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Estimating Flood Damages in the Fraser River Basin

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Water Planning & Management Branch
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Inland Waters Directorate
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Vancouver, B.C.

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- POWER DEVELOP

- UPDATE 1963 STUDY
- 1963 STUDY - SUPERFICIAL -

ESTIMATING FLOOD DAMAGES IN THE FRASER RIVER BASIN

Report for the Fraser River Joint Advisory Board, Fraser River Upstream Storage Study.

by

Archie N. Book and Romeo Princic

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Inland Waters Directorate, Pacific Region
Water Planning and Management Branch
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Errata

Title Page	& Yukon Region
Report - Page 1	despite
Appendix B - Page 44	undertaking

RESUME

Le présent rapport décrit les méthodes employées pour évaluer les possibilités de dommages causés par les inondations et les bénéfices structuraux que l'on peut retirer grâce à la construction d'ouvrage de contrôle contre les inondations dans la vallée du Fraser. Bien qu'il fixe les dommages-intérêts de la vallée, il porte essentiellement sur les méthodes d'analyse et indique l'exactitude des résultats. Donc, il offre de bonnes lignes directrices pour les études futures.

La première partie du rapport élabore un plan général. Il fixe les coûts et fait connaître les avantages de l'aménagement dans une plaine inondable. Par la suite il met l'emphase sur un des plus importants aspects des études sur les dommages causés par les inondations, le processur employé pour calculer la moyenne des dommages annuels. Il laisse entendre que lorsque des digues font partie d'un ouvrage de protection dans un bassin, une prime non reconnue est incluse dans les évaluations des pertes moyennes annuelles de salaire et de propriété. Cette prime reflète la valeur implicitement donnée aux pertes immatérielles et à ceux qui courent des risques. Selon la présente étude, les pertes moyennes annuelles de ce genre peuvent atteindre jusqu'à 70%.

La deuxième partie du rapport décrit les technique employées pour évaluer les fonctions synthétiques étapes-dommages. Elle indique (1) comment on s'est servi des techniques de moyenne pour obtenir des évaluations justes des possibilités des dommages aux récoltes et aux résidences. (2) comment les cartes inondations-intensités furent dressées aux fins d'accélerer le processus d'évaluation. (3) comment furent colligées et analysées les données relatives aux études sur le terrain dans le but de fournir des évaluations acceptables des dommages commerciaux et industriels et des pertes de salaire, et (4) comment on a combiné des pronostics sur l'accroissement général et sur la flambée des prix pour faire de justes prédictions sur les dommages futurs.

ABSTRACT

This report describes the methods used to estimate potential flood damages and structural flood control benefits in the Fraser Valley. Although it includes estimates of damages for the valley, it focuses primarily on methods of analysis and indicates the accuracy of the results. Therefore, it provides a good set of guidelines for future studies.

The first part of the report develops a general framework. It defines the costs and benefits of occupying a floodplain. It then concentrates on one of the most critical aspects of flood damage studies - the procedure used to calculate average annual damages. It suggests that, for basins in which dykes form a part of a protection scheme, an unrecognized premium is included in estimates of average annual property and income losses. This premium reflects the value implicitly assigned to risk-taking and intangible losses. In the present study, it could be as much as 70% of the computed average annual losses.

The second part of the report describes the techniques used to estimate synthetic stage-damage functions. It shows 1) how averaging techniques were used to obtain accurate assessments of potential damages to crops and residences, 2) how flood-depth maps were developed to speed the estimating process, 3) how field survey data were collected and analysed to provide reasonable assessments of commercial and industrial damages and income losses, and 4) how simple growth and price change projections were devised and used to make adequate forecasts of future damages.

ACKNOWLEDGEMENTS

Many people, particularly personnel within the Department of the Environment, provided valuable editorial and technical comments during the preparation of this report. Their assistance is sincerely acknowledged.

We would like to offer special thanks to G.R. Shanks, B.F.J. Friesen, and A. LeFevre, and their assistants P. Fisher and W. Bedford, for their creative help in carrying out the field research required for assessing residential, commercial, and industrial flood damages. Without their contributions, this report would be worth considerably less.

