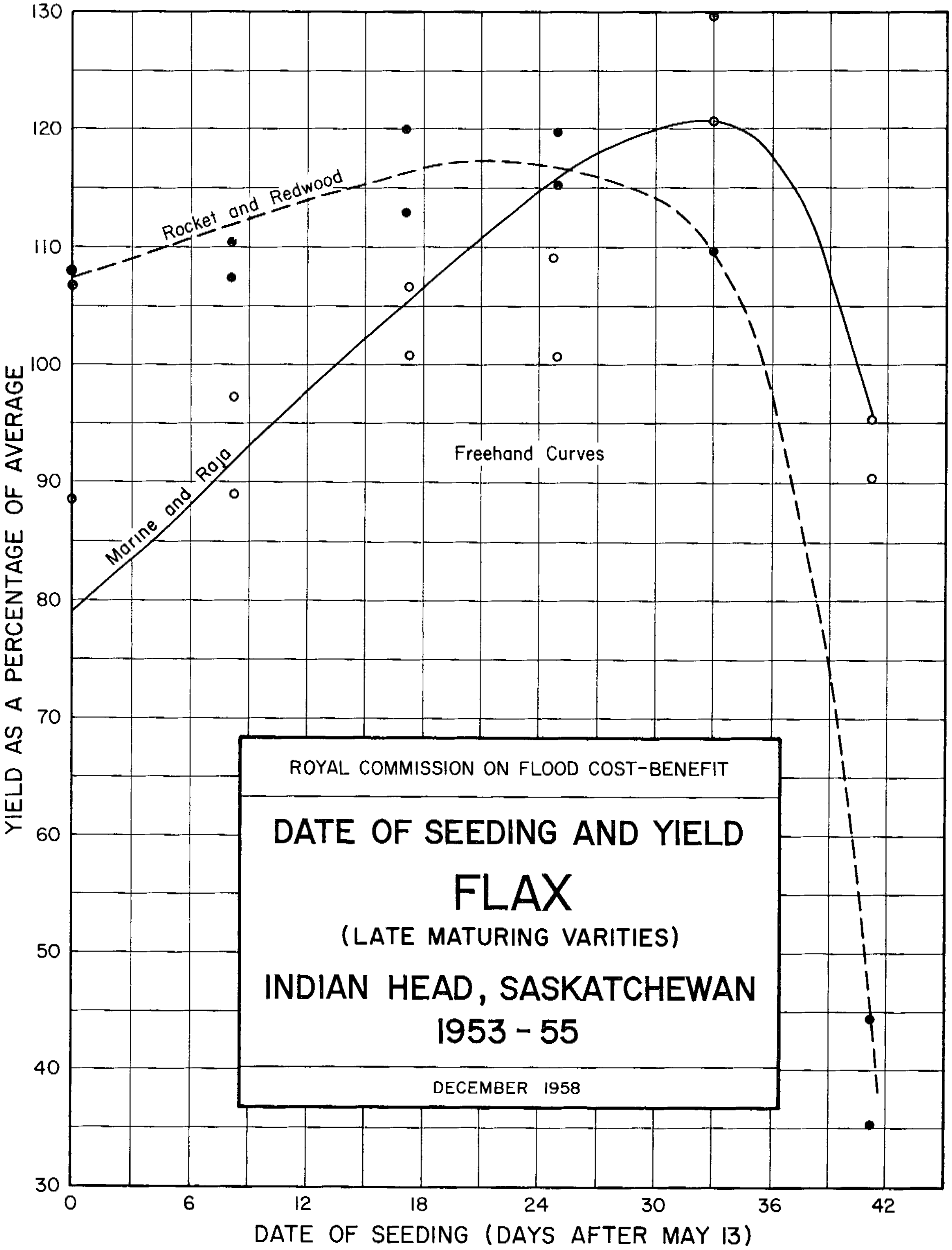
DECEMBER 1958

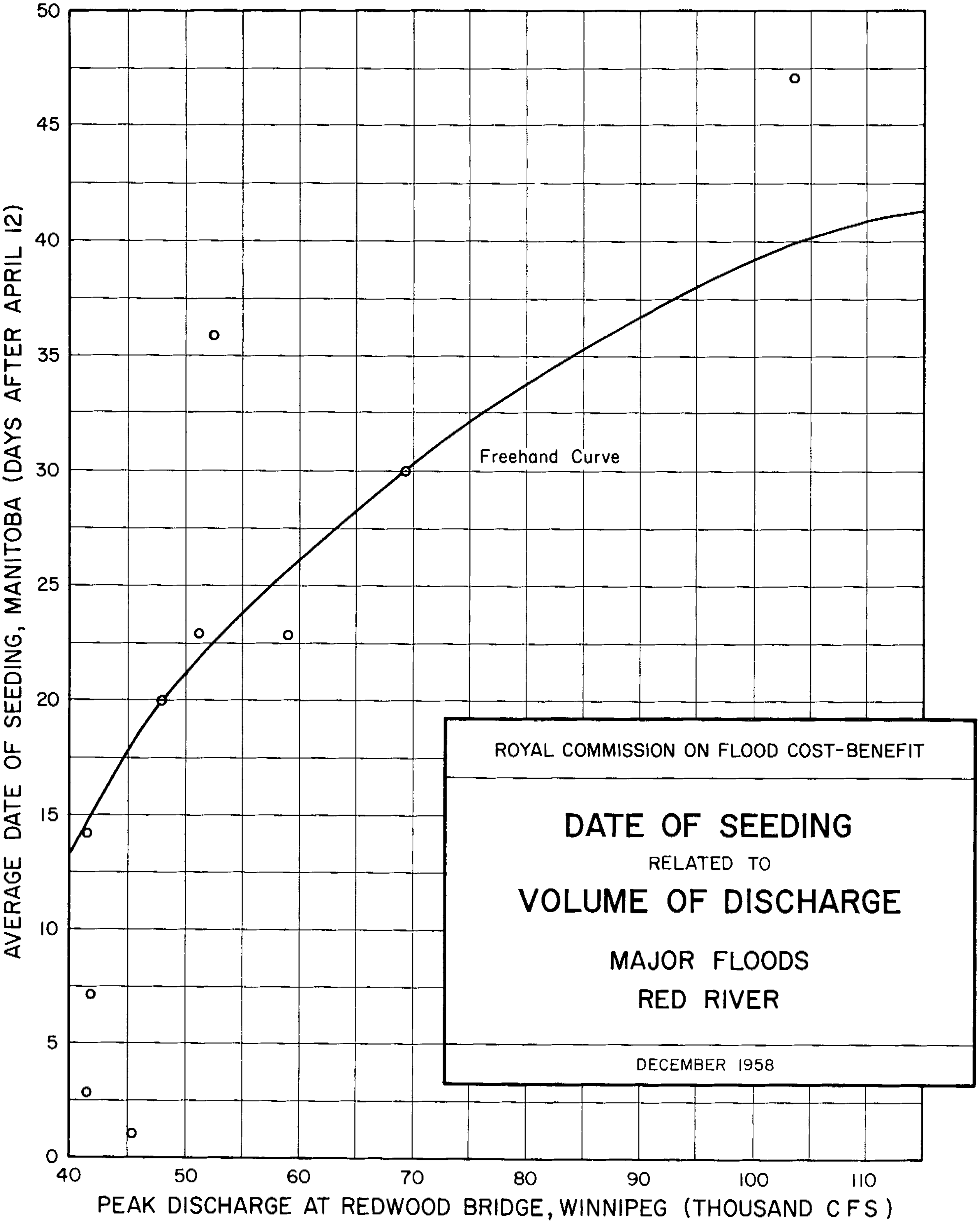
ROYAL COMMISSION ON FLOOD COST-BENEFIT

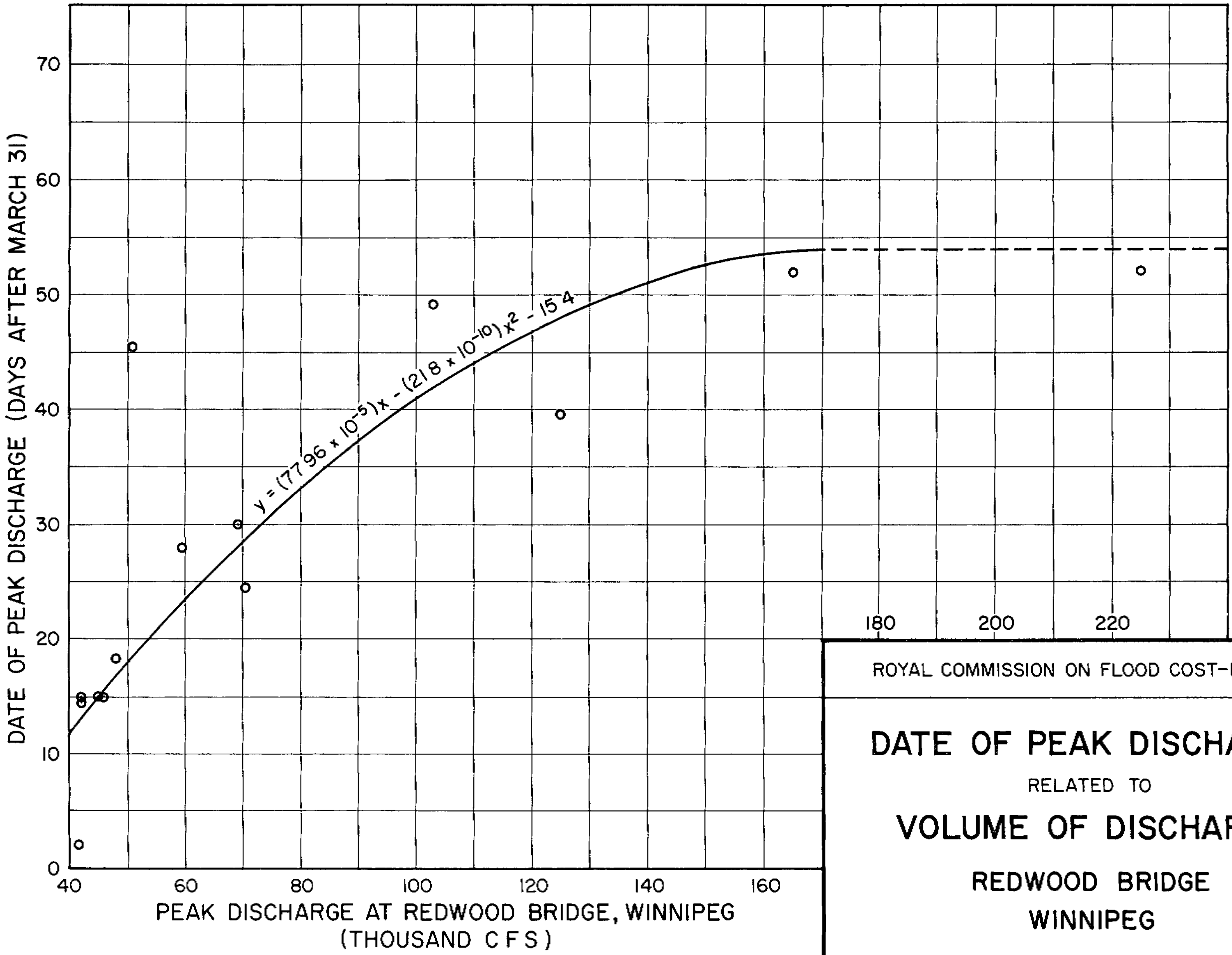
DATE OF SEEDING AND YIELD
BARLEY
MELITA, MANITOBA
1940 - 47

DECEMBER 1958




ROYAL COMMISSION ON FLOOD COST-BENEFIT
DATE OF SEEDING AND YIELD
FLAX
(LATE MATURING VARITIES)
INDIAN HEAD, SASKATCHEWAN
1953 - 55
DECEMBER 1958
YIELD AS A PERCENTAGE OF AVERAGE
DATE OF SEEDING (DAYS AFTER MAY 13)
Rocket and Redwood
Marine and Raja
Freehand Curves
130
120
110
100
90
80
70
60
50
40
30
0
6
12
18
24
30
36
42


ROYAL COMMISSION ON FLOOD COST-BENEFIT
DATE OF SEEDING
RELATED TO
VOLUME OF DISCHARGE
MAJOR FLOODS
RED RIVER
DECEMBER 1958
Freehand Curve
AVERAGE DATE OF SEEDING, MANITOBA (DAYS AFTER APRIL 12)
PEAK DISCHARGE AT REDWOOD BRIDGE, WINNIPEG (THOUSAND CFS)
0
5
10
15
20
25
30
35
40
45
50
40
50
60
70
80
90
100
110



ROYAL COMMISSION ON FLOOD COST-BENEFIT

DATE OF PEAK DISCHARGE

RELATED TO

VOLUME OF DISCHARGE

REDWOOD BRIDGE
WINNIPEG

DECEMBER 1958

of weight gain Experience at the University of Manitoba in the 1950 flood indicated that hogs which were moved and housed in temporary quarters failed to gain any weight during the flood period The loss of weight was valued at 14 cents a pound for beef cattle and 17 cents a pound for hogs

(c) Non-Farm Income

The loss of income to non-farm workers in the flooded area of the Red River Valley was estimated by first estimating the number of non-farm workers in each reach and then applying to these data an estimate of the loss of income that would be suffered by each worker

Census data indicated that in Census Division No 2 in Manitoba, which is a rural division in the southern half of the Red River Valley, there were, in 1951, about twelve non-farm workers for every one hundred people Applying this ratio to an estimate of the total population affected by each of the selected floods, gave an estimate of the total non-farm labor force affected

Loss of income was based on an estimated annual income per worker of $3,480 This total, which is 75 percent of the equivalent income in Greater Winnipeg, covers return to capital equipment used by the worker, business profits and salaried income as well as wages It is intended to cover all forms of non-farm income earned in the area The census of manufacturing indicates that income per employee in the Red River Valley area is about 73 percent of income per employee in Metropolitan Winnipeg

It was assumed that losses would amount to one month's income for a 1948 flood, two months' income for a 1950 flood and three months' income for an 1852 and 1826 flood

(d) Rental Value of Homes

An estimate of the total assessed value of residential property flooded in 1950 was obtained by applying damages to assessed value ratios by flood level to the record of damages incurred in 1950 It was assumed that the rental value of a house per month was equal to 2 5 percent of its equalized assessed value, which is the equivalent of 1 percent of its market value The loss of the use of housing in the area was then estimated on the basis of a loss of one month's use for houses flooded below the floor level, two and a half months for flooding of one foot over the floor level, three months for houses flooded to a depth of two feet and so on

Losses in the other floods were estimated by adjusting the 1950 data for the difference in depth of flooding and in the case of the larger floods by including an estimate for the additional number of houses involved

2 **Extra Costs**

(a) Evacuation Costs

Analysis of a sample of the evacuation costs reported for 1950 by people in rural areas showed an average expenditure in terms of today's prices of $2 65 per person for moving out of the flooded area It was assumed that these costs would be slightly higher for floods of the 1852 and 1826 magnitude Accordingly evacuation costs for the total population affected by flooding were calculated on the basis of the following schedule of costs per person

Flood Magnitude	Cost per Person
1948	$2 65
1950	2 65
1852	3 20
1826	3 75

(b) Extra Food Costs

People forced to evacuate by the flood would incur extra food costs because of the necessity of eating in restaurants, buying more highly prepared foods or buying foods away from their usual source of supplies This extra cost was estimated at $7 50 per person per month which is one-third of the average food expenditure per person per month in Canada It was assumed that these extra costs would last for one month in a 1948 flood, two months in a 1950 flood, two and a half months in an 1852 flood and three months in an 1826 flood

(c) Extra Work

The extra costs incurred in the form of moving furniture to protect it from flooding and cleaning up after the flood were estimated at somewhat nominal amounts

(d) Extra Feed for Livestock

In 1950 the cost of providing extra feed for livestock evacuated because of the flood amounted to $6 00 per head of livestock affected On the basis of an average inundation period of 24 days, this is the equivalent of 25 cents per head of livestock per day Using this rate, 25 cents per animal per day, the following schedule of costs was established

Flood Magnitude	Average Inundation Period	Cost per Animal Affected
1948	15 days	$3 75
1950	24 days	6 00
1852	27 days	6 75
1826	34 days	8 50

(e) Moving Livestock

On the basis of data supplied by Winnipeg livestock dealers, the cost of moving livestock was estimated at the rate of 40 cents per mile per truck load It was estimated that a truck would carry 20 horses or cattle and 60 sheep or hogs Using these data, costs were estimated on the basis of the following schedule

Flood Magnitude	Average Distance Travelled	Cost per Trip	No of Trips
1948	20 miles	$ 8 00	103
1950	30 miles	12 00	536
1852	40 miles	16 00	909
1826	46 miles	18 40	1,079

3 Damages to Property

(a) Farm Buildings and Non-Farm Residential Property

A careful analysis was made of the flood damages awarded on farm buildings and on non-farm residential property in 1950 These data were analyzed by flood level and a schedule of the average damages by flood level was prepared for each type of property

Damages that would be incurred at other flood levels were then prepared by increasing (or decreasing in the case of the 1948 flood magnitude) the depth of flooding on the properties affected in 1950 and recording the damages at this new flood level In addition, an estimate was prepared of the additional properties that would be affected in the larger floods and the average depth to which these properties would be flooded On this basis, total damages to this type of property were estimated for each of the four flood magnitudes considered These totals were then increased by 25 percent to bring them to a 1957 price basis

(b) Personal Property, Farm and Non-Farm

An analysis of the awards made in the Red River Valley for damages to personal property indicated that in 1950, damages to personal property amounted to just under 30 percent of the damages to farm buildings and urban dwellings It was assumed that the same ratio would apply in each of the three other floods The totals obtained on this basis were then increased by 15 percent to put them on a 1957 price basis

(c) Grain, Livestock and Machinery

Damages suffered by farmers on grain, livestock, poultry and bees, farm supplies, grass and gardens and farm equipment in 1950 were covered by the Manitoba Flood Relief Fund An analysis of these data showed the following schedule of damages

Depth of Flooding Over Main Floor of Farmhouse	Damages per Cultivated Acre
2½ ft or less	$2 63
2½ ft to 4½ ft	3 40
Over 4½ ft	3 51

This schedule of damages, together with information on rates of damages in individual municipalities was used in estimating losses incurred at the 1948, 1852 and 1826 flood levels The resulting totals were adjusted to a 1957 price basis with a weighted price index of grain, livestock, farm equipment and machinery

(d) Business Real Property

An estimate of the damages suffered by business property in 1950 was obtained from the assessment records of the Red River Valley Board These damages amounted to about 13 percent of the total damages suffered by non-farm residential property in 1950 It was assumed that the same ratio would apply for each of the other floods Accordingly, damages to business real property in all floods were estimated as 13 percent of damages to non-farm dwellings

(e) Business Stocks and Fixtures

An estimate of the damages suffered by business stock and fixtures in 1950 was obtained from the records of the Manitoba Flood Relief Fund Where the damages awarded were clearly less than the assessed value of the damage, the latter figure was used, since the Flood Relief Fund did not attempt to compensate completely for this type of damage The resulting total for 1950 amounted to 167 percent of the damages to business real property It was assumed that this same ratio would hold in all floods and damages to business stock and fixtures were estimated accordingly

(f) Schools and Churches

An estimate of the damages suffered in 1950 by public schools was obtained from the records of the Department of Education For private schools, churches, convents and meeting halls, an estimate of 1950 damages was obtained from the records of the Manitoba Flood Relief Fund Total damages in 1950 to this type of property amounted to about 8 percent of the damages to farm buildings and urban dwellings It was assumed this same ratio would hold for all flood levels and damages were estimated accordingly

4 Utilities and Railroads

Estimates of the property damages and flood-fighting costs incurred by the two railroads, the Manitoba Power Commission and the Manitoba Telephone System were prepared by the firms concerned on the basis of information about flood levels and areas affected supplied by the Commission

5 Government Property

(a) Roads and Bridges

Estimates of the damages that would be caused to roads and bridges were prepared by the Department of Public Works These estimates were based on records of the damages caused by the 1950 flood

(b) Flood-Fighting Costs

Expenditures for flood fighting by both provincial and municipal governments in 1950 amounted to 33 cents per acre flooded in the Red River Valley This amount was increased to 41 cents to allow for the rise in prices since 1950 and applied to the acreage flooded for the 1948, 1852 and 1826 flood magnitudes

Table 7 2

FLOOD DAMAGES AND LOSSES RED RIVER VALLEY EMERSON TO PROPOSED GREATER WINNIPEG FLOODWAY (ST NORBERT)

Flood Frequency (Average) Once in Every	11 years	46 years	150 years	460 years
Flood Magnitude in c f s (Emerson)	52 000 (1948)	94,000 (1950)	137,000 (1852)	182 000 (1826)
Loss of Income				
Farm Crops	$ 275,000	$ 1,852 000	$ 3,525,000	$ 4,191,000
Livestock	24,000	233,000	493 000	699,000
Non-Farm	217,000	724,000	1,472,000	1,622,000
Rental Value of Homes	41 000	232,000	404 000	493,000
Sub-Total	$ 557,000	$ 3,041,000	$ 5 894,000	$ 7,005 000
Extra Costs				
Evacuation Costs—People	$ 10,000	$ 27,000	$ 44 000	$ 56,000
Extra Living Costs	28 000	151,000	256,000	339 000
Extra Work—Clean-up	34,000	156,000	236 000	277,000
Extra Feed for Livestock	11 000	95,000	184,000	274,000
Cost of Moving Livestock	2,000	6 000	14,000	19,000
Sub-Total	$ 85 000	$ 435,000	$ 734,000	$ 965,000
Damages to Property				
Farm Buildings	$ 219,000	$ 1,184 000	$ 2 355 000	$ 3,090,000
Non-Farm Residential	486,000	2,022,000	3,177,000	3,805,000
Personal Property—Farm and Non-Farm	188,000	852 000	1,471,000	1,833,000
Grain, Livestock and Machinery	127,000	581 000	934,000	1,213,000
Business, Stocks and Fixtures	91,000	452,000	710 000	850,000
Business Real Property	54,000	270,000	424,000	508,000
Schools and Churches	56,000	261 000	443,000	552,000
Sub-Total	$1 221 000	$ 5,622 000	$ 9 514,000	$11 851 000
Utilities and Railroads				
Manitoba Telephone System	$ 31,000	$ 51,000	$ 216,000	$ 272 000
Manitoba Power Commission		62,000	89,000	114,000
C P R	6,000	100 000	625 000	640,000
C N R	4,000	634 000	1,281 000	1,603,000
Sub-Total	$ 41,000	$ 847,000	$ 2,211,000	$ 2,629,000
Government				
Roads and Bridges	$ 250,000	$ 1,203,000	$ 2,400 000	$ 2 800,000
Flood Fighting Costs	28,000	130,000	214,000	253,000
Sub-Total	$ 278,000	$ 1,333,000	$ 2,614,000	$ 3,053,000
TOTAL	$2,182,000	$11,278,000	$20,967,000	$25 503 000

Table 7 3

FLOOD DAMAGES AND LOSSES RED RIVER VALLEY ALL REACHES ACREAGE AND DAMAGE PER ACRE

Flood Magnitude in c f s at Emerson	Frequency of Occurrence Years	Frequency of Occurrence Percent	Flood Damage	Acreage Flooded	Damage per Acre
40,000	6 2	16 1			
52,000 (1948)	11	9 1	$ 2 182,000	67,400	$32 37
70,000	21	4 8	3 010,000	92,200	32 65
82,000	31	3 2	4,846,000	145,300	33 35
94,000 (1950)	46	2 2	11,278,000	316,500	35 63
137,000 (1852)	150	67	20,967,000	523,000	40 09
182,000 (1826)	460	22	25,503,000	616 000	41 40

NOTE Damages for the 21 and 31 year floods were obtained by interpolating damage per acre data from a damage per acre-acreage flooded chart and applying this to an estimate of the total acreage flooded obtained from an unpublished report of the Red River Basin Investigation

Table 7 4

FLOOD DAMAGES AND LOSSES RED RIVER VALLEY BY REACHES EMERSON TO PROPOSED GREATER WINNIPEG FLOODWAY (St NORBERT)

Flood Frequency (Average) Once in Every	11 Years	46 Years	150 Years	460 Years
Flood Magnitude in c f s (Emerson)	52,000 (1948)	94,000 (1950)	137,000 (1852)	182,000 (1826)
	(Thousands of Dollars)			
REACH 1—(R M 's of Montcalm, Rhineland and Franklin and Town of Emerson)				
Loss of Income	$ 239	$ 842	$ 1,925	$ 2 489
Extra Costs	40	145	250	344
Damages to Property	431	1 871	3,209	3,886
Utilities and Railroads	14	198	708	902
Government	99	353	729	922
Total	$ 823	$ 3 409	$ 6 821	$ 8,543
REACH 2—(R M 's of Morris and DeSalaberry and the Town of Morris)				
Loss of Income	$ 301	$ 1,241	$ 2,181	$ 2,496
Extra Costs	37	162	254	322
Damages to Property	650	2,829	4,365	5,415
Utilities and Railroads	23	386	780	893
Government	168	575	1,091	1,206
Total	$1,179	$ 5,193	$ 8,671	$10,332
REACH 3—(R M 's of Ritchot and Macdonald and Southern part of Fort Garry and St Vital)				
Loss of Income	$ 17	$ 958	$ 1,788	$ 2,020
Extra Costs	8	128	230	299
Damages to Property	140	922	1,940	2,550
Utilities and Railroads	4	263	723	834
Government	11	405	794	925
Total	$ 180	$ 2,676	$ 5,475	$ 6,628
TOTAL	$2,182	$11,278	$20 967	$25,503

CHAPTER 8

FLOOD DAMAGES IN THE ASSINIBOINE RIVER VALLEY

On the Assiniboine River, estimates of flood damages were prepared for floods of three different magnitudes, namely for floods that might be expected to occur on the average once every 10, 25 and 100 years These floods will be referred to respectively as a 10 percent flood, a 4 percent flood and a 1 percent flood The estimated magnitude of each of these floods is shown below The 1956 flood was just under 20,000 c f s There is no recent flood as large as 25,000 c f s, but the flood of 1923 amounted to 21,000 c f s

	Once in Every	Peak Flood Flow in c f s at Portage la Prairie
10 percent flood	10 years	19,000
4 percent flood	25 years	25,000
1 percent flood	100 years	36,000

On the Assiniboine, the peak flow is reached at Portage la Prairie Below that point the land slopes away from the river, so that once the river overtops its banks, much of the flood water flows overland to the south and enters the Red River through the La Salle River For this reason, in the larger floods, the flow at Headingley is lower than it is at Portage la Prairie

Damage estimates were prepared for four different reaches of the river These reaches were A Headingley to Portage la Prairie, B Portage la Prairie to Brandon, C The City of Brandon, and D Brandon to Millwood Discharge-damage relations for all but the Portage to Brandon reach are shown in Plate 20

A Reach 1, Portage la Prairie to Headingley

A summary of the flood damages that would be caused by each of the four selected floods is given in Table 8 1 These damages have been separated into the following main groups

1 Loss of Income
2 Extra Costs Occasioned by Floods
3 Damages to Personal, Farm and Business Property
4 Flood Losses Incurred by Utilities and Railroads
5 Flood Losses Incurred by the Government

A description of the methods used in preparing each of these estimates is given below

1 Loss of Income

(a) Farm Income Field Crops

Because the characteristics of flooding in the Assiniboine River Valley differ in some respects from those in the Red River, the procedures followed in estimating loss of crop income for the Red River Valley were modified in several respects Examination of data on the dates of the maximum discharges for various historical floods indicated no clear relationship between the lateness of the date of maximum discharges and the size of the flood In the absence of such a relation there is no particular reason to assume that the size of the loss of income per acre will be related to the size of the flood Accordingly, for the Assiniboine Valley, the loss of crop income per acre was calculated by taking the average loss per acre for each crop, using the dates when flooding occurred in a particular series of historical floods The years chosen were 1922, 1923, 1927, 1955 and 1956 The average losses calculated on this basis were then applied to the flooded acreage for a 10 percent flood, a 4 percent flood and a 1 percent flood, giving an estimate of the total loss of crop income for each of these floods

Because the land slopes away from the river between Portage la Prairie and Winnipeg, land in this region would not begin to dry out until the river had returned to bank-full stage and water had ceased to flow out over the land While the dykes on the river in this region are in the process of being raised to a level which will give protection up to about 22,500 c f s, it is probable that, for floods of a 4 percent magnitude (25,000 c f s at Portage la Prairie) or larger, the dykes would be so badly eroded that the river would continue to flow over the land until it had receded to a level of 16,000 c f s The land near Portage la Prairie would begin to dry out as soon as this stage was reached but further down the river, some additional time would elapse before water would recede from the land On the average, it was assumed that four weeks would elapse between the date that the river receded to bank-full stage and the average date of seeding

Several important floods have occurred on the Assiniboine River since the P F R A report on *Conservation and Flood Control* was published in 1952 In the light of the information gained from this more recent flood experience, the estimates of the acreage that would be flooded in a number of major floods were reviewed and important revisions were made for the Portage la Prairie to Headingley reach of the river Estimated acreages in the remaining reaches of the river were left unchanged These revised estimates, together with the unrevised data, are as follows

ACREAGE FLOODED, MAJOR FLOODS

	Maximum Flow at Portage	Flooded Area		
		Headingley to Portage la Prairie	Portage to Brandon	Brandon to Millwood
	(c f s)		(acres)	
10% Flood	19,000	10 000	800	50,000
4% Flood	25 000	204,800	16,000	57,000
1% Flood	36,000	435,200	27,000	58,000

The loss of crop income for various reaches of the Assiniboine was estimated to be as follows

TOTAL LOSS OF FIELD CROP INCOME

Size of Flood	Headingley to Portage la Prairie	Portage to Brandon	Brandon to Millwood
10% Flood	$ 66,240	$ 1,395	$265,050
4% Flood	1,356,595	41 850	292,950
1% Flood	2 882 765	125,550	292,950

A detailed statement of the basis on which these estimates were prepared is given in Appendix E

(b) Farm Income Livestock

Loss of income to livestock was estimated on the same basis as that used for the Red River Valley

For dairy cattle, it was assumed that on the average one month's output of all cows in the flooded area would be lost in a 10 percent flood, one and a half months' output in a 4 percent flood and two months' output in a 1 percent flood

It was estimated that cattle, beef and hogs would be away from their normal surroundings for the following periods for a 10 percent flood, 30 days, for a 4 percent flood, 40 days, and for a 1 percent flood, 50 days

(c) Non-Farm Income

In estimating the loss of non-farm income in flooded areas, an estimate was first prepared from census data of the number of non-agricultural workers affected Gross loss of income per worker was estimated at the rate of $3,480 per year, the same rate used in the Red River Valley area

On the basis of a study of hydrographs for various sized floods, it was estimated that on the average a worker would be away from his job and hence suffer a loss of income for the following lengths of time

Size of Flood	Time Lost	Length of period river in excess of 16,000 c f s
In a 10% flood	1 month	15 days
In a 4% flood	1 month	19 days
In a 1% flood	1½ months	24 days

Some workers, such as those in the construction industry, would be able to return to work immediately after the flood waters had receded Others who worked in premises that had been flooded might be away from their regular occupation for several months In the Assiniboine area, flood waters are expected to reach only a moderate depth, say 2 to 3 feet, thus business premises might escape flooding over the first floor level

(d) Rental Value of Homes

On the basis of an analysis of the 1950 flood records, it was estimated that the average equalized assessed value of homes in the area from Portage to Winnipeg would be $1,500 It was estimated that the monthly rental value of a house would be 2½ percent of its assessed value (this corresponds to 1 percent of estimated market value) It was assumed that the use of the house would be lost for one month where flooding above the floor level occurred

2 **Extra Costs**

(a) Evacuation Costs

Evacuation costs were estimated by applying a cost per person to the total population of the flooded area Costs per person were the same as those used for the Red River Valley The estimated population of the flooded area, based on an analysis of census data, and evacuation cost per person, is as follows

	Number of People Affected	Evacuation Cost per Person
10% Flood	115	$2 65
4% Flood	4,474	2 65
1% Flood	8,069	3 20

(b) Extra Food Costs

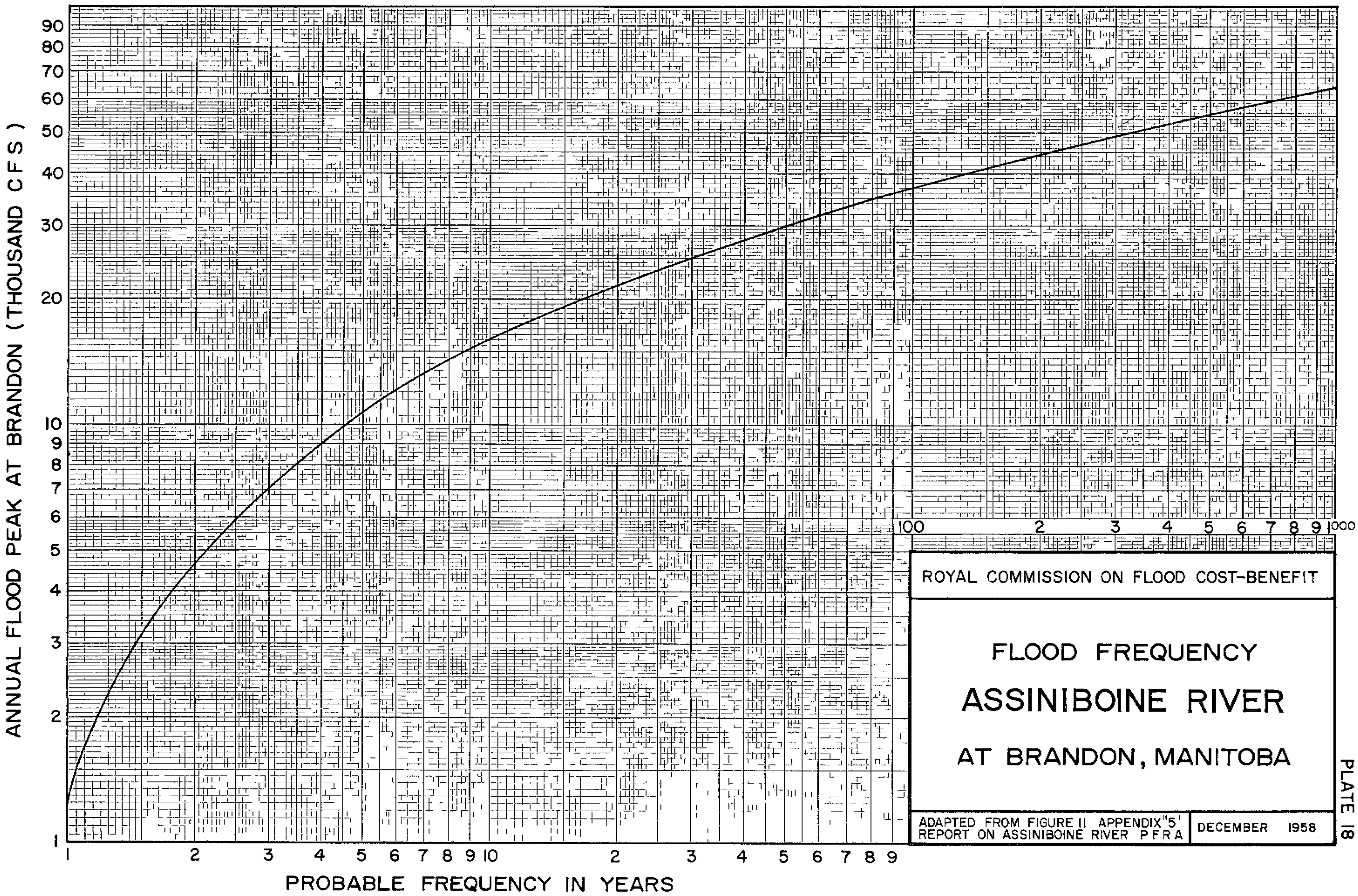
These extra costs were estimated to be $7 50 per person per month, which is one-third of the average monthly food expenditure per person in Canada It was assumed that these extra costs would last for one month in the two smaller floods and for one and a half months in the 1 percent flood

(c) Extra Work

The costs involved in the way of extra work occasioned by the flood, work of moving furniture and cleaning up after the flood, were estimated at somewhat nominal values

(d) Extra Feed for Livestock

This cost was estimated at $6 00 per head of livestock affected for a 10 percent flood, the cost incurred in the 1950 flood in the Red River Valley This was increased by 25 cents per day for each additional day of inundation occurring in the larger floods In the Headingley to Portage area, these costs were as follows



ROYAL COMMISSION ON FLOOD COST-BENEFIT

FLOOD FREQUENCY

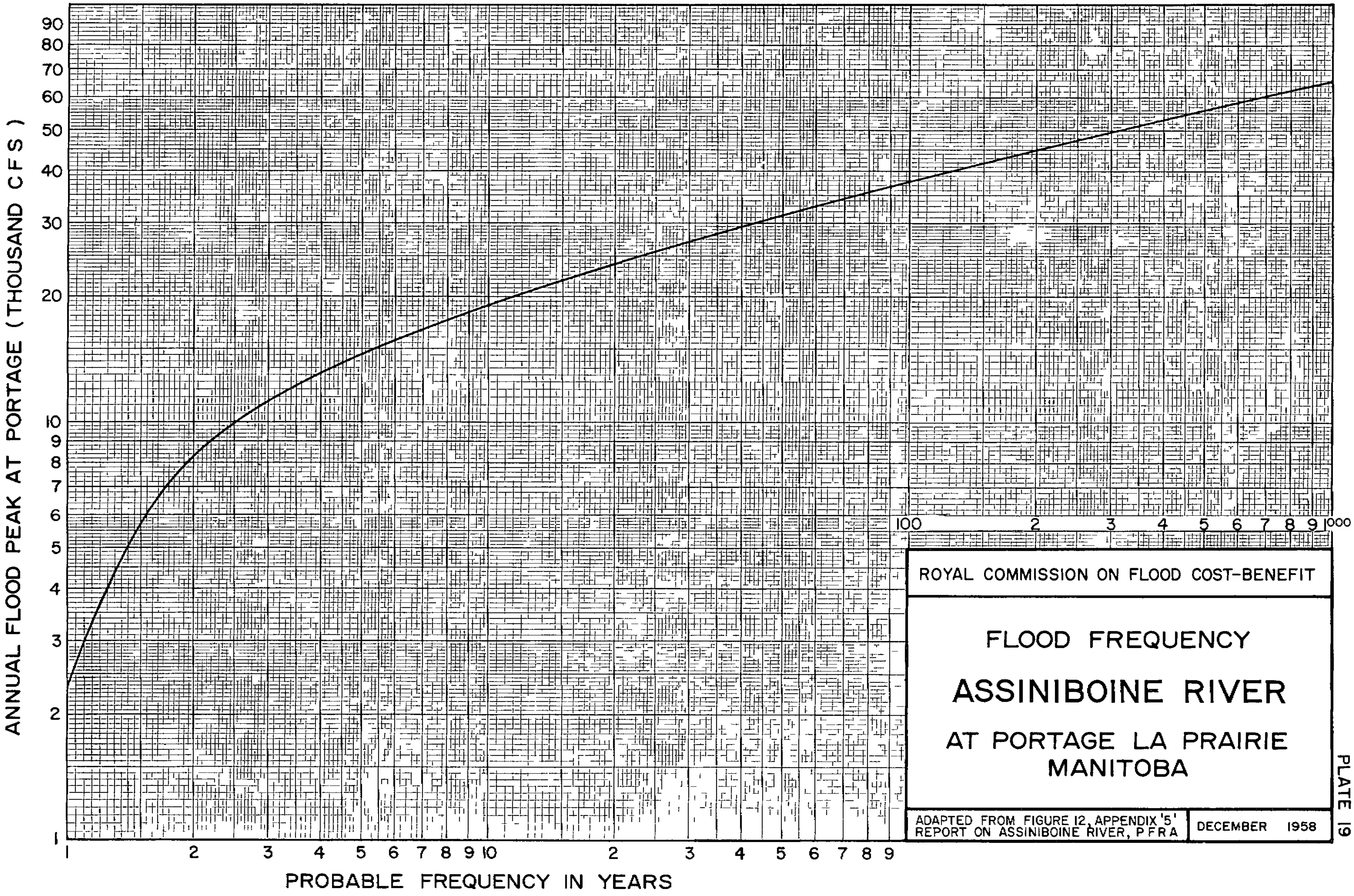
ASSINIBOINE RIVER

AT BRANDON, MANITOBA

ADAPTED FROM FIGURE 11 APPENDIX "5"
REPORT ON ASSINIBOINE RIVER P F R A

DECEMBER 1958

PLATE 19



ROYAL COMMISSION ON FLOOD COST-BENEFIT

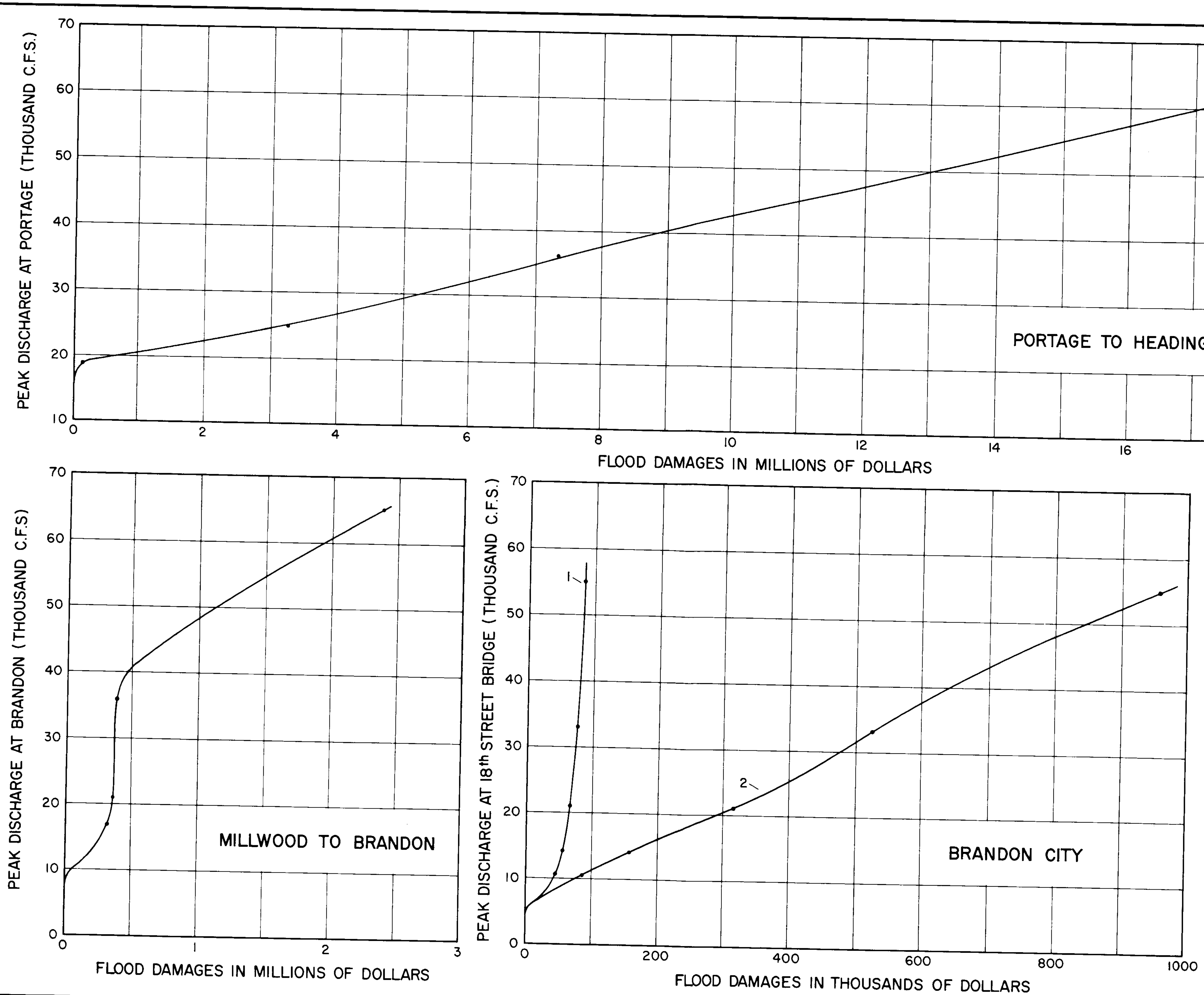
FLOOD FREQUENCY

ASSINIBOINE RIVER

AT PORTAGE LA PRAIRIE MANITOBA

ADAPTED FROM FIGURE 12, APPENDIX '5' REPORT ON ASSINIBOINE RIVER, P F R A

DECEMBER 1958



LEGEND

Curve 1 shows flood damages and losses with no flooding behind the Brandon dyke.