Any errors or omissions remain our responsibility.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

PART I

GENERAL METHODOLOGY

CHAPTER I

INTRODUCTION

STUDY OBJECTIVE

Since the 1800's, urban and rural developments have encroached upon the floodplain in the Fraser Valley. Despit vast dyking systems and upstream reservoirs that currently provide some protection for most of these areas, the threat of flooding and the possibility of extensive damage being suffered by floodplain activities still remains. In order to assess the magnitude of the problem, the present study was conceived to measure the potential flood damage in the entire Fraser River System, the impact that major floods would have on British Columbia, and the ameliorating effects that proposed dykes and reservoirs would have on the flood hazard. Major emphasis was placed on assessing flood damage potential in the Lower Fraser Valley, Kamloops, Prince George and Quesnel because these areas incorporate almost all of the urban and rural developments threatened by floods in the basin.

REPORT ORIENTATION

Many studies of flood hazards and potential damages have appeared since the early 1940's. Many devices have been used and proposed to eliminate these hazards and many methods have been adopted to assess the costs of floods and the benefits of flood control measures. Out of these studies has arisen a body of literature that has gradually reduced, to manageable proportions, the array of problems involved in such assessments.

This report describes the methods devised and used in the Fraser Study to estimate potential flood losses and the benefits of structural flood control measures. Although it applies specifically to the Fraser River, it is intended to be general enough to serve as a guide for other studies. Thus, while it does enumerate potential flood losses (Appendix H), it concentrates primarily on methods and indicates the significance of different types of damage and the accuracy of the results. In the process, it offers both modifications of existing techniques where the latter appear inadequate, and adaptations of standard procedures where data are either unobtainable or unpredictable.

Chapter I provides a general description of the costs of flooding and the benefits of flood control. It outlines four recognized costs of flooding and presents one of these, the opportunity cost of foregoing certain activities because of the flood hazard, in some depth.

Chapter II describes the process by which potential, average annual values of flood damages are calculated. It notes some of the technical problems that evolve when engineering and hydrological concepts are translated literally into economic terms. It illustrates the standard procedures for measuring structural flood control benefits, examines alternatives that might be used to improve analyses, and outlines the method employed in the current Fraser River Study.

Chapters III through IX are devoted exclusively to describing the methods used to estimate the losses of income and property that would occur in the event of a Fraser River flood. They summarize the steps used to evaluate specific types of damage, such as residential and agricultural, and comment upon the accuracy of the results. They also develop a crude model depicting a likely growth pattern for the Lower Fraser floodplain and present a method for predicting the impact that such a pattern will have on the flood damage potential of the region.

This report does not examine the benefits of all structural means of flood control nor does it consider the benefits of non-structural alternatives. However, its narrow focus should not be construed as an indication of the significance of the role alternatives can play in a flood control scheme. It is simply a reflection of the terms of reference under which this study was undertaken.[1/]

1/ For an excellent and enlightening discussion on the benefits of non-structural ways of approaching the flood problem (i.e. zoning and flood insurance) and of emergency measures and other structural means of flood control, see Lind (1967: 345-357). For an extensive presentation of optimum combinations of structural and non-structural flood control measures, see James (1965).

THE COSTS OF FLOODING AND THE BENEFITS OF FLOOD PROTECTION

The benefits of providing flood protection are defined as the reduction in costs due to flooding that occurs with the introduction of protective measures. These costs can be grouped into four categories: 1) loss of property and income, 2) risk-taking, 3) intangibles and 4) restrictions on the use of the floodplain by certain activities because of the flood problems. This categorization facilitates a clear identification of the costs of using a floodplain and an understanding of the real benefits of flood control measures.

1. PROPERTY AND INCOME LOSSES

The first cost is conceptually simple. Floods destroy property and disrupt economic activity thereby inflicting losses on an economy. These losses are classified as "primary" and "secondary" damages. Primary losses are those that occur directly to economic activities located on the floodplain. They incorporate such factors as residential, agricultural, commercial and industrial property damage, destruction of roads, railways and utilities, losses of profits and income of those employed on the floodplain, frictional costs involved in transferring and deferring production of flood disrupted industries and losses of rents accruing to homes that must be abandoned during high water periods. Secondary losses are permanent income losses that occur to industries located off the floodplain as a consequence of flood-inflicted severances of linkages with suppliers and/or consumers. They arise either because production delays and losses are caused by disruptions of the inter-industrial flow patterns of intermediate goods or because final sales to consumers are interrupted. Both primary and secondary losses and techniques of assessing them are the subject of discussion in Chapters III through IX and warrant no further attention here.

Standard methods of estimating flood damages require the calculation of the potential average annual values of these damages over a given period. The specific steps in the calculation will be described in detail in Chapter II, but at present, a simplified explanation is required. Initially, the frequencies of occurrence of given annual maximum water levels are derived from historical data. Then, the probability distribution of these levels for any one year is assumed to mirror the historical pattern. Next, the damage that will occur in the event that the river rises to each level is estimated. Finally, the potential average value of damage is computed on the basis of the probability distribution of these losses. This average value is assumed to represent the average cost of flooding per annum (given no changes in floodplain conditions).

The benefits of flood control are estimated as the amount by which flood protection measures reduce the estimated annual value of damages. Normal growth[2/] in economic activity, and subsequently in the size of benefits, is incorporated into the analysis in the projection of the stream of annual benefits. This stream of benefits is discounted to its present value. It is then assumed that, given the opportunity, floodplain dwellers will pay an amount for flood protection equal to the size of the benefits they receive in the form of the reduction of the present value of the average annual losses over a specified period. This willingness to pay is assumed to equal the benefits of flood protection.

2. RISK-TAKING

Lind (1967: 346-349) points out that this procedure ignores the question of uncertainty and thereby fails to account for the second cost listed above - the cost associated with risk-taking. He suggests that people may be interested in more than just mean values; they may also be concerned with avoiding very large losses in a catastrophic flood or in the variance of the distribution of losses. He rightfully states that if this is the case and if people are willing to pay a premium for avoiding these risk-associated costs, then an estimate based on the average value of the losses underestimates the total costs of flooding and the benefits of flood prevention by the amount of the premium.

2/ Normal growth is defined as growth in economic activity that will occur whether or not a flood protection structure is built. Benefits of protecting such activity are measured as the reduction of potential damages that this activity would incur if left exposed. Project-induced growth is distinct; it provides "enhancement benefits" which are discussed extensively later in this chapter.

The benefits of reducing the costs of risk (as indicated by the premium people are willing to pay) are not usually included systematically in the benefits of flood protection. This is because of practical problems of measurement. Nevertheless, in practice, an attempt is made to account for the risk factor because optimal levels of protection that would be determined from average annual values on the basis of "marginal benefit = marginal cost" criteria are frequently exceeded. Typically, higher than optimal standards[3/] as suggested by principles of marginalism are introduced because larger scale projects are purported to provide risk-reduction benefits. It is contended that if these benefits were incorporated into the benefit estimates, then the marginal benefits would exceed the marginal costs presently calculated using only average annual values.

Lind (1967: 349) maintains that this argument is essentially correct provided no alternative means, such as flood insurance, are available to eliminate risk at a lower cost.[4/] And since, to date, institutional constraints have kept flood insurance out of the scope of alternatives of approaching flood problems, in the Canadian context at least, it is legitimate to admit some risk premium as a benefit of a flood prevention project.

3. INTANGIBLES

The third cost listed above is labelled "intangibles". This encompasses costs such as loss of life and limb, psychological disturbances and social upheaval which are difficult, if not impossible, to measure in monetary terms. Loss of life looms particularly important in analyses of flood problems as a further reason for justifying extensive structural flood control measures. This cost, while very real, is probably exaggerated inso-

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3/ The most common practice is to build a structure so as to protect against some large "design" flood determined more by political decree or arbitrary selection than by any stated economically rational criterion.