Curve 2 shows damages and losses in the absence of the Brandon dyke (natural condition).

• Estimated points.

ROYAL COMMISSION ON FLOOD COST-BENEFIT

DISCHARGE-DAMAGE RELATIONS

ASSINIBOINE RIVER VALLEY
VARIOUS REACHES

DECEMBER 1958

Size of Flood	Cost per Head of Livestock
10% Flood	$ 6 00
4% Flood	7 50
1% Flood	10 00

(e) Cost of Moving Livestock

An estimate of the average distance that livestock would be moved was based on a study of the size of the flooded areas, costs per truck mile were the same as those used for the Red River Valley

3 Damages to Property

(a) Farm Residences and Other Farm Buildings

In the area between Portage la Prairie and Winnipeg, the best evidence indicates that for the most part, flooding would occur only to a depth of from 2 to 3 feet This would be true for both the larger and smaller floods, the major difference in the larger floods being that the flow over the banks would continue for a longer period and would cover a larger area If it is assumed that for drainage reasons the farmstead is usually located at a spot slightly above the general elevation, then the typical flood level would probably be just below the main floor level in the house Accordingly it was assumed that, in this area, 10 percent of all the houses would be flooded just over the main floor, 60 percent would be flooded to a level of 1 foot below the floor level, and the remaining 30 percent would be subject to basement flooding (flooding of less than 1 foot)

Damages were estimated on the basis of the following schedule which was obtained from the records of flood damage payments made in the Red River Valley in 1950

Flood Level	Damages per Farmstead
Basement Flooding	$ 441 00
1 Foot Below Floor Level	707 00
Over Floor Level	1 025 00

These damages were increased 25 percent to allow for the price rise since 1950 The total number of farms in the flooded area was estimated on the basis of census data on the average size of farm in this area

(b) Non-farm Residential

It was assumed that the flooding pattern in small towns would be the same as in rural areas, with 10 percent of the houses flooded over the main floor, 60 percent flooded to a depth of —1 foot and the remaining 30 percent subject to basement flooding only Damages were based on the record of damage payments made on non-farm residences in the Red River Valley in 1950 These were as follows

Flood Level	Damage per Dwelling
Basement Flooding	$265 00
1 Foot Below Floor Level	325 00
Just over Main Floor	675 00

The number of non-farm dwellings in the flooded area was estimated by first obtaining an estimate of the non-farm population in the flooded area and then assuming one dwelling for every 3 5 persons Damages were increased by 25 percent to convert them to 1957 prices

(c) Personal Property, Farm and Non-farm

Damages to personal property were estimated by applying a ratio of 289 to the total 1950 property damages to farm buildings and non-farm residences This was increased by 15 percent to bring it to a 1957 price basis

(d) Grain, Livestock and Machinery

In 1950 flood damage payments on property of this type in the Municipality of Macdonald amounted to $1 15 per cultivated acre Since the depth of flooding in this area in 1950 was moderate, it was assumed that these data were the most suitable for estimating damages of this type in the area between Portage la Prairie and Winnipeg These estimates were adjusted to a 1957 price basis with a price index of grain, livestock and machinery

(e) Small Business

Damages to the buildings, inventories and fixtures of small business firms were assumed to bear the same ratio to non-farm residential property damage as the ratio realized in the 1950 flood in the Red River Valley

(f) Schools and Churches

Damages to schools and churches were estimated by using the 1950 ratio of damages shown for property of this kind to the total of non-farm residential damage plus farm building damages, in the Red River Valley area

4 Utilities and Railroads

These damages were estimated by the railroads and utilities concerned on the basis of maps showing flooded areas and information on depth of flooding provided by the Commission

5 Government Property

(a) Roads and Bridges

In 1955 and 1956, damages to roads and bridges in the area between Portage la Prairie and Winnipeg amounted to about $82,000 or $ 93 per acre of land flooded It was assumed that damages per acre would be slightly higher in larger floods because of higher velocity and because more bridges would be dislodged Accordingly damages were estimated on the following schedule

Size of Flood	Damages per Acre
10% Flood	$ 73
4% Flood	.93
1% Flood	1.13

(b) Flood Fighting Costs

These costs were estimated on the basis of an estimated expenditure of $150,000 on the dykes for the 4 percent and higher floods plus an additional expenditure of 40 cents per acre of area flooded, 40 cents per acre representing the amount expended (in terms of 1957 prices) by municipalities in the Red River Valley area in 1950 Actual expenditures by provincial and municipal governments in the Portage to Winnipeg area in 1955 amounted to $115,000 In addition, the armed services contributed the equivalent of perhaps $50,000

While the Commission has attempted to make these estimates of flood damages as complete as possible, a variety of minor items have undoubtedly been omitted Thus, no allowance has been made for the loss of soil from erosion due to floods or of the extra cost of levelling the land afterwards This was omitted because no firm data were available on which to base an estimate While damage of this type might be serious for individual farmers, it seems unlikely it would be large in overall terms Further, no specific allowance is included for the mental anguish and suffering occasioned by a flood since, by its nature, this harm cannot be measured in monetary terms

Every attempt has been made to check our damage estimates and make them as realistic as possible Nevertheless, it may be that for some types of damage our estimates may be too high For others, they may err on the low side However, we feel confident that overall they represent a fair appraisal of the damages that can be expected to occur

Table 8 1

FLOOD DAMAGES AND LOSSES ASSINIBOINE RIVER HEADINGLEY TO PORTAGE LA PRAIRIE

Flood Frequency (Average) Once in Every	10 years	25 Years	100 Years
Flood Magnitude in c f s (at Portage)	19 000	25 000	36,000
LOSS OF INCOME			
Farm Crops	$ 63,000	$1,454,000	$3,090,000
Livestock	4,000	122 000	316,000
Non-farm		175 000	472,000
Rental Value of Homes	1,000	32 000	68,000
Sub-Total	$ 68,000	$1 783 000	$3 946,000
EXTRA COSTS			
Evacuation Costs—People	$ *	$ 12 000	$ 26 000
Extra Living Costs	1,000	34,000	91,000
Extra work—clean-up, repair to grounds, etc	3,000	62,000	133 000
Extra feed for Livestock	2,000	61,000	174,000
Cost of moving Livestock	*	2 000	7,000
Sub-Total	$ 6 000	$ 171 000	$ 431,000
DAMAGES TO PROPERTY			
Farm Buildings	$ 12,000	$ 290 000	$ 618,000
Non-farm Residential		96,000	211,000
Personal Property—Farm and non-farm	3 000	103,000	220 000
Grain, Livestock and Machinery	9,000	191 000	415 000
Business		34 000	75,000
Schools and Churches	1 000	31 000	66 000
Sub-Total	$ 25,000	$ 745 000	$1,605,000
UTILITIES AND RAILROADS			
Manitoba Power Commission	$	$ 37,000	$ 70,000
Manitoba Telephone System		13,000	27 000
C N R		77,000	420 000
C P R		3 000	18 000
Sub-Total	$	$ 130 000	$ 535,000
GOVERNMENT			
Roads and Bridges	$ 7,000	$ 190 000	$ 487 000
Flood Fighting Costs	25,000	232,000	324,000
Sub-Total	$ 32,000	$ 422,000	$ 811,000
TOTAL	$131,000	$3,251,000	$7,328 000

*Less than $500 00

Table 8.2

FLOOD DAMAGES AND LOSSES ASSINIBOINE RIVER PORTAGE LA PRAIRIE TO BRANDON

Flood Frequency (Average) Once in Every	10 Years	25 Years	100 Years
Flood Magnitude in c.f.s. (at Brandon)	16,000	23,500	36,000
Loss of Income Crops	$1,200	$36,000	$108,000
Damages to Roads and Bridges		9,500	12,000
TOTAL	$1,200	$45,500	$220,000

B Reach 2, Flood Damages, Portage la Prairie to Brandon

1 Loss of Farm Income Field Crops

Loss of field crop income was estimated on the same basis as was used for the Portage to Winnipeg area. Details on this estimate are given in Appendix E.

2 Damages to Roads and Bridges

For roads and highways, damages per acre were assumed to be of the same magnitude as in the Millwood to Portage Reach.

C Reach 3, City of Brandon

Estimates of the flood damages and flood losses that would occur to the City of Brandon were prepared for some five different flood elevations. A discharge-damage relationship showing the damages that would occur in the absence of all dykes and the damages that would occur even if the dykes held at all flood levels is shown in Plate 20. In preparing this relationship use was made of a detailed contour map of the Brandon flats and a provisional rating curve supplied by the P.F.R.A.

The flood damage estimates include damages to residential and personal property, damages to industrial property (principally Brandon Packers), loss of income, losses suffered by the Brandon Experimental Farm and losses to market gardeners.

Damages to residential dwellings and personal property were estimated on the basis of the damages to assessed value relationships that had been prepared for the Greater Winnipeg area. These relationships were applied to information on the assessed value of dwellings in the flooded area, after adjustment to an equalized basis. Damages and losses for the Brandon Packers and for the Brandon Experimental Farm were based on information supplied by these two organizations.

Losses to market gardeners were based on an estimate of the net income per acre earned by market gardeners which was worked out on the basis of data on prices, yields and production expenses for various crops. These data were supplied by the Horticultural Branch of the Provincial Department of Agriculture. It was assumed that on the average, the loss to market gardeners in a flood year would amount to two-thirds of their normal net income. This assumes that floods will recede early enough in some years to permit the harvesting of a partial crop. No data on recorded experience were available to check the validity of this assumption but it appears reasonable in the light of our estimates for farm income losses in the upper Assiniboine Valley. A summary of these damage estimates for selected discharges is given in Table 8.3.

Table 8.3

DAMAGES AND OTHER FLOOD LOSSES, CITY OF BRANDON SELECTED DISCHARGES

	Damages under Natural (no Dyke) Conditions				Damage, Area not Protected by Dyke
Discharge	Residential, Real and Personal	Market Garden	All Other	Total	Total
10,600	$ 33,500	$52,100	$	$ 85,600	$43,900
14,200	82,500	54,200	19,100	155,800	58,000
21,000	163,000	54,200	99,700	316,900	66,600
33,000	300,500	54,200	168,100	522,800	73,900

D Reach 4, Flood Damages, Brandon to Millwood

The valley area from Brandon to Millwood consists of very fertile farm land which is confined between the steep banks of the Assiniboine River Valley The land in the valley bottom slopes away from the river so that once the river leaves its banks, almost the entire area is inundated This slope of land away from the river also makes it difficult for the water to drain off the land after the flood waters have receded As a result, the farm land dries out very slowly after it has been flooded

Except for roads and bridges, there is an almost complete absence of property in this area Accordingly, our estimates of flood losses have been confined to the loss of field crop income and damages to roads and bridges

1 Loss of Farm Income Field Crops

Loss of field crop income in this reach was estimated on the same basis as was used for the Portage to Winnipeg area

2 Damages to Property Roads and Bridges

For the two smaller floods, damages to roads and highways were estimated on the basis of the damages reported for 1955 and 1956 Damages for the 1 percent flood were increased by 25 percent to allow for the higher velocity and greater amount of erosion that would occur even though the area flooded would be almost unchanged

Table 8 4

FLOOD DAMAGES AND LOSSES ASSINIBOINE RIVER BRANDON TO MILLWOOD

Flood Frequency (Average) Once in every	10 Years	25 Years	100 Years
Flood Magnitude in c f s (at Brandon)	16 000	23 500	36 000
Loss of Income Crops	$292,980	$323,820	$323,820
Damages to Roads and Bridges	35,000	43 000	54 000
Total Damages	$327 980	$366 820	$377 820

CHAPTER 9

GROWTH AS A FACTOR IN BENEFIT-COST ANALYSIS

1 Relation of Growth to Benefit Cost Analysis

In evaluating the benefits that can be obtained from various schemes for flood control, some attention must be given to the growth in income and property values that may reasonably be expected to occur in the flood-prone area, for if benefits based on present income and property values give a favourable benefit-cost ratio, say 2 to 1, this ratio will be increased by this prospective growth. Once the project such as a floodway is completed, its annual costs will remain unchanged but annual benefits will increase gradually as additional growth takes place. In attributing benefits on the growth side, it would be incorrect to include flood protection benefits to property which is built in the flood-prone area as a result of the flood protection measures. Only benefits arising out of the growth that can be anticipated in the absence of any flood protection measures are included.

When the effects of growth are included in a benefit-cost ratio the size of the ratio may be increased substantially. Thus Table 9.1 shows the effects of different annual percentage rates of growth in benefits upon a benefit-cost ratio of 1.0. The precise theoretical basis on which these ratios are calculated is explained in Appendix F.

Table 9.1

EFFECTS OF DIFFERENT RATES OF GROWTH IN BENEFITS UPON A BENEFIT COST RATIO OF 1.0

Annual Rate of Growth in Benefits	Growth Benefit-Cost Ratio
r = 2.0%	1.50
r = 2.25%	1.58
r = 2.5%	1.69
r = 3%	1.89
r = 4%	2.33

These data show that if the annual flood protection benefits can be expected to grow at a rate of 2 percent per annum over the 50-year life of the project, a project which has a benefit-cost ratio of 1.0 on the basis of present income and property values will have a benefit-cost ratio of 1.50 for the 50-year life of the project (assuming interest at 4 percent). Other benefit-cost ratios, based on present values only, would be increased proportionately. Thus on a project where the benefit-cost ratio based on present values is 2.0, the corresponding ratio incorporating the effects of growth at 2 percent per annum would be 3.00 (again assuming interest at 4 percent).

It should be noted that the growth ratios presented here incorporate increased future benefits on a discounted basis. For any project whose construction is being planned and justified today this is the proper basis of evaluation. However, to the extent consideration is being given to the possibility of increasing the size of a particular project, such as the Floodway, at some future date or the construction at that time of some auxiliary project, it is desirable also to have an estimate of how much present benefit-cost ratios will have increased in size by various future dates. Table 9.2 gives the benefit-cost ratios for periods 5, 10, 15, 20 and 25 years hence, that correspond to a ratio today of 1.0. These ratios are given for a number of different values of r, the annual percentage rate of growth in benefits, (with interest at 4 percent).

Table 9.2

PATTERN OF BENEFIT COST RATIOS AT VARIOUS FUTURE DATES WHERE GROWTH IN BENEFITS OCCURS

Annual Rate of Growth Benefits (percent)	Number of Years from Date 0	5	10	15	20	25
r = 1.5	1.0	1.08	1.16	1.25	1.35	1.45
r = 2.0	1.0	1.10	1.22	1.35	1.49	1.64
r = 2.5	1.0	1.13	1.28	1.45	1.64	1.85
r = 3.0	1.0	1.16	1.34	1.56	1.81	2.09

For example, if annual benefits are assumed to grow at the rate of 2.5 percent per annum, a project, which today only gives a benefit-cost ratio of 1.0, would show a ratio of 1.28 if it were considered for construction ten years from now and a benefit-cost ratio of 1.85 if considered for construction 25 years from now. It is not necessary, of course, to make any commitment at this time about the construction of projects at future dates. However, it is desirable to form some opinion as to which projects may become justifiable from a benefit-cost point of view and may, in fact, be constructed at some future date. Such data have relevance to the question of constructing projects in such a form as to ensure a possible expansion in their size at some future date.

2 Growth in the Greater Winnipeg Area 1957 to 1982

In order to measure the effects of anticipated growth upon benefit-cost ratios in the Greater

Winnipeg area, a detailed estimate has been prepared of the amount of property and income that may be expected to be in existence 25 years hence On the basis of these data, an estimate has then been prepared of the damages that would be caused by floods of different sizes This estimate shows that by 1982 annual damages for floods of all sizes would amount to $23,243,500 This is an increase of 80 percent over the 1957 level and, in terms of growth rates, implies an annual rate of growth in benefits of between 2 25 and 2 5 percent Assuming the rate of growth were 2 25 percent per annum over the 50-year life of the project, and referring back to Table 9 1 it can be seen that the increase in flood damages that can be anticipated because of the growth in prospect for Greater Winnipeg will increase the benefit-cost ratios which are based on present property values and present incomes by a factor of 1 58 for a four percent interest rate In round numbers it would seem safe to conclude that the inclusion of prospective growth increases benefit-cost ratios for the Greater Winnipeg area by a factor of 50 percent, that is, to one and one-half times the ratios that are based on current values only

In preparing estimates of future property and income the following procedures were followed It was assumed that the population of the Greater Winnipeg area would amount to 700,000 by 1981 This is somewhat below the estimate of 760,000 for 1981 made by the Metropolitan Planning Commission and a little higher than the estimate contained in *Prospects for Development in Manitoba*[1] which places the population for the metropolitan area at 647,000 in 1980

The estimated location of this population within the metropolitan area is shown in Table 9 3

Group A consists of areas that have only limited space left for development, whereas both groups B and C still have large undeveloped areas available The total increase shown in each of the three groups follows closely the projected growth estimates made by the Metropolitan Planning Commission of Greater Winnipeg The detailed estimates for individual municipalities were prepared after a discussion of the problem with officers of the Metropolitan Planning Commission It may be noted that estimates contained in a brief presented by the City of Winnipeg to the Greater Winnipeg Investigating Committee show an even larger proportion of the total increase centering in Group B, an area that is very vulnerable to major floods In this latter estimate some 58 percent of the population increase is allocated to Group B compared with only 50 percent in the estimate used by the Commission

[1] A Submission to the Royal Commission on Canada s Economic Prospects by the Government of Manitoba

Table 9 3

POPULATION GROWTH, METROPOLITAN WINNIPEG, 1956-81

Group A	1956	1981	Increase 1956-81
Winnipeg and Brooklands	261,000	291,000	30,000
St James	26,000	31,000	5 000
East Kildonan	19,000	24,000	5,000
West Kildonan	15 000	24 000	9,000
Sub-Total	321,000	370 000	49,000
Group B			
St Boniface	29 000	71,000	42 000
St Vital	24 000	64,000	40 000
Fort Garry	13 000	58 000	45,000
Transcona	8 000	16 000	8,000
Tuxedo	1,000	11 000	10,000
Sub-Total	75,000	220,000	145,000
Group C			
Assiniboia	4,000	26,000	22,000
Charleswood	5,000	23,000	18,000
Old Kildonan	1,000	23,000	22,000
North Kildonan	4,000	38,000	34,000
Sub-Total	14,000	110,000	96,000
Total All Groups	410,000	700,000	290,000

The additional number of dwellings that would be required in each area as a result of this anticipated population growth was estimated by use of data on the number of persons per dwelling based on the 1951 census A slight decline in the average number of persons per dwelling was assumed It was further assumed that some 80 percent of these dwellings would be single family residences or duplexes and that the balance would be apartments Within municipalities these additional dwellings were allocated to the spaces set aside for future residential growth in the map prepared by the Metropolitan Planning Commission (*See Plate* 21, *and Greater Winnipeg*, 1981, *Diagram* 7)

In estimating the growth in business and institutional property the following procedure was followed At the present time there is in existence 65 sq feet of ground floor area of business (commercial and industrial) property and 18 square feet of institutional and government property for every inhabitant in the Greater Winnipeg area It was assumed that there would be the same square footage of business and institutional property per inhabitant in 1982 Multiplying these unit values by a population of 700,000 gives an estimate of the total square footage of business and institutional property that could be expected to exist in Winnipeg in 1982 It could be argued that with a rising level of per capita income the amount of such property per person might increase However, this would be at least partially offset by a depreciation in existing property that was in excess of any replacement Details of this estimate are shown in Table 9 4

Table 9 4

ESTIMATED GROWTH IN NON-RESIDENTIAL PROPERTY GREATER WINNIPEG, 1957-82

	Business	Institutional and Government
	(Square Feet)	
Present Ground Floor Area for Property in Metropolitan Winnipeg	26,535,000	7,549,000
Square Footage per Capita	65	18
Total Required for a population of 700,000 in 1982	45,500,000	12,600,000
Additional Required by 1982	18 965,000	5,051,000

To allocate this additional space throughout the Greater Winnipeg area the following method was used It was assumed that a certain proportion of this additional space would be constructed in new residential areas To determine how much of the total could be allocated in this way, a number of existing residential areas were analyzed The areas selected were ones with a minimum amount of industrial and central business property, but each had at least one main traffic artery and a share of commercial property serving a largely suburban market

This analysis showed that the equalized assessed values of commercial and institutional buildings in these areas represented about 10 percent of the equalized assessed value of residential buildings These data also showed that for each resident there was about 8 2 square feet of commercial property and 10 8 square feet of institutional (including rinks and meeting halls) property in these areas These last two factors were applied to the estimated population growth for each area to obtain estimated requirements for commercial and institutional property that would be located in the new residential areas

It was further assumed that one-half of the additional business property would be industrial, since about one-half of the existing business property in the metropolitan area is industrial The expected growth in the square footage of industrial property by 1982 was then allocated to different areas of Metropolitan Winnipeg in proportion to the acreage of land area that has been set aside for industrial growth in the Metropolitan Planning Commission's plan for the future growth of the area

After these two steps had been taken, the balance of business and government and institutional property was then allocated to existing developed areas in direct proportion to the amount of property of this type now in existence in these areas This makes some allowance for the more intensive development that occurs within the centre of a city as the total area expands A summary of these allocations by area is shown in Table 9 5

Having tentatively allocated by areas the additional residential and non-residential property that can be expected to exist in Greater Winnipeg by 1982, flood damage estimates were then prepared on the basis of this larger amount of property In preparing these damage estimates use was made of the various flood damage rates we had already developed

For residential property it was assumed that the average equalized assessed value of the new dwellings constructed between 1957 and 1982 would be the same as the present average equalized assessed value in each municipality While it might be reasonable to assume some increase in the average value of residential property as the community becomes more wealthy this would be offset, in part, by depreciation on existing properties, not offset by replacements The same applies to personal property, although here our estimates probably represent an understatement of future potential damages because replacement rates are much higher for this type of property

Damages to business inventories and fixtures are also based on the assumption that the value of stock and fixtures per square foot of business property would be the same in 1982 as at present and that, for this reason, damages to this equipment per square foot of business property would also be the same at any given flood level This, too, is probably an understatement since there has been a long term trend towards an increased value of machinery and equipment per square foot of business floor area and the rate of replacement in this field is fairly high

Estimates of loss of income were presented earlier in the loss of income study It will be recalled that they assumed an increase of two-thirds in the level of per capita income by 1982, the amount of increase forecast by the Gordon Commission for all Canada

For a variety of other flood losses such as evacuation costs, extra costs of clean-up, damages to railways and public utilities and damage to municipal streets, roads and sewers it was simply assumed that damages for this group would bear the same ratio to all other damages in any given flood as they do at present

Flood fighting costs were increased by about 20 percent at Mile 53 (foot of Oakenwald in Fort Garry) and at Mile 42 (opposite Seven Oaks) in line with a probable lengthening of the main dyking system

On the basis of these damage estimates, frequency-damage relations were prepared and to demonstrate the effects of growth, benefits for three major floodways were calculated on the basis of expected 1982 income and property conditions These benefits are presented in Table 9 6 For the city as a whole, benefits can be expected to be from 83 to 86 percent higher in 1982 than they are today The increase in benefits is particularly large, about 245 percent, in the south end of the city (Mile 53) It is somewhat below the overall average in the centre of the city

An increase in benefits of 85 percent over a 25-year period implies an annual growth rate of 2 5 percent Referring to Table 9 1 it can be seen that when the growth rate is 2 5 percent the benefit-cost ratio which incorporates growth benefits on the basis of their discounted present value is increased by 69 percent for an interest rate of 4 percent

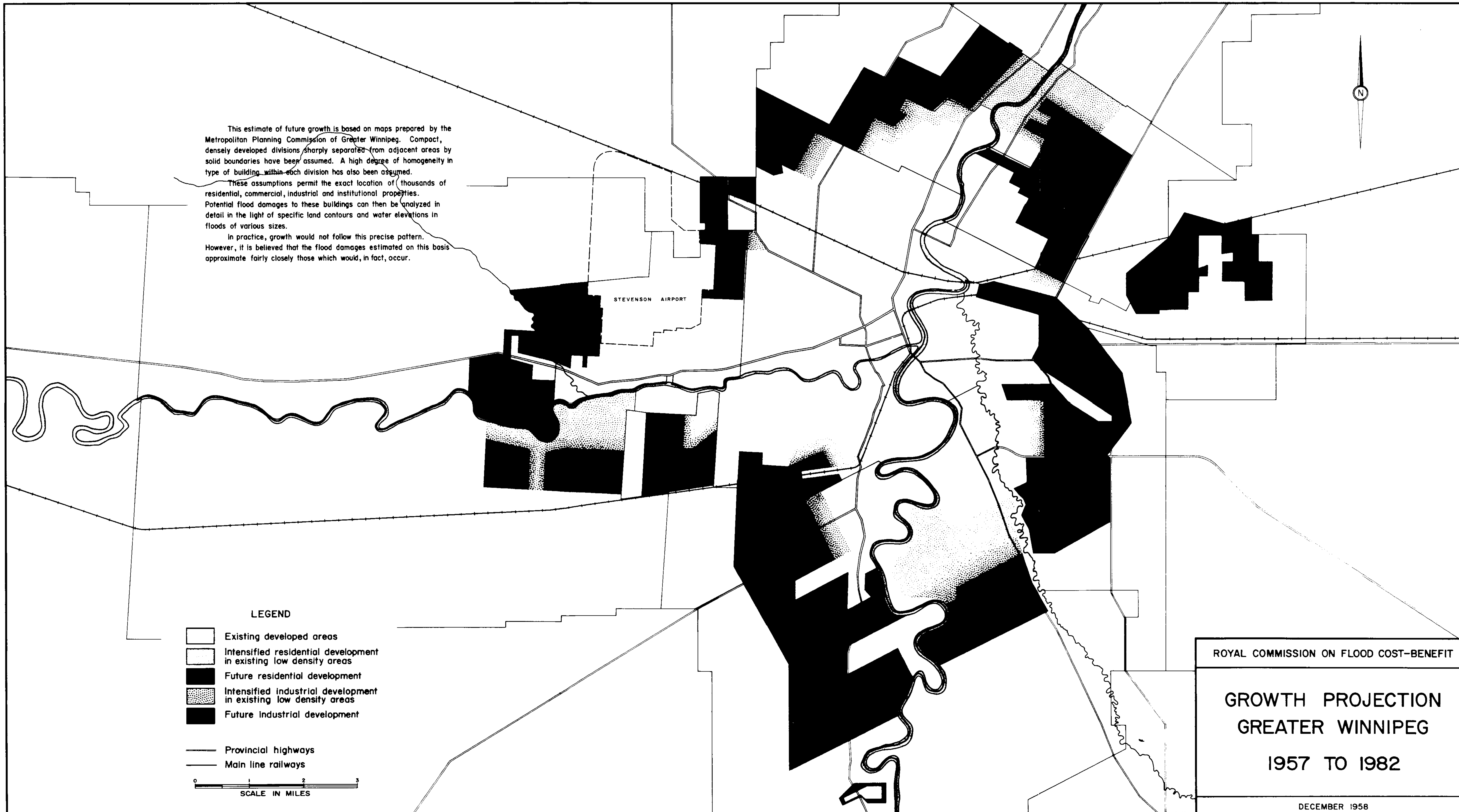

This estimate of future growth is based on maps prepared by the Metropolitan Planning Commission of Greater Winnipeg. Compact, densely developed divisions sharply separated from adjacent areas by solid boundaries have been assumed. A high degree of homogeneity in type of building within each division has also been assumed.
These assumptions permit the exact location of thousands of residential, commercial, industrial and institutional properties. Potential flood damages to these buildings can then be analyzed in detail in the light of specific land contours and water elevations in floods of various sizes.
In practice, growth would not follow this precise pattern. However, it is believed that the flood damages estimated on this basis approximate fairly closely those which would, in fact, occur.
STEVENSON AIRPORT
N
LEGEND
Existing developed areas
Intensified residential development in existing low density areas
Future residential development
Intensified industrial development in existing low density areas
Future industrial development
Provincial highways
Main line railways
0 1 2 3
SCALE IN MILES
ROYAL COMMISSION ON FLOOD COST-BENEFIT
GROWTH PROJECTION
GREATER WINNIPEG
1957 TO 1982
DECEMBER 1958
GJM

Table 9 5

ALLOCATION OF ESTIMATED FUTURE GROWTH IN GREATER WINNIPEG

1957 1982

Area	Population Growth	Number of New Living Units	Total Industrial and Commercial Growth	Total Institutional and Governmental Growth
			(Square footage of ground floor)	
Group A	49 000	14 425	9 620 000	2 198 000
Group "B"	145 000	40 866	8 139 000	1 809 000
Group 'C	96 000	26 473	1 206 000	1 044 000
TOTAL	290 000	81 764	18 965 000	5 051 000

Area	INDUSTRIAL AND COMMERCIAL GROWTH: In new residential areas (Mostly commercial)	In new industrial areas (Mostly industrial)	Residual growth in present built up areas	INSTITUTIONAL AND GOVERNMENTAL GROWTH: In new residential areas	Residual growth in present built up areas
	(Square footage of ground floor)			(Square footage of ground floor)	
Group "A	405 000	3 035 000	6 180 000	531 000	1 667 000
Group 'B'	1 192 000	6 031 000	916 000	1 561 000	248 000
Group C"	789 000	417 000		1 034 000	10 000
	2 386 000	9 483 000	7 096 000	3 126 000	1 925 000
		18 965 000		5 051 000	

Table 9 6

AVERAGE ANNUAL BENEFITS — GREATER WINNIPEG FLOODWAYS

Comparison of 1957 and 1982

Floodway Design	Reach I Mile 53			Reach II Confluence			Reach III Redwood Bridge			Total		
	1957	1982	Percent Increase	1957	1982	Percent Increase	1957	1982	Percent Increase	1957	1982	Percent Increase
	(Benefits shown in Thousands of Dollars)											
40 768	$ 830	$2 845	243%	$4 658	$7 168	54%	$2 107	$3 883	84%	$ 7 595	$13 896	83%
60 768	1 009	3 505	247%	5 558	8 575	54%	2 560	4 881	91%	9 127	16 961	86%
80 768	1 118	3 869	246%	6 166	9 400	52%	2 867	5 364	87%	10 151	18 633	84%

CHAPTER 10

BENEFIT-COST ANALYSIS

The development of dependable benefit cost ratios was, of course the ultimate technical goal which the Commission had to reach before it could consider its conclusions and recommendations Much research was necessary and was undertaken by the Commission and its personnel to that end as will be observable to the reader of this report

Research was necessary first on the engineering aspects of the various and numerous proposals examined by the Commission While a great deal of engineering work had already been carried out by the Red River Basin Investigation it was necessary to adapt these earlier studies to the specific requirements of a benefit cost analysis Thus extensive engineering studies had to be made to estimate the elevations that the water would reach at various locations for the entire reach of floods The establishment of a specific flood elevation for each possible discharge entailed the drawing up of rating curves for each point that was considered representative for purposes of the benefit cost study The rating curves representing conditions as they would exist in the absence of dykes or other improvements are termed in this report as natural conditions

The fundamental part of these studies was the establishment of a relationship between the flows of the Red and Assiniboine Rivers which together make up the flood peak in the Greater Winnipeg area In estimating the contribution from the Assiniboine River, due consideration had to be given to the fact that high flood peaks on the Assiniboine are greatly modified by overland flow to the Sale River and in very high flows to Lake Manitoba The former consideration is particularly important

The next step was to show the reduction in water elevation or discharge that each project or combination of projects would produce These reductions are shown on Plates 24 26 and 28 31 For example with a total flow of 160 000 c f s at Redwood Bridge which is below the confluence of the Assiniboine and Red Rivers, the flood elevation would be 762 3 (34 7 ft above city datum) Of this flow 28 000 c f s would be from the Assiniboine in Winnipeg and 129 000 c f s from the Red at Ste Agathe and 3 000 c f s from the overflow of the Assiniboine through the Sale River The use of a 60 768 floodway alone would take off 64 900 c f s and reduce the elevation at Redwood Bridge to 755 2 The additional use of a 25 000 c f s Portage Diversion would reduce the Assiniboine flow to 13 000 c f s through Winnipeg and eliminate the overflow from the Assiniboine and would lower the water level to 751 7 The addition of a third project, the Russell Reservoir would further reduce the Assiniboine flow to 3,000 c f s This combination of projects would reduce the elevation of the water level at Redwood Bridge to 749 5 and would eliminate any overflow to the Sale River The elevation of the top of the dykes, less one foot at Redwood Bridge, is 751 5

Before this engineering data could be translated into terms of benefits it was also necessary to undertake an economic study of the flood damages that would occur at different flood levels These studies were also exhaustive

On the basis of these data, each proposal was then examined first standing on its own feet, separate and distinct from any other proposal thereafter when these individual studies had been completed, the practicability of each was considered as part of a combination of two or more projects

In this chapter it will be found that, while each project is dealt with on an individual basis reference is made, where applicable to the part it may play in the overall plan of the Commission for flood prevention (*See Chapter* 11) In the following chapter the feasibility of various combinations of benefits will be considered

As was explained in Chapter 5 a benefit cost ratio is a measure of the extent to which the benefits that result from any flood prevention proposal will exceed the cost of the project Where the ratio is 2 0 it means that over the amortization period of the project, the flood damages eliminated will be twice as large as the cost of the project

In calculating these ratios both costs and benefits are reduced to an annual basis Annual costs include interest and amortization charges on the cost of the project, and any maintenance or operating costs connected with it In the present analysis annual costs were calculated on the basis of a 4 percent rate of interest and a 50 year amortization period Flood prevention benefits are obtained by means of the frequency damage analysis described in Chapter 5 Benefits in the form of improved water supply have been included wherever some reasonably accurate basis of estimate could be found

In estimating flood benefits in the Greater Winnipeg area it has been necessary to make some allowance for the protection already afforded to the city by the existing dyking system

The conventional approach to this problem is to assume that these dykes will eliminate all flood damages caused by floods which remain below a certain elevation In this approach which can be called the freeboard approach, two or three feet of freeboard are allowed on a dyking system, depending on its width, depth, type of construction and other factors This means that the dyke is assumed to eliminate all damages caused by floods of up to two or three feet below the top of the dyking system However for the City of Greater Winnipeg area, this approach did not seem entirely appropriate since, when the existing main dyking system was designed, it was intended that emergency dykes should be added to the top of it whenever floodwaters threatened to overtop the present dyking system which is for the most part, four feet below the 1950 flood level

Accordingly an alternative approach was adopted In this alternative it is assumed that as the level of the river rises the risk of flooding behind the present dyking system gradually increases Thus instead of assuming that the dyking system including the temporary additions made to it in a flood emergency is completely safe up to a certain elevation and then fails completely at any higher elevation an attempt has been made to assess the risks inherent in the system at various elevations These risks are many

(a) To begin with there are a large number of ungated sewer outlets under the present dyking system which would have to be disconnected and blocked in a flood emergency The Greater Winnipeg Dyking Board listed 71 ungated sewer outfalls to the river and stated that there were undoubtedly many more the locations of which were not known Emergency pumps would have to be installed in order to take care of the sewage and runoff normally discharged by these outlets

(b) There would also be a serious danger from underground conduits such as pipes sewers and culverts which could fail in times of high water and either undermine the dykes or flood the sewers beyond the capacity of the pumps

(c) In the older sections of the city, the danger from this is particularly great because of old long forgotten structures now blocked with loose material which might give way under the pressure created by high flood levels

(d) Other risks of flooding arise out of the difficulties that may be encountered in building up the long lines of flood defence The Red River Basin Investigation estimated that emergency dykes ranging in height from one to five feet would be needed over a length of 43 miles to provide protection against a flood of the 1950 magnitude A substantial mileage of the defence system is located in the south end of the city in undeveloped areas where there are few access roads and where a failure would flood large sections of Greater Winnipeg In a wet spring which is more probable in a flood year, access roads could become impassable for heavy trucks and earth moving equipment

(e) A further risk arises from the fact that in all areas frost or wet ground conditions might make it difficult to secure suitable borrow material for temporary dyke construction Wet weather would also impede dyke construction and create a risk that the temporary dykes would be overtopped by flood waters before they had been raised to the required height

(f) Finally there is the risk that the dykes themselves might fail either because of seepage or as a result of wave action or water pressure

After assessing these various risks our engineering advisors prepared an estimate of the percentage risks of flooding within the main dyking system for each of the three reaches in the Greater Winnipeg area In preparing this table, they were aided by the similar estimates prepared by individual municipalities that appeared in the Sixth Annual Report of the Dyking Commission 1957 These estimates are shown in Table 10 1

Table 10 1

RISKS OF FLOODING WITHIN THE PRIMARY DEFENCE SYSTEM THREE REACHES, GREATER WINNIPEG

Elevation at James Ave	Flood Frequency	Percentage Risks of Flooding Reach 1	Reach 2	Reach 3
26	5 [illegible]%	1%	5%	1%
27	4 4%	10%	10%	5%
28	3 8%	25%	55%	25%
29	3 3%	55%	65%	45%
30	2 8%	80%	80%	70%
31	2 3%	100%	90%	85%
32	2 1%	100%	100%	100%

NOTE

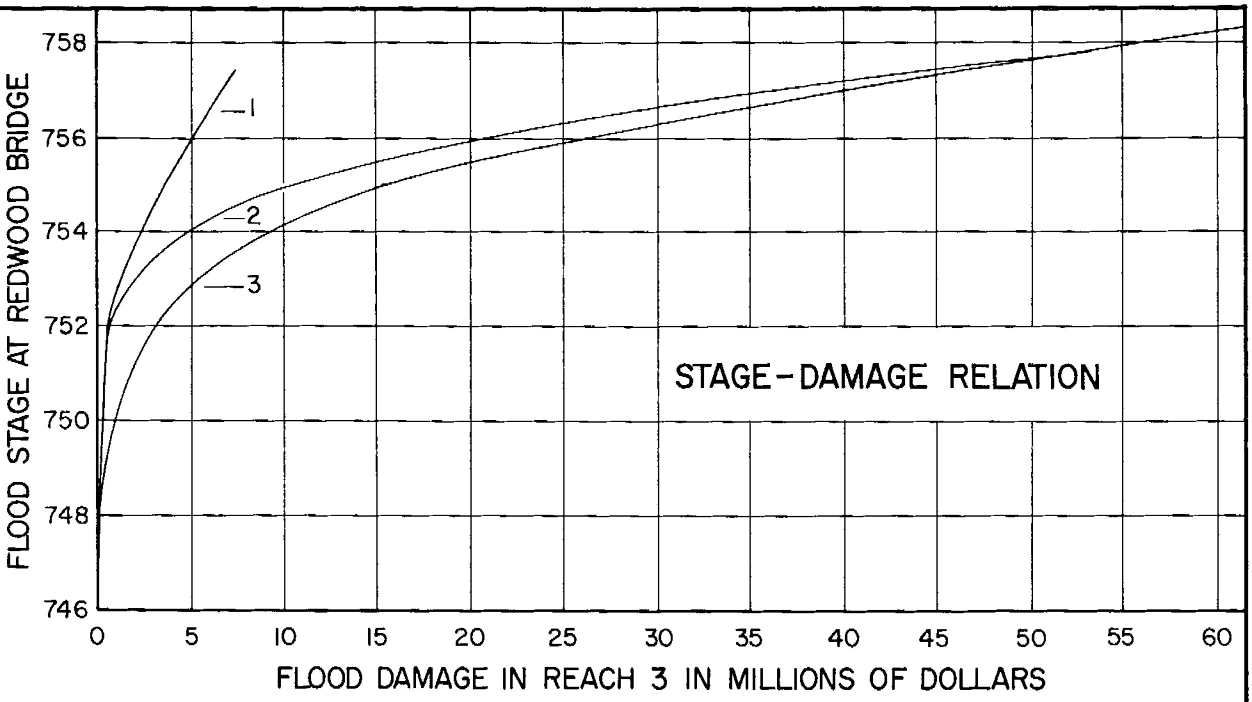
Reach 1 includes St Vital and Fort Garry

Reach 2 includes Wards I and II in Winnipeg St Boniface St James Tuxedo Brooklands and Rosser

Reach 3 includes Ward III in Winnipeg East Kildonan West Kildonan Old Kildonan North Kildonan Transcona and East and West St Paul

Elevations are given in terms of feet above city datum at James Avenue

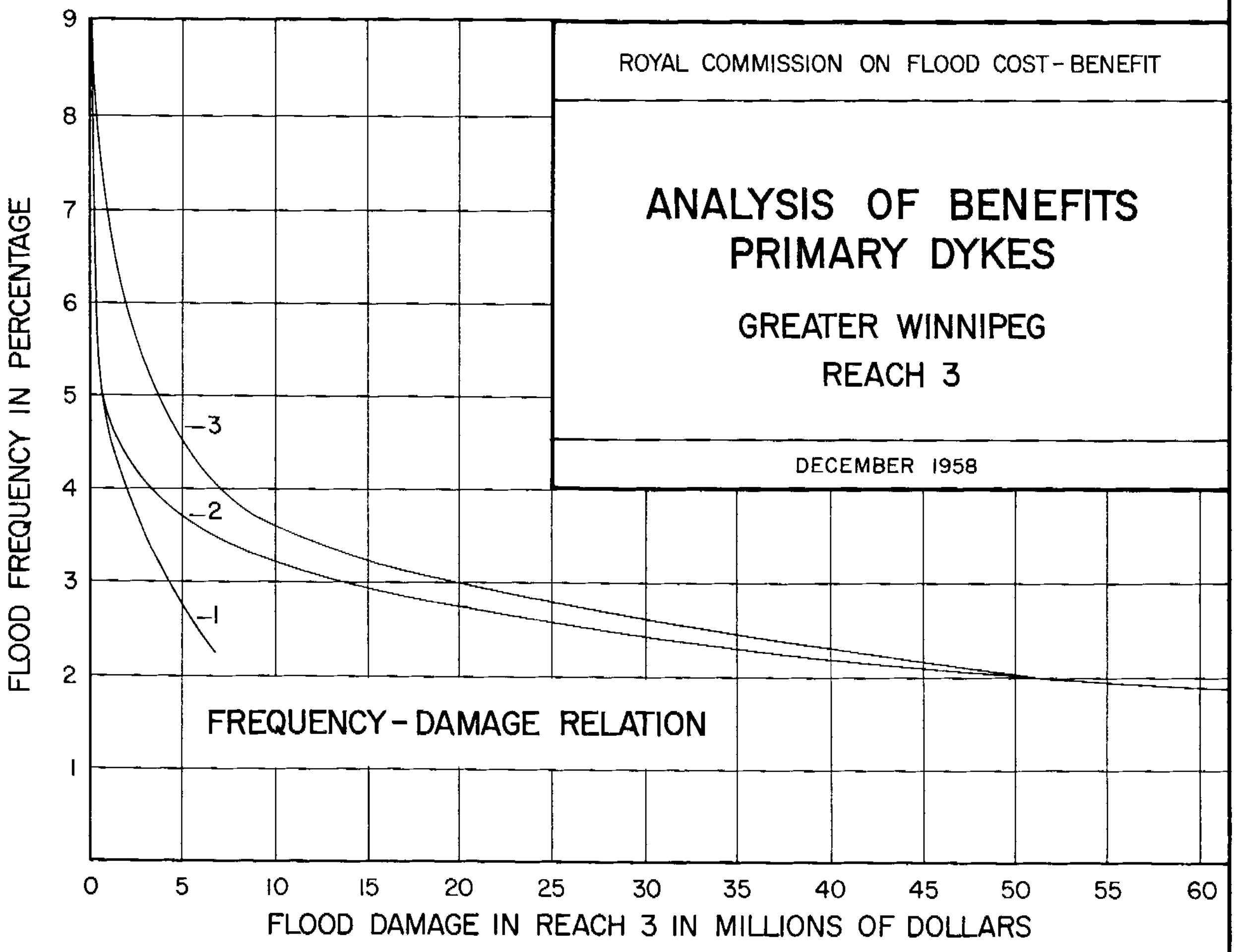
PLATE 22



1 Flood damages and losses with no flooding behind the primary line of defence

2 Flood damages with progressive failure of the flood defence system

3 Flood damages in the absence of all dykes (natural conditions)



ROYAL COMMISSION ON FLOOD COST-BENEFIT

ANALYSIS OF BENEFITS PRIMARY DYKES

GREATER WINNIPEG REACH 3

DECEMBER 1958

In utilizing these data it was necessary to prepare for each reach an estimate of the flood damages and losses that would occur under two different assumptions.

First an estimate was prepared on the assumption that the dykes remained intact and all flooding was prevented behind the main dyking system. Such an estimate for Reach 3 is shown as Line 1 in the Stage Damage Relation on Plate 22.

Second, an estimate was prepared showing the damages that would occur under natural conditions in the absence of all dykes. Such an estimate for Reach 3 is shown in line 3 on Plate 22.

On the basis of these two estimates and the data given in Table 10.1 a third estimate of flood damages was prepared which shows the damages that would occur with progressive failure of the flood defence system in the face of higher and higher water elevations. This estimate appears as line 2 in Plate 22 and is prepared in the following manner. The data in Table 10.1 indicate that in a 3.3 percent flood (29 ft. at James Avenue) the risk of flooding in Reach 3 is 45 percent. This means that for such a flood the damages caused by flooding behind the main dyking system would amount on the average to 45 percent of the additional damages that would result from the absence of any flood defence. Accordingly the corresponding point for line 2 is plotted 45 percent of the distance from line 1 to line 3 at an elevation of 754.6, the elevation reached by a flood of this frequency at Redwood Bridge. Other points on line 2 are plotted in a similar way. Thus line 2 begins to diverge from line 1 at the elevation where some risk of flooding behind the main dyking system begins and gradually approaches line 3 as higher elevations are reached and the risk of flooding increases. It merges completely with line 3 at the point where the risk of flooding behind the primary line of defence becomes 100 percent.

This approach attributes to the primary defence system a benefit corresponding to the area between lines 2 and 3 in the frequency damage chart on Plate 22. This amounts to an annual benefit of $850,200 for all three reaches.

If the "freeboard approach" had been adopted it would be necessary to assume that the dykes were completely safe to an elevation of about 29.5 feet above city datum at James Avenue in order to give the dyking system this same annual benefit. Thus, in effect our approach attributes a very substantial part of the benefit that arises from the elimination of the more frequent floods to the primary defence dyking system. Benefits attributable to the Greater Winnipeg Floodway and other projects are additional benefits that arise from the elimination of damages in the larger, less frequent floods, damages which cannot be prevented by the main dyking system.

The approach used by the Commission is conservative since the attribution of a smaller benefit to the main dyking system would have left a larger benefit for other projects and would have resulted in higher benefit-cost ratios on these projects.

Having adopted this basis for the treatment of the dyking system, benefit cost ratios were

Table 10.2

BENEFIT COST ANALYSIS
GREATER WINNIPEG FLOODWAYS

Project Design	Capital Cost	Annual Cost at 4 Percent	Annual Benefit	Average Benefit Cost Ratio
20 766 Floodway	$50 220 000	$1 675 800	$5 058 500	3.02
40 768 Floodway	41 724 000	2 303 400	7 595 000	3.30
60 768 Floodway	57 361 000	3 161 700	9 127 200	2.89
80 768 Floodway	71 496 000	3 931 800	10 151 400	2.58
100 770 Floodway	77 485 000	4 275 900	10 408 300	2.43

Increase in Size of Floodway	Increase in Annual Cost	Increase in Annual Benefit	Incremental Benefit Cost Ratio
From 0 to 20 000 c.f.s.	$1 675 800	$5 058 500	3.02
From 20 000 to 40 000 c.f.	627 600	2 536 500	4.04
From 40 000 to 60 000 c.f.s.	858 200	1 532 200	1.79
From 60 000 to 80 000 c.f.	770 100	1 024 200	1.33

NOTE Floodway designations refer to the capacity of the floodway in thousands of cubic feet per second for a given water surface elevation at the floodway inlet. Thus 20 766 indicates a floodway with a capacity of 20 000 second feet for a water surface elevation at the inlet of 766 feet above mean sea level.

Annual benefits are based on income and property values in existence in 1957.

then calculated for various flood protection measures. This was carried out first considering each project by itself. This analysis indicated that certain projects could be eliminated and provided a basis for judging the relative merits of the remaining projects.

1. Diversions

(a) Greater Winnipeg Floodway

Before evaluating the benefits of the Greater Winnipeg Floodway it was necessary to decide how the control structure just below the floodway inlet should be operated. Two alternative methods of operation were considered.

With the first method when the river level in the city approached the top of the dykes which would occur at a flow of about 80,000 c.f.s., the water level above the control structure would be raised above the natural level, thus diverting more water down the floodway and keeping water levels within the city below the top of the existing primary dyking system. This method of operation would afford more protection to Greater Winnipeg but it would raise water levels upstream of the intake structure and cause some additional damage in that area.

In the second method of operation, the control structure would be operated at all times to keep the upstream water level at the same elevation as it would have reached in the absence of a floodway.

Although the Commission recognized that the first method of operation offered some additional margin of protection to Winnipeg and would attribute larger benefits to the floodway they decided to adopt the more conservative basis of estimation afforded by the second method. An analysis of benefits carried out on this basis indicates that all floodways in the size range from 20,000 c.f.s. to 100,000 c.f.s. have favourable benefit cost ratios (*See Table* 10.2). The highest ratio, 3.30 is shown by the 40,000 c.f.s. floodway. But even a floodway with a design capacity of 100,000 c.f.s. has an overall benefit cost ratio of 2.43.

However, when consideration is given to incremental benefit cost ratios it becomes evident that it would not be economical to build a floodway with a capacity much in excess of 80,000 c.f.s. This relationship between average and incremental benefit cost ratios is shown in more detail in Plate 23. This Plate shows that the incremental benefit cost ratio falls to 1.0 at a floodway capacity of about 90,000 c.f.s. Up to that point, the additional cost of increasing the size of the floodway is more than offset by the additional benefits this increase in size provides. Beyond that point the additional benefits fall below the additional cost of providing them. All of the above ratios are based on the benefits derived from present property and incomes only. They make no allowance for the additional benefits justified by the prospective growth of the Greater Winnipeg Area. (*See Chapter* 9)

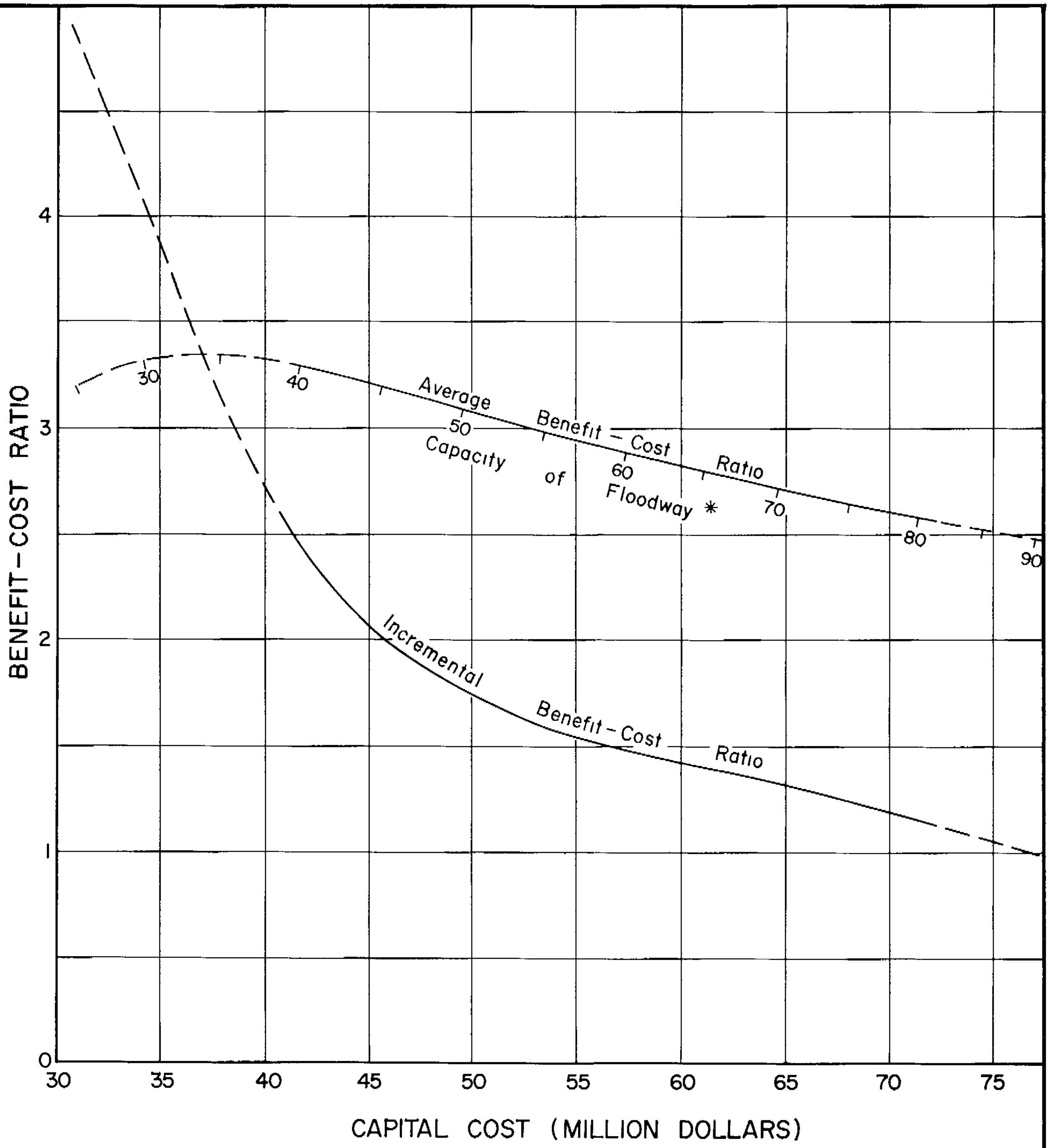
Not only the favourable benefit cost ratios but a number of other considerations recommend the Greater Winnipeg Floodway. It provides a fairly uniform degree of protection to all parts of Greater Winnipeg. Since it is located on the main stem of the Red River it will provide dependable protection to the city for

Table 10.3

DISTRIBUTION OF FLOWS GREATER WINNIPEG FLOODWAY

Natural Conditions			With Floodways in Existence		
Peak Flow at Redwood	Assiniboine Flow at Headingley	Flow at Floodway Inlet	Flow in Floodway 40,768	60,768	80,768
(1)	(2)	(3)	(4)	(5)	(6)
		(Thousand cubic feet per second)			
40	8	32	3.5	4.8	7.4
60	9	51	12.7	17.3	25.3
80	12	68	21.5	30.7	42.3
100	16	84	30.8	45.3	61.0
120	20	100	36.8	54.7	73.2
140	23	117	40.6	60.5	80.6
160	28	132	43.5	64.9	86.3
180	32	148	46.4	69.3	92.0
200	34	166	49.4	73.9	98.0
220	37	183	52.5	78.5	104.0

NOTE. The flow in the river channel below the floodway inlet can be obtained by subtracting columns (4), (5) or (6) from Column (3). The flow at Main Street or Redwood Bridge with the floodway in existence can be obtained by adding this latter result to Column (2). For example if a 40,768 floodway had been constructed then in a flood that would have resulted in a flow of 160,000 c.f.s. at Redwood Bridge under natural conditions the flow in the river Channel below the floodway inlet would be 88,500 c.f.s. (132,000−43,500). The flow at Main Street or Redwood Bridge would be 116,500 c.f.s. (88,500+28,000).

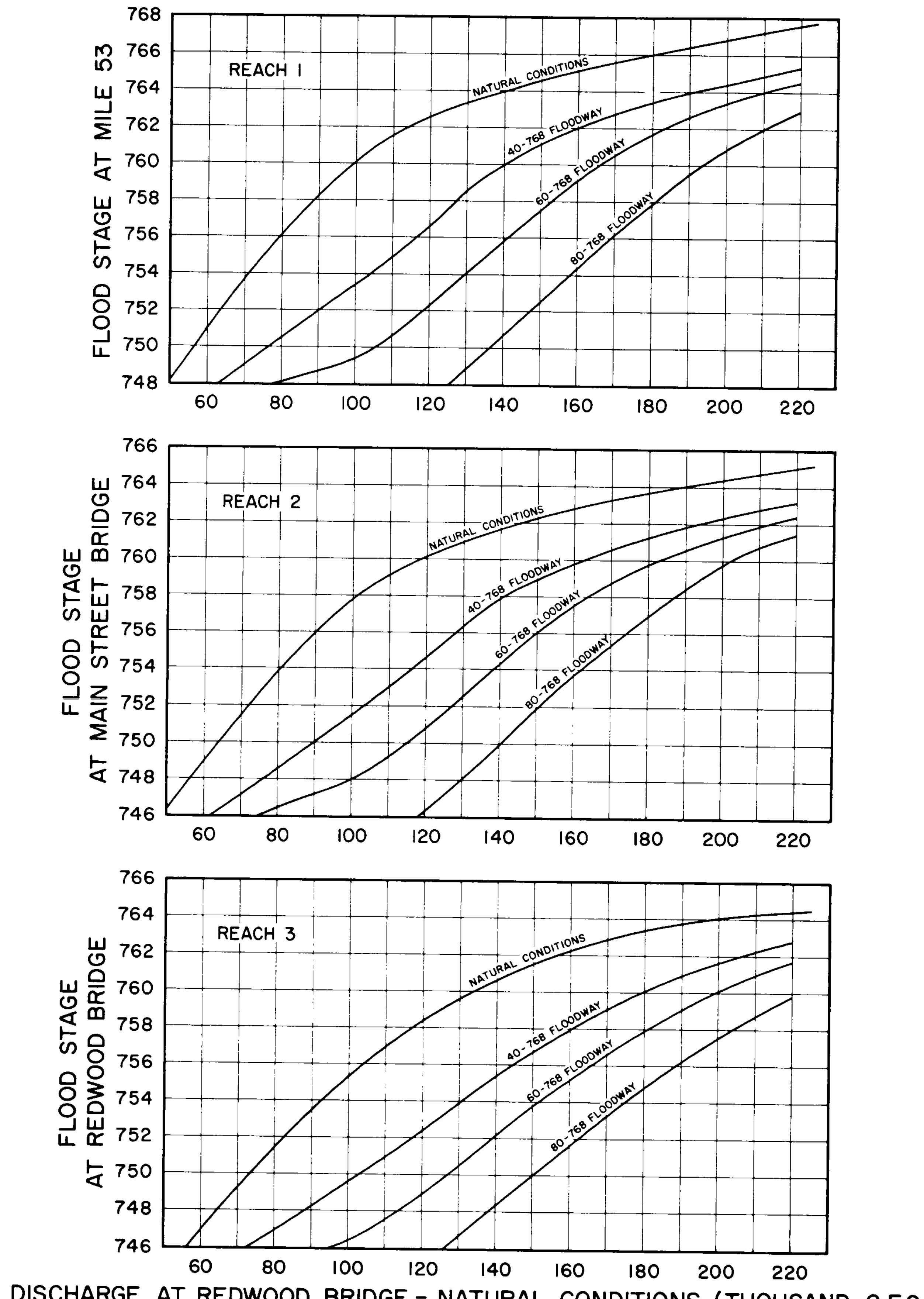


* Design capacity of floodway is stated in thousands of cubic feet per second
Calculations are based on floodway designs 40-768, 60-768 and 80-768

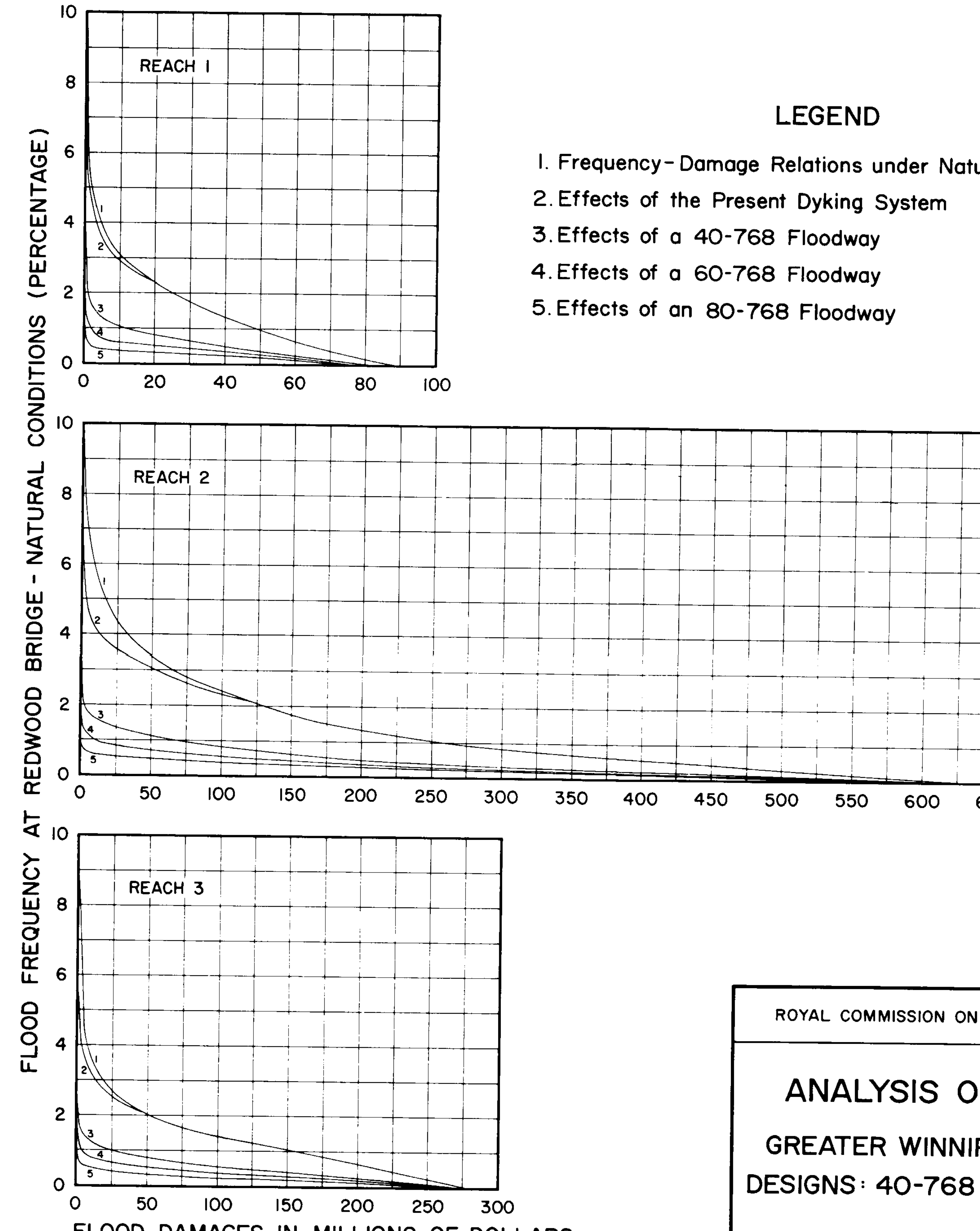
ROYAL COMMISSION ON FLOOD COST-BENEFIT

AVERAGE AND INCREMENTAL
BENEFIT - COST RATIOS
RELATED TO
CAPACITY AND CAPITAL COST
GREATER WINNIPEG FLOODWAY

DECEMBER 1958



STAGE-DISCHARGE RELATIONS



FREQUENCY-DAMAGE RELATIONS

LEGEND

1. Frequency-Damage Relations under Natural Conditions
2. Effects of the Present Dyking System
3. Effects of a 40-768 Floodway
4. Effects of a 60-768 Floodway
5. Effects of an 80-768 Floodway

ROYAL COMMISSION ON FLOOD COST-BENEFIT

ANALYSIS OF BENEFITS

GREATER WINNIPEG FLOODWAYS
DESIGNS: 40-768; 60-768; 80-768

REACHES 1, 2 AND 3 - GREATER WINNIPEG

DECEMBER 1958

any likely distribution of flows from the Red and Assiniboine Rivers It can be made large enough to provide almost any required degree of protection to the city Once constructed, its capacity could be increased significantly at a later date, if additional protection was desired, by lining the channel and increasing the velocity of flow It introduces no additional hazards for the city and it would create only a minor amount of inconvenience or dislocation during the period when it was under construction All of these considerations made it evident that the Greater Winnipeg Floodway would rank high among those projects from which a final selection was made

vides dependable protection Thus, it was clear that a floodway should provide the foundation of any flood protection plan for the city

(b) The Portage Diversion

The amount of flood protection that the Portage Diversion will provide for Greater Winnipeg depends on a number of factors

In part it depends on the amount of flow which the Assiniboine River contributes to the flood peak at Redwood Bridge The greater this contribution, the more flood protection the diversion will afford

In considerable degree, also, the effectiveness of the Portage Diversion depends on the

Table 10 4

EFFECTS OF 25,000 C F S PORTAGE DIVERSION UPON FLOW AT HEADINGLEY

Natural Conditions		With a 25,000 c f s Diversion		
Flow at Portage	Flow at Headingley	Flow beyond Portage	Flow at Headingley	Discharge Reduction at Headingley
(1)	(2)	(3)	(4)	(5) (2) - (4)
15,000	15 000			15 000
20,000	20,000			20,000
25 000	22 000			22 000
30,000	24 500	5,000	5 000	19,500
35,000	26,600	10,000	10 000	16 600
40,000	28,500	15 000	15 000	13 500
45 000	30,000	20 000	20,000	10 000
50 000	31,700	25,000	22,000	9,700
55,000	33 200	30,000	24 500	8,700
60 000	34 500	35 000	26 600	7,900

The benefits attributed to each of these floodways were calculated from frequency-damage charts Discharge-elevation curves and frequency-damage curves for the 40-768, 60-768 and 80-768 designs of the floodway are shown in Plate 24 Our preliminary analysis indicated that any final selection would come from the size range covered by these three designs For different flows at Redwood Bridge under natural conditions, Table 10 3 shows the amount which, on the average, could be expected to come down the Red and Assiniboine Rivers and the volume of water that would flow through each of these same three floodways, if they were constructed

Of all the projects considered by the Commission it was clearly evident that the floodway alone met all the key requirements needed in any flood protection project for Greater Winnipeg It does everything any other plan would do and more than most It is the only plan that provides an adequate degree of protection for the city at a reasonable cost Moreover, because it is located on the river which contributes the major part of any flood flow, it provides dependable protection

amount of overflow that occurs on the Assiniboine River once the channel capacity of the river is exceeded, and on what happens to this overflow When the river overflows its banks much of the overflow never returns to the river but goes into overland storage or flows southeast along the LaSalle River and enters the Red River at St Norbert At very high flows, some of the water also flows north into Lake Manitoba

The flood water that goes into overland storage or flows into Lake Manitoba will have no effect on the flood peaks in Greater Winnipeg In addition, to the extent that the flow which reaches Winnipeg via the La Salle and Red Rivers is delayed until the flood peak in Winnipeg is past, there will be no contribution to flood peaks at Redwood Bridge However, in the larger floods, it is anticipated that some of the overflow to the Red via the La Salle would arrive in time to increase the flood level in Winnipeg

One peculiar result of this overflow is that a Portage Diversion with a given capacity may provide more flood protection to Winnipeg in floods of moderate size than it does in larger ones. This is evident from the data in Table 10.4. These data show the extent to which a 25,000 c.f.s. Portage Diversion will reduce the flow entering Winnipeg via Headingley for different sizes of flood flow at Portage la Prairie. Thus, when there is a flow of 25,000 c.f.s. at Portage la Prairie, the flow in the Assiniboine can be diverted entirely into Lake Manitoba and, as a result, the flow entering Winnipeg via Headingley will be reduced by 22,000 c.f.s. The remaining 3,000 c.f.s. would have gone into overland storage in any case. In contrast, when a flood of 50,000 c.f.s. occurs at Portage la Prairie, the 25,000 c.f.s. diversion will only reduce the flow at Headingley by 9,700 c.f.s. This difference reflects the fact that in larger floods, a substantial part of the water which is diverted into Lake Manitoba would have gone into overland storage under natural conditions. For this reason, only part of the diversion's capacity is effective in reducing the flow at Headingley.

This can be shown in detail as follows. Engineering estimates indicate that when a flood level of 50,000 c.f.s. (*see Column* 1) occurs at Portage la Prairie only 31,700 c.f.s. (*See Column* 2) reaches Headingley. If 25,000 c.f.s. is diverted out of the river at Portage la Prairie the flow below Portage will be 25,000 c.f.s. (*Column* 3) and engineering data indicate that 22,000 c.f.s. (*Column* 4) of this will reach Headingley. Thus, at a flood level of 50,000 c.f.s. at Portage, the diversion will reduce the flow at Headingley from 31,700 c.f.s. to 22,000 c.f.s. or by 9,700 c.f.s. (*Column* 5).

As a result of this effect, at higher flows on the Assiniboine River a larger diversion may be relatively more effective than a smaller one. Thus in the example cited above, a 40,000 c.f.s. diversion would have reduced the flow at Headingley to 10,000 c.f.s., giving a reduction at Headingley of 21,700 c.f.s. This is more than twice as large as the reduction produced by a 25,000 c.f.s. Portage diversion for this particular flow (50,000 c.f.s.).

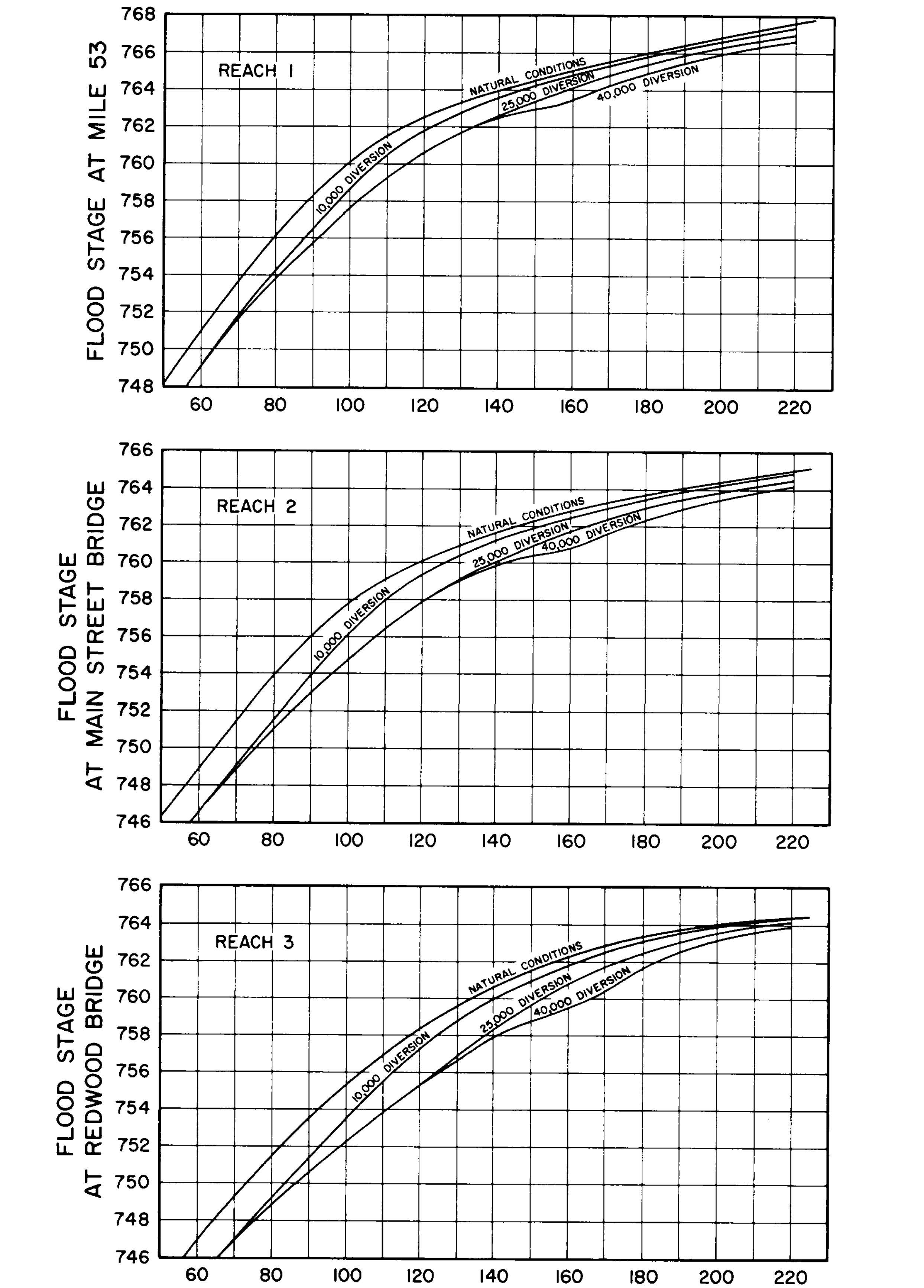
In assessing the effectiveness of the Portage Diversion it must be recognized that the flood protection it affords is that which is provided on the average. In the 1950 flood, the contribution of the Assiniboine River to the flood peak at Redwood Bridge was only about 8,000 c.f.s. Thus, the maximum flood protection a diversion at Portage could have given Winnipeg in 1950 would have been that provided by the elimination of this 8,000 c.f.s. There is, however, reason to believe that the flow on the Assiniboine River in 1950 was unusually low. If a flood of the 1950 magnitude were to recur the contribution of the Assiniboine River could easily amount to 20,000 c.f.s. or more. Our estimates show that *on the average* a flow of 16,000 c.f.s. on the Assiniboine at Portage la Prairie can be expected whenever there is a flow of 100,000 c.f.s. at Redwood Bridge. Nevertheless, because in a particular flood the actual