4/ Of course the magnitude of the value of the risk-premium currently assumed in studies may not be correct.

far as few deaths have actually resulted from flooding (Eckstein,1958:141). Moreover, it is far from clear that dams and dykes will reduce deaths. Certainly, they will eliminate small floods (which would probably cause little loss of life anyway) and in the case of dams, reduce the peaks of large ones. However, structural measures capable of completely eliminating the possibility of flooding seldom, if ever, prove economically feasible. Consequently, a flood warning and evacuation system must always be a part of flood protection networks. Moreover, in the case of levees, there is no guarantee that a structure will not weaken and burst unexpectedly causing more loss of life than would have occurred in its absence. Thus, while loss of life may be a significant factor, it is questionable whether structural measures are effective means of reducing this cost.

4. COSTS OF RESTRICTED USE

The last cost is, conceptually, the most difficult of the four. Clearly there is some opportunity cost of having only restricted use of a floodplain but the true measure of the benefits of reducing flood hazards and thereby enhancing land values has been the subject of considerable, controversial discussion.

United States Senate Document 97 (U.S. Senate, 1962), borrowing from the earlier "Green Book" (U.S. Inter-Agency Committee, 1958: 39), defined project-induced (enhancement) benefits as the increase in the net income of the floodplain that occurs when a flood reduction project induces a change of land use. It stated that these benefits were to be measured as the difference in net earnings of the floodplain before and after a project is introduced. To obtain the net figure, all associated costs except the rental value of the land had to be subtracted from the gross returns. Thus, U.S. Senate Document 97 proposed measuring the benefits of the project as if it were in isolation from the rest of the economy. It did not consider relevant the origin of the activities that would locate on a floodplain once protection was provided.

Krutilla (1966: 186), following some general statements by Eckstein (1958: 133), presented an alternative "correct" measure of project-induced benefits. He suggested that there was perhaps little real economic gain in land enhancement because it represented merely a diversion of economic activity from non-floodplain areas. He defined real economic gain in terms of the project's contribution to the national product and stated that the remainder of the land enhancement described in U.S. Senate Document 97 was simply an income transfer from owners of non-floodplain to owners of floodplain land. He maintained that the true estimate of the benefit was the difference between the increase in floodplain land values and the income redistribution between owners of the floodable and non-floodable land under study.

Lind (1966: 77-87 and 1967: 350-354) expanded on this approach of assessing project-induced benefits.[5/] He proposed the now accepted theory that the measure of land enhancement benefits was only the difference between the profits that an activity could earn off the floodplain and those it could earn on the floodplain, given flood protection and the initial set of prices and rents. He showed that this assessment would provide an upper bound for project-induced benefits (Lind, 1966: 67-70).

The precise formula Lind proposed was the following (Lind, 1967: 350):

$$\text{Enhancement benefit} = (S_{Fi} - P_f) - (S_{Ui} - P_u)$$

where S_{Fi} = net earnings of activity i at floodplain location after flood protection is provided (exclusive of land costs).

P_f = rental value of land on floodplain before protection is provided (i.e. in the initial state of equilibrium).

S_{Ui} = net earnings of activity i located on unflooded land.

P_u = initial equilibrium rental value of unflooded land.

5/ His explanation of enhancement benefits is the most detailed and exact to date. His proposal has been adopted as the correct measure by the United States Government (U.S. Water Resources Council, 1970: P.III B-2-6). This latest U.S. document also suggests that, where the data required to use Lind's method is lacking, an alternative measure for enhancement benefits is the damage that induced-growth activities would suffer in the absence of protection if they were to locate on the floodplain. However, our experience suggests that this has no necessary relationship with Lind's result. Consequently the Fraser Study adhered as closely as possible to Lind's method for computing enhancement benefits.

Because of past difficulties in interpreting enhancement benefits and because of the apparent divergence between Lind's measure of benefits and that proposed by McKean in his general explanation of pecuniary spillovers (McKean, 1958: 136-150), it is worthwhile to explain Lind's formula more fully.