Table 10.5

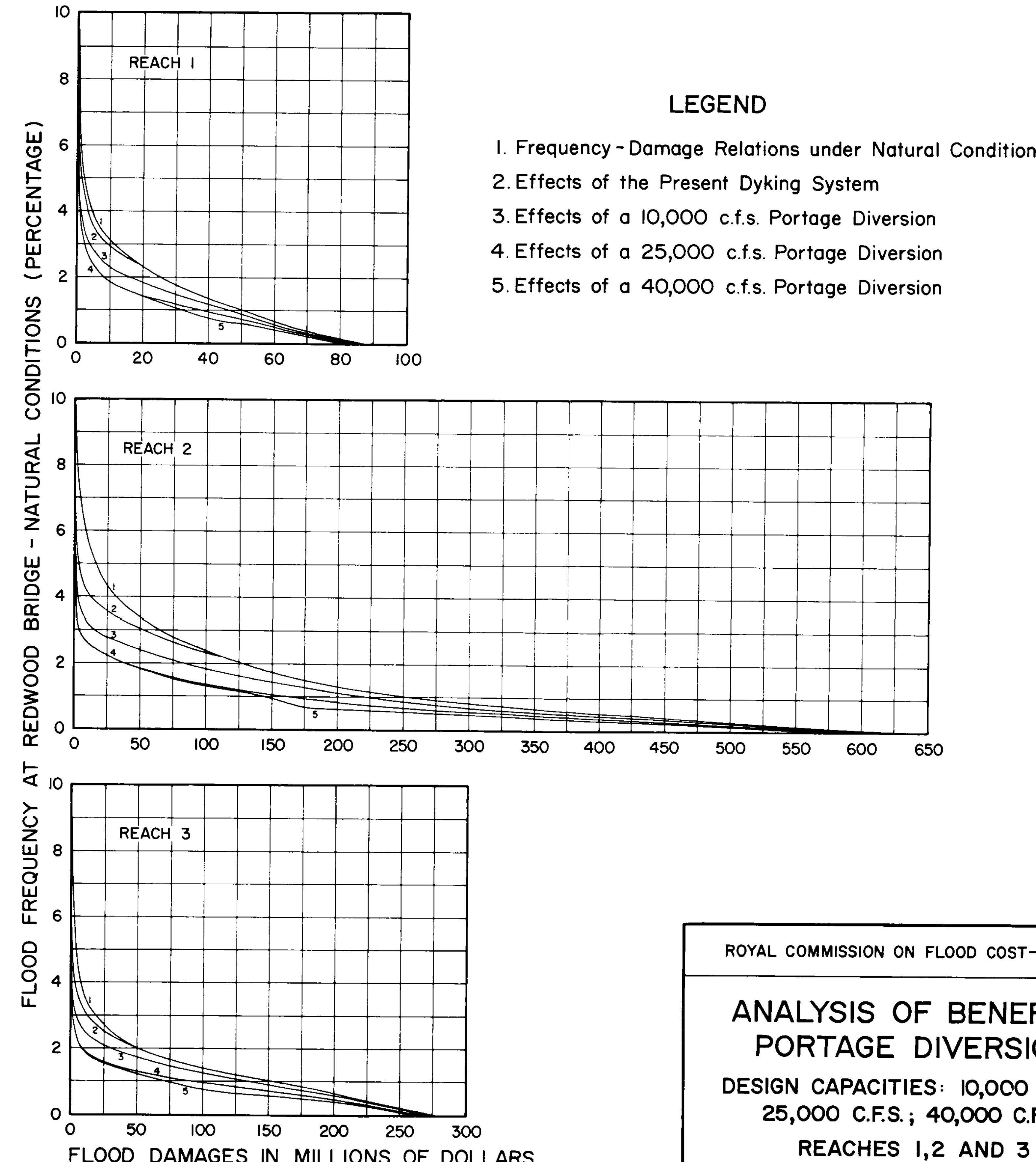
BENEFIT COST ANALYSIS — PORTAGE DIVERSIONS

Project Size	Total Capital Cost	Annual Cost	Average Annual Benefit	Benefit-Cost Ratio
HIGH BLUFF				
10,000 c.f.s. Diversion	$ 5,709,000	$ 342,800	$2,357,800	6.88
25,000 c.f.s. Diversion	8,672,000	506,200	4,586,600	9.06
40,000 c.f.s. Diversion	10,861,000	630,100	5,436,900	8.63
FORT LA REINE				
10,000 c.f.s. Diversion	$ 6,584,000	$ 396,100	$2,357,800	5.95
25,000 c.f.s. Diversion	11,010,000	635,900	4,586,600	7.21
40,000 c.f.s. Diversion	14,097,000	803,100	5,436,900	6.77

Increase in Size	Increase in Annual Cost	Increase in Annual Benefit	Incremental Benefit-Cost Ratio
HIGH BLUFF			
From 0 to 10,000 c.f.s.	$ 342,800	$2,357,800	6.88
From 10,000 c.f.s. to 25,000 c.f.s.	163,400	2,228,800	13.64
From 25,000 c.f.s. to 40,000 c.f.s.	123,900	850,300	6.86
FORT LA REINE			
From 0 to 10,000 c.f.s.	$ 396,100	$2,357,800	5.95
From 10,000 c.f.s. to 25,000 c.f.s.	239,800	2,228,800	9.29
From 25,000 c.f.s. to 40,000 c.f.s.	167,200	850,300	5.09



STAGE-DISCHARGE RELATIONS



FREQUENCY-DAMAGE RELATIONS

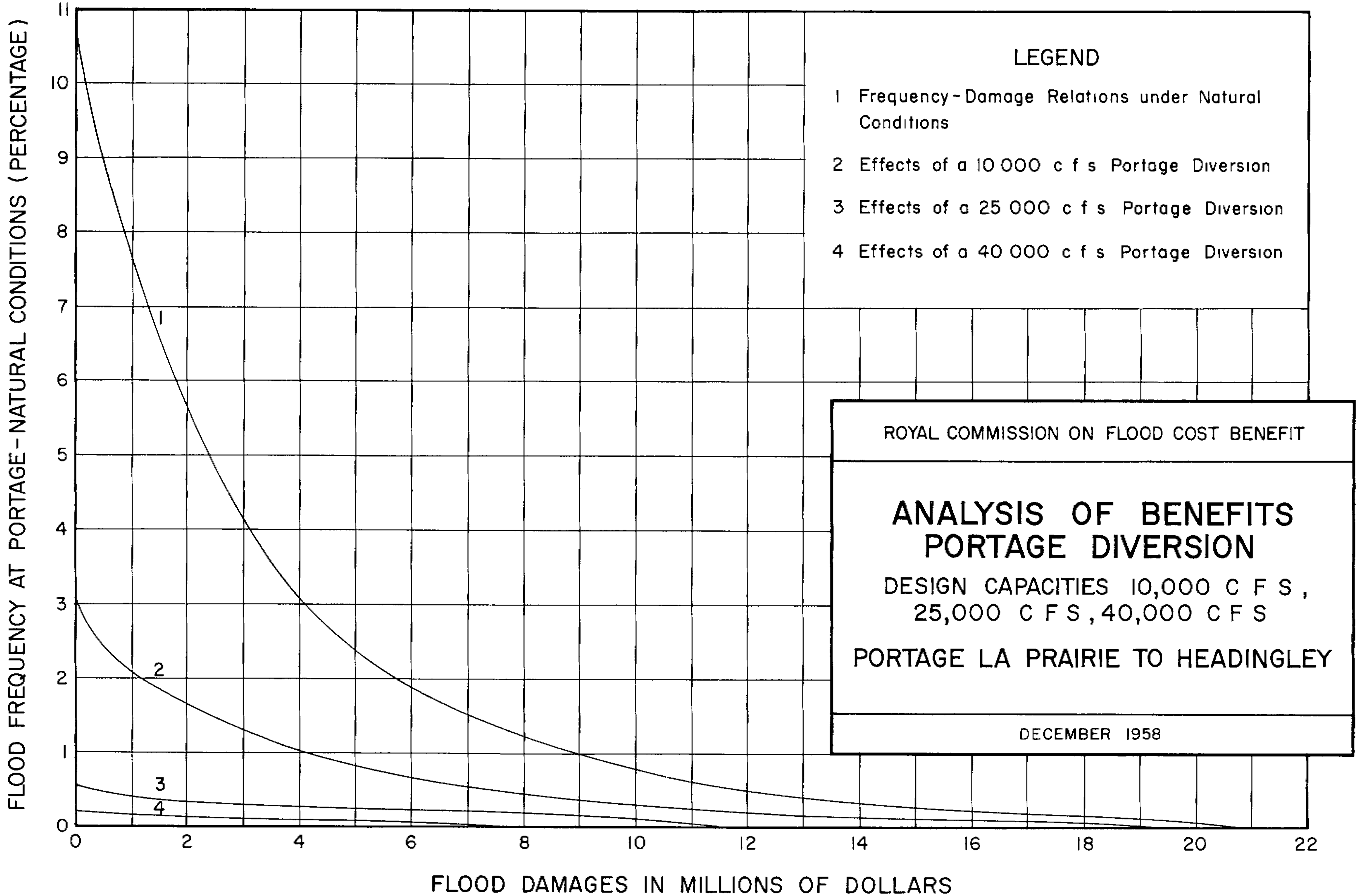
ROYAL COMMISSION ON FLOOD COST-BENEFIT

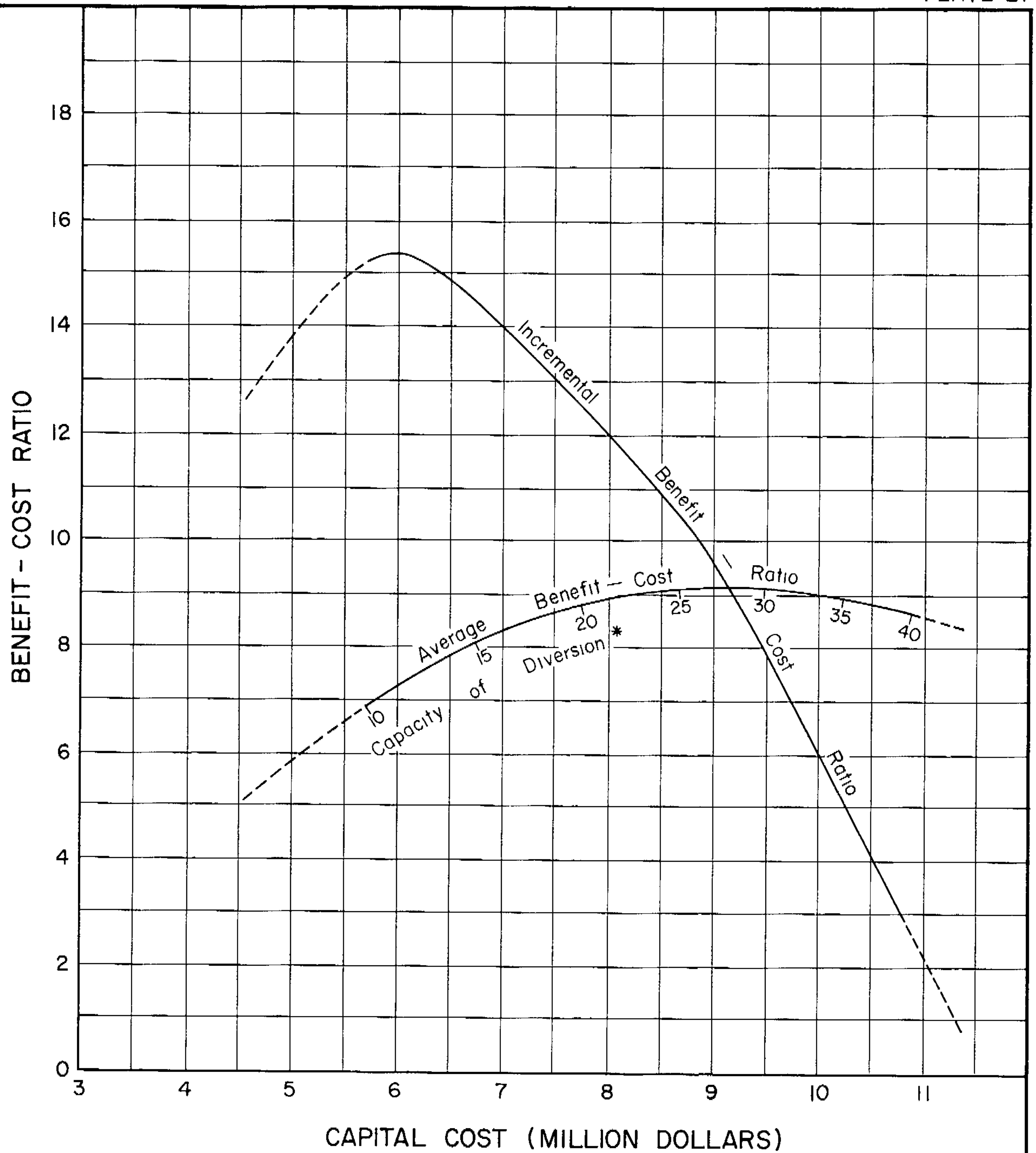
ANALYSIS OF BENEFITS PORTAGE DIVERSION

DESIGN CAPACITIES: 10,000 C.F.S.; 25,000 C.F.S.; 40,000 C.F.S.

REACHES 1,2 AND 3
GREATER WINNIPEG

DECEMBER 1958


LEGEND
1 Frequency - Damage Relations under Natural Conditions
2 Effects of a 10 000 c f s Portage Diversion
3 Effects of a 25 000 c f s Portage Diversion
4 Effects of a 40 000 c f s Portage Diversion
ROYAL COMMISSION ON FLOOD COST BENEFIT
ANALYSIS OF BENEFITS
PORTAGE DIVERSION
DESIGN CAPACITIES 10,000 C F S, 25,000 C F S, 40,000 C F S
PORTAGE LA PRAIRIE TO HEADINGLEY
DECEMBER 1958
FLOOD FREQUENCY AT PORTAGE - NATURAL CONDITIONS (PERCENTAGE)
FLOOD DAMAGES IN MILLIONS OF DOLLARS
0
1
2
3
4
5
6
7
8
9
10
11
0
2
4
6
8
10
12
14
16
18
20
22



* Design capacity of Portage Diversion is stated in thousands of cubic feet per second

ROYAL COMMISSION ON FLOOD COST-BENEFIT

AVERAGE AND INCREMENTAL

BENEFIT - COST RATIOS

RELATED TO

CAPACITY AND CAPITAL COST

PORTAGE DIVERSION

HIGH BLUFF ROUTE

DECEMBER 1958

flow on the Assiniboine may either exceed or fall short of this average expected flow the flood protection afforded by a Portage Diversion to Greater Winnipeg is less dependable than that provided by flood protection works on the Red River

To assess the flood protection that the Portage Diversion would provide for Greater Winnipeg stage discharge and frequency damage curves were prepared showing the effects of the diversions with design capacities of 10 000 c f s, 25 000 c f s and 40 000 c f s These curves are shown in Plate 25 Corresponding curves showing the effects of these three Portage Diversions in the area between Portage la Prairie and Winnipeg are shown in Plate 26

Benefit cost ratios for all three Portage Diversions are extremely high (*See Table* 10 5) Thus on the High Bluff route, ratios of 6 88 9 06 and 8 63 were obtained for the 10 000 c f s 25 000 c f s and 40 000 c f s diversions respectively Because of the higher cost, benefit cost ratios for the Fort La Reine route were somewhat lower For the incremental benefit cost ratios a peak is reached at some point between a 10 000 c f s and 15,000 c f s capacity and beyond that point these ratios begin to fall A more precise analysis of the incremental ratios is shown in Plate 27 The data in this chart indicate that for the High Bluff route the incremental benefit cost ratios reach a peak of just over 15 0 at about 12 000 c f s and then fall steadily reaching 1 0 at a capacity in excess of 40 000 c f s Ratios on the Fort La Reine route would be slightly lower than this but would follow a similar pattern

Thus these data indicate that the Portage Diversion would be an extremely beneficial flood control project A 25 000 c f s High Bluff Diversion for example, would yield annual benefits that were over nine times as large as its annual cost Moreover the incremental benefit cost ratios indicate that it would be economical to increase the size of the project to a capacity of about 40 000 c f s Up to that point the additional benefits obtained exceed the additional costs by a substantial margin It provides a significant degree of flood protection not only to the City of Winnipeg but to the farming area between Portage la Prairie and Winnipeg as well

(c) Eastern Tributaries Diversion

On the basis of data given in the report of the Red River Basin Investigation it was estimated that the operation of the Eastern Tributaries Diversion would produce discharge reductions varying from about 4 000 c f s for a flood of the 1948 magnitude up to 8 000 to 9 000 c f s for floods of over 200 000 c f s Its operation produces stage reductions of between 1 0 and 2 feet in Greater Winnipeg, and an average stage reduction of 5 feet at St Norbert and 3 feet at Ste Agathe and 2 feet at Morris

On the basis of a frequency damage analysis it was estimated that the operation of this project by itself, with no other flood protection works except the present dyking system in existence would produce annual benefits of $1 457 300 in the Greater Winnipeg area and annual benefits of $26 600 in the Red River Valley Annual costs would amount to $652 000, thus giving a benefit cost ratio of 2 28 However since the initial flood protection to Greater Winnipeg can be provided much more economically by other methods this relatively favourable ratio cannot be used to justify the construction of this project The incremental benefit cost ratio obtained when the Eastern Tributaries Diversion is considered in combination with other flood protection works is discussed in Chapter 11

2 Storage Reservoirs

(a) Russell Reservoir

A storage reservoir on the Assiniboine River near Russell Manitoba would not only provide flood control benefits throughout the length of the valley and in Greater Winnipeg but it would also make it possible to maintain higher minimum flows in the river during dry periods Both flood control and water supply benefits have been included in this analysis

For the City of Brandon and the valley area above Portage la Prairie flood control benefits were based on the frequency discharge chart given in Appendix 5 of the Assiniboine Report (*See Plate* 18) This plate indicated that the Russell Reservoir would reduce the natural flows by amounts ranging from 7,000 c f s for a 10 percent flood up to 14 000 c f s for a 1 percent flood

For the rural area east of Portage la Prairie and for the City of Winnipeg the effects of the Russell Reservoir were analyzed on the assumption that it would produce a reduction of 10 000 c f s at Portage la Prairie This conclusion is supported by the data given in Table 10 6, which show the effects the Russell reservoir would have had at Brandon in a number of historical floods and one theoretical flood The reduction in flows in the City of Winnipeg that have been attributed to the Russell Reservoir in this analysis are somewhat larger than those shown for Headingley in the Assiniboine Report (*see Appendix* 2 *p* 28) This difference reflects the allowance that has been made for the reduction in flows reaching Greater Winnipeg via overflow from the Assiniboine to the Sale River It has been assumed that the Russell Reservoir would be operated to give relief to Brandon and other areas subject to flooding even though this would prevent achievement of a maximum reduction in Winnipeg The stage discharge curves, and frequency damage curves that were used in the calculation of these benefits are shown in Plates 20, 28 and 31

Any improvement in low water flows on the Assiniboine River would benefit Greater Winnipeg and a number of towns and cities along the river such as Brandon and Portage la Prairie In Greater Winnipeg this benefit would arise mainly from the better sewage dilution that this improvement would provide For Brandon and Portage la Prairie it would provide a more dependable potable water supply as well as giving better dilution of sewage The benefits that would arise from these improvements have been evaluated in the following manner

It has been estimated that a guaranteed minimum flow of 2,100 c f s at Redwood Bridge would relieve the Greater Winnipeg Sanitary District from the necessity of ever converting its existing plant to secondary treatment, although future plants in the suburbs would provide both primary and secondary treatment The saving effected in this way would amount to about $492 000 in annual terms

Since minimum summer flows at Redwood Bridge now amount to about 250 c f s the additional flow required is about 1,850 c f s The Russell Reservoir could provide a minimum flow at Headingley of 600 c f s instead of the present 160 c f s or about 24 percent of the additional flow needed Accordingly it was assumed that a benefit of 24 percent of $492 000 or $118 000 could be assigned to the Russell Reservoir for its sewage dilution effects in Greater Winnipeg The balance of the additional water needed to provide the required minimum flow at Redwood Bridge might be obtained from a water supply channel from Lake Manitoba to the Assiniboine River as proposed in the Report of the Lakes Winnipeg and Manitoba Board

Table 10 6

EFFECTS OF RUSSELL RESERVOIR CITY OF BRANDON

Year of Flood	Flow without Reservoir	Flow with Reservoir	Reduction by Russell Reservoir
	c f s	c f s	c f s
1%	36 500	23 000	13 500
1923	23 000	11 000	12 000
1922	21 300	10 000	11 300
1927	17 100	9 000	8 100
1948	15 900	9 000	6 900
1913	14 900	8 000	6 900
1936	10 700	6 000	4 700
1916	9 140	8 000	1 140

Source Report on *Conservation and Flood Control Assiniboine River* Appendix 2 Fig 12 and p 28

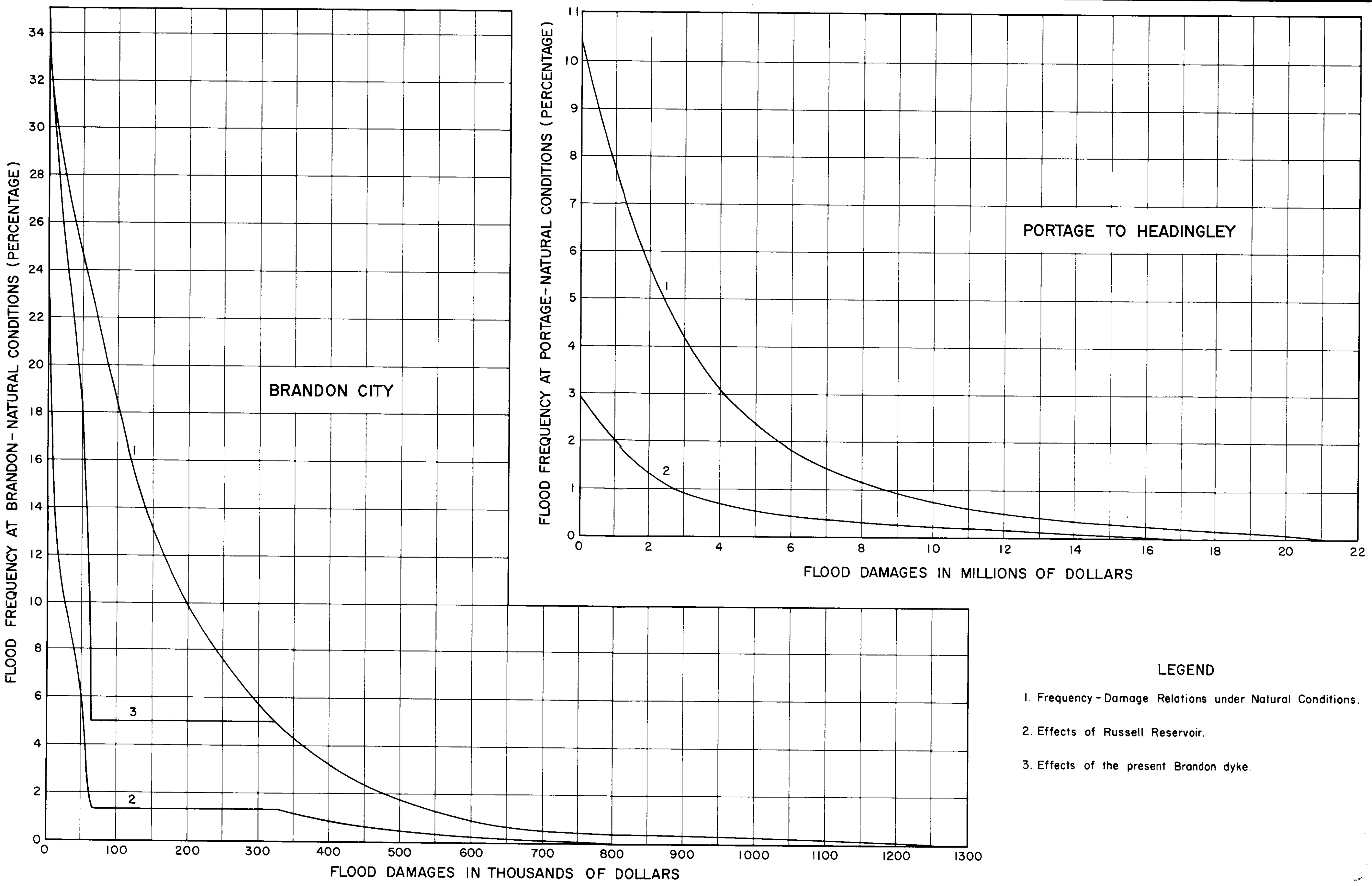
For the cities of Brandon and Portage la Prairie, information provided by the Public Health Department of the Province of Manitoba indicated that no significant sewage dilution benefits can be assigned to the Russell Reservoir Brandon has reached a size where primary sewage treatment has become necessary irrespective of whether the Russell Reservoir is constructed or not Once this degree of treatment has been installed natural river flows should be sufficient to provide the dilution needed for the effluent of the primary treatment plant Portage la Prairie is introducing a lagooning system and Camp Shilo now has both primary and secondary treatment

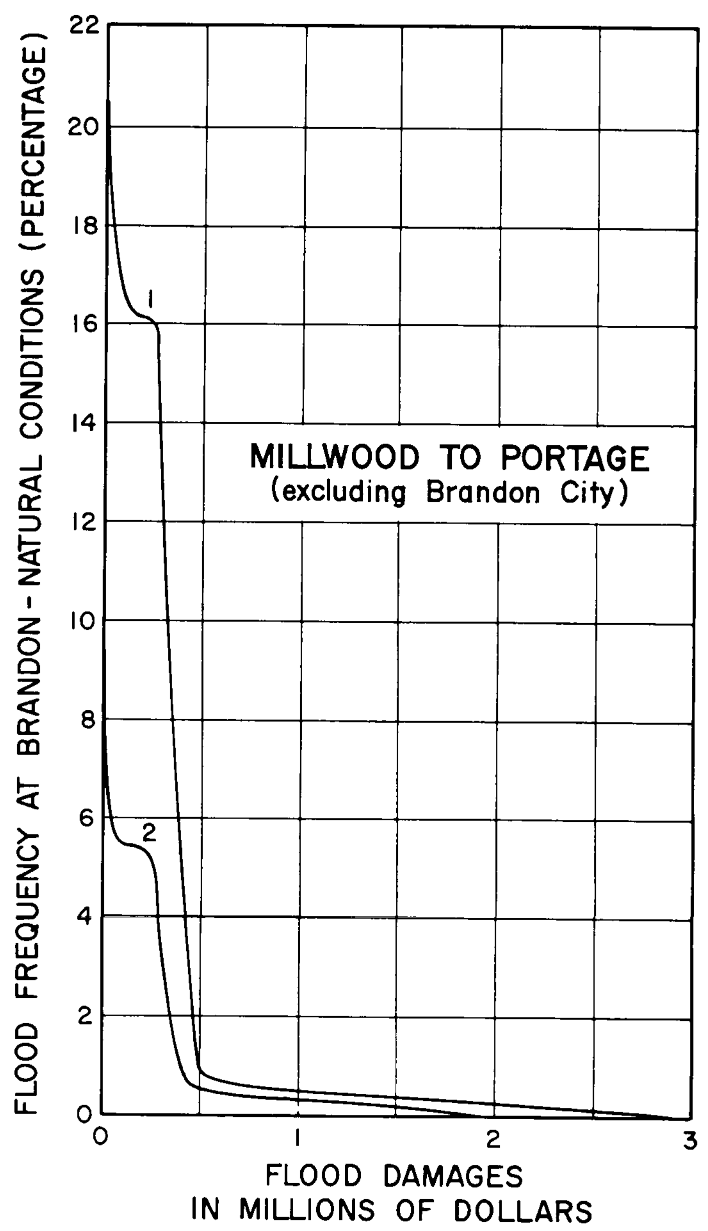
In assessing requirements for potable water it must be recognized that flows on the Assiniboine River are much more stable than those on the Red River Thus in the forty one years of record covering the period from 1917 to 1957, there have only been 43 days during which the minimum daily flow fell below 20 c f s at Brandon and only 216 days in which it fell below 40 c f s During this same 41 year period, at Portage la Prairie which can be assumed to have about the same minimum flow as Headingley there have been only 12 days in which the flow has fallen below 40 c f s and only 43 days in which it has fallen below 60 c f s The lowest minimum flow on record at Brandon is 7 c f s which was reached on February 21 1942 and at Headingley it is 20 c f s reached on December 11 1936 Average daily water consumption currently amounts to 4 3 c f s in Brandon and 2 4 c f s in Portage la Prairie

Because water supply is plentiful in most periods benefits attributable to the improvement of minimum flows must be limited to the cost of the most economical method of overcoming the relatively short periods of exceptionally low flows No detailed analysis was made of what these methods might be On a fairly arbitrary basis annual benefits of $10,000 were assigned for the effects of Russell Reservoir in finding an improved water supply to Brandon Portage la Prairie and other towns along the Assiniboine River This would permit the expenditure of a capital sum of about $200 000 for projects designed to alleviate any occasional water supply problems Benefits significantly larger than this may be properly attributable to the Russell Reservoir but no further exploration of this problem has been made

Thus the total annual water supply benefits assigned to the Russell Reservoir amount to $128 000 Of this total $118 000 is for benefits to Greater Winnipeg, and the remaining $10 000 is for benefits on the Assiniboine River upstream from Winnipeg

The method of operation for the Russell Reservoir proposed in the Report on Conservation and Flood Control Assiniboine River is as follows Prior to the break up each spring a forecast of the runoff would be made and the





LEGEND

1. Frequency - Damage Relations under Natural Conditions.

2. Effects of Russell Reservoir.

3. Effects of the present Brandon dyke.

ROYAL COMMISSION ON FLOOD COST-BENEFIT

ANALYSIS OF BENEFITS RUSSELL RESERVOIR

ASSINIBOINE RIVER VALLEY VARIOUS REACHES

DECEMBER 1958

reservoir would be emptied to the extent necessary to permit storage of the total runoff If the predicted runoff exceeded the reservoir s capacity it would be emptied completely Of the total storage capacity of the reservoir, 450,000 acre feet some 350 000 acre feet has been assigned for low water regulation leaving 100,000 acre feet for the control of summer floods Because the reservoir can be completely emptied within about three weeks it is not anticipated that there would be any significant conflict between operating the reservoir for the maintenance of low water flow and its use for flood control purposes

The benefit cost ratio for Russell Reservoir considered as a separate project is 6 18 a higher ratio than has been obtained on any project other than the Portage Diversion Costs, benefits and the benefit cost ratio are as shown below

RUSSELL RESERVOIR

Capital Cost	$6 450,000
Annual Cost	333 900
Annual Benefits	2 062 400
Benefit cost Ratio	6 18

The high benefit cost ratio obtained on this project indicates that it deserves to be considered seriously as a component in any combination of projects finally selected

(b) Ste Agathe Detention Basin

Evaluation of the Ste Agathe Detention Basin is complicated because of the additional damages that this proposal will cause in the area to the south of the dam Two different approaches were examined In the first or *additional damage approach,* the additional damages that would be caused by the operation of the dam were estimated placed on an annual basis and deducted from the annual benefits that the proposal would provide This approach is similar to that used by the Red River Basin Investigation It differs slightly from their approach inasmuch as they capitalized the additional annual damages and added them to the actual construction cost of the proposal whereas in this analysis the additional flood damages caused by the proposal were deducted from the benefits provided in the area to the north of the proposed dam The net annual benefits obtained in this way were then compared with the annual cost of the plan to obtain a benefit cost ratio

In the second, or *flooding rights approach* it was assumed that before the proposed detention basin could be operated it would be necessary to acquire flooding rights from individual property holders in the area affected These flooding rights would be written into land titles in the area affected by the detention basin's operation and would give flood control authorities the right to flood additional land and property in the Red River Valley south of the proposed dam or the right to flood property already affected by floods to a greater depth and more frequently The cost of these flooding rights are added to the construction cost of the project and this total capital cost provides the basis for a second benefit cost ratio

Under both approaches it is necessary to recognize that some of the benefits attributable to a flood storage project such as the Ste Agathe Detention Basin may be lost if mistakes are made in forecasting the size and peak dates of different floods If flood storage occurs too early during a given flood the storage potential of the project may be exhausted before the flood peak arrives For this reason, the benefit-cost ratio on a flood storage project should be discounted to some extent when it is compared with the benefit cost ratios obtained on other projects such as a floodway or channel improvement

Additional Damage Approach

The additional damages that would be caused in the Red River Valley by the operation of the Ste Agathe Detention Basin were estimated by the Red River Basin Investigation In our study these estimates were revised in the following ways Damages to property were increased by 12 percent to allow for the rise in costs from 1952 to 1957 Loss of farm income was re estimated on the basis of the methods adopted for this study This revised total was then converted to an equivalent annual amount and deducted from the annual benefits of the project

Annual benefits annual costs and the benefit-cost ratio were as follows

Annual Benefits	
Greater Winnipeg	$4 570 000
Ste Agathe to St Norbert	53,000
Total	$4 623 000
Additional Annual Damages	147 900
Net Annual Benefits	$4 475 100
Annual Costs	451,300
Benefit Cost Ratio	9 92

Thus using this approach the comparatively high benefit cost ratio of 9 92 is obtained However in this approach no allowance has been made for the additional risks of loss of life and the mental strain and anxiety which would result from flooding an area to a greater depth and more frequently than would occur under natural conditions

Flooding Rights Approach

In estimating the cost of acquiring flooding rights it was assumed that it would be necessary to pay $30 per acre to acquire the right to flood farm land and buildings on an average of once in every 100 years more frequently than would occur under natural conditions On urban property it was assumed that the cost of acquiring the right to cause a given amount of flood damage on the average of once in every 100 years would be equal to 100 percent of that damage

On this basis the cost, benefits and benefit cost ratio on the Ste Agathe Detention Basin would be as follows

Cost of Flooding Rights	**Thousand Dollars**
Urban Property	$ 6 300
Rural Property	11 270
Cost of Construction	9 234
Total Capital Cost	26 804
Annual Cost	1 269
Annual Benefit	4 623
Benefit cost Ratio	3 64

The benefit cost ratio of 3 64 obtained under the *flooding rights approach* is much smaller that that obtained when the *additional damage approach* is use This is due to the fact that the cost of acquiring flooding rights exceeds the cost of the payment of property damages and other flood losses In part this reflects the known fact that in practice the acquisition of flooding rights is a difficult and expensive process In part al o, it reflects the fact that flooding rights give some compensation for the anxiety and inconvenience caused by flooding Because of the difficulty of estimating losses of this type no allowance has been made for them in the additional damage approach However it is extremely doubtful whether even acquisition of flooding rights is a really practical approach Where this approach is used in the United States, it is customary to move all people out of the area in which flooding rights are acquired This is clearly not a practical approach for the Red River Valley Moreover even if this difficulty were overlooked and flooding rights were acquired it seems likely that after a few years the existence of these rights would be forgotten Thus, when the time came for flood control authorities to exercise their rights it might be found that many new owners would have purchased property in the area without any real awareness of this claim on their property This could make it very difficult for the flood control authorities to make their claim effective and operate the dam in the prescribed manner

In view of the many uncertainties involved in the Ste Agathe Detention Dam this Commission has decided that it can not be recommended It is true that if the *additional damage approach* is adopted a high benefit cost ratio is obtained But operation of the plan in this way involves the deliberate flooding of people in the valley area to protect residents of Greater Winnipeg and the people in the valley area north of Ste Agathe It is doubtful if the payment of the additional damages that would be caused can be considered adequate compensation to these people for undergoing more severe and more frequent flooding On the other hand if an attempt were made to pay in advance for the right to flood properties in the area the additional costs involved reduces the benefit cost ratio for the project to a level which is not far out of line with that shown on other projects such as the Greater Winnipeg Floodway and the removal of Lister s Rapids and well below the ratio obtained for the Portage Diversion Since these other projects make it possible to plan for a much larger amount of overall protection and do not introduce the additional hazards and uncertainties of the Ste Agathe Dam, they must be clearly given preference

(c) Pembina River Reservoir

The Red River Basin Investigation estimated that the operation of this reservoir could have reduced the 1948 and 1950 flood flows by 1 100 and 1 500 c f s It is estimated that this would produce the following stage reductions

	Stage Reductions	
	at 52 000 c f s flow in Red River	at 95 000 c f s flow in Red River
Emerson	0 3	0 2
Morris	0 5	0 2
Ste Agathe	0 4	0 3
St Norbert	0 4	0 3
Winnipeg (Redwood Bridge)	0 3	0 2

If the Pembina River Reservoir was operated by itself without any flood protection works in existence it would produce annual flood benefits in Greater Winnipeg of $509 300 and in the Red River Valley area of $27 400 Annual costs excluding maintenance would amount to $251 300 The benefit cost ratio for this project considered separately is 2 14 Since this project can only provide a small amount of protection to Greater Winnipeg and since its benefit cost ratio is well below that obtained on other flood protection works such as the Greater Winnipeg Floodway and the Portage Diversion it cannot be recommended as a primary basis of flood protection for Greater Winnipeg The benefits it produces in combination with other projects are shown in Chapter 11

The Pembina River Reservoir might also provide significant benefits in the form of a larger and more assured potable water supply for an area in the Red River Valley that is now extremely short of water This water would also be suitable for irrigation livestock and other purposes Possible benefits arising from this aspect of the Reservoir will be discussed further in Chapter 11

3 Channel Improvement

The flow of the Red River through Greater Winnipeg is restricted in some degree by an out crop of rock in the bed of the river a few miles below Winnipeg in the area known as Lister s Rapids The Commission has been well aware that many people in Winnipeg have held the view that the city s flood problem might be largely solved by removing this rocky outcrop thus enlarging the channel and allowing the water to flow more freely Because this view has been so widely held the Commission has made a very careful and thorough examination not only of the possibility of channel improvement in the Lister s Rapids area but also of the feasibil ity of extending the improvement gained in this way through the city by improving the channel right through the metropolitan area The re sults of our examination of these two proposals are presented below

(a) Removal of Lister's Rapids

The Red River Basin Investigation examined 22 different designs for channel improvement below Winnipeg and from these designs selected three of the most promising for further con sideration These three Trial 12, Trial B and Trial C showed the smallest cost per foot of stage reduction at Redwood Bridge and provided a practical degree of stage reduction

Trial 12 involved widening of the natural channel between Mile 40 2 and Mile 32 6 (from just below Bergen cut off to a point 2½ miles upstream from Old St Andrews Church) Trial B involved deepening the channel from Mile 40 9 to Mile 27 3 (from Bergen cut-off to a point near Lockport) with very little widening Trial C included widening in addition to deepen- ing to produce a more efficient channel in the same area as Trial B

In evaluating the benefits attributable to these projects the city was divided up into five main reaches and a representative point was selected in each reach for the calculation of stage reductions and damages These five areas and the representative points are as follows

Areas	Representative Points
1 St Vital and Fort Garry	Mile 53 (opposite Oakenwald Ave)
2 Winnipeg Ward I and St Boniface	Mile 48 (near the extension of McMillan Ave)
3 Winnipeg Ward II St James Tuxedo Brooklands Rosser	James Avenue
4 Winnipeg Ward III	Redwood Bridge
5 East Kildonan West Kildonan North Kildonan Old Kildonan East and West St Paul and Transcona	Mile 42 (near Seven Oaks Avenue)

The stage reductions that would result at each of these points if Trials 12 B and C were pro ceeded with have been calculated by the Pro vincial Water Resources Branch These stage reductions for different flows at Redwood Bridge would be shown in Table 10 7

Table 10 7

FLOOD STAGE REDUCTIONS AS A RESULT OF REMOVAL OF LISTER'S RAPIDS

Flood Flow at Redwood Bridge c f s	Mile 42	Redwood Bridge	James Avenue	Mile 48	Mile 53
TRIAL 12		Stage Reductions in Feet			
100 000	1 7	1 5	1 0	1	
120 000	1 7	1 5	8		
140 000	1 7	1 4	5		
160 000	1 5	1 2	3		
180 000	1 2	9	2		
200 000	9	7	2		
TRIAL B					
100 000	[illegible] 6	2 9	2 3	1 4	1 1
120 000	3 4	2 8	1 8	1 2	7
140 000	3 2	2 6	1 2	7	5
160 000	2 8	2 3	8	3	2
180 000	2 3	1 8	5	1	
200 000	1 7	1 5	4		
TRIAL C					
100 000	6 4	4 5	3 9	2 8	2 1
120 000	5 9	4 4	3 2	2 3	1 5
140 000	5 3	4 0	2 3	1 5	1 2
160 000	4 6	3 6	1 7	9	7
180 000	3 7	3 0	1 3	4	3
200 000	2 8	2 6	1 1	1	

Table 10 8

BENEFIT COST ANALYSIS — REMOVAL OF LISTER'S RAPIDS

Project	Total Capital Cost	Annual Cost	Average Annual Benefit	Benefit Cost Ratios
Trial 12	$5 674 000	$ 290 500	$1 294 500	4 46
Trial B	14 925 000	764 200	3 296 000	4 31
Trial C	29 326 000	1 501 600	5 156 000	3 43
Increase in Size		Increase in Annual Costs	Increase in Annual Benefit	Incremental Benefit Cost Ratios
Trial 12 to Trial C		$1 211 100	$3 861 500	3 19
Trial B to Trial C		737 400	1 860 000	2 52

When compared with the annual cost of these three trials the benefits attributable to these stage reductions provide benefit cost ratios of 4 46 for Trial 12 4 31 for Trial B and 3 43 for Trial C (*See Table* 10 8)

The benefit cost ratios for all three trials are quite favourable Incremental benefit cost ratios were also prepared showing a comparison of the additional benefit and additional cost obtained from extending Trial 12 to the size of Trial C and Trial B to the size of Trial C An incremental comparison of Trial 12 and B is not justified since the former project involves channel widening whereas the latter involves channel deepening Increasing Trial 12 to the size of Trial C gives an incremental benefit cost ratio of 3 19 Increasing Trial B to the size of Trial C gives an incremental ratio of 2 52

The benefit cost ratios obtained here are much more favourable to Lister s Rapids than those anticipated in the R P B I Report, Appendix E This latter report concluded (page 73) that "The benefits that could be obtained by these means (channel improvements below Greater Winnipeg) are very limited In reaching its conclusions the R P B I may have been unduly influenced by the 1950 flood in which the south end of the metropolitan area experienced the greatest amount of flooding However for floods greater than those in 1950 flooding becomes much more extensive in the central area of the city This is shown by the following table which shows for each of the five reaches total equivalent annual damages for floods of all magnitudes

TOTAL EQUIVALENT ANNUAL DAMAGES

Reach 1	St Vital and Fort Garry	$1 331 600
Reach 2	St Boniface and Ward I	5 344 400
Reach 3	Ward II and Western Municipalities	2 547 800
Reach 4	Ward III	2 461 600
Reach 5	Northern Municipalities	1,185 200

In estimating the benefits for Trials 12 B and C in each of these five reaches it was assumed that the risk of flooding within the defence system in each area was independent of the risk in each of the other reaches This assumption requires further examination for the implementation of any of these three trials will produce a much greater stage reduction at the north end of the city than it will at the south end At a time when the flood defences at Mile 53 are completely overtopped they may be comparatively safe at Mile 42 The assumption that the risks in one reach are independent of those in other reaches will only be justified to the extent that flooding in one reach can be prevented from spreading to other adjacent reaches It seems likely that if a moderate portion of the flood fighting expenditures were allocated to the construction of temporary dykes at strategic intervals between the main dyking system and adjacent areas of higher ground any failure of the primary dyking system in one area could be prevented from spreading to other areas To the extent that this is true the assumption that the risks in each reach are independent is justified

While the benefit cost ratios for each of the three trials are somewhat larger than those on the Greater Winnipeg Floodway a number of considerations favour the choice of the Greater Winnipeg Floodway in preference to the removal of Lister s Rapids as the basic core of any flood protection scheme in the Greater Winnipeg area For suppose we compare Trial C which has a capital cost of $29 326 000 and a benefit cost ratio of 3 43 with a 20 000 c f s floodway (20 766) which has a capital cost of $30 220 000 and a benefit cost ratio of 3 02 On both projects the capital cost and the amount of benefits are of about the same size However the benefit cost ratios indicate that a still larger measure of flood protection is justified in the Greater Winnipeg area than would be provided by either of these projects, and the incremental benefit cost ratios give a clear preference to the floodway scheme The incremental benefit cost ratio obtained by increasing the size of the floodway from 20 000 c f s to 40 000 c f s is quite large 4 04 whereas for removal of Lister s Rapids the incremental ratio for the extension from Trial B to Trial C is 2 52 and since this ratio is declining as the size of the project increases, it would undoubtedly be still smaller for any further extension in size

Not only the benefit cost analysis but other considerations favour the floodway in preference to the removal of Lister s Rapids The degree of protection provided to various parts of the city is more uniform in the case of the floodway than it is for Lister's Rapids which offers a large stage reduction in the north end of the city and only moderate or very small stage reductions in the south end of the city Further as was pointed out in Chapter 4, the removal of Lister s Rapids would result in higher river velocities in the city and this would result in increased erosion and a possible damaging effect on bridge piers On the other hand, the removal of Lister s Rapids would improve navigation below Greater Winnipeg

Accordingly the Commission decided to choose the Greater Winnipeg Floodway in preference to the removal of Lister s Rapids as the basis of a flood protection plan for Greater Winnipeg However because of the high benefit cost ratios obtained for Trial 12 and Trial B it was decided that some further consideration should be given to the possibility of using one of these trials in combination with the floodway and a Portage Diversion Benefits, costs and benefit cost ratios for each of the three trials are shown in Table 10 8

(b) Channel Improvement Extended through Greater Winnipeg

As was explained in Chapter 4, at the Commission s request, an engineering study was prepared of the stage reductions that would be obtained if channel improvements in the Lister s Rapids area were extended upstream throughout the Greater Winnipeg area Three plans were studied in detail Each plan provided for channel improvements both through and below Greater Winnipeg

The benefit cost ratios obtained on these three plans were as follows

Plan No 1 (110 000 c f s) — 2 09
Plan No 2 (130,000 c f s) — 1 62
Plan No 3 (140 000 c f s) — 1 49

Although these benefit cost ratios are all larger than 1 0, they are much less favourable than those obtained on the Greater Winnipeg Floodway For example an expenditure of $66 547,000 on channel improvements gives an annual benefit of only $7 120 000 and a benefit cost ratio of 2 09 whereas an expenditure of $57 361 000 on a 60 000 c f s floodway gives the larger annual benefit of $9 127 200 and a benefit cost ratio of 2 89 Thus the Greater Winnipeg Floodway is clearly a much more economic scheme for flood control in Greater Winnipeg than a plan for channel improvement through the city Moreover for the two larger channel improvement schemes the incremental benefit-cost ratios are below 1 0 On the basis of these data the Commission concluded that this scheme did not deserve further consideration Benefits, costs and benefit cost ratios for these three schemes are given in Table 10 9

Table 10 9

BENEFIT COST ANALYSIS

CHANNEL IMPROVEMENTS BELOW AND THROUGH WINNIPEG

Project Design	Total Capital Cost	Annual Cost	Average Annual Benefit	Benefit Cost Ratio
Scheme No I (110 000 c f s)	$ 66 547 000	$3 407 600	$7 120 000	2 09
Scheme No II (130 000 c f s)	106,936 000	5 475 700	8 857,500	1 62
Scheme No III (140 000 c f s)	122 949 000	6 295 600	9 395 000	1 49

Increase in Size	Increase in Annual Cost	Increase in Benefits	Incremental Benefit Cost Ratio
To Scheme No I	$3 407 600	$7 120 000	2 09
From Scheme No I to Scheme No II	2 068 100	1 737 500	84
From Scheme No II to Scheme No III	819 900	537 500	66

(c) Channel Improvement South of Winnipeg

Two schemes for channel widening in the area south of Winnipeg were given preliminary analysis The first scheme would provide for a channel with a capacity of 95,000 c f s from St Norbert to a point 10½ miles south of Ste Agathe Its capital cost would be about $14 million The second scheme would provide at a capital cost of $50 million for a similar channel from St Norbert to Emerson Under both schemes an addition would have to be made to the Greater Winnipeg Floodway to offset the loss of natural storage that this scheme would cause The cost of this addition has been estimated at roughly $10 million Thus the total cost of the two schemes would be of the order of $24 million and $60 million respectively

No detailed benefit cost analysis of these schemes was carried out since preliminary data indicated that expenditures of this magnitude would not be economically justified Even if all flooding in the area south of Winnipeg were completely eliminated the capital expenditure that would be justified to achieve this would be only $15 712,000 Since each of these schemes would cost a good deal more than this and since they would each eliminate only part of the total damage it is clear that the benefit cost ratio for both schemes would be well below one Thus the Commission has been forced to conclude that a channel improvement scheme designed to reduce flooding in the valley area south of Winnipeg would not be economically justified

4 **Dykes**

(a) Dyking System in Greater Winnipeg

The Report of the Red River Basin Investigation advances a proposal for a system of dykes through Greater Winnipeg that would provide protection to a level of 28 5 feet above city datum

To analyze this proposal it was assumed that the existing dyking system is safe to Stage 25 feet This provides a freeboard allowance of 1½ feet It was further assumed that the dyking system proposed would be completely safe to 28½ feet above datum, the design level which allows 3 feet of freeboard A stage of 28½ feet corresponds to approximately 95,000 c f s at Redwood Bridge or a 3½% flood

The capital cost of building dykes up to Stage 28½ feet was assumed to be $10 million and to require a construction period of two years This allows an increase of $1 million over the cost estimated by the R R B I to cover increased construction costs and the rise in the cost of property acquisition since 1952 On this basis the following annual costs and benefits were obtained

Total annual benefits of dykes safe to 28½ feet	$711 000 00
Annual benefits on dykes safe to Stage 25	$129 500 00
Additional benefits from increasing dykes from 25 to 28½ feet	$581 500 00
Annual cost at 4% interest of additional dykes	$484 100 00
Benefit cost ratio on construction of additional dykes	1 2

The benefit cost ratio for this project is quite low for a project considered separately and would undoubtedly be below 1 0 if it were considered in combination with other projects In addition the costs estimated by the Red River Basin Investigation appear to be on the low side Since the benefit cost ratio is comparatively low and since raising a dyking system often creates an unwarranted feeling of confidence and induces additional building in low lying areas, the Commission decided that this proposal did not deserve further consideration

(b) Existing Dykes City of Brandon

The existing dyke in the City of Brandon which protects a settled area in the Brandon flats on the south side of the river was constructed between 1954 and 1956 at a cost of $50 000 With some emergency work, it withheld the spring floods of 1954 1955 and 1956 the peak flow at Brandon during this period being 18 900 c f s The top of the present dyke corresponds to a flow of about 29,000 c f s

In evaluating this dyke an allowance of 1½ feet was made for freeboard With this amount of freeboard it can be assumed that the dyke would be safe for flows of up to 21,000 c f s On this basis the benefit cost ratio is 7 99 to 1

Capital Cost of Dykes	$50 000
Annual Cost (including interest & amortization)	$ 2 470
Annual Benefits Basis 1½ Feet Freeboard	$19,740

The high benefit cost ratio shown by the existing dyke at Brandon might suggest the desirability of improving and strengthening this dyke However there are some additional hazards and costs not included in this ratio For example, the above costs do not include any provision for maintenance or for the cost of pumping sewage over the dyke in flood periods Further, since there is no shortage of good residential land in the Brandon area it would be undesirable to take any steps that would encourage the construction of additional properties in the flats Then too if the Russell Reservoir is constructed it will provide a substantial amount of additional protection to this area

Thus, this Commission cannot recommend any further addition to the present dyke in Brandon

(c) Dykes Red River Valley

A preliminary analysis of the benefits that would be provided by a system of dykes on either side of the Red River from St Norbert to about Letellier including ring dykes around eight towns and villages gave the following result

Capital Cost	
Valley Dykes	$8,384 000
Ring Dykes	1 337 000
Total	$9,721 000
Annual Cost	$ 475,000
Annual Benefit	$ 191 200*
Benefit cost Ratio	40

Since the benefit cost ratio was well below 1 0 no further consideration was given to this project

A separate analysis was made of a ring dyke for the town of Morris This proposed dyke would give the town protection to an elevation of 782 7 feet or one foot above the 1950 flood peak In analyzing this project it was assumed that the dyke would be 100 percent effective to elevation 779 7, or two feet below the 1950 flood level This allows three feet of freeboard The following result was obtained

Capital Cost	$403 100
Annual Cost	$ 19 700
Annual Benefit	$ 83,900
Benefit cost Ratio	4 26

This favourable ratio would suggest that ring dykes for other towns in the valley might be economical

* Does not include any allowance for the additional damage that would be caused to buildings situated between the dykes and the river

CHAPTER 11

BENEFIT-COST ANALYSIS OF PROJECTS IN COMBINATION

When two or more flood protection schemes are considered in combination it is usually found that the total annual benefit provided by the combination is substantially less than the sum of the benefits obtained from each of the projects considered separately This is due to the fact that in considerable part the capacity of the separate schemes provides duplicate protection for smaller floods It is only in the larger less frequent floods that this duplication disappears For largely the same reasons the incremental benefit cost ratio for any project considered as an addition to some existing project is sharply lower than its own separate benefit cost ratio

In order to make some selection among the many different possible combinations of projects the following approach was adopted As was explained in Chapter 10 in our initial survey of individual projects it was determined that the Greater Winnipeg Floodway should form a basic part of any combination of schemes designed to provide flood control for Greater Winnipeg Further since the Portage Diversion provides a higher benefit cost ratio than any other alternative plan it was also decided that it should form part of any combination Attention was given first to combinations of the three Portage Diversions with the 40 768 60 768 and 80 768 Greater Winnipeg Floodways Data on benefits costs and benefit cost ratios for each of these projects are given in Table 11 1 All data are for the High Bluff rather than the Fort la Reine Diversion

The highest benefit cost ratio obtained from these combinations is that of 3 44 for a combination of a 40 000 c f s Floodway and a 40 000 c f s Portage Diversion In general in all three cases, increasing the size of the Portage Diversion in combination with a given size of Floodway increases the size of the benefit cost ratio This is what could be expected because the incremental benefit cost ratios on the Portage Diversion when considered separately remain high right up to a diversion capacity of 40,000 c f s (*See Plate* 27)

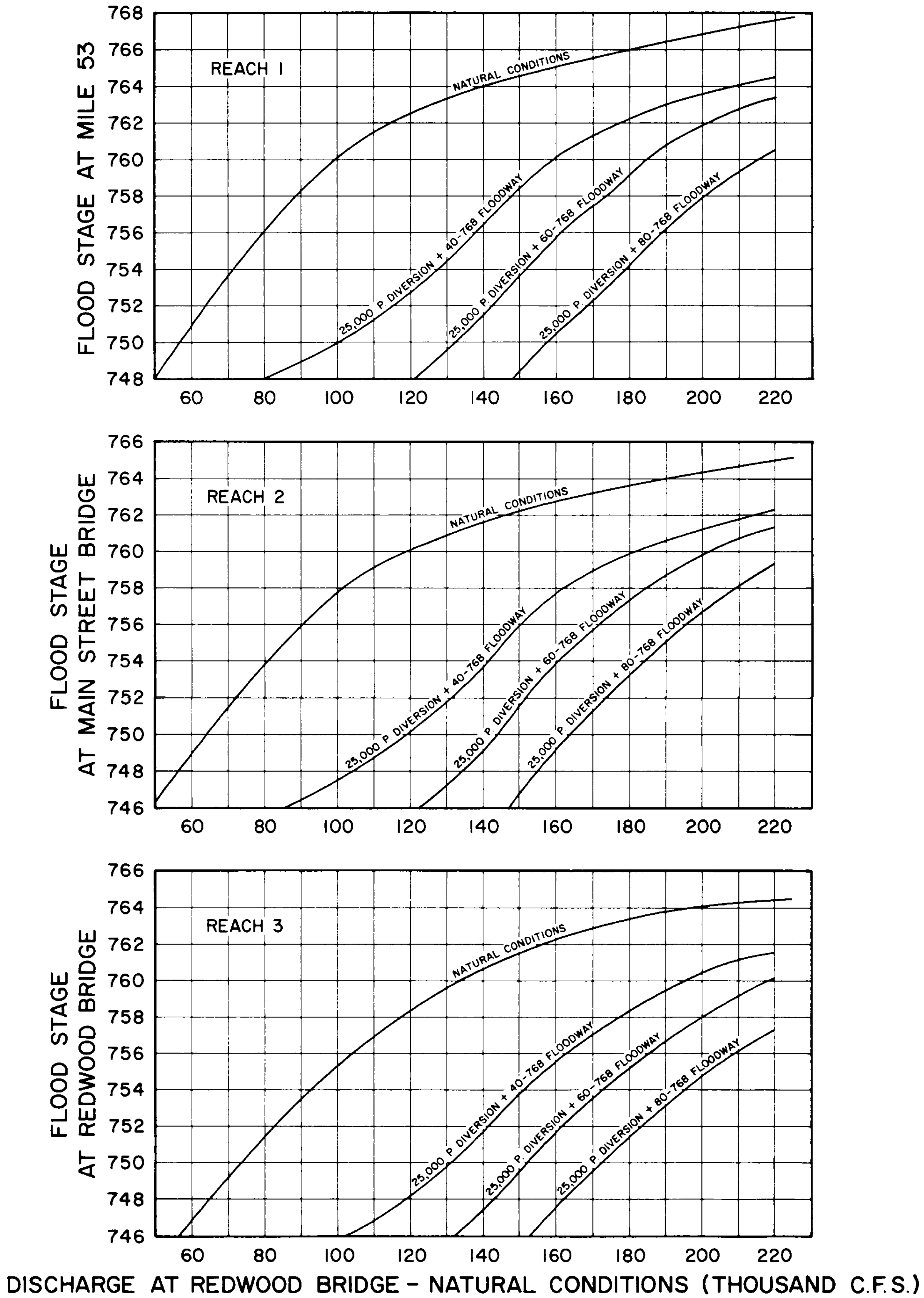
Although the Greater Winnipeg Floodway must be relied on to provide a major part of the protection required in Greater Winnipeg, a diversion or retention of some 40 000 c f s on the Assiniboine River is also justified if the most economical form of flood protection is to be provided in the city

Some question may be raised as to why flood protection measures with a capacity of 40 000 c f s should be provided on the Assiniboine River since in most years the Assiniboine River contributes no more than 20 percent of the peak flood flow at Redwood Bridge Its justification lies in the lower cost of diversion works on the Assiniboine A Portage Diversion of 40 000 c f s along the High Bluff would cost only $10 861 000 or just over one quarter of the cost of a 40 000 c f s floodway and less than 20 percent of the cost of a 60 000 c f s floodway This lower cost in large measure accounts for the high benefit cost ratios obtained in the Portage Diversion

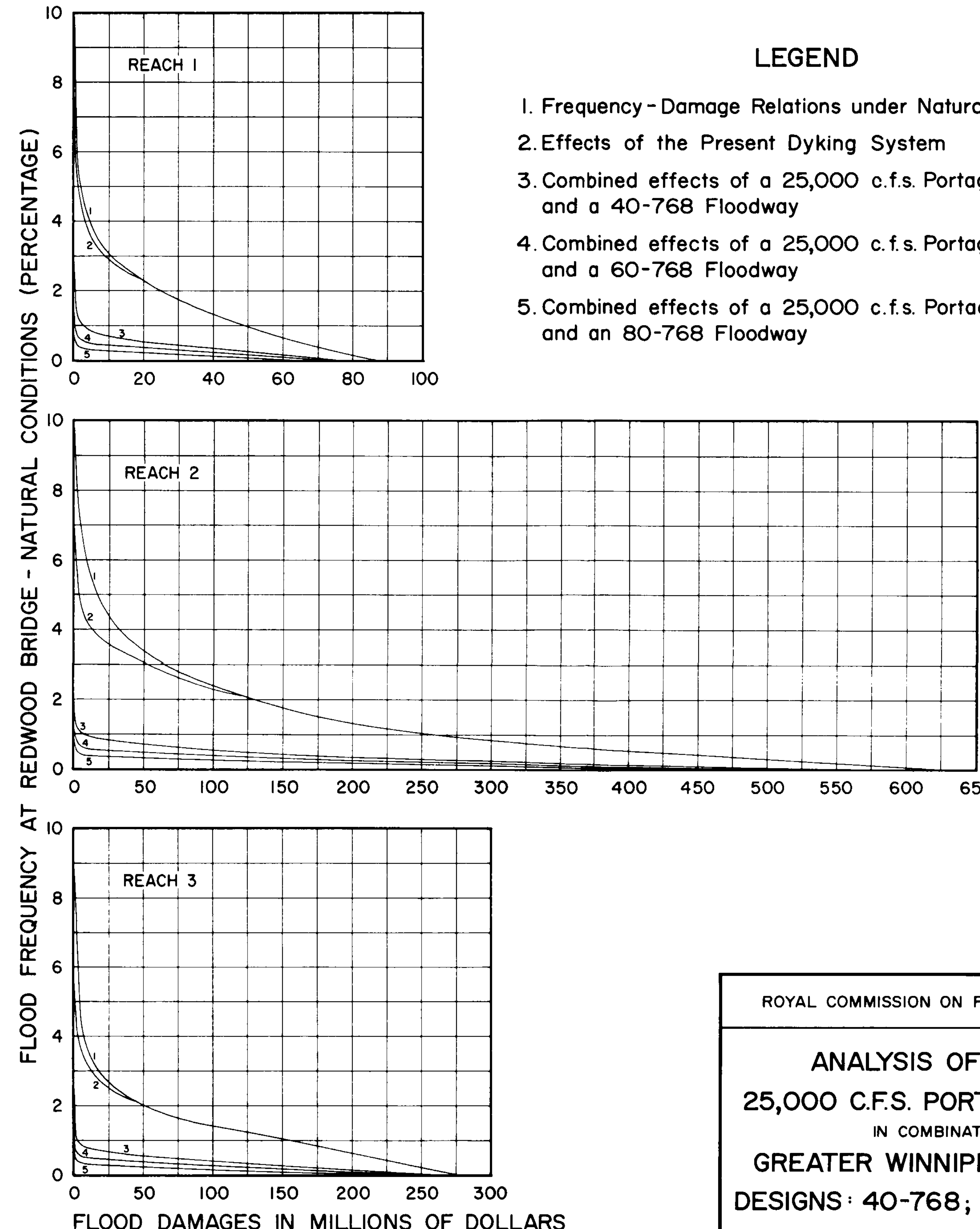
Table 11 1

BENEFIT COST ANALYSIS
GREATER WINNIPEG FLOODWAY AND PORTAGE DIVERSION IN COMBINATION

Greater Winnipeg Floodways and Portage Diversions	Total Capital Cost	Annual Cost	Annual Benefit	Benefit Cost Ratio
		(Thousands of Dollars)		
40 768 plus 10 000 P D	$47 433	$2 646	$ 8 461	3 20
60 768 plus 10 000 P D	63 070	3 505	9 836	2 81
80 768 plus 10 000 P D	77 145	4 275	10 691	2 50
40 768 plus 25 000 P D	50 396	2 810	9 384	3 34
60 768 plus 25 000 P D	66 033	3 668	10 451	2 85
80 768 plus 25 000 P D	80 108	4 438	11 178	2 52
40 768 plus 40 000 P D	52 585	2 934	10 087	3 44
60 768 plus 40 000 P D	68 222	3 792	10 839	2 86
80 768 plus 40 000 P D	82 297	4 562	11 465	2 51



STAGE-DISCHARGE RELATIONS



FREQUENCY-DAMAGE RELATIONS

LEGEND

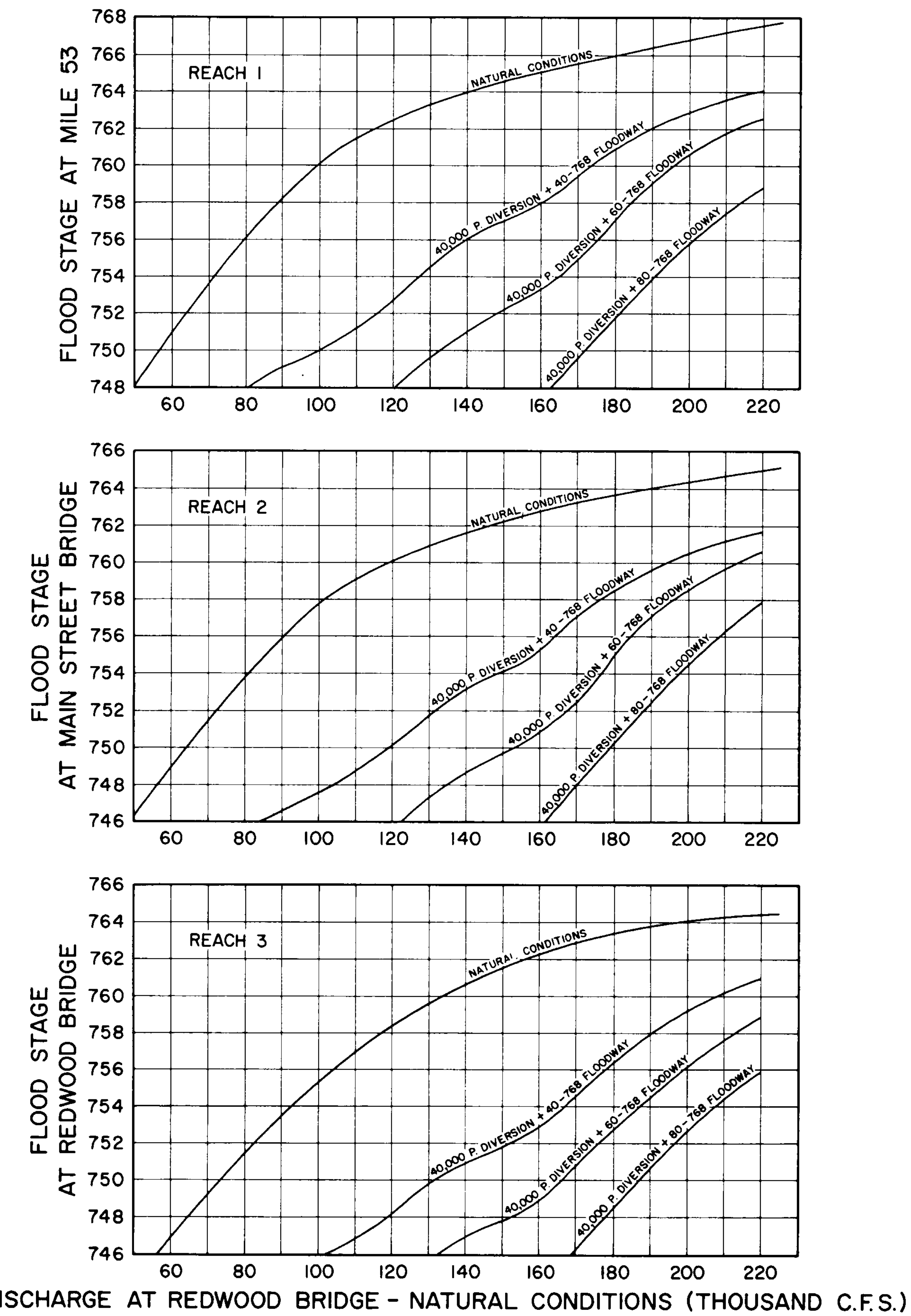
1. Frequency-Damage Relations under Natural Conditions
2. Effects of the Present Dyking System
3. Combined effects of a 25,000 c.f.s. Portage Diversion and a 40-768 Floodway
4. Combined effects of a 25,000 c.f.s. Portage Diversion and a 60-768 Floodway
5. Combined effects of a 25,000 c.f.s. Portage Diversion and an 80-768 Floodway

ROYAL COMMISSION ON FLOOD COST-BENEFIT

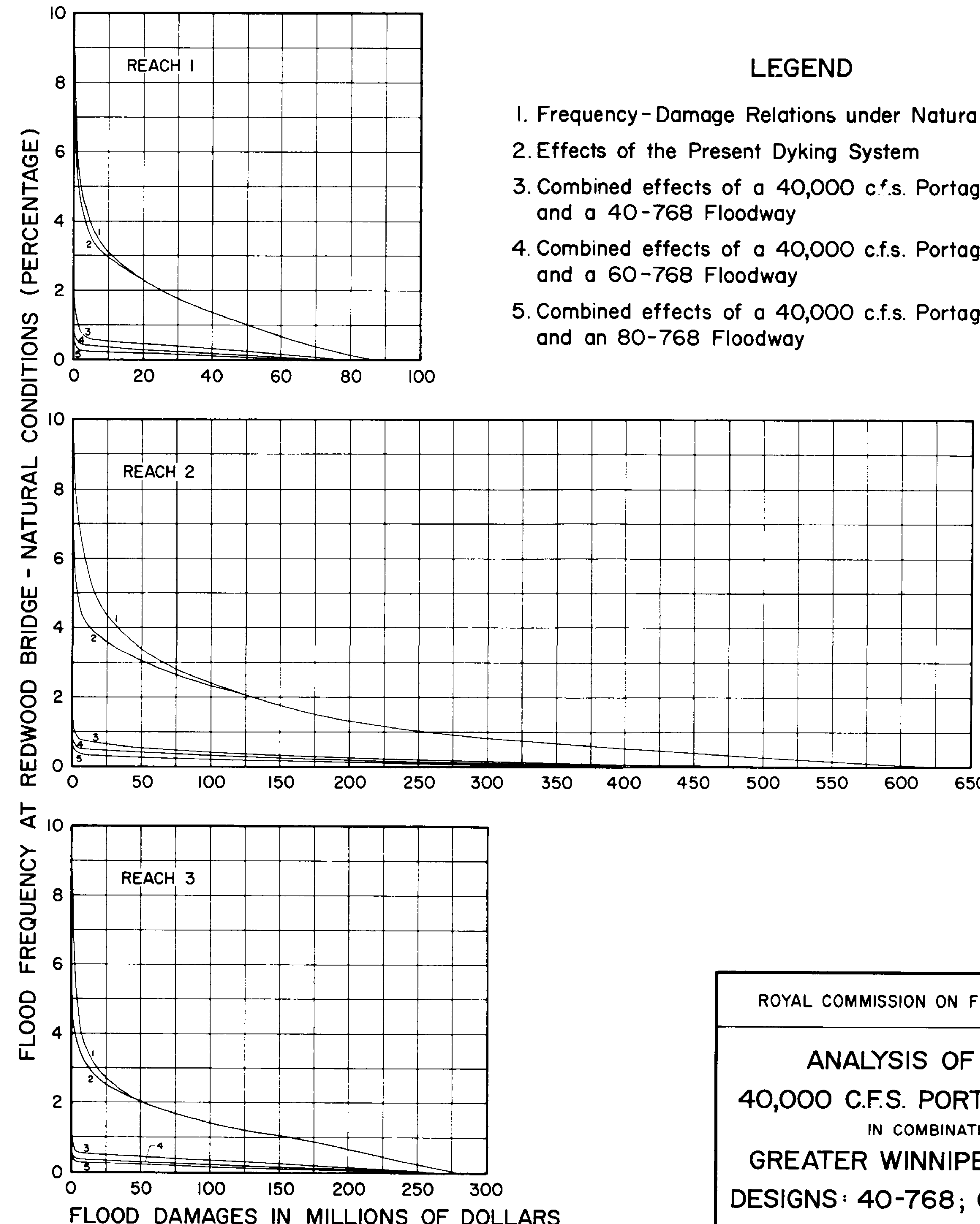
ANALYSIS OF BENEFITS
25,000 C.F.S. PORTAGE DIVERSION
IN COMBINATION WITH
GREATER WINNIPEG FLOODWAYS
DESIGNS: 40-768; 60-768; 80-768

REACHES 1, 2 AND 3 - GREATER WINNIPEG

DECEMBER 1958



STAGE-DISCHARGE RELATIONS



FREQUENCY-DAMAGE RELATIONS

LEGEND

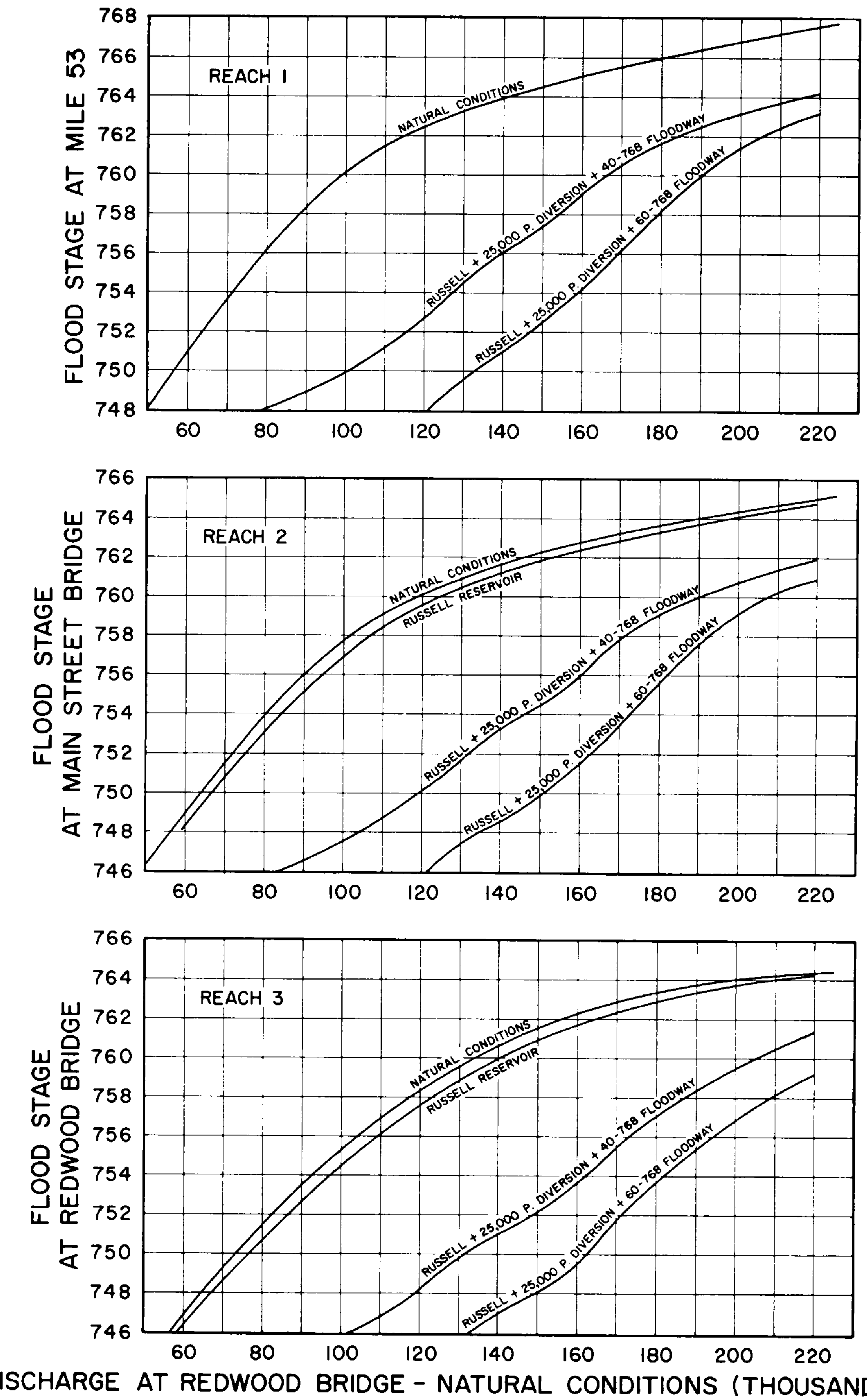
1. Frequency-Damage Relations under Natural Conditions
2. Effects of the Present Dyking System
3. Combined effects of a 40,000 c.f.s. Portage Diversion and a 40-768 Floodway
4. Combined effects of a 40,000 c.f.s. Portage Diversion and a 60-768 Floodway
5. Combined effects of a 40,000 c.f.s. Portage Diversion and an 80-768 Floodway

ROYAL COMMISSION ON FLOOD COST-BENEFIT

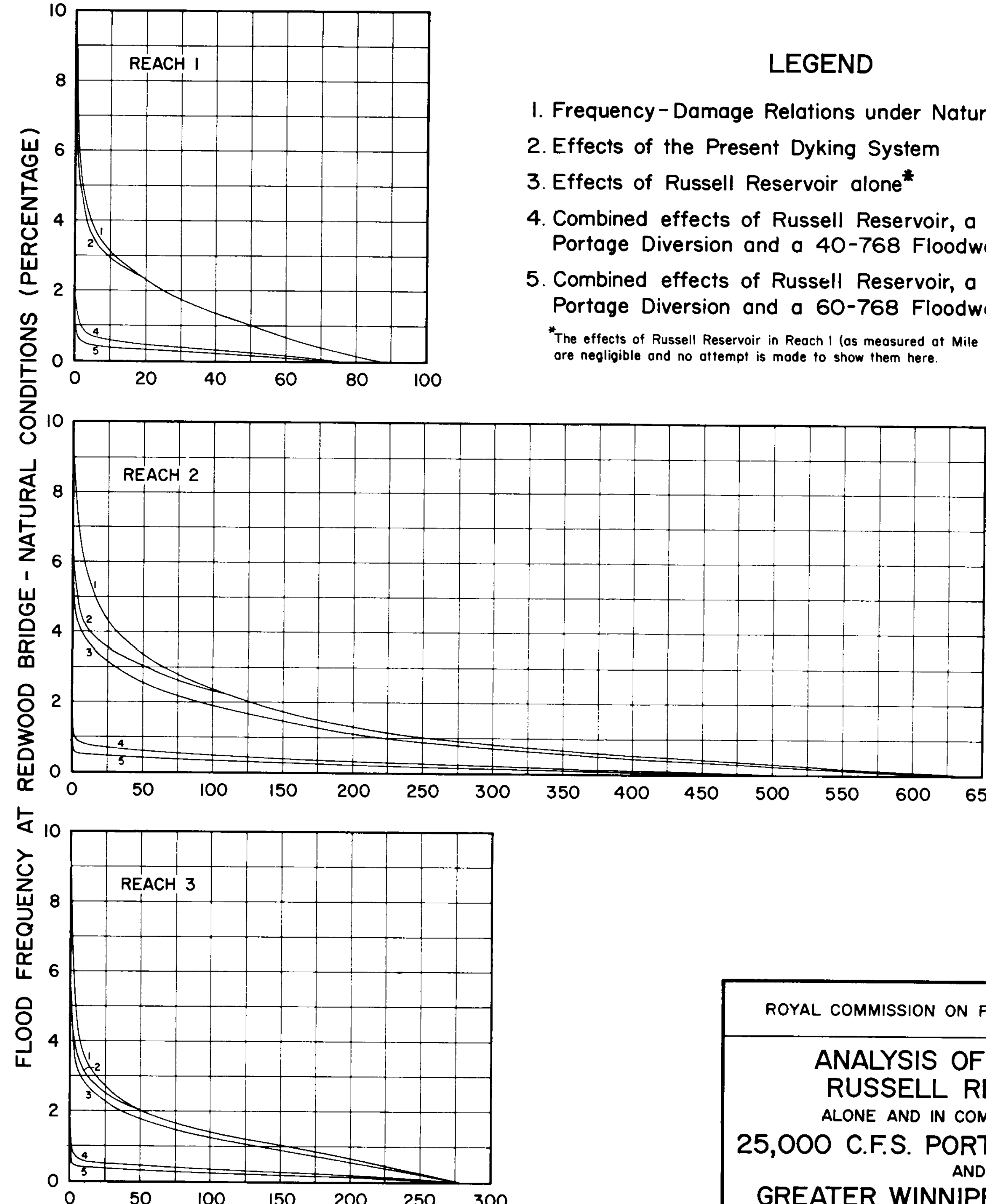
ANALYSIS OF BENEFITS
40,000 C.F.S. PORTAGE DIVERSION
IN COMBINATION WITH
GREATER WINNIPEG FLOODWAYS
DESIGNS: 40-768; 60-768; 80-768

REACHES 1,2 AND 3 - GREATER WINNIPEG

DECEMBER 1958



STAGE-DISCHARGE RELATIONS



FREQUENCY-DAMAGE RELATIONS

LEGEND

1. Frequency-Damage Relations under Natural Conditions
2. Effects of the Present Dyking System
3. Effects of Russell Reservoir alone*
4. Combined effects of Russell Reservoir, a 25,000 c.f.s. Portage Diversion and a 40-768 Floodway
5. Combined effects of Russell Reservoir, a 25,000 c.f.s. Portage Diversion and a 60-768 Floodway

*The effects of Russell Reservoir in Reach I (as measured at Mile 53) are negligible and no attempt is made to show them here.