The heart of the problem rests in location theory. Given a choice, a rational entrepreneur will locate on a floodplain only if he can earn a larger net income there than he can on unfloodable land. The costs he must consider are the normal ones associated with location decisions plus costs uniquely related to floodplain areas. The latter include both flood protection expenses and residual damages that occur when the protection works fail. Now suppose an entrepreneur is trying to decide whether or not to build on a floodplain. Further, assume that in his initial cost calculations, he can exclude the cost of flood protection works (like dykes and dams) because the government will provide the works at no extra charge. Then clearly, he will select the floodplain option only if his profit level, exclusive of flood protection expenditures at that site, is greater than or equal to the profit level on unfloodable land.

If a government (or collection of interested parties) wishes to know whether or not it is economically feasible to build a dyke or dam and occupy a floodplain, it cannot ignore the opportunity cost of not locating on unfloodable land. No rational entrepreneur would be willing to pay more for protective structures than the difference between the potential net returns on the floodplain and the net returns at unflooded locations. The economic rent that could be earned at alternative sites must be considered an opportunity cost to be incorporated into the assessment of the real benefits of occupying the floodplain.

A concise statement of the foregoing argument is that the willingness of activities to pay more for floodplain than non-floodplain land depends upon the amount by which the net returns[6/] earned at the floodplain site exceed those earned in non-floodplain areas. It will therefore be worthwhile to invest in a flood protection project exclusively on the basis of enhancement benefits only when the total site

6/ Exclusive of flood protection costs but including residual damages.

advantage of the plain is greater than the total project cost. In symbols, this will occur when

$$\sum_{i=1}^{n} \left[(S_{Fi} - P_f) - (S_{Ui} - P_u)\right] > D$$

where D is the cost of flood prevention and S_{Fi}, S_{Ui}, P_f and P_u are equivalent to the symbols in Lind's formula (with the express understanding that S_{Fi} excludes project costs). As long as $[(S_{Fi} - P_f) - (S_{Ui} - P_u)] > 0$ for each activity that is expected to occupy a floodplain, and as long as the sum of these potential profits is greater than project costs, a government agency can claim that enhancement benefits justify the construction of protective works on the basis of economic efficiency criteria.[7/]

SUMMARY

This report describes the methods used to estimate the economic value of potential flood damages and flood prevention benefits. Although it enumerates the estimated damages and describes how they were used to determine benefits of flood control measures, its primary concern is to present a detailed outline of the techniques employed and the adequacy of the results derived.

Four costs of flooding are considered in this study. These are 1) property and income losses, 2) risk-taking, 3) intangibles and 4) restrictions on floodplain use. In this analysis, the last is identified explicitly, the third is given only minor consideration, the second is taken into account indirectly, and the first is clearly defined for individual flood levels.

7/ The criteria must, of course, be based on the principle that marginal benefits equal marginal costs. When this principle is used in an analysis, the reduction of residual damages must be included along with enhancement benefits in the computation of the optimum level of the flood control structures (See footnote 6, Chapter II).

Estimating property and income losses is the subject of most of the subsequent chapters. As such, the significance of these losses for individual flood levels is well explained. However, because risk is introduced implicitly into the analysis when these damages are assessed in terms of damage-frequency functions, the real value of reducing property and income losses becomes obscure. As Chapter II indicates, the final calculation of the average annual economic benefits of flood control in the Fraser Valley therefore represents a combination of risk- and damage-reduction benefits (plus a separate computation of the value of reducing restrictions on floodplain use).

CONCLUSION

This presentation of the four costs of flooding is brief but it provides an adequate overview of the concepts involved in flood control studies and clarifies or identifies several specific problem areas. It also sets the stage for introducing and examining, in the following chapter, the procedures used to compute average annual values of flood damages and, in subsequent chapters, the methods adopted for evaluating potential economic losses during given flood levels.

CHAPTER II

COMPUTING AVERAGE ANNUAL VALUE OF FLOOD DAMAGES

INTRODUCTION

One of the most significant determinants of the magnitude of potential flood damage estimates is the procedure used to obtain the average annual value of flood damages. Although there is a standard, mechanical approach to the problem, frequently its unwitting use leads to an abuse of economic data. The relationship between the average annual value of damages and the four costs of flooding outlined in Chapter I is sometimes poorly understood. Engineering data often are translated literally into economic terms. The result can be a misrepresentation of the economic costs of flooding and the benefits of flood control.