ROYAL COMMISSION ON FLOOD COST-BENEFIT

ANALYSIS OF BENEFITS RUSSELL RESERVOIR

ALONE AND IN COMBINATION WITH

25,000 C.F.S. PORTAGE DIVERSION

AND

GREATER WINNIPEG FLOODWAYS DESIGNS: 40-768; 60-768

REACHES 1, 2 AND 3 - GREATER WINNIPEG

DECEMBER 1958

In combination with a Greater Winnipeg Floodway, the Portage Diversion retains its very favourable benefit-cost position This is particularly true of the 25,000 c f s and 40,000 c f s Diversions The reasons why this is true are fairly clear If a Greater Winnipeg Floodway with a capacity of 40,000 c f s were constructed, a reasonable degree of protection would have been provided to Greater Winnipeg for all floods of less than 115,000 c f s Thus, the circumstances under which the additional protection provided by the Portage Diversion would be required would be in those very major floods ranging from 115,000 c f s to 200,000 c f s or larger, and in floods of this magnitude it is quite likely that there would be a large flow on the Assiniboine In controlling this flow, a substantial degree of flood protection on the Assiniboine River would be extremely valuable

In order to determine the most economical size of floodway, let it be assumed that a 40,000 c f s Greater Winnipeg Floodway plus flood protection works on the Assiniboine River with a capacity of 40,000 c f s have been adopted as the core of the city's flood protection What additional expenditures would be justified for increasing the size of the floodway? The data in Table 11 2 provide the basis for an answer to this question These data indicate that in combination with a 40,000 c f s Portage Diversion an increase in the capacity of the floodway from 40,000 c f s to 60,000 c f s yields an incremental benefit-cost ratio of only 88 In other words the additional annual benefit obtained from such an addition to the capacity of the floodway is slightly less than the cost of providing it This is true even though the over-all benefit-cost ratio is 2 86 For the further increase from 60,000 c f s to 80,000 c f s, the incremental ratio is lower still, being only 81 However, throughout the range of floodway capacities from 40,000 to 80,000 c f s the additional benefits and additional costs are fairly close together

The benefits in this comparison are based on present property values and incomes only If allowance is made for the growth now in prospect for the Greater Winnipeg area, these incremental ratios would be about 50 percent higher, that is, 1 32 and 1 22 instead of 88 and 81 The stage-discharge and frequency-damage charts used in the calculation of benefits for the 25,000 c f s and 40,000 c f s Portage Diversions in combination with the 40-768 to 80-768 floodways are shown in Plates 29 and 30

Because the separate benefit-cost ratio yielded by the Lister's Rapids removal project, Trial B, was comparatively high, an analysis was made to determine the additional benefit it would provide in combination with a 40,000 c f s Portage Diversion and a major floodway The results of this analysis are as follows

	Benefit-Cost Ratio
Trial B plus 40-768 + 40 P D	2 87
Trial B plus 60-768 + 40 P D	2 44

	Incremental Benefit-Cost Ratio
For addition of Trial B to 40-768 + 40 P D	68
For addition of Trial B to 60-768 + 40 P D	49

These data show that Trial B would not be economically justified when considered as an addition to a project involving a 40,000 c f s capacity Portage Diversion and a 40,000 c f s or 60,000 c f s floodway Substantially the same results would have been obtained if Trial B had been considered in combination with the Russell Reservoir and the 25,000 c f s Portage Diversion together with a 40,000 c f s or 60,000 c f s Greater Winnipeg Floodway The incremental-ratios for Trial B in such a combination are well below 1 0, namely, 68 in combination with a 40,000 c f s Portage Diversion and a 40-768 Floodway and 49 in combination with a 40,000 c f s diversion and a 60-768 floodway Accordingly, no further consideration was given to this project

Two other projects, which gave very favourable benefit-cost ratios when considered as

Table 11 2
INCREMENTAL BENEFIT COST ANALYSIS
GREATER WINNIPEG FLOODWAYS AND PORTAGE DIVERSION IN COMBINATION

Increase in Project*	Increase in Annual Cost	Increase in Annual Benefit	Incremental Benefit-Cost Ratio
From 40,000 c f s P D to 40,000 c f s P D +40-768	$2,303,400	$4,650 200	2 02
From 40 000 c f s P D +40-768 to 40 000 c f s P D +60-768	858,300	752,000	88
From 40,000 c f s P D +60-768 to 40,000 c f s P D +80-768	770,100	626 300	81

*Basis High Bluff Diversion

separate projects were also analyzed in combination with the floodway and Portage Diversion These two projects are the Russell Reservoir and the Eastern Tributaries diversion The Russell Reservoir was considered primarily as an alternative to the increase in the size of the Portage Diversion from 25 000 c f s to 40 000 c f s The Eastern Tributaries Diversion was analyzed in combination with a 40 000 c f s Portage Diversion and a 40 768 and 60 768 Floodway

On the Assiniboine River the benefit cost analysis indicates that protective works with a capacity of about 40 000 c f s are economically justified Protection of roughly this amount can be provided either by the construction of a 40 000 c f s diversion at Portage la Prairie or by construction of a 25 000 c f s diversion at Portage together with the Russell Reservoir

Attention of the Commission was also drawn to the fact that the P F R A are currently investigating a proposal for the construction of a large storage reservoir west of Portage la Prairie It is possible that this project might provide substantially the same flood protection benefits in the area downstream from Portage la Prairie as the Russell Reservoir and the 25 000 c f s Portage Diversion For this reason the Commission recommends that the benefits and cost of this proposal should be analyzed as soon as the engineering data are available

A number of considerations favour the choice of the Russell Reservoir plus the 25 000 c f s Diversion in preference to the 40 000 c f s Portage Diversion The Russell Reservoir provides flood protection to the City of Brandon and to farmlands in the Assiniboine River Valley between the site of the Reservoir and Portage la Prairie areas which would not otherwise be protected The Russell Reservoir also makes it possible to maintain higher minimum water levels downstream from the reservoir and thus provides a valuable benefit in the form of a more assured potable water supply and a better sewage dilution for cities and towns along the river For the City of Winnipeg it provides better sewage dilution and in combination with a water supply channel from Lake Manitoba should make it possible to avoid the very considerable expense of converting the existing sewage disposal plant from primary to secondary treatment The Manitoba Hydro electric steam power plant at Brandon would also benefit from this more assured water supply While an annual water supply benefit of $128 000 has been included in our benefit cost analysis on this project a complete study of the water supply problem has not been made since this is beyond the scope of this Commission s task However we are reasonably confident that there are additional water supply benefits which have not been included in our analysis

On the other hand if the Russell Reservoir is to be operated so as to provide an optimum benefit to Greater Winnipeg an accurate flood forecast would be required Its location is 200 miles north and west of Greater Winnipeg and the spring break up is likely to occur later there than it does in Winnipeg In addition it normally requires about 10 to 13 days for the flow of water to travel downstream from the site of the Russell Reservoir to Winnipeg Nevertheless since the Russell Reservoir has a peak storage capacity of 600 000 acre feet, it would be possible to reduce the flow immediately below the reservoir by an average of 15 000 c f s per day for a 20 day period, or by an average of 10,000 c f s for a 30 day period To permit this reduction the reservoir would have to be completely emptied in advance of the flood period

It is also true that from a benefit cost point of view the 40 000 c f s diversion is slightly more favourable than the combination of a 25 000 c f s diversion with the Russell Reservoir In combination with a 60,000 c f s Greater Winnipeg Floodway the 40 000 c f s High Bluff Diversion gives a benefit cost ratio of 2 86 compared with a ratio of 2 73 for a 25 000 c f s High Bluff Diversion and the Russell Reservoir Moreover the incremental benefit cost ratio obtained by increasing the size of the diversion from 25 000 c f s to 40,000 c f s is 3 13 whereas the incremental benefit cost ratio obtained from the Russell Reservoir is only 1 41 As against this, in serious floods the Russell Reservoir provides more dependable flood protection for the City of Portage la Prairie If the 40 000 c f s High Bluff Diversion were constructed flood protection would be provided in the form of a long dyke but this form of protection is less certain

Taking into account all these considerations this Commission decided to recommend the Russell Reservoir in combination with the 25 000 c f s High Bluff Portage Diversion in preference to the 40 000 c f s Diversion The High Bluff route for the Portage Diversion is clearly preferable to the Fort La Reine route because it gives approximately the same benefits and costs $2 338 000 less

In analyzing the effects of the Eastern Tributaries Diversion in combination, it was assumed that the intake structure of the floodway would be operated so as to maintain natural water levels upstream of the floodway Under this method of operation the discharge reduction produced by the Eastern Tributaries Diversion at Redwood Bridge gives a larger stage reduction than it would in the absence of the Greater Winnipeg Floodway Due to the shape of the Redwood Bridge rating curve, a given discharge reduction produces a much larger stage reduction at a low flow than it does at a higher flow Maintenance of the natural water level upstream of Winnipeg reduces the benefit that would accrue to the area south of Winnipeg However because the size of the damages in this area is smaller than in the city this method of operation attributes a larger benefit to the Eastern Tributaries scheme than any other method of operation

The benefit cost data indicate that the additional benefit provided by the Eastern Tributaries Diversion in combination with a floodway and Portage Diversion is not large enough to justify the cost of the project Thus the incremental benefit cost ratio for the Eastern Tributaries Diversion in combination with a 40 768 Floodway and a 40,000 c f s Portage Diversion is only 59 Such an expenditure is considerably less economical than the expenditure required to increase the size of the floodway from 40 000 to 60 000 c f s This latter expenditure has an incremental benefit cost ratio of 88 (*see Table* 11 2)

When considered in combination with a 60,000 c f s Greater Winnipeg Floodway, a 25,000 c f s Portage Diversion and the Russell Reservoir the Pembina Dam provides only enough flood control benefits to give an incremental benefit cost ratio of 32 It provides additional flood control benefits of $27 400 in the Red River Valley and additional benefits of $52 000 in Greater Winnipeg The engineering studies that the Red River Basin Investigation made of this project were not complete and it is possible that more thorough study will show further flood control benefits

In addition to its flood control benefits the Pembina Dam might provide substantial benefits in the form of an improved and dependable supply of water for the water short Pembina triangle This water supply would be of substantial value for household farm industrial and commercial use, for irrigation and for sewage dilution However, a major engineering and economic study would be required to determine the dollar benefits that could be attributed to this water supply

After careful consideration this Commission decided it could not recommend this project as a flood control measure on the basis of the engineering data presently available However it does recommend that an exhaustive study be made of the Pembina River with a view to evaluating completely the flood control and water supply benefits that might accrue from the construction of a dam and reservoir on this river

RECOMMENDATIONS

On the basis of the above analysis and some further considerations explained below the Royal Commission on Flood Cost Benefit voted to recommend the following combination of projects

(a) A 60 000 c f s Greater Winnipeg Floodway
(b) A 25 000 c f s Portage Diversion on the High Bluff route
(c) The Russell Reservoir

In conjunction with the construction of the Portage Diversion the Commission also recommended that the channel capacity between Portage la Prairie and Winnipeg should be maintained at its present level

The capital cost of this combination is estimated to be $72 5 million (with a 60 768 Floodway) and its overall benefit cost ratio based on present property values and incomes is 2 7 If allowance is made for the growth that can be reasonably anticipated to occur in Greater Winnipeg over the next 25 years, a benefit cost of about 4 1 is obtained for this combination These ratios are based on a 4 percent interest rate

In arriving at its final decision the Commission was guided by two general considerations It was felt that it would be desirable to provide Winnipeg with protection against at least a 1 percent flood that is, a flood which can be expected to occur on the average of once in one hundred years in this instance a flow of about 150 000 cubic feet per second Beyond that point, the degree of protection should be as large as was consistent with a favourable benefit cost ratio In deciding on the final size of the various projects particular attention was given to the marginal or incremental benefit cost ratio which measures the additional benefit obtained from any increase in the size of a project compared with the additional cost of obtaining this benefit

For various combinations of the Greater Winnipeg Floodway and the Portage Diversion, the benefit cost analysis indicated that the retention or diversion of 40 000 c f s on the Assiniboine together with a Greater Winnipeg Floodway in the size range from 40 000 c f s to 60 000 c f s would be justified A 40 768 Floodway plus a 40,000 c f s Portage Diversion would provide protection against a flood of 147 000 c f s with a water level in the Red River through Winnipeg about one foot below the top of the existing dyking system For the 60 768 Floodway 40 000 c f s Portage Diversion combination the protection provided is 174,000 c f s Thus any project in this size range meets one of the general guiding considerations adopted by the Commission the provision of protection against a 1 percent flood

By itself the Portage Diversion has a very high benefit cost ratio and this is true even for the largest size of this diversion for which designs are available the 40 000 c f s design These high ratios reflect the fact that because of the comparatively short length of the diversion the cost per 1 000 c f s of water diverted is comparatively low Moreover once a smaller diversion has been constructed the additional cost of increasing its capacity is small Thus for the High Bluff Diversion, although it costs $5 709 000 to build a 10 000 c f s diversion, it costs only $2 963 000 to increase its size from 10 000 c f s to 25 000 c f s and only $2 189 000 to increase its size from 25,000 c f s to 40 000 c f s

As was pointed out above, when the Greater Winnipeg Floodway is considered in combination with the retention or diversion of 40 000 c f s on the Assiniboine River the incremental benefit cost ratio remains above 1 0 until a 40,000 c f s Floodway is reached Beyond that point the incremental ratio is slightly below 1 0 At 60 000 c f s the incremental benefit cost ratio is about 9 and at 80,000 it is about 8 This indicates that in combination with flood protection works of up to a capacity of 40 000 c f s for the Asssiniboine River the additional cost of any increase in the size of the floodway is just slightly larger than the additional benefit obtained from this increase

In these ratios benefits are based on present property values and incomes only When allowance is made for the growth that can be expected in Greater Winnipeg during the next twenty-five years these ratios can be increased by a factor of 50 percent On this basis the incremental benefit cost ratio at 60 000 c f s would be 1 32 and at 80 000 c f s 1 22

In recommending the construction of a 60 000 c f s Floodway the Commission felt it was desirable to give some attention to the future growth of Greater Winnipeg Unless provision is made now for the additional flood protection that this expected growth justifies it will be very difficult if not impossible to do so in the future In combination with the projects recommended on the Assiniboine River a 60 000 c f s Floodway around Winnipeg would provide a degree of flood protection for the city that would ensure its continued growth and prosperity

In addition it was felt that it was desirable to have a larger proportion of the flood protection works on the main stem of the Red River than would be justified on the basis of the benefit cost analysis alone Because about 80 percent of the flood flows in Greater Winnipeg originate on the Red River flood protection works on the Red provide a more reliable form of protection than projects on the Assiniboine

To sum up the three projects recommended will provide the following benefits

(a) They will provide complete protection to all parts of Greater Winnipeg outside the primary dyking system for all floods of up to 169 000 c f s A flood flow of 169,000 c f s can be expected to be equalled or exceeded on the average of once in 160 years With such a flood flow it can be expected that, on the average about 76 000 c f s would flow through Winnipeg with a flood elevation about one foot below the top of the existing dyking system some 66 000 c f s would flow through the floodway channel some 10 000 c f s would be held back by the Russell Reservoir and 25 000 c f s would be diverted into Lake Manitoba by the Portage Diversion Since not all of the 35 000 c f s withheld or diverted on the Assiniboine produces an equivalent reduction in Winnipeg the total of the above exceeds 169,000 c f s

In addition if a larger flood than 169 000 c f s were to occur in the Greater Winnipeg area, there would be a possibility of obtaining a considerable additional margin of protection Thus, with the construction of temporary dykes that would allow the water level in the channel to be raised by 4 feet there would be a possibility of carrying an additional 22 000 c f s through the city Further if the floodway gates were operated in such a way as to raise the water level at St Norbert to 3 feet above its natural level in any given flood, it would be possible to pass an additional 11 000 c f s through the floodway Thus with this combination of projects it would be possible to fight a flood of up to 200,000 c f s in the Greater Winnipeg area

(b) They will provide complete protection to the area between Portage la Prairie and Winnipeg for all floods below 55 000 c f s on the Assiniboine

(c) The Russell Reservoir will provide protection in the Brandon area for all floods of less than 33 000 c f s for the area behind the dyke and for all floods of less than 16,000 c f s for the area outside the dyke

(d) The Russell Reservoir will protect the area from Millwood to Brandon for floods of up to about 16 000 c f s

(e) The Russell Reservoir provides a number of important supplementary benefits in the form of improved water supply and sewage benefits and also creates a lake which will have recreational benefits

Finally on the basis of existing property and income this combination of projects gives a benefit cost ratio of 2 7 In other words over a long period of time the expenditure involved some $72 5 million will yield a benefit in terms of flood damages prevented of about $2 70 for every $1 00 invested in this project

If allowance is made for the growth that may be anticipated for the Greater Winnipeg area this ratio becomes 4 1 which means that the province and city will get a net return, in terms of flood damages prevented and other ancillary benefits of $4 10 for every $1 00 invested in these three projects

For convenient reference, a summary of the benefits, costs and benefit cost ratios on the various projects is presented in Tables 11 3 to 11 6

Table 11 3

BENEFIT COST ANALYSIS — SUMMARY
MAJOR FLOOD PROTECTION PROPOSALS (CONSIDERED SEPARATELY)

Project	Total Capital Cost	Annual Cost	Average Annual Benefit	Benefit Cost Ratio
GREATER WINNIPEG FLOODWAYS				
40 768 Floodway	$41 724 000	$2 303 400	$ 7 595 000	3 30
60 768 Floodway	57 361 000	3 161 700	9 127 200	2 89
80 768 Floodway	71 436 000	3 931 800	10 151 400	2 58
PORTAGE DIVERSIONS				
10 000 c f s High Bluff Diversion	5 709 000	342 800	2 357 800	6 88
25 000 c f s High Bluff Diversion	8 672 000	506 200	4 586 600	9 06
40 000 c f s High Bluff Diversion	10 861 000	630 100	5 436 900	8 63
10 000 c f s Fort la Reine Diversion	6 584 000	396 100	2 357 800	5 95
25 000 c f s Fort la Reine Diversion	11 010 000	635 900	4 586 600	7 21
40 000 c f s Fort la Reine Diversion	14 097 000	803 100	5 436 900	6 77
EASTERN TRIBUTARIES DIVERSION	11 330 000	652 000	1 483 900	2 28
RUSSELL RESERVOIR	6 450 000	333 900	2 062 400	6 18
STE AGATHE DETENTION BASIN				
Additional Damage Approach	9 234 000	451 300 (a)	1 475 100	[illegible]
Flooding Rights Approach	26 804 000	1 269 000 (a)	4 623 000	3 64
PEMBINA RESERVOIR	5 140 000	251 300 (a)	536 700 (b)	2 14
REMOVAL OF LISTER S RAPID				
Trial 12	5 674 000	290 500 (a)	1 294 500	4 46
Trial B	14 925 000	764 200 (a)	3 296 000	4 31
Trial C	29 326 000	1 501 600 (a)	5 156 000	3 43
CHANNEL IMPROVEMENT EXTENDED THROUGH GREATER WINNIPEG				
Plan No 1 (110 000 c f s)	66 547 000	3 407 600 (a)	7 120 000	2 09
Plan No 2 (130 000 c f s)	106 936 000	5 475 700 (a)	8 857 500	1 62
Plan No 3 (140 000 c f s)	122 949 000	6 295 600 (a)	9 395 000	1 49
EXTENSION OF EXISTING GREATER WINNIPEG DYKES	10 000 000	484 100 (a)	581 500	1 20

(a) Exclude Maintenance Costs
(b) Includes Flood Protection Benefits Only

Table 11 4

BENEFIT COST ANALYSIS — SUMMARY
MAJOR FLOOD PROTECTION PROPOSALS (CONSIDERED IN COMBINATION)

Project Combination	Total Capital Cost	Annual Cost	Average Annual Benefit	Benefit Cost Ratio
40 768 Floodway plus 10 000 c f s High Bluff Diversion	$47 433 000	$2 646 200	$ 8 461 400	3 20
60 768 Floodway plus 10 000 c f s High Bluff Diversion	63 070 000	3 504 500	9 835 900	2 81
80 768 Floodway plus 10 000 c f s High Bluff Diversion	77 145 000	4 274 600	10 690 700	2 50
40 768 Floodway plus 25 000 c f s High Bluff Diversion	50 396 000	2 809 600	9 383 500	3 34
60 768 Floodway plus 25 000 c f s High Bluff Diversion	66 033 000	3 667 900	10 450 800	2 85
80 768 Floodway plus 25 000 c f s High Bluff Diversion	80 108 000	4 438 000	11 178 300	2 52
40 768 Floodway plus 40 000 c f s High Bluff Diversion	52 585 000	2 933 500	10 087 100	3 44
60 768 Floodway plus 40 000 c f s High Bluff Diversion	68 222 000	3 791 800	10 839 100	2 86
80 768 Floodway plus 40 000 c f s High Bluff Diversion	82 297 000	4 561 900	11 465 400	2 51
40 768 Floodway plus 25 000 c f s High Bluff Diversion plus Russell Reservoir	56 846 000	3 143 500	10 090 900	3 21
60 768 Floodway plus 25 000 c f s High Bluff Diversion plus Russell Reservoir	72 483 000	4 001 800	10 921 100	2 73
40 768 Floodway plus 40 000 c f s High Bluff Diversion plus Lister s Rapids Trial B	67 510 000	3 697 700 (a)	10 609 100	2 87
60 768 Floodway plus 40 000 c f s High Bluff Diversion plus Lister s Rapids Trial B	83 147 000	4 556 000 (a)	11 215 600	2 44
40 768 Floodway plus 40 000 c f s High Bluff Diversion plus Eastern Tributaries Diversion	63 915 000	3 585 500	10 473 500	2 92
60 768 Floodway plus 40 000 c f s High Bluff Diversion plus Eastern Tributaries Diversion	79 552 000	4 443 800	11 176 700	2 52
60 768 Floodway plus 25 000 c f s High Bluff Diversion plus Russell Reservoir plus Pembina Reservoir	77 623 000	4 253 100 (b)	11 000 500 (c)	2 59

(a) Excludes maintenance costs on Lister s Rapids—Trial B
(b) Excludes maintenance cost on Pembina Reservoir
(c) For Pembina Reservoir flood protection benefits only are included

Table 11 5

INCREMENTAL BENEFIT COST ANALYSIS — SUMMARY
MAJOR FLOOD PROTECTION PROPOSALS (CONSIDERED SEPARATELY)

Increase in Size	Increase in Annual Cost	Increase in Annual Benefit	Incremental Benefit Cost Ratio
GREATER WINNIPEG FLOODWAY			
From 40 768 to 60 768	$ 558 300	$1 532 200	1 79
From 60 768 to 80 768	770 100	1 024 200	1 33
PORTAGE DIVERSION (High Bluff Route)			
From 10 000 c f s to 25 000 c f s	163 400	2 228 800	13 64
From 25 000 c f s to 40 000 c f	123 900	850 300	6 86
REMOVAL OF LISTER S RAPIDS			
From Trial 12 to Trial C	1 211 100 (a)	3 861 500	3 19
From Trial B to Trial C	737 400 (a)	1 860 000	2 52
CHANNEL IMPROVEMENT EXTENDED THROUGH GREATER WINNIPEG			
From Plan 1 (110 000 c f s) to Plan 2 (130 000 c f)	2 068 100 (a)	1 737 500	84
From Plan 2 (130 000 c f s) to Plan 3 (140 000 c f s)	819 000 (a)	537 500	66

(a) Excludes maintenance cost

Table 11 6

INCREMENTAL BENEFIT COST ANALYSIS — SUMMARY
MAJOR FLOOD PROTECTION PROPOSALS (CONSIDERED IN COMBINATION)

Increase in Size	Increase in Annual Cost	Increase in Annual Benefit	Incremental Benefit Cost Ratio
INCREASE 40 768 FLOODWAY			
(a) by adding 25 000 c f s High Bluff Diversion	$ 506 200	$1 788 500	3 53
(b) by adding 40 000 c f s High Bluff Diversion	630 100	2 492 100	3 96
INCREASE 40 768 FLOODWAY PLUS 25 000 C F S HIGH BLUFF DIVERSION			
(a) to 40 768 Floodway plus 40 000 c f s High Bluff Diversion	123 900	703 600	5 68
(b) by adding Russell Reservoir	333 900	707 400	2 12
(c) to 60 768 Floodway plus 25 000 c f s High Bluff Diversion	858 300	1 067 300	1 24
INCREASE 60 768 FLOODWAY PLUS 25 000 C F S HIGH BLUFF DIVERSION			
(a) to 60 768 Floodway plus 40 000 c f s High Bluff Diversion	123 900	388 300	3 13
(b) by adding Russell Reservoir	333 900	470 300	1 41
INCREASE 40 768 FLOODWAY PLUS 40 000 C F S HIGH BLUFF DIVERSION			
(a) by adding Lister s Rapids Trial B	764 200	522 000	68
(b) by adding Eastern Tributaries Diversion	652 000	386 400	59
INCREASE 60 768 FLOODWAY PLUS 40 000 C F S HIGH BLUFF DIVERSION			
(a) by adding Lister s Rapids Trial B	764 200	376 500	49
(b) by adding Eastern Tributaries Diversion	652 000	337 600	52
INCREASE 60 768 FLOODWAY PLUS 25 000 HIGH BLUFF DIVERSION PLUS RUSSELL RESERVOIR			
(a) by adding Pembina Reservoir	251 300	79 400	32

CHAPTER 12

FLOOD INSURANCE

Under its Terms of Reference this Commission was asked to examine the feasibility and cost of a scheme of flood insurance for those parts of the Red and Assiniboine River valleys that would not be protected by other measures recommended by the Commission

The Commission first examined the practical difficulties that have kept insurance companies from operating in this field then studied in some detail the attempt that was recently made to develop a flood insurance program under the sponsorship of the Federal Government in the United States and, on the basis of these studies made an assessment of the practicability of a flood insurance scheme for Manitoba Our study is confined to floods resulting from rising lakes and streams and does not apply to flooding resulting from hurricanes or excessive rains It is also limited to areas in which the cost of flood prevention measures exceeds the losses and damages resulting from the floods In other areas it is more economical to construct some flood control measure and prevent the damages in question

The few private companies that have attempted to write flood insurance policies on property in areas subject to recurrent floods have discovered that the difficulties are many If uniform rates are charged the company finds itself loaded up with an adverse selection of risks because people in highly flood prone areas are the ones most likely to take out a policy On the other hand if an attempt is made to charge rates proportionate to the risk of loss the cost exceeds the amount that most property owners either can pay or are willing to pay Their experience has also indicated that there is usually a very limited market for flood insurance and that while there may be a heavy demand for it in the years immediately following a flood property owners do not usually maintain it in force after the lapse of several floodless years

But even if a large proportion of property owners in flood prone areas were willing to take out insurance and keep up their payments the scheme would still face problems With most types of insurance there is a wide spread of risk In contrast properties in areas subject to recurrent floods are almost certain to be flooded and the frequency with which this is likely to occur can be predicted with some degree of accuracy only the time of occurrence of the flood is uncertain A given area may be free from floods for a long period of time and then be flooded several times within a few years Further, for other types of insurance the number of claim payments that have to be made in any one year does not vary widely On the other hand when a major flood occurs, all or many of the properties in a given area may be subject to a large amount of damage at the same time

The predictability of floods gives flood insurance something of a self insurance character Regular annual amounts are accumulated in order to meet large irregularly occurring damages But because the flood could occur only a few years after premium payments begin and because a large number of properties are flooded together, any flood insurance scheme runs a heavy risk of having to pay out a very large amount of money at an early stage in its life If the properties insured by one company are distributed over a large number of different river basins the risk will be spread to some extent But rather large reserves are still required if bankruptcy of the scheme at an early stage is to be avoided

The inability of the private insurance industry to make available a program of flood insurance coupled with the concern created by the serious damages caused by floods in Kansas and Missouri in 1951 and in the Northeastern States in 1955 led to a demand for a government sponsored flood insurance program in the United States This demand culminated in the passage by Congress in August, 1956 of The Federal Flood Insurance Act of 1956 (Public Law 1016 84th Congress) In general terms the Bill provided for a flood insurance program with an overall maximum liability of $3 billion (the President was given authority to increase this amount by $2 billion) a limit of $250 000 for any one person firm or business and a limit of $10 000 for any one dwelling The Housing and Home Finance Agency was given the responsibility of setting up an administrative organization and producing a detailed plan for implementing the Bill As a result the Federal Flood Indemnity Administration was set up an Advisory Committee from the insurance industry was appointed and a group of engineering advisors from the Federal Government was selected

The F F I A readily reached agreement with the Advisory Committee and on procedures for handling the sale of the insurance and the adjustment of claims through the regular insurance industry Estimation of probable losses and the setting of rates however proved a formidable problem and although a solution was worked out it was at best a compromise

A very rough approximation to a rate was obtained by comparing an estimate of the annual flood loss which would be covered by insurance with the total amount of insurance authorized It was estimated that the annual loss covered by insurance would be $90 million and since the maximum amount of insurance that can be granted is $3 billion it would require a rate of 3 percent to cover such a loss

A more precise method of setting rates involves the use of the frequency damage approach In Chapter 5 of this volume we explained the way in which annual damages and annual benefits can be estimated for a particular area This same approach can be applied to particular properties The annual damages that can be anticipated for a given house is equal to the damages caused by floods of different sizes multiplied by their probability of occurrence This annual damage plus an expense loading would be the annual premium that would be required to cover the risk of flood damages to that particular house

While this method is very precise in theory it is difficult to apply in practice because not only is a knowledge of the flood frequencies in different areas required but precise information is also needed on the elevation of the house and the damages that would be caused by floods of different sizes Thus a great deal of precise information would be needed and this would be expensive to acquire

To illustrate this method an estimate was prepared of the annual flood damages that can be expected on a house on Kingston Crescent and a farm in the Morris area A house which was flooded to a depth of four feet over the main floor in 1950 and had an estimated market value in that year of $13 000 can be expected to incur flood damages over a period of years which will amount to $280 per year on the average Of this total just over one fourth would be due to damage to personal property For a farm of 640 acres in the Morris area located on the edge of the area flooded in 1948 it was estimated that on the average flood damages would amount to $450, or about 70c per acre This total includes loss of farm income, as well as damages to buildings personal property livestock and machinery

The compromise method adopted by the Federal Flood Indemnity Administration called the River Basin Method involved the division of the entire country into a number of different areas or river basins These areas were then grouped into six different rating areas with each of these areas being given a different rate based on the probability of flooding in that area Variations in the base rate were made for type of construction location of personal property applicability of co insurance and property over water Limits were placed on the amount of coverage in each area so that the amount of insurance placed in all these areas at different rates would give an overall average rate of about 3 percent Perhaps the principal defect of this system of rating is the uniformity of rates within areas This uniformity means that property on the edge of a river will pay the same premium as property on high ground As a result it is almost certain that a high proportion of the people who take out policies will be in areas where the risk of flooding is great

Under the proposed scheme it was intended that the Federal Government should absorb 40 percent of the annual cost plus administrative expenses leaving only 60 percent to the individual policyholder However Congress did not appropriate funds for the proposed scheme and federal flood insurance has not been instituted in the United States Nevertheless the Federal Flood Indemnity Administration were very generous in making available the records of this flood insurance plan and these proved extremely helpful to the Commission s own study

In applying the above information to the situation that exists in Manitoba it becomes clear that any attempt to set up a flood insurance scheme for Manitoba only would face a number of special difficulties Because the settled area of the province is so small, the weather conditions that produced flooding in one area might well apply throughout the whole insured area Hence, the claim payments under the scheme would be highly concentrated in particular years This would make a large reserve fund necessary to keep the scheme from going bankrupt Further most floods in Manitoba are of the slow rising type and can be predicted well in advance For this reason it is possible to reduce potential flood damage by moving property such as automobiles cattle and furniture out of the flood zone or by building temporary dykes to protect the areas subject to flooding If potential flood losses were covered by insurance the steps taken to move or protect property might be considerably less prompt and vigorous

In addition, the climatic conditions which produce a serious flood—heavy fall rains, an early freeze up heavy snowfall a severe winter a late spring with heavy rains during the breakup—are of a type that make possible the anticipation of a flood well in advance of its occurrence In these circumstances, if there were only a short waiting period before an insurance policy became effective the insurance schemes would be faced with an adverse selection of risks Policy sales would be heavy in a year when a potential flood situation began to develop and light in years when there was little risk of a flood A waiting period of at least five or six months would be required to eliminate any element of adverse selection

Because floods in Manitoba are slow rising and prolonged, assessing damages and making claim payments would also be more difficult The effects of prolonged flooding may only be fully apparent many months after the flood has passed This is particularly true of structural damage to buildings and the loss of income from crops

In the light of the above considerations this Commission has concluded that it would not be advisable for the Province of Manitoba to enter into any general flood insurance program Both the past experience of the private insurance industry and the special difficulties that would face a program confined to Manitoba alone support this conclusion

If any government is to back a flood insurance plan in Canada, it should be the Federal Government A national plan can get a spread of risks which is not possible within a single province

An alternative to a flood insurance plan might be a flood assistance fund which would be applicable only in floods of major importance In practice the governments already find it necessary to assist those subject to serious flooding When a major flood occurs the government must help the people to rehabilitate themselves or run the risk of a whole area deteriorating If assistance to flood victims were planned on a regular basis it might eliminate a good deal of the fear and uncertainty which now face people in areas subject to flooding

An assistance fund would be less expensive than a legally enforceable insurance plan since it would only cover minimum essential losses For the same reason it would be less likely to undermine the efforts of the people affected to protect their property from being flooded But an assistance fund would be more equitable if administered by the Federal Government Otherwise the people of this province would find themselves paying the full cost of relieving their own flood disasters and at the same time through their tax payments to the Federal Government paying part of the cost of disasters elsewhere

Although we have not recommended a flood insurance scheme we have made an estimate of what it would cost to pay the flood losses that may be expected in an area to which a flood insurance scheme would be applicable, namely the Red River Valley area between Emerson and St Norbert

Annual damages from floods of all sizes in this area are estimated to amount to $731 000 Thus if an amount of $731 000 were set aside annually and accumulated in a fund, it would provide sufficient funds to compensate people in the area for all flood damages This would apply on the average over a long period of time

THE FOREGOING REPORT WITH FINDINGS AND RECOMMENDATIONS IS RESPECTFULLY SUBMITTED

Chairman

Arthur S Beaubien

December 31, 1958

COMMISSIONER J. McDOWELL'S REPORT

The Royal Commission on Flood Cost Benefit has been carrying on its enquiry investigation and survey for over the past two years

As a member of the Commission, I have given careful consideration and study to all matters pertaining thereto including submissions tendered and opinions expressed by experts and others

One of the basic and possibly main considerations in connection with the problems herein and their possible solution is one of economics not only for the present generation but those of the future generation

In the past we have had recommendations such as those contained in the Red River Basin Investigation Report in connection with the City of Winnipeg the Red River and the Assiniboine River Valley This report recommended the following projects

(a) a floodway from St Norbert via Bird s Hill entering the Red River at Lockport,
(b) the Ste Agathe Detention Basin
(c) the Russell Dam,
(d) the diversion of the Assiniboine River into Lake Manitoba at Fort la Reine or at High Bluff

As a member of this Commission, it is necessary to consider the dual authority and responsibility of our two senior Governments in respect of navigable streams The Dominion Government has authority over and is responsible for, the water that flows in such stream while the Provincial Government has authority over and is responsible for the bed of such streams

Pursuant to Provincial legislation Drainage Boards have been set up in certain districts in Manitoba and through the authority of such Boards a vast amount of drainage has gone into both the Red River and the Assiniboine River resulting in an excessive deposit and accumulation of silt in these rivers

Having regard to the foregoing I do hereby recommend

1 That there be established A Navigable Rivers Authority responsible for the carrying out under the direction and supervision of The Provincial Department of Public Works of all navigable river projects

2 That 75% of the costs of any and all such projects be paid for by The Dominion Government and the remainder, or 25% of said costs be paid for by The Provincial Government

Pursuant to a reference of the Lieutenant Governor in Council there is on file in the Department of Public Works and in the Department of the Attorney General a legal opinion as to the respective responsibilities of the Dominion Government and the Provincial Government in connection with navigable rivers

3 That the Lister s Rapids be removed and thus restore main control of the Red River to the dam at Lockport

In the engineering study done by the R R B I 22 different designs for channel improvement below Winnipeg were investigated Of these 22, two of the trials trial 12 and trial B showed the smallest cost per foot of stage reduction at Redwood Bridge and provided a practical degree of stage reduction

Trial 12 involved widening of the natural channel between Mile 40.2 and Mile 32.6 (from just below Bergen Cut off to a point 2½ miles upstream from the Old St Andrew s Church)

Trial B involved deepening the channel from Mile 40.9 to Mile 27.3 (from Bergen Cut off to a point near Lockport) with very little widening

The estimated capital cost of these projects, all taking an assumed construction period of five years was as follows

(1) Trial 12 $5 674 000 which would take 1½ feet off the flood stage at Redwood Bridge equal to the 1950 flow, and have a cost benefit ratio of 4.46,
(2) Trial B an estimated cost of $14 925 000 which would take 2.9 feet off the flood stage at Redwood Bridge with a flow comparable to the 1950 flow and have a cost benefit ratio of 4.31

This shows a good cost benefit but I think this work can be done at far less expenditure I call your attention to how they took the rock out of the Detroit River without using coffer dams

The Red River Investigation Report is authority for the fact that removal of the Lister s Rapids would only reduce the level of the Red River at the University in South Fort Garry approximately three inches

4 That the Cross Sections of The Red River be widened in such manner and to such extent as qualified authority deems advisable where such river flows through the Municipalities of Fort Garry and St Vital and Other Municipalities south of the perimeter road

5 That an extensive removal of silt and other objects deposited in the river beds be undertaken by dredging

The diver s report submitted to this Commission shows the depth of the Red River to be at Bergen Cut off 28 feet at the Redwood Bridge 26 feet at the Canadian National Bridge at Lombard St 12 feet and at the mouth of the Assiniboine River 15 feet

To enable the Red River to carry a full load throughout its Greater Winnipeg course the bed thereof should bear a uniform and proper level in relation to its hydraulic gradient This can be accomplished by removal of silt and other objects

6 That a Dam be erected on The Assiniboine River at Russell Manitoba

It has been estimated that this dam could be erected at a cost of $6 500 000 to $7 000 000 and that it would help to eliminate the flooding of the areas adjacent to the flow of the river from Russell to Brandon

The construction of a dam at Russell would greatly benefit the City of Brandon by assuring of its having a better and steadier supply of water

7 That at Brandon the river be straightened the present dyke widened and provision made for the impoundment of a larger supply of water

This work could be done by means of a hydraulic dredge and the Brandon flats could be built up by using the same as a depository for the silt removal

This operation incidentally would be to the benefit of future industrial demand and growth in population

8 That a Dam be erected on The Assiniboine River at Holland Manitoba

This dam should, if adequate footings can be established, be of such a magnitude as to utilize the river channel which runs through the adjacent hilly country and build up an impoundment of water to the extent of 4 000,000 acre feet

Further if this impoundment could be built up to a high enough head it would permit of the diverting of water to South Eastern Manitoba through the Morris River Basin

9 That if adequate footings cannot be established at Holland to build up a head water as aforesaid then a series of Dams should be erected between Holland and Brandon

10 That consideration be given to a Larger Basin being provided in The Assiniboine River at Portage la Prairie so as to not only maintain that City s present water supply but to assure of an adequate supply for future needs

In my opinion what is referred to as the High Bluff diversion into Lake Manitoba should only be resorted to after it has been definitely established that all other means of control are exhausted This diversion would cost $9,000 000 00 plus an annual maintenance cost of $82 400 00

11 That the silt and other obstructions such as islands be removed from The Assiniboine River throughout its course from Portage la Prairie to Headingley

12 That certain new Channels be cut in the course of The Assiniboine River from Portage la Prairie to Headingley and that the old channels be not blocked off but kept free to take care of high water

* * * * * * *

I am unable to approve of or join in my fellow commissioners' recommendation for the construction of a floodway

It is estimated roughly that the cost of constructing this floodway would be $64 000 000 00 plus an annual maintenance cost of $225 000 00

If, as proposed these costs were amortized over a period of 50 years with interest at 5%, it would entail an annual payment of $3,760,000 00 or a grand total of $188 000 000 00 over the 50 year period

Since the tabling of the Red River Basin Investigation Report, certain public works have been brought into being which will greatly help to safeguard Greater Winnipeg from future flooding

These works consist of the Perimeter Road which through the foresight skill and ability of senior officials of the Department of Public Works is so constructed as to form a ring dyke around Greater Winnipeg

To appreciate the value of the Perimeter Road as a ring dyke one has only to recall the flood of 1950 and what would have been the result if the lake proportion of accumulated water south of Greater Winnipeg had permeated into the River Heights area This was prevented by the erection of a dyke, the base of which was McGillivray Boulevard