This Chapter deals with the mechanics and philosophy underlying computations of the average annual value of flood damages. It outlines the traditional approach, illustrates problems that have arisen with the application of the procedure, and suggests ways of improving standard practices. Finally, it describes the method used in the present study and explains the meaning of the average annual value derived on the basis of this technique.

THE AVERAGE ANNUAL VALUE CRITERION

Estimates of the probability distribution of flood damages used to determine the average annual value of losses depend largely on information on stream-flow characteristics. The traditional approach involves establishing the historical frequency of recurrences of yearly peak discharges of water (measured in cubic feet per second at a specific point in a river). A cumulative frequency distribution is developed to reflect the frequency at which specified rates of flow are equalled or exceeded. The frequency of occurrence is expressed both in terms of recurrence intervals (eg. "one in 200-year flood"), and as a probability distribution of discharges. Past events are assumed to mirror future conditions so that the historical probability distribution of discharges defines the probability of given discharges being equalled or exceeded in each consecutive year in the future. A typical frequency discharge curve is presented in Figure 1 as:

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

where p = a measure of probability ranging between 0 and 1.0 and Q = discharge in cubic feet per second.[1/]

Associated with the discharge at a given point along a river is a unique water level or stage (measured in feet above datum which is often taken to be sea level). Thus, a relationship between discharge and stage can be established and described as the following function (Figure 2):

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

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

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

When a river overflows its banks and inundates its floodplain, it causes flood damage. The amount of damage that occurs depends on the level of economic activity on the flood plain and on flood characteristics such as the velocity of the current and the depth of flooding. For any specific area, damage is assumed to be contingent on the stage to which the river rises. Thus, a fourth function, a stage-damage function, is required in the analysis. It is shown in Figure 4 as:

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

where D = flood damage in dollars.

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

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

where p = the probability of incurring damages (ranging from 0 to 1.0).

1/ While p = U(Q) is perhaps a more readily understood function, its inverse Q = Q(p) is used here because it is more easily employed in the construction of the damage-frequency function to be explained later in the text.