Further the bridges being erected as part of the Perimeter Road are being so constructed as to provide for considerable control of the flow of water passing beneath them

More engineering studies should be made in the upper reaches of the Red River from Winnipeg to Emerson This is essential and some joint effort with the United States is necessary to remedy what has become a chronic situation In the flood year of 1950 water reached an estimated maximum discharge at Redwood Bridge of 103 600 c f s With the present set up of the Perimeter Road forming a ring dyke around Winnipeg the volume of water entering Winnipeg can be controlled In my opinion it would appear to be unnecessary and uneconomical to provide for anything higher than the 1950 flood as we can now take care of 110 000 c f s with this ring dyke control

Conditions have changed since the 1826 1852 and 1861 floods With roads now built well above prairie level it is easier to impound water by blocking of the eveners or culverts

A review of what happened on the Assiniboine River during the 1956 flood will show that by using the Trans Canada Highway as a dyke to contain the water between the highway and the river resulted in most of the water being held and returned to the river bed flow If this had not been done a very large area beyond the highway would have been inundated, causing much more devastation over a large area

If we clean out the Red River and the Assiniboine River by dredging and removal of obstacles therein as well as remove the Lister s Rapids and raise our permanent dykes we could take care of a flood as high or higher than the one which occurred in 1950

Finally, I must stress the importance of reasonable financing costs to carry out these works

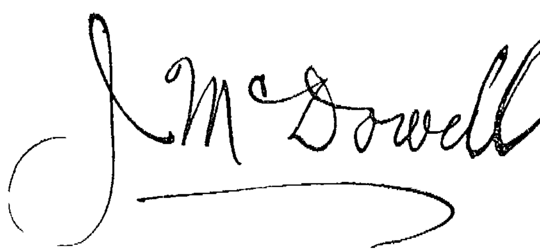
I would recommend that a survey and study be made of the system adopted by the Federal Government of the United States for the financing of public works

Under the United States system the cost of any and all projects in the public interest which are undertaken by any state of the union can be paid for by the issuance of interest, tax free bonds These projects include such works as canals docks schools and roads, etc

If a similar system were in existence in Canada, it would enable the provinces and municipalities to more readily and satisfactorily fulfill their obligations

Prior to the Dominion Income Tax Act, the provinces had available to them a field in which to get what is referred to as cheap money Surely it is only reasonable that lenders have a fair return on their money over and above the income tax they are required to pay on income from money loaned This could be accomplished by the issuance of tax free interest coupon bonds and result in benefits to people at the municipal level

Respectfully submitted



Commissioner

January 7 1959

Appendix A

J S McDIARMID
Lieutenant Governor

SEAL

CANADA
PROVINCE *of* MANITOBA

ELIZABETH THE SECOND by the Grace of God of the United Kingdom Canada and Her other Realms and Territories QUEEN Head of the Commonwealth Defender of the Faith

M N HYRHORCZUK
Attorney General

WHEREAS a Report on Investigations into Measures for the Reduction of the Flood Hazard in the Greater Winnipeg Area has been prepared by the Red River Basin Investigation Water Resources Division Engineering and Water Resources Branch Department of Resources and Development of the Government of Canada

AND WHEREAS it is deemed expedient and advisable in the public interest that a public inquiry be undertaken to determine the value of the benefits which would accrue as compared to the cost of some or all of the considered measures in the said report were to be implemented and to appraise the benefits that might accrue from any other project directed toward the reduction of the flood hazard in the Red River and Assiniboine River basins

AND WHEREAS the said matter is within the jurisdiction of the Legislature of the Province of Manitoba and is connected with and affects the good government of the Province

AND WHEREAS sections 80 and 93 of The Manitoba Evidence Act provide in part as follows

80 (1) The Lieutenant Governor in Council where he deems it expedient to cause inquiry to be made into and concerning any matter within the jurisdiction of the Legislature and connected with or affecting

(a) the good government of the province or the conduct of any part of the public business thereof

(b)

(c)

(d)

(e)

(f) any matter which in his opinion is of sufficient public importance to justify an inquiry may if the inquiry is not otherwise regulated appoint one or more commissioners to make the inquiry and to report thereon

(2) The Lieutenant Governor in Council may revoke modify or enlarge the scope of any commission

93 The Lieutenant Governor in Council may make provision either generally in regard to all commissions issued and inquiries held under this Part or specially in regard to any such commission and inquiry for all or any of the matters following that is to say

(a) the remuneration of commissioners and persons employed or engaged to assist in the inquiry including witnesses

(b) the payment of incidental and necessary expenses and

(c) generally in respect of all such acts matters and things as are necessary to enable complete effect to be given to every provision of this Part

NOW KNOW YE THAT under and by virtue of all the powers privileges and prerogatives vested in or appertaining to Her Majesty and under and by virtue of Part V of The Manitoba Evidence Act it is ordered as hereinafter set forth

1 A Commission is hereby established to be known as the Royal Commission on Flood Cost Benefit (hereinafter called the commission) consisting of the persons hereinafter named together with such other persons as may hereafter be appointed to the commission by Order in Council

2 The members of the commission shall be

(1) Henry William Manning

(2) William Culver Riley

(3) Walter James Macdonald

(4) Arthur Samuel Beaubien

(5) John McDowell

3 The Chairman of the commission shall be Henry William Manning

4 Any three members shall constitute a quorum

5 The members of the commission shall be empowered to settle and regulate the procedure of the commission

6 The commission may employ a secretary and such staff and consultants and other assistance as it may require

7 A member or members of the commission or a member of the staff of the commission may travel beyond the boundaries of the Province of Manitoba to inquire into matters relating to the purposes objects and duties of the commission

8 The purposes objects and duties of the commission shall be as follows

(1) To make full inquiry respecting and to make findings as to the value of the benefits that would likely accrue if any or all of the considered measures set forth in the Report on Investigations into Measures for the Reduction of the Flood Hazard in the Greater Winnipeg Area were implemented as compared with the costs likely to be incurred in implementing those measures and to make recommendations as to which if any of such measures should be implemented and to what extent

(2) In particular and without limiting the generality of clause (1) to make such inquiry and findings and such recommendations as aforesaid respecting the following measures

(a) Channel improvements

(b) Dyking

(c) Flood storage

(i) Russell reservoir

(ii) Pembina River reservoir

(iii) Ste Agathe detention basin

(d) Flood diversions

(i) Eastern tributaries diversion

(ii) Omands Creek diversion

(iii) Portage diversion

(iv) Greater Winnipeg floodway

(3) To make such inquiry and findings and such recommendations as set out in clause (1) of this section 8 respecting any other measures that are of the same general nature or have the same objectives as those to which reference is made in clauses (1) and (2) of this section 8 and that the commission deems might be beneficial and worthy to be the subject of inquiry and report whether or not they have been considered in the report to which reference is made in the preamble hereto and in particular with respect to the value of the benefits likely to accrue from any such other measures as compared with the costs likely to be incurred in respect thereof

9 Without limiting the general scope of its powers and duties as hereinbefore set out the commission may treat as benefits that would accrue and may value as such

(a) avoidance of possible damage to property business and industrial and economic prospects and

(b) direct benefits such as accompanying water supply irrigation works and hydro electric generating plants

10 The commission shall include in its findings a report as to the practicability and the estimated cost of a plan to provide flood insurance coverage for the residents and owners of property in areas

(a) that are from time to time subject to flooding by the waters of the Red River or the Assiniboine River or any tributary of either of them and

(b) that will not be protected from such flooding by the implementation of the recommendations of the commission

11 The commission shall hold public hearings at such times and in such places as it may deem advisable

12 The commission shall make to the President of the Council a report setting forth its findings and recommendations

13 On the certificate of the Chairman of the commission approved by the President of the Council there shall be paid the amounts hereinafter mentioned namely

(a) Honoraria to the members of the commission except in the case of Commissioner John McDowell who is precluded from accepting any remuneration under the Legislative Assembly Act in such amounts as the Lieutenant Governor in Council may direct
(b) Travelling and living expenses of the members except in the case of Commissioner John McDowell who is precluded from accepting same under The Legislative Assembly Act
(c) Advances on account of the matters mentioned in clauses (a) and (b) of this section 13 or any of them
(d) Remuneration of such staff and consultants as may be employed by the commission
(e) All other incidental and necessary expenses incurred by the commission in all or any of its proceedings and undertakings including the maintenance of an office or offices

14 The expenditures authorized in section 13 shall be paid from the Consolidated Fund and charged to Appropriation No 3—Royal Commission on Flood Cost Benefit of the Executive Council

IN TESTIMONY WHEREOF We have caused these Our Letters to be made patent and the Great Seal of Our Province of Manitoba to be hereunto affixed

WITNESS His Honour John Stewart McDiarmid Lieutenant Governor of Our said Province of Manitoba

AT OUR GOVERNMENT HOUSE at Our City of Winnipeg in the Province of Manitoba this eighteenth day of December in the year of Our Lord one thousand nine hundred and fifty six and in the fifth year of Our Reign

BY COMMAND

F PRITTON PAINE
Provincial Secretary

Appendix B

PUBLIC HEARINGS
LIST OF BRIEFS PRESENTED

CITY OF WINNIPEG—ROOM 200 LEGISLATIVE BUILDINGS

1 City of Winnipeg
2 City of St Boniface
3 Winnipeg Chamber of Commerce
4 Municipality of St Vital
5 Canadian Manufacturers Association
6 Metropolitan Planning Board
7 Downtown Business Association of Winnipeg
8 Winnipeg Builders Exchange
9 Municipality of Charleswood
10 Elmer D Shier
11 Association of Professional Engineers
12 Town of Selkirk
13 Municipality of East Kildonan
14 Town of Tuxedo
15 Manitoba Farmers Union
16 Municipality of St Francois Xavier
17 Mr and Mrs S M Allman
18 City of St James
19 Municipality of Cartier
20 Mr J L Bickert
21 American Industries—Dr P Steinchein

CITY OF BRANDON—COURT HOUSE

22 City of Brandon—Brandon Chamber of Commerce
23 Assiniboine River Control Group
24 Miniota Flood Control Group
25 Muncipality of Woodnorth
26 Muncipality of Sifton
27 Mr Williams
28 Village of Binscarth
29 Mr D M Cameron Melita
30 Village of Wawanesa
31 Mr Rod Clement M L A Russell, Man
32 Mr O McKay Reeve of Whitehead
33 Mr Shea of Brandon

PORTAGE LA PRAIRIE—COURT HOUSE

34 City of Portage la Prairie
35 Oakville and District Chamber of Commerce
36 Muncipality of Victoria
37 Municipality of Cartier
38 Municipality of Westbourne
39 Mr Dan (Jason) Prystach
40 Municipality of Caldwell
41 A J Moore—W J Tully
42 Mr Saunderson
43 Mr R A Balko
44 Mr A C Sissons
45 Mr Wilfred Metcalfe
46 Mr W J Healy
47 Mr C I Ogletree
48 Mayor H L Henderson
49 Mr Wood Oakville

TOWN OF MORRIS—MUNICIPAL HALL

50 Southern Red River Valley Conservation Group
51 Municipality of Hanover
52 Agricultural Institute of Canada Morden Branch
53 Morden Chamber of Commerce
54 Municipalities of Thompson—Dufferin—Roland
55 Mr Beverly Mustard Chairman Tobacco Creek Watershed Flood Control Committee

Appendix C

LIST OF MEETINGS WITH OUTSIDE GROUPS

U S Army Corps of Engineers in St Paul Minnesota	January 10 11 1957
Construction Aggregate Corporation of Chicago Mr J R Sensibar Mr G J Rocke Mr Clyde Davis	January 24 1957
St Anthony Falls Hydraulic Laboratory meeting with Dr Lorenz G Straub in St Paul Minnesota	January 28 1957
Mr Carl H Giroux Director of Industrial Resources International Cooperation Administration Washington D C	April 13 1957
Mr H G Riesen Regional Director of P F R A	June 4 1957
Meeting of the Chairman of the Commission with Mr M Carter McFarland in Washington and Mr Bradford Smith in Philadelphia re Flood Insurance	July 1957
Meeting with Members of Various Utilities	May 29 1957
Meeting in Fargo with officials of the U S Department of Agriculture Soil Conservation Service North Dakota State Water Conservation Commission the Missouri Souris Project U S Department of the Interior Bureau of Reclamation Bismarck Corps of Engineers U S Army St Paul	July 8 1957
Construction Aggregate Corporation Mr C J Rocke Mr Clyde Davis	August 20 1957
Dr Lorenz G Straub Director of St Anthony Falls Hydraulic Laboratory	September 25 1957
Visit to Winnipeg of Mr E P Murphy Consulting Engineer from Ottawa	September 26 1957
Mr Gordon MacKenzie Director of P F R A Regina Mr R H Clark Department of Northern Affairs Ottawa	October 23 1957
Meeting with practical construction contractors	November 19 1957
Meeting with Real Estate Experts	November 20 1957
Meeting with Bridge Experts	November 26 1957
Meeting with Dyking Commission	November 27 1957
Visit of the Commissioners to Washington D C to study Flood Insurance	December 4 5 and 6 1957
Ellicott Dredging Company	January 11 1958
Meeting in Fargo with Corps of Engineers U S Army North Dakota State Water Conservation Commission Soil Conservation Service Watershed Planning State Conservation Service	January 29 1958
Eastern Tributaries Diversion Meeting	February 7 1958
Visit to the Mississippi River Commission and U S Army Corps of Engineers Experimental Station at Vicksburg Miss	February 23 24 25 1958
Meeting with Dr Lorenz G Straub of St Anthony Falls Hydraulic Laboratory in Minneapolis re Mudry Report on Channel Improvements	February 28 1958
Meeting re Loss of Farm Income	March 5 1958
Meeting in Letellier with Red River Valley group re Pembina Dam	April 17 1958
Meeting with Mr R C Huggard re Ellicott Dredging Report	April 17 1958
Meeting with Lower Red River Valley Water Commission	September 17 1958
Meeting in Russell with Representatives of the area	September 27 1958

Meeting with Representatives of the City of Portage la Prairie Municipality of Portage la Prairie Municipality of Cartier and Municipality of St Francois Xavier	October 10 1958
Meeting with North Dakota State Water Commission and Visit to Garrison Dam	October 17 1958
Meeting with Mr Gordon MacKenzie and Mr R H Clark	October 22 1958

Mr R Calton Director of Planning and Research U S Army Corps of Engineers has visited with the Commission on the following dates

June 3 and 4 1957	February 25 and 26 1958
November 12 1957	May 22 and 23 1958
	June 19 and 20 1958
	July 24 and 25 1958
	December 18 and 19 1958

The Public Hearings of the Commission were held as follows

Winnipeg	May 7 and 8 1957
Brandon	May 16 1957
Portage la Prairie	May 17 1957
Morris	June 5 1957

Appendix D

ACKNOWLEDGEMENTS

The Commission wishes to acknowledge the valuable cooperation of the Corps of Engineers, U.S. Army, St. Paul District and the Mississippi River District, the Federal Flood Indemnity Administration of the Housing and Home Finance Agency, the Mississippi River Commission and many other U.S. Federal and State Government Departments and Agencies; the Water Resources Branch, Canada, the Water Resources Branch, Manitoba, the Lower Red River Valley Water Commission and many other Federal and Provincial Government Departments and Agencies which provided information, reports and technical data that have been essential to the completion of the Commission's Report.

The Commission appreciates the information and advice that have been given by Municipalities, Associations and individuals that have submitted briefs or have made oral representation to the Commission.

The Commission extends a special word of appreciation to Mr. I. H. Calton, Mr. J. A. Griffiths and Mr. E. Kuiper for their valuable contribution to the various phases of our study.

Appendix E

ADDITIONAL DETAILS ON METHODS FOLLOWED IN THE PREPARATION OF STAGE-DAMAGE ESTIMATES

I DAMAGE TO ASSESSED VALUE RELATIONSHIPS

As was explained above in Chapter 6 the records of the Red River Valley Board and the Manitoba Flood Relief Fund provided us with much of the basic data used in our estimates of flood damages to residential and other types of property The following paragraphs describe the way in which these data were utilized to provide our basic damages to assessed value relationships

For the Greater Winnipeg area a sample was selected from all the houses on which the Red River Valley Board made reconstruction payments in 1950 This sample was chosen so as to include a fairly complete representation of all the more deeply flooded houses The number and percent of the total number of houses flooded for each flood level that were included in the sample are given in the following table

Table E 1

SAMPLE OF HOUSES FLOODED IN 1950 — GREATER WINNIPEG

Flood Level over Main Floor	Number of Houses in Sample	Total Houses Flooded in 1950
4 feet and higher	847	847
3 feet above	256	512
2 feet above	262	786
1 foot above	191	955
Just over Floor Level	146	438
Below Floor Level		
1 foot to 3 feet	644	6 440
4 feet or more	567	567
Total	2 913	10 545

NOTE All houses having a selling value of $10 000 or more were included

From the information available in the original cards the following information was recorded for each house name of owner and address ground floor area type age estimated selling price level of flooding in 1950 and final damages awarded by the Red River Valley Board Data on the equalized assessed value for each house in the sample were recorded from city assessment offices This sample was then matched up with the data on damages to personal property recorded in the files of the Manitoba Flood Relief Fund Since these latter files also included a record of claim payments made by various insurance companies to people who carried 'floater' policies they provided a relatively complete picture of damages to personal property

The data in this sample were then analysed with I B M equipment to provide straight line least squares relationships between damages to real and personal property on the one hand and on the other hand the equalized assessed value of the house and the ground floor area Relationships between these variables were obtained for different flood levels and for different age groups and types of houses For the analysis of houses by age groups all houses were grouped into three categories namely old houses built before 1920 medium age houses built from 1920 to 1935 and new houses built from 1936 to 1950 For the analysis of types of houses all houses were classified into three groups bungalows one and one half stories and two or more stories Not all of these relationships were used in our final assessment of flood damages since in some instances the differences were not judged significant and in other cases there was not enough information on the type or age of properties flooded to permit application of these data For example not enough information was available on the proportion of bungalows as compared to other types of houses at different levels of flooding to permit application of a flood damages assessed value relationship according to type of house

The results of this analysis are presented in Plates 32 to 37 Plates 32 and 33 show the regression lines by flood levels for real and personal property related to equalized building assessments for dwellings in Greater Winnipeg Plates 34 and 35 show similar regression lines by flood levels for real and personal property related to the ground floor area of the dwelling Plate 36 is a scatter diagram showing at one particular flood level the way in which the individual observations are distributed around the regression line measuring the average relationship between these real property damages and equalized building assessment Finally Plate 37 shows for two age groups of houses the different relationships obtained for real property damages per square foot of floor area at different flood levels

II DAMAGES TO INVENTORIES AND EQUIPMENT BUSINESS AND INSTITUTIONAL BUILDINGS

Flood damages to fixtures machinery and equipment inventories and supplies and other contents of buildings were estimated on the basis of information obtained from a questionnaire sent to a selected sample of business firms in the Greater Winnipeg area The sample included all larger firms 20 percent of the medium sized firms and 5 percent of the smaller firms Each business firm circulated was asked to provide information on the flood damages and flood fighting costs that would occur on his premises for three major depths of flooding the value of his inventories and fixtures etc the ground floor area of his building and the loss of income he suffered in 1950 These data were tabulated to show damages per square foot of floor area for different depths of flooding The two relationships obtained are shown in Plate 38

A copy of the questionnaire used in this survey is shown below

CONFIDENTIAL

ROYAL COMMISSION ON FLOOD COST-BENEFIT

Survey of Possible Flood Damages
Business, Industrial and Institutional

Name

Address

Nature of Business or Institution

1 What is the area of your main floor? sq feet

2 How high is your main floor above ground level? feet

3 Value of inventory fixtures and equipment
Include data for basement and main floor only

(a) Value of fixture machinery and equipment $

(b) Value of inventory (merchandise raw materials supplies etc) $

4 Flood Damages

How much damage do you estimate would be caused by floods of the following magnitudes

Flood level at your location	Damage to fixtures machinery and equipt	Damage to merchandise raw materials supplies etc
(a) feet of water at ground level (The level reached in 1826)	$	$
(b) feet of water above below ground level (The level reached in 1852)	$	$
(c) feet of water above below ground level (The level reached in 1861)	$	$

NOTES

(i) Include damages at this address only

(ii) Where water level is shown as a given number of feet below ground level basement flooding may still occur You are asked to assume that in each instance the dykes would be overtopped and the sewer pumping stations would be out of action so that your basement might flood even if the water had not reached ground level in your area

(iii) Where merchandise or equipment can be conveniently and quickly moved to higher levels on your premises you may wish to assume the loss to these items would be zero but before you assume any removal of property to other buildings remember that in a major flood covering a large portion of Winnipeg storage space in other premises may be difficult to secure

(iv) Include as machinery fixtures or equipment anything that is not an integral part of the building

5 Extra costs to your business that might result from a major flood

Include

(a) Costs of moving equipment and inventory to higher levels

(b) Extra storage costs of the same

(c) Cost of clean up after a flood

(d) Cost of fighting floods (sand bagging pumping etc)

TOTAL of above for flood at your location equal to

feet of water on ground	$
feet of water above below ground	$
feet of water above below ground	$

6 *Loss of Income*

(a) Were you in business in Winnipeg in 1950? (yes or no)

If yes what loss of income did your business suffer as a result of the 1950 flood? $

How large was this loss as a percent of your annual net income before tax? percent

(INCLUDE loss of gross revenues less any reduction in operating costs i e supplies materials labor fuel power etc)

DO NOT INCLUDE any loss that was later recovered as a result of increased business during the flood rehabilitation period

Signed

Official Position

Please complete and return before July 31st to

Royal Commission on Flood Cost Benefit
2nd Floor 149 Colony Street
WINNIPEG Manitoba
Telephone No SPruce 4 1451

If you have any questions regarding this questionnaire please do not hesitate to telephone us or come into our office

III Gross Income Greater Winnipeg Method of Estimation

As a basis for estimating the loss of income that would occur in Greater Winnipeg during major floods an estimate was prepared of the gross income produced in the area The basis on which this estimate was prepared is as follows

(a)	Total Personal Income Manitoba 1956	$1 071 (million)
(b)	Farm Income Manitoba	$ 130 (million)
(c)	Non farm Income Manitoba	$ 941 (million)
(d)	Civilian Labor Force Manitoba 1956 June 1	310 000
(e)	Armed Services Manitoba (1951) June 1	6 000
(f)	Total Labor Force (d plus e) June 1	316 000
(g)	Less Unemployed (8 000) June 1	308 000
(h)	Agricultural Labor Force Manitoba (reduced from 80 000 to allow for non agricultural work performed by farm workers)	60 000
(i)	Employed Non Agricultural Labor Force 1956 (g f)	248 000
(j)	Income per Employed Person — Non Agricultural (c − i)	$3 794
(k)	Addition to cover Depreciation and Difference between national and personal income — 10%	$ 379
(l)	Gross Income per Employed Person Manitoba Non Agricultural	$4 173
(m)	Gross Income per Employed Person Greater Winnipeg 1956 102 percent of provincial average (102×4 173) =	$4 256
(n)	Gross income per employed person Greater Winnipeg 1957 (increase in average weekly earnings March 1956 to March 1957) = (4 256 × 105 4) = 4 486—say	$4 500
(o)	Civilian Labor Force Greater Winnipeg June 1 1956	163 761
	Persons with jobs	162 151
	Armed forces	1 500
		163 651
	Estimate based on ratio of labor force to population supplied by Dominion Bureau of Statistics	
(p)	Gross Income per annum Greater Winnipeg basis 1956 labor force = 163 651 × 4 500 =	$736 429 500
(q)	Gross Income per annum Greater Winnipeg 1957 (Index of employment for Greater Winnipeg shows an increase of 1 6 percent for May 1957 over May 1956) = 736 429 500 ×101 6 =	$748 212 400
(r)	Gross Income per month Greater Winnipeg 1957 = 62 3 million or (in round figures)	$ 60 000 000

Gross income includes loss of depreciation on major facilities—since depreciation will continue even in absence of use and may occur at an accelerated rate It also includes a factor to adjust personal income to a net national income basis

IV Loss of Field Crop Income

A *Red River Valley St Norbert to Emerson*

Estimates of loss of field crop income were prepared for the following three reaches in the valley

Reach 1—Franklin Montcalm and Rhineland

Reach 2—Morris and DeSalaberry

Reach 3—Ritchot Macdonald Fort Garry and St Vital

(a) Areas flooded

The estimated areas flooded in each of the three reaches in floods of the magnitudes of those that occurred in 1948 1950 1852 and 1826 are as follows

	Reach 1	Reach 2	Reach 3
1948	24 100 acres	40 000 acres	3 100 acres
1950	84 000 "	125 500 "	107 000
1852	146 000	196 000 "	181 000
1826	185 800	224 200	206 000

(b) Acreage seeded to various crops

The allocation of land to various crops and other uses in each of these three reaches was estimated to be as follows

	Reach 1	Reach 2	Reach 3
	(Percent of total area)		
Total seeded	68 0	74 0	68 0
Wheat	26 0	37 0	33 0
Barley	21 0	17 0	16 5
Oats	10 0	11 0	14 0
Flax	5 0	6 0	4 0
Other	6 0	3 0	5
Summer fallow	18 0	18 0	18 0
Pasture	4 6	3 7	4 5
Unimproved	7 4	3 0	6 1

(Estimates based on data given in the 1951 census and on information with respect to cultivated acreage for Canadian Wheat Board delivery points)

The acreage seeded to various crops in each flood was estimated by applying the above percentages to the total flooded areas in each reach

(c) Average yields

Estimated yields for each crop were based on data compiled by the Evans Statistical Service for the following delivery points

Reach 1—Letellier Dominion City and Emerson

Reach 2—Morris and St Jean

Reach 3—Ste Agathe and Silver Plains

Source of Data Income data from *National Accounts Income and Expenditure 1950 56* employment and civilian labor force data from *Survey of Labor Force* Dominion Bureau of Statistics Income in Greater Winnipeg as percent of provincial average based on data given in *Taxation Statistics* 1955 Department of National Revenue Ottawa data on Armed Forces from *Census of Canada* 1951 Vol *IV* data on employment and average hourly earnings from current Monthly Reports Dominion Bureau of Statistics

These yields were as follows

	Wheat (12 Yr Av)	Oats (8 Yr Av)	Barley (8 Yr Av)	Flax (8 Yr Av
Reach 1	17 7	36 0	25 0	9 1
Reach 2	17 3	28 7	20 6	9 3
Reach 3	16 6	30 8	18 6	8 4

The above yields were corrected by provincial average ratios between the yields for the period covered by the above averages and the average yield for a 22 year period The corrected estimates were as follows

	Wheat	Oats	Barley	Flax
Reach 1	16 82	32 69	23 97	8 80
Reach 2	16 45	26 14	19 74	9 07
Reach 3	15 74	28 04	17 83	8 19

(d) Estimate of date seeding would have taken place in 1950 1852 1826 and 1948 in the Red River Valley had the water not been on the land

There is reason to believe that the disaster conditions which produce a flood would also produce late seeding even if the water were not on the land Examination of peak discharge figures and dates of seeding in Manitoba indicated a relationship of this type From this relation it was estimated the date of seeding in the Red River Valley had the flood not covered the land would have been as follows

1948	May 12
1950	May 21
1852	May 24
1826	May 25

(e) Estimate of date ground would be suitable for seeding after floods of 1852 1950 1826 and 1948

It was assumed that there was a positive relationship between the volume of discharge and the date of the flood peak After examination of a series of high discharge years a relationship was calculated The theoretical dates for the flood years were (for Winnipeg)

1948	April 28
1950	May 12
1852	May 23
1826	May 23

An examination of the data seemed to indicate that the number of days it took the Red River to return to its banks after the peak depended upon the maximum discharge A theoretical straight line relationship was calculated and the following figures for the lag after the peak were determined

1948	10
1950	15
1852	33
1826	46

Since some land would be free from water almost immediately and other land not until the above number of days had passed the latter were divided by two to give an average lag

Finally it was assumed that after the water receded from the land it would take 30 days for the land to dry Thus for Winnipeg the dates when the land would be suitable for seeding were

1948 April 28 plus 5 plus 30 = June 2
1950 May 12 plus 8 plus 30 = June 19
1852 May 23 plus 11 plus 30 = July 9
1826 May 23 plus 23 plus 30 = July 15

Since the peak would have been reached further down in the valley at an earlier date it was estimated that the land would be dry 5 days earlier in Reach 1 3 days earlier in Reach 2 and 1 day in Reach 3 for the three larger floods and 3 2 and 1 day earlier for the 1948 flood

Once the dates of seeding with and without flood water had been calculated the decline in yield which results when seeding takes place in the former rather than the latter remained to be determined

There are some experimental data available on crop yields as a function of the date of seeding (Manitoba Experimental Stations Progress Reports 1936 1947 Melita Report Agricultural Institute Review Jan Feb 1957 Page 18 Flax a Good Cash Crop by P J Olson) From these data curves showing the percentage of the average of the yield at various seeding dates were determined (See plates 12 13 14 and 15 Chapter 7)

Applying these curves to the dates calculated above the declines in yield can be estimated

YIELD IF WATER HAD NOT BEEN ON LAND

Reach 1	Wheat	Barley	Oats	Flax
1948	16 8	24 0	32 7	8 8
1950	16 8	23 0	32 7	8 8
1852	15 6	22 0	32 7	8 8
1826	15 3	21 7	32 7	8 8
Reach 2	**Wheat**	**Barley**	**Oats**	**Flax**
1948	16 4	19 7	26 1	9
1950	16 4	19 0	26 1	9
1852	15 3	18 1	26 1	9
1826	15 0	17 8	26 1	9 1
Reach 3	**Wheat**	**Barley**	**Oats**	**Flax**
1948	15 7	17 8	28 0	8 2
1950	15 7	17 1	28 0	8 2
1852	14 8	16 4	28 0	8 2
1826	14 5	16 1	28 0	8 2

YIELDS WITH FLOOD

Reach 1	Wheat	Barley	Oats	Flax
1948	11 2	18 8	28 8	8 80
1950	2 8	14 8	21 4	8 80
1852		8 1	11 0	4 4
1826		6 2	8 4	3 0
Reach 2	**Wheat**	**Barley**	**Oats**	**Flax**
1948	10 9	15 3	22 6	9 1
1950	1 8	11 2	16 6	9 1
1852		6 0	8 0	4 5
1826		4 5	5 9	3 0
Reach 3	**Wheat**	**Barley**	**Oats**	**Flax**
1948	10 6	13 3	23 7	8 2
1950	1 1	9 9	17 0	8 2
1852		4 9	8 4	4 1
1826		3 4	5 5	3 0

It has also been assumed that the delay in the seeding date would cause a reduction in the quality of the final crop by two grades in the case of barley and wheat

These were corrected by a ratio of 12 and 8 to 22 year averages of provincial yields The resulting yields were

Wheat	Oats	Barley	Flax
20 27	27 80	21 26	8 82

ABSOLUTE YIELDS WITH NO INUNDATION

Year	Wheat	Oats	Barley	Flax
1922	20 27	27 80	21 26	8 82
1923	20 27	27 80	21 26	8 82
1927	20 27	27 80	21 26	8 82
1955	20 27	27 80	20 75	8 82
1956	20 27	27 80	21 26	8 82

YIELDS WITH INUNDATION AS A PERCENTAGE OF THE YIELD ON FLOOD FREE LAND

Year	Wheat	Oats	Barley	Flax
1922		28 6	37 4	50
1923		41 7	42 6	65
1927		41 7	42 6	65
1955			29 9	
1956			25 5	

ABSOLUTE YIELDS WITH INUNDATION

Year	Wheat	Oats	Barley	Flax
1922		8 0	8 0	4 4
1923		11 6	9 1	5 7
1927		11 6	9 1	5 7
1955			6 4	
1956			5 4	

It is assumed that the price per bushel of wheat is $1 35 of barley 93c oats 62c and of flax $2 70 It is further assumed the operating cost per acre is for wheat $12 05 barley $11 90 oats $11 10 flax $11 60 and summer fallow $2 50 In flood years it was assumed that the grades for barley and wheat would be lower The prices applicable would be 89c and $1 24

The loss of income per acre from each field crop in each flood year was calculated as follows

Year	Wheat	Oats	Barley	Flax
1922	$17 81	$8 64	$10 37	$11 93
1923	17 81	8 64	10 37	8 42
1927	17 81	8 64	10 37	8 42
1955	17 81	8 64	9 90	14 71
1956	17 81	8 64	10 37	14 71

Total area (occupied land) of the Municipalities of Portage la Prairie Cartier St Francois Xavier and Macdonald is 865 134 acres

DISTRIBUTION OF AREA AMONG FIELD CROPS

Crop	Acres	Percent of Total Occupied Land
Wheat	180 746	20 89
Oats	98 601	11 40
Barley	209 843	24 26
Flax	25 217	2 91

The losses per each field crop in each flood year are weighted by the percentage shown directly above and divided by 100 00 since it is assumed that no loss of income occurs due to flooding of unimproved or summer fallow acreage In addition to the above losses it was estimated that the cost of re seeding in 1922 would increase the loss by $3 00 per seeded acre for that year

Thus the loss per acre of occupied land in each flood year is

1922	$9 35
1923	7 46
1927	7 46
1955	7 54
1956	7 65
Average	7 89

Loss* in 10% flood $7 89 × 8 000 = $ 63,120
Loss in 4% flood $7 89 × 204 800 × 9 = 1 454 285
Loss in 1% flood $7 89 × 435 200 × 9 = 3 090 355
Loss in 1% flood $7 89 × 1 105 900 × 9 = 7 852 996

*Average loss per acre multiplied by total area multiplied by percent of total area that consists of occupied farm land

C *Assiniboine River Millwood to Brandon*

The method of estimation followed here is the same as that used in Part B An average was taken of the actual loss in several flood years namely 1922 1923 1927 1936 1947 1948 1954 1955 1956 In these years the flood stage was passed in Brandon and in Millwood on the following dates

	Brandon	Millwood	Medium Point
1922	June 19	June 6	June 13
1923	June 1	May 18	May 25
1927	May 31	May 14	May 23
1936	May 3	Not Available	April 24*
1947	July 16	No flood	July 7
1948	June 4	May 17	May 26
1954	July 27	July 5	July 16
1955	June 17	May 25	June 6
1956	June 24	May 28	June 11

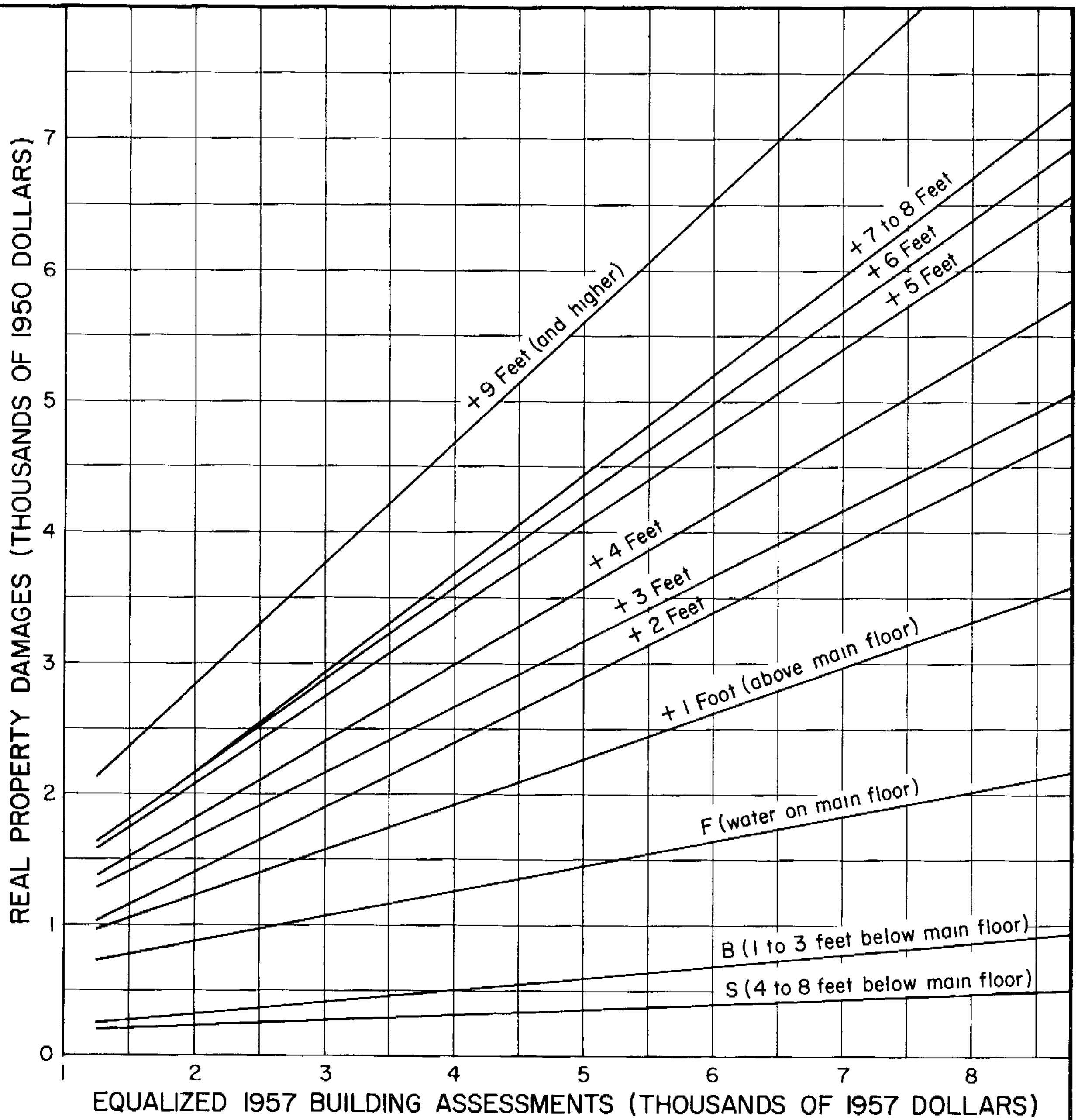
*Estimate

Where flooding occurred at Brandon but not at Millwood it was assumed that flooding was confined to the reach from St Lazare to Brandon

The area flooded between Millwood and Brandon is a flat river bottom with the land sloping away from the river As a result the land would dry out very slowly being confined to the area between the river banks and the edge of the valley It is estimated that it would require about 30 days for the land to dry sufficiently to permit seeding On this basis the land for the reach from Millwood to Brandon would have been dry enough to work on the following dates (average dates for the reach)

1922	July 13	1947	August 6
1923	June 24	1948	June 25
1927	June 22	1954	August 19
1936	May 24	1955	July 6
		1956	July 11

In the above years wheat seeding was general in Manitoba on the following dates (see *Report on Crops*



NOTE

Equations of regression lines for successive water levels shown above are

+ 9 Feet (and higher)	y - 0 92013 x + 984
+ 7 to 8 Feet	y - 0 75719 x + 648
+ 6 Feet	y - 0 70034 x + 762
+ 5 Feet	y - 0 66249 x + 745
+ 4 Feet	y = 0 58311 x + 652
+ 3 Feet	y - 0 50064 x + 654
+ 2 Feet	y 0 49584 x + 413
+ 1 Foot	y = 0 34895 x + 513
F	y = 0 18713 x + 500
B	y 0 09535 x + 123
S	y - 0 03691 x + 172