DETERMINING THE AVERAGE ANNUAL VALUE OF FLOOD DAMAGES

FIG. 1 - DISCHARGE-FREQUENCY FUNCTION

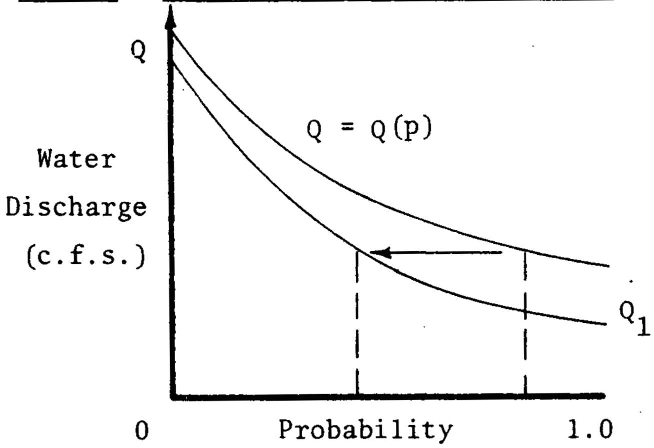


FIG. 2 - STAGE-DISCHARGE FUNCTION

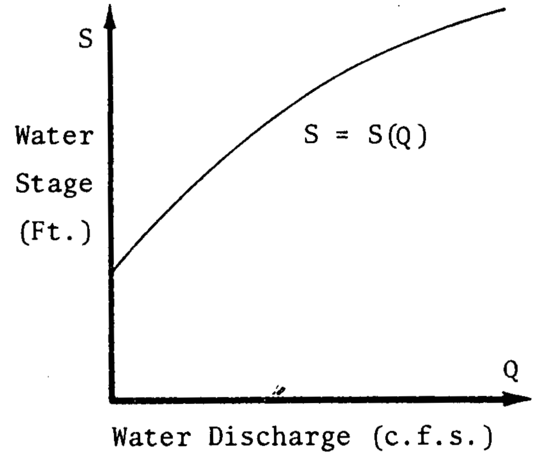


FIG. 3 - STAGE-FREQUENCY FUNCTION

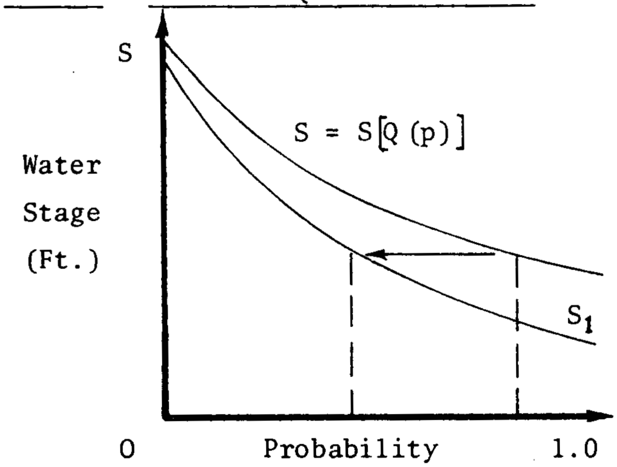


FIG. 4 - STAGE-DAMAGE FUNCTION

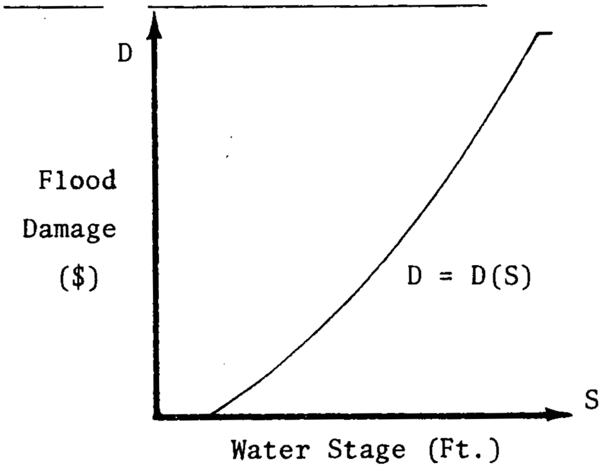
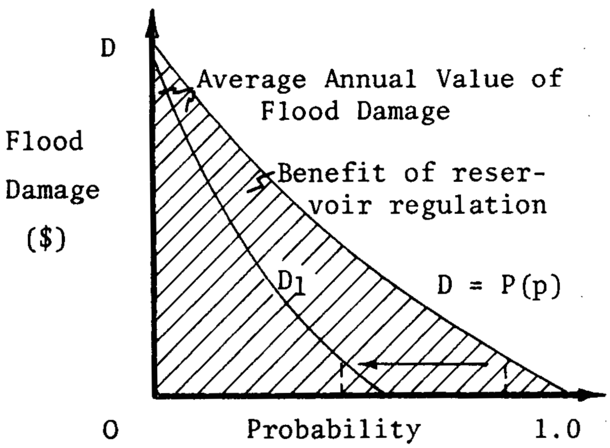


FIG. 5 - DAMAGE-FREQUENCY FUNCTION



This last equation represents the damage-frequency function shown in Figure 5. It is interpreted as defining the probability that given magnitudes of flood damage will be equalled or exceeded in any one year. The area under this curve represents the average annual value of flood damage under the assumption that no changes in floodplain activities or prices occur over time.

For this study, estimates of damages were required for a 60-year time period. Since normal growth in economic activity and relative price changes are expected to alter the structure of flood damages over this period, these factors had to be incorporated into the analysis. This was done by estimating the potential flood damage for each relevent flood and for each year under study, given projected changes in prices and economic activities on the floodplain. Thus, a stream of damages was computed for each flood for a span of sixty years. Then, the present value of these damages was calculated and summed. This gave the present worth of flood damages for each flood stage under the assumption that each stage occurs annually. By integrating the resulting "total present worth of damage-frequency" curve, the present worth of the total value of flood damages over the required sixty years was obtained.