ROYAL COMMISSION ON FLOOD COST-BENEFIT

REAL PROPERTY DAMAGES

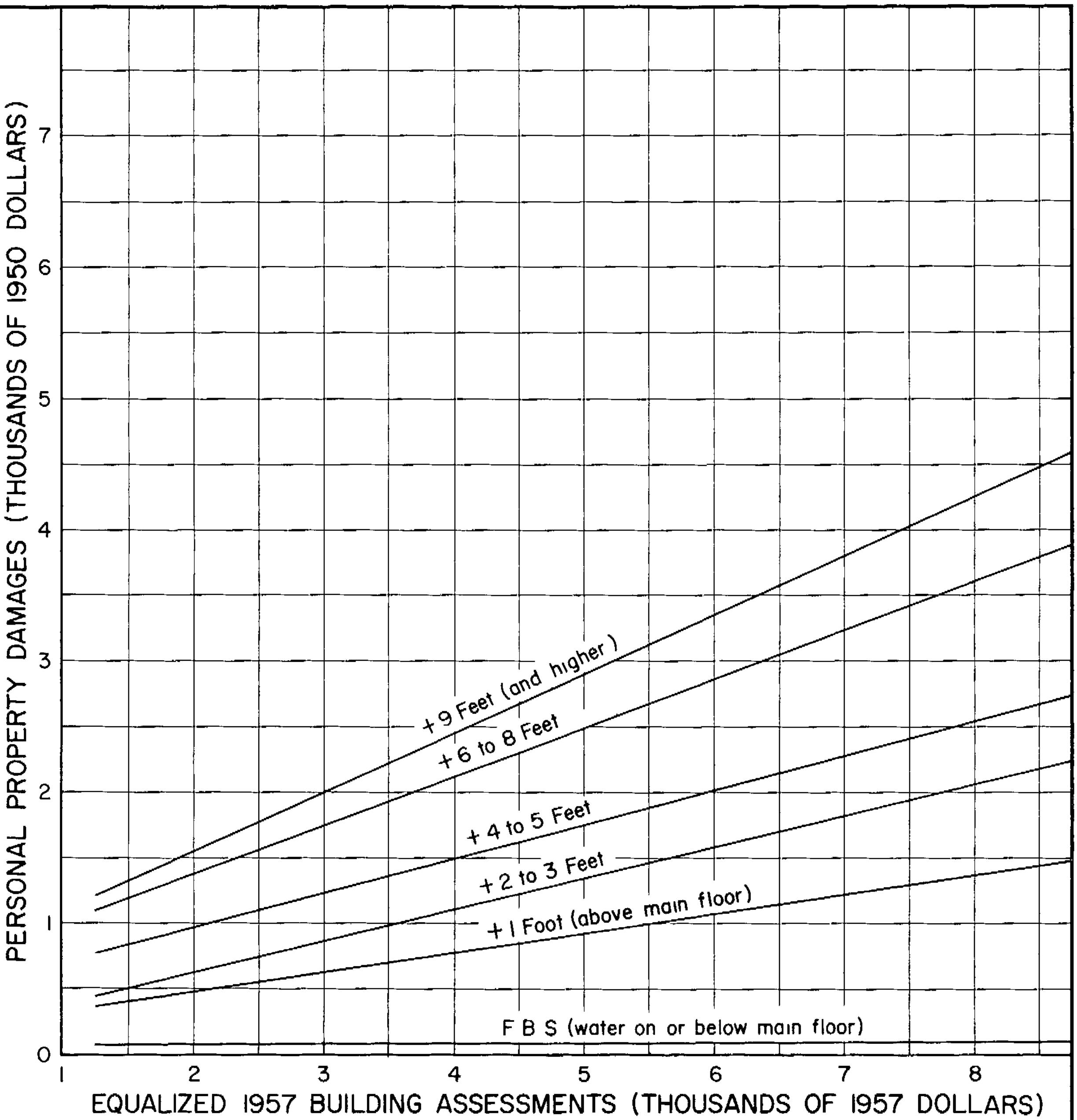
RELATED TO

EQUALIZED BUILDING ASSESSMENTS

BY FLOOD LEVEL

DWELLINGS IN GREATER WINNIPEG

DECEMBER 1958



NOTE

Equations of regression lines for successive water levels shown above are

+ 9 Feet (and higher)	y = 0 45125 x + 651
+ 6 to 8 Feet	y - 0 37274 x + 625
+ 4 to 5 Feet	y = 0 25686 x + 469
+ 2 to 3 Feet	y = 0 23918 x + 148
+ 1 Foot	y = 0 14509 x + 198
F B S	y - 0 00366 x + 71

ROYAL COMMISSION ON FLOOD COST-BENEFIT

PERSONAL PROPERTY DAMAGES

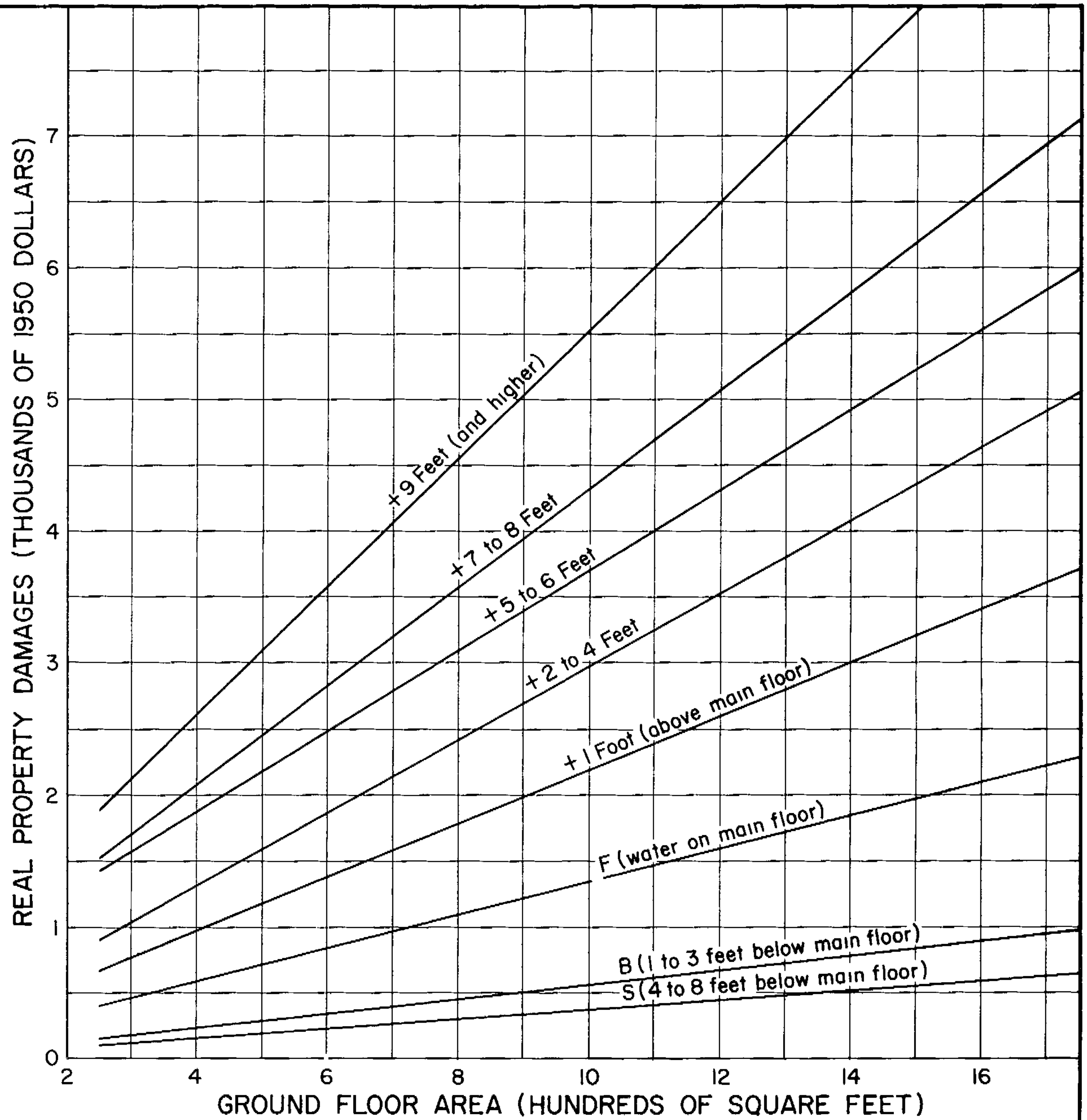
RELATED TO

EQUALIZED BUILDING ASSESSMENTS

BY FLOOD LEVEL

DWELLINGS IN GREATER WINNIPEG

DECEMBER 1958



NOTE

Equations of regression lines for successive water levels shown above are

+9 Feet (and higher)	y = 4 84950 x + 672
+7 to 8 Feet	y - 3 75117 x + 557
+5 to 6 Feet	y - 3 02782 x + 682
+2 to 4 Feet	y = 2 76568 x + 216
+1 Foot	y = 1 98929 x + 193
F	y = 1 24678 x + 105
B	y = 0 51971 x + 34
S	y - 0 35724 x + 14

ROYAL COMMISSION ON FLOOD COST-BENEFIT

REAL PROPERTY DAMAGES

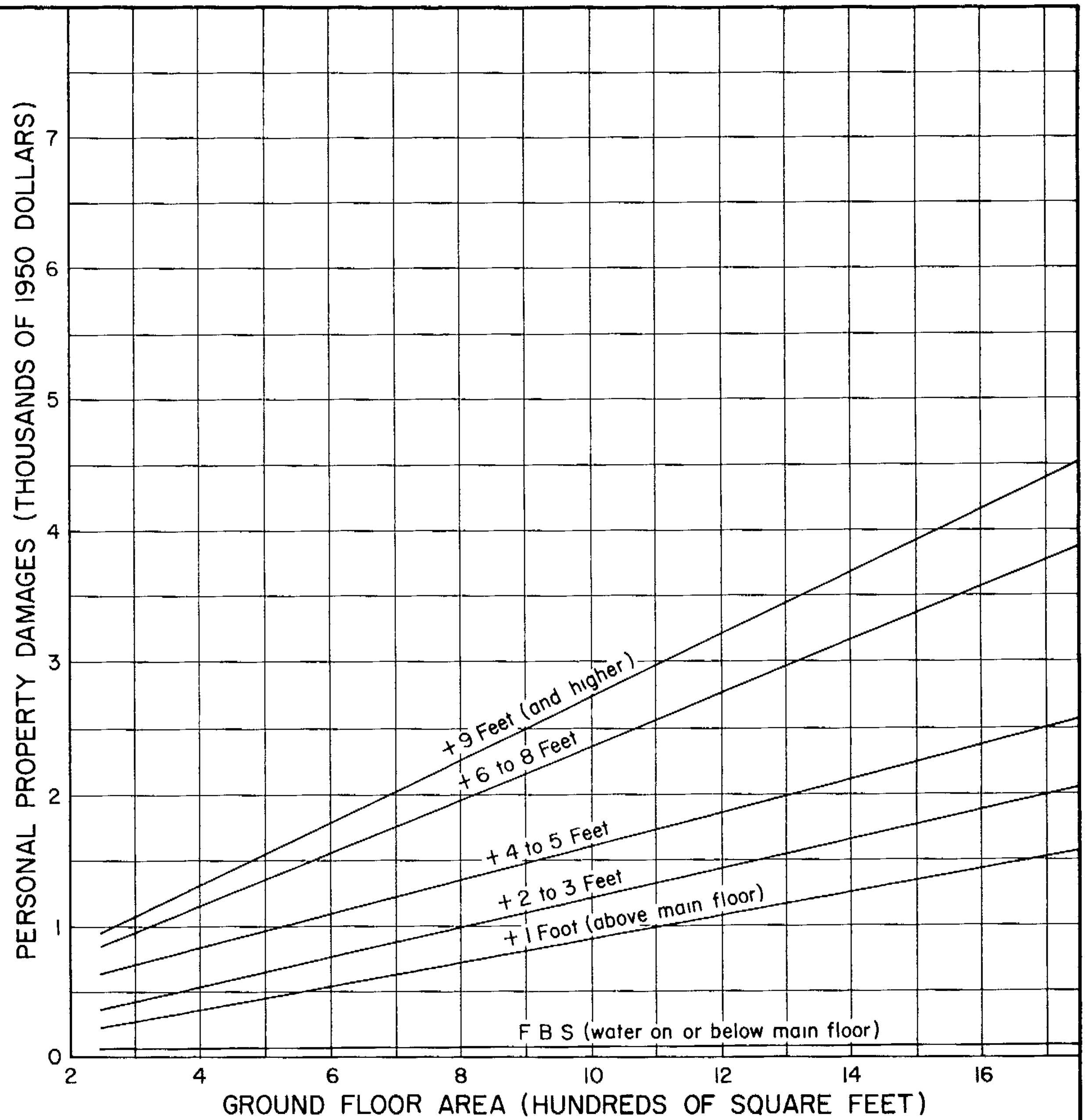
RELATED TO

GROUND FLOOR AREA

BY FLOOD LEVEL

DWELLINGS IN GREATER WINNIPEG

DECEMBER 1958



NOTE

Equations of regression lines for successive water levels shown above are

+9 Feet (and higher)	y = 2 36483 x + 368
+6 to 8 Feet	y = 2 00695 x + 350
+4 to 5 Feet	y = 1 26273 x + 340
+2 to 3 Feet	y 1 09457 x + 109
+1 Foot	y - 0 88145 x + 26
F B S	y = 0 02093 x + 54

ROYAL COMMISSION ON FLOOD COST-BENEFIT

PERSONAL PROPERTY DAMAGES

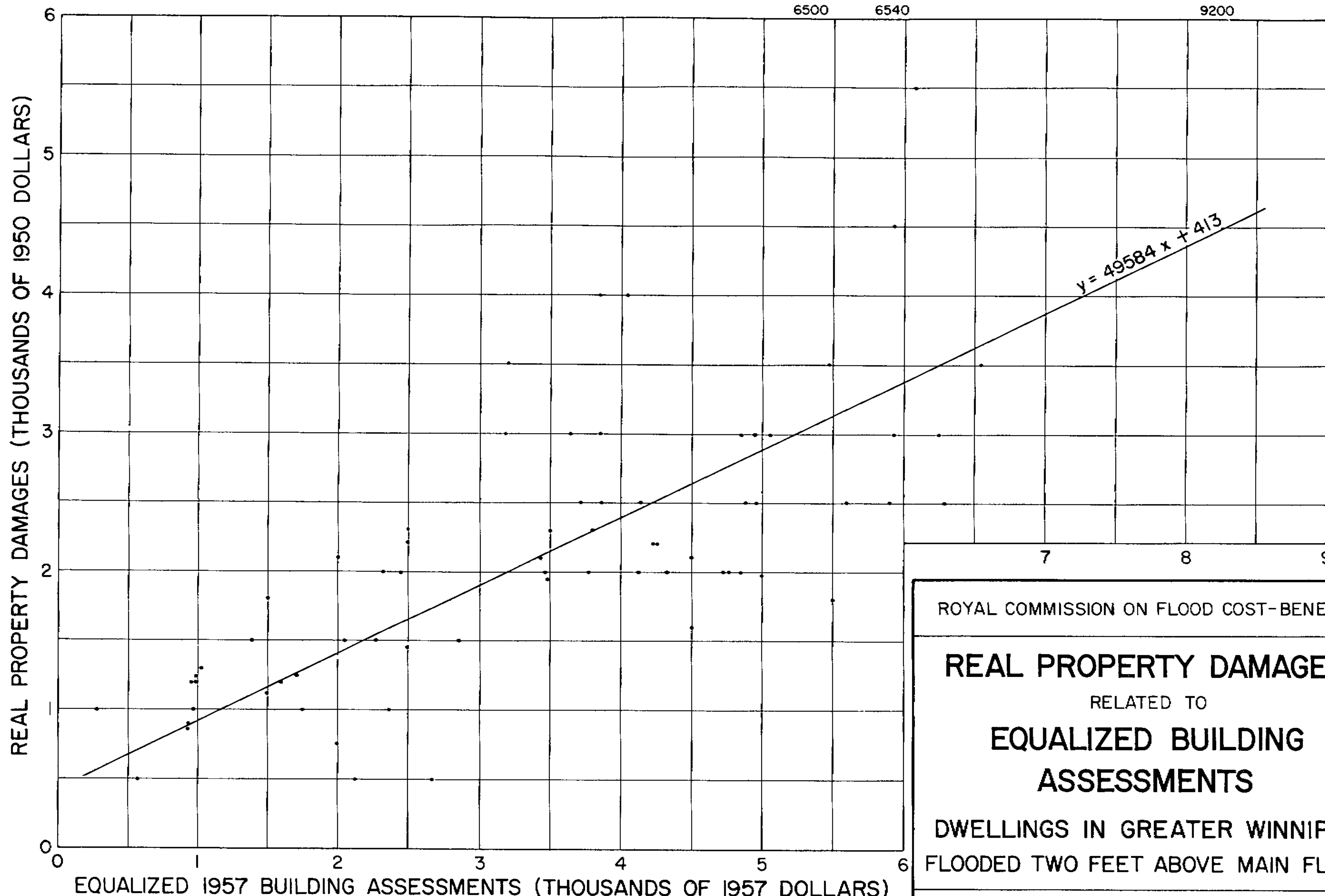
RELATED TO

GROUND FLOOR AREA

BY FLOOD LEVEL

DWELLINGS IN GREATER WINNIPEG

DECEMBER 1958



ROYAL COMMISSION ON FLOOD COST-BENEFIT

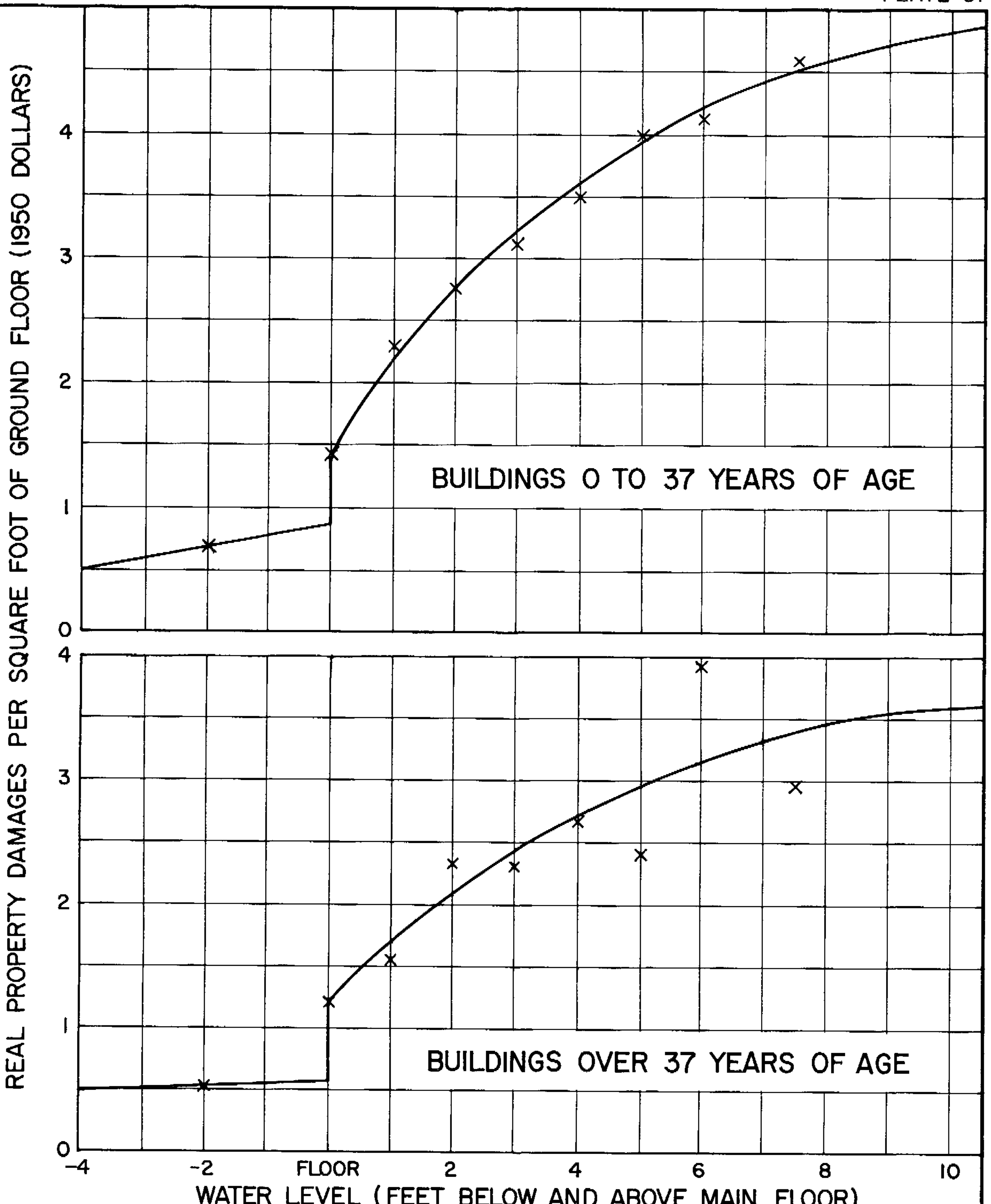
REAL PROPERTY DAMAGES

RELATED TO

EQUALIZED BUILDING ASSESSMENTS

DWELLINGS IN GREATER WINNIPEG
FLOODED TWO FEET ABOVE MAIN FLOOR

DECEMBER 1958



ROYAL COMMISSION ON FLOOD COST-BENEFIT

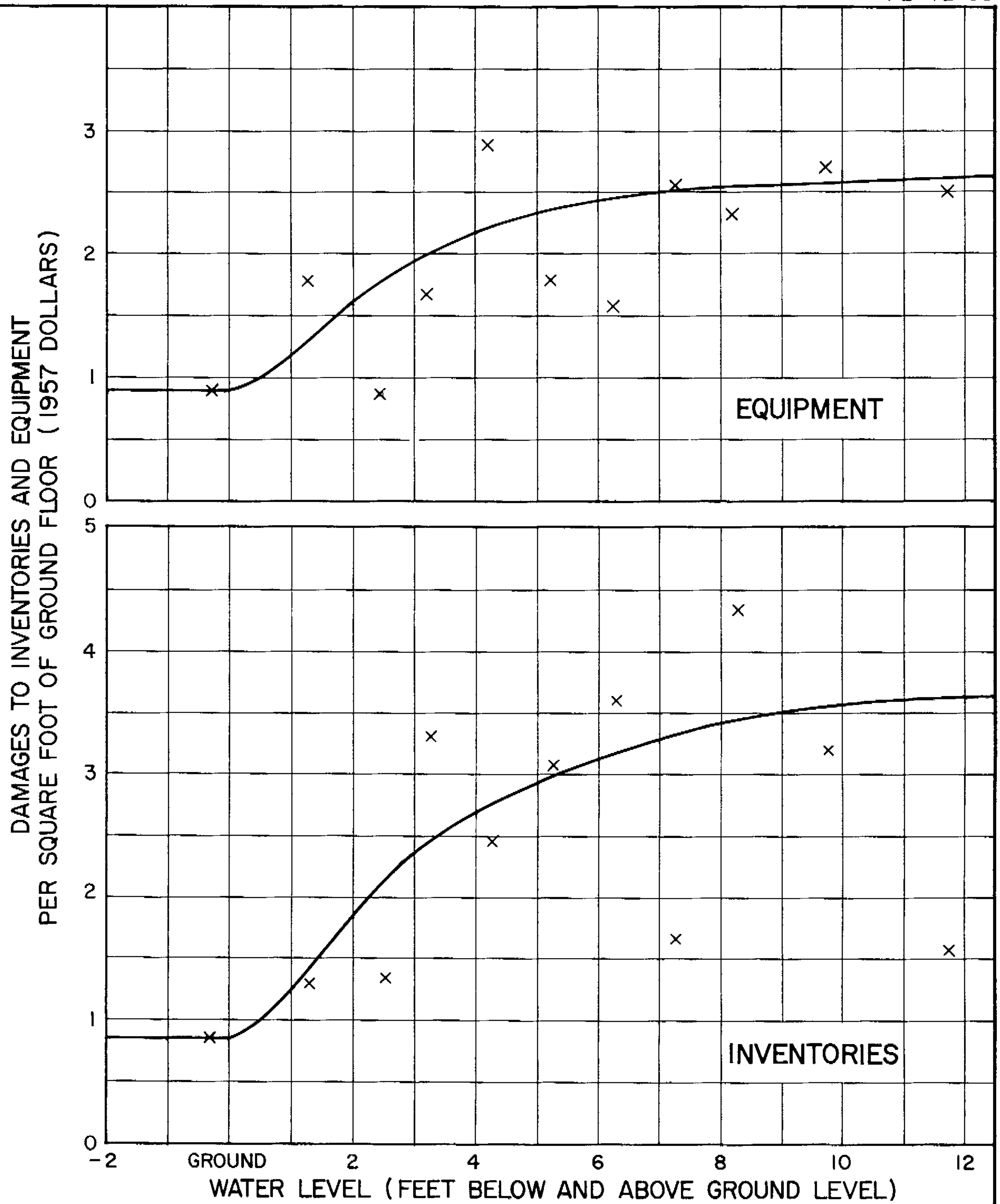
REAL PROPERTY DAMAGES BY FLOOD LEVEL

TO

DWELLINGS IN GREATER WINNIPEG FOR TWO MAJOR AGE GROUPS

PER SQUARE FOOT OF GROUND FLOOR

DECEMBER 1958



NOTE

The term EQUIPMENT' includes machinery and fixtures

The term INVENTORIES includes merchandise raw materials and supplies

ROYAL COMMISSION ON FLOOD COST-BENEFIT

DAMAGES TO EQUIPMENT AND INVENTORIES BY FLOOD LEVEL

BUSINESS AND INSTITUTIONAL BUILDINGS IN GREATER WINNIPEG

PER SQUARE FOOT OF GROUND FLOOR

DECEMBER 1958

Appendix F

RELATION OF GROWTH TO BENEFIT-COST ANALYSIS

When benefits arising out of future growth are included in a benefit cost ratio it is necessary to discount benefits that will only appear some time in the future. The correct approach would appear to be as follows.

Let the following series stand for the annual costs of the flood protection scheme under consideration C_1 C_1 C_1 C_1 $\cdots$ C_1 for n years where n is the period over which the project is to be evaluated normally 50 years. Then the present capital cost of the project will be as follows

$$Cn = C_1 + \frac{C_1}{(1+i)} + \frac{C_1}{(1+i)^2} + \frac{C_1}{(1+i)^3} + \cdots + \frac{C_1}{(1+i)^1}$$

$$= C_1 \left[1 + \frac{1}{(1+i)} + \frac{1}{(1+i)^2} + \cdots + \frac{1}{(1+i)^{n-1}} \right]$$

where i is the interest rate.

Next let the annual benefits resulting from the project be as follows

B_1 B_2 $\cdots$ Bn

The present value of these benefits will be given by the formula

$$B = B_1 + \frac{B_2}{(1+i)} + \frac{B_3}{(1+i)^2} + \cdots + \frac{Bn}{(1+i)^1}$$

If it is assumed that no growth occurs so that the annual benefits remain constant and equal to B_1 then

$$Bn = B_1 + \frac{B_1}{(1+i)} + \frac{B_1}{(1+i)^2} + \cdots + \frac{B_1}{(1+i)^1}$$

$$= B_1 \left[1 + \frac{1}{(1+i)} + \frac{1}{(1+i)^2} + \cdots + \frac{1}{(1+i)^1} \right]$$

In this instance the ratio of the present value of benefits to the present capital cost of $Bn \div Cn$ is also equal to the benefit cost ratio $B_1 \div C_1$ that is constant annual benefits divided by annual costs.

If we now assume that the annual benefits are gradually increasing the above equality is no longer true that is $B_1 \div C_1$ cannot be taken as a correct representation of $Bn \div Cn$.

To simplify let us assume that B_1 grows at a constant annual rate r then

$$Bn = B_1 \left[1 + \frac{1+r}{1+i} + \frac{(1+r)^2}{(1+i)^2} + \cdots + \frac{(1+r)^{n-1}}{(1+i)^{n-1}} \right]$$

Rather than attempt to reduce this to a general formula the above equations have been evaluated for particular values of r and i. Table 9 1

(Chapter 9) shows ratios of Bn to Cn where Bn is the present value of the total benefit over the 50 year life of the project and Cn is the capital cost of the project calculated for different values of r the annual percentage rate of growth of benefits and i the rate of interest.

Appendix G

INDEX OF ENGINEERING DATA USED

The following index is a list of engineering reports on which the Commission based its findings

The publishing of the complete reports would have made the main report so voluminous that it was felt that they should be left intact in a single volume in the archives of the Commission and that the few organizations interested in the development of the engineering data could obtain the use of them at the above source The index of the volume is listed below

A A report prepared by the Department of Resources and Development Water Resources Division dated October 1953 and entitled Report on Investigations into Measures for the Reduction of the Flood Hazard in the Greater Winnipeg Area The following appendices form a part of this report

Appendix A—Geography and Development
Appendix B—History of Floods on the Red River
Appendix C—Flood Runoff Analysis
Appendix D—Flood Magnitudes and Frequencies
Appendix E—Channel Improvements and Dyking
Appendix F—Flood Storage
Appendix G—Flood Diversions
Appendix H—The Assiniboine River

B A report prepared by the Department of Agriculture Prairie Farm Rehabilitation Branch dated December 1952 and entitled Report Conservation and Flood Control Assiniboine River

The following appendices form a part of this report

Appendix 1—Hydrologic Study Volumes I II and III
Appendix 2—Head Water Storage
Appendix 3—Channel Improvements Dyking and Drainage
Appendix 4—Diversion at Portage la Prairie
Appendix 5—Effect of Proposed Flood Control Projects

C Reports prepared by the Templeton Engineering Company in 1957 and 1958

The index of the volume is listed below

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LIST OF PLATES

LIST OF TABLES

* * * * * *

Table H 1

ESTIMATED CAPITAL AND ANNUAL COSTS — SUMMARY MAJOR FLOOD PROTECTION PROPOSALS

	Construction Period Assumed	Estimated Capital Cost	Interest during Construction Period	Total Estimated Economic Cost	Annual Cost at 4%			
					Interest	Amortization	Maintenance	Total
Greater Winnipeg Floodway	(Years)							
20 766 Floodway	5	$30 220 000	$3 022 000	$33 242 000	$1 329 700	$217 700	$128 400	$1 675 800
40 766 Floodway	5	44 081 000	4 408 100	48 489 100	1 939 600	317 600	164 600	2 421 800
60 766 Floodway	5	61 284 000	6 128 400	67 412 400	2 696 500	441 600	227 600	3 365 700
40 768 Floodway	5	41 724 000	4 172 400	45 896 400	1 835 900	300 600	166 900	2 303 400
60 768 Floodway	5	57 361 000	5 736 100	63 097 100	2 523 900	413 300	224 500	3 161 700
80 768 Floodway	5	71 436 000	7 143 600	78 579 600	3 143 200	514 700	273 900	3 931 800
60 770 Floodway	5	54 195 000	5 419 500	59 514 500	2 380 600	389 800	224 900	2 995 300
80 770 Floodway	5	68 127 000	6 812 700	74 939 700	2 997 600	490 900	277 000	3 765 500
100 770 Floodway	5	77 485 000	7 748 500	85 233 500	3 409 300	558 300	308 300	4 275 900
145 773 Floodway	5	93 965 000	9 396 500	103 361 500	4 134 500	677 000	394 200	5 205 700
Portage Diversions								
10 000 c f s High Bluff Diversion	2½	5 709 000	285 500	5 994 500	239 800	39 300	63 700	342 800
25 000 c f High Bluff Diversion	2½	8 672 000	433 600	9 105 600	364 200	59 600	82 400	506 200
40 000 c f s High Bluff Diversion	2½	10 861 000	543 100	11 404 100	456 200	74 700	99 200	630 100
10 000 c f s Ft la Reine Diversion	2½	6 584 000	329 200	6 913 200	276 500	45 300	74 300	396 100
25 000 c f s Ft la Reine Diversion	2½	11 010 000	550 500	11 560 500	462 400	75 700	97 800	635 900
40 000 c f s Ft la Reine Diversion	2½	14 097 000	704 900	14 801 900	592 100	97 000	114 000	803 100
Russell Reservoir	2½	6 450 000	322 500	6 772 500	270 900	44 400	18 600	333 900
Eastern Tributaries Diversion	2½	11 330 000	566 500	11 896 500	475 900	77 900	98 200	652 000

Table H 2

ESTIMATED CAPITAL AND ANNUAL COSTS — SUMMARY MAJOR FLOOD PROTECTION PROPOSALS

Project	Construction Period Assumed	Estimated Capital Cost	Interest During Construction Period	Total Estimated Economic Cost	Annual Cost at 4% Interest	Annual Cost at 4% Amortization	Annual Cost at 4% Total(a)
	(Years)						
Ste Agathe Detention Basin							
Additional Damage Approach	2½	$ 9 234 000	$ 461 700	$ 9 695 700	$ 387 800	$ 63 500	$ 451 300
Flooding Rights Approach	2½	26 804 000	461 700	27 265 700	1 090 600	178 600	1 269 200
Pembina Reservoir	2½	5 140 000	257 500	5 397 500	215 900	35 400	251 300
Removal of Lister s Rapids							
Trial 12	5	5 674 000	567 400	6 241 400	249 700	40 800	290 500
Trial B	5	14 925 000	1 492 500	16 417 500	656 700	107 500	764 200
Trial C	5	29 326 000	2 932 600	32 258 600	1 290 300	211 300	1 501 600
Channel Improvement Extended Through Greater Winnipeg							
Scheme 1 (110 000 c f s)	5	66 547 000	6 654 700	73 201 700	2 928 000	479 500	3 407 500
Scheme 2 (130 000 c f s)	5	106 936 000	10 693 600	117 629 600	4 705 200	770 500	5 475 700
Scheme 3 (140 000 c f s)	5	122 949 000	12 294 900	135 243 900	5 409 800	885 900	6 295 700

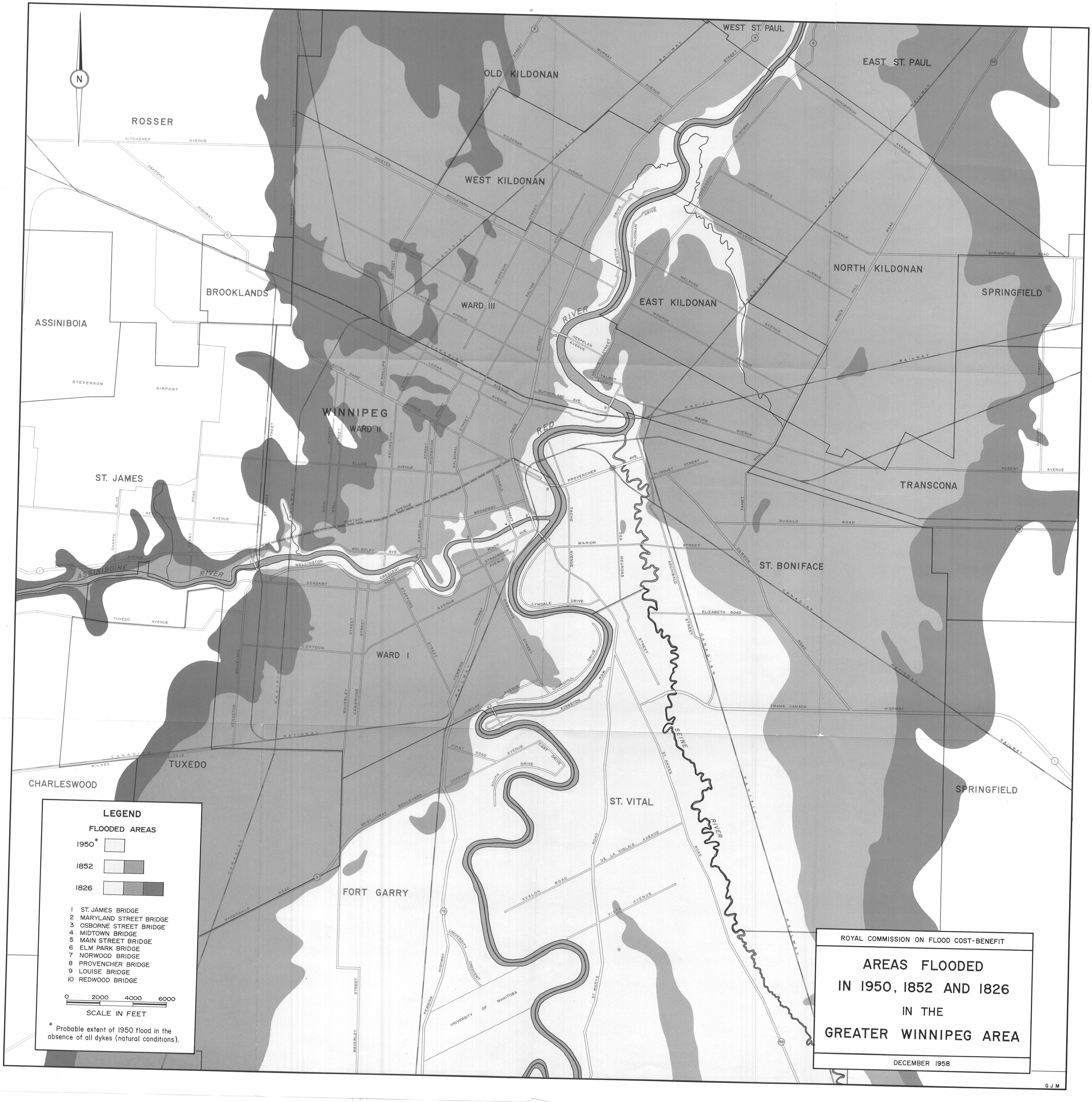
(a) Excludes maintenance costs

Table H 3

ANALYSIS OF ANNUAL DAMAGES AND BENEFITS BY SIZE OF FLOOD EFFECTS OF PROPOSED COMBINATION ON GREATER WINNIPEG*

Size Range of Flood	Average Annual Damages in Natural Condition (1)	Av Annual Benefits Attributable to Existing Dyking System (2)	Av Annual Damages in Existing Condition (1)—(2) (3)	Av Annual Benefits Attributable to Proposed Combination* (4)	Residual Av Annual Damages not Eliminated by Proposed Combination (3)—(4) (5)	Percent of Average Annual Damages Eliminated (4) – (3) × 100 (6)
Floods to 1950 Level (< 103 600 c f s)	$ 1 493 900	$756 000	$ 737 900	$ 737 900		100 0%
Floods 1950 1861 Level (103 600 125 000 c f s)	2 276 000	94 200	2 181 800	2 181 800		100 0%
Floods 1861 1852 Levels (125 000 165 000 c f s)	3 779 000		3 779 000	3 776 200	2 800	99 9%
Floods 1852 1826 Levels (165 000 225 000 c f s)	3 287 500		3 287 500	2 888 700	398 800	87 9%
Floods above 1826 Level (< 225 000 c f s Max Prob)	2 034 200		2 034 200	780 700	1 253 500	38 4%
Total for All Floods of All Sizes	$12 870 600	$850 200	$12 020 400	$10 365 300	$1 655 100	86 2%

*60 768 Floodway plus 25 000 c f s Portage Diversion plus Russell Reservoir


ROYAL COMMISSION ON FLOOD COST-BENEFIT
AREAS FLOODED
IN 1950, 1852 AND 1826
IN THE
GREATER WINNIPEG AREA
DECEMBER 1958
LEGEND
FLOODED AREAS
1950*
1852
1826
1 ST. JAMES BRIDGE
2 MARYLAND STREET BRIDGE
3 OSBORNE STREET BRIDGE
4 MIDTOWN BRIDGE
5 MAIN STREET BRIDGE
6 ELM PARK BRIDGE
7 NORWOOD BRIDGE
8 PROVENCHER BRIDGE
9 LOUISE BRIDGE
10 REDWOOD BRIDGE
0 2000 4000 6000
SCALE IN FEET
* Probable extent of 1950 flood in the absence of all dykes (natural conditions).
N
WEST ST. PAUL
EAST ST. PAUL
OLD KILDONAN
ROSSER
WEST KILDONAN
NORTH KILDONAN
EAST KILDONAN
SPRINGFIELD
BROOKLANDS
ASSINIBOIA
WARD III
WINNIPEG
WARD II
ST. JAMES
TRANSCONA
ST. BONIFACE
WARD I
TUXEDO
CHARLESWOOD
ST. VITAL
FORT GARRY
SPRINGFIELD
RED RIVER
ASSINIBOINE RIVER
SEINE RIVER
G J M