THE BENEFITS OF PROVIDING STRUCTURAL FLOOD PROTECTION

1. RESERVOIRS

Damming a river is one of the most common structural methods of providing flood protection. Proper reservoir regulation has the effect of reducing the frequency of large floods and eliminating small ones. During peak run-off periods, only a certain rate of flow of water is allowed through a reservoir's control gates. If the inflow exceeds the permissible outflow, the reservoir's storage capacity is used to hold back the excess. As long as its capacity is not surpassed, it can effectively reduce the expected level of the water downstream by extending the peak run-off over a longer time horizon than would be the case on an uncontrolled river.

In Figures 1 and 3, a reservoir's effect on the normal size of the discharges and water levels downstream can be depicted by a leftward shift of the discharge and stage-frequency curves, from Q to Q_1 and from S to S_1 respectively. The implication of this movement is that a given discharge or stage will occur less frequently under controlled than under natural conditions.2/

The impact of the reservoir on the damage-frequency function is likewise to shift it leftward as illustrated in Figure 5. This shift can easily be traced to the movement in the stage-frequency function. The benefits that can be attributed to the reservoir in the form of a reduction of the mean annual value of flood damages are computed as the area between the D and D_1 curves.

2. LEVEES

Dykes or levees are also commonly used to reduce flood damages in an area. They function differently from reservoirs because they have no effect on the discharge or level of water reached during peak run-off periods.3/ Instead, they act directly on the stage-damage function by preventing water below certain stages from causing any damage at all.

The standard approach in dealing with levees is to examine them in terms of the maximum safe level up to which they can withstand high water. A levee is assumed to prevent all flood damages that would occur in its absence during all water stages up to this maximum safe level (U.S. Department of the Army, 1962: 36-39). Figure 6 illustrates a situation in which it is assumed that no stage up to the level associated with the probability of occurrence p_1 causes flood damage because a levee provides complete protection. All stages above this level are assumed to inflict

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2/ Alternatively, the curves may be thought of as shifting downwards. This is the traditional approach. The concept is best illustrated by the sample statement 'A reservoir has the effect of reducing the discharge of a one-in-ten flood from 600,000 cfs. to 400,000 cfs.' Since the frequency-shift concept used in the text reduces the chances of making errors in the economic analysis, it has been adopted in this report instead of the usual approach. However, the same conclusion should result from the careful application of either method.

3/ Actually, they can affect the water levels by constricting the stream and causing changes in sediment loadings. These factors are ignored in the present analysis.

damage every time they are reached. The benefits credited to the levee are assumed to be equal to the value of the shaded area under the frequency-damage curve in Figure 6.

3. COMBINING RESERVOIRS AND LEVEES

It is seldom feasible to build dykes or dams that, by themselves, supply "adequate" flood control, defined in engineering terms as "reliable" protection against a flood of a given recurrence interval (in the present study, it is classified as a 26 foot flood measured at Mission, B.C.). Consequently, structural flood prevention programs include both levee and dam construction, and problems arise in measuring and separating the benefits attributable to each.

The standard procedure for allocating benefits between upstream storage projects and levees is to distribute the benefits among individual projects according to the sequence in which they are to be built, thereby satisfying the criteria required for economic efficiency on a project-by-project basis. Usually one set of projects (i.e. levees) is taken as "given", because in most cases a prior political decision will have been made to construct several levees. All of the benefits represented by the shaded area "A" in Figure 7 are attributed to these dykes. Next, the economic impact of several reservoirs are examined in sequence.

If dykes provide some degree of protection, the impact of a new reservoir on flood damage is confined to its effect on the frequency of floods that exceed the maximum safe levels of the dykes. A reservoir can capture none of the benefits of flood prevention for water crests of less than this level even though it may have some influence on these stages.[4/] Dykes absorb all of the benefits. If this condition exists, then the correct measure of the benefits of a reservoir clearly is equal to area "B" lying between damage functions D and D_1, in Figure 7 because the reservoir has the effect of shifting the damage-frequency curve from D to D_1.

4/ As previously stated, confusion is most easily avoided at this point in the economic analysis if the impact of the reservoir is thought of as reducing the frequency of recurrence of a given flow (or amount of flood damage) rather than as reducing the level of a flow of a given frequency.

FIGURE 6

DETERMINING THE BENEFITS OF DYKING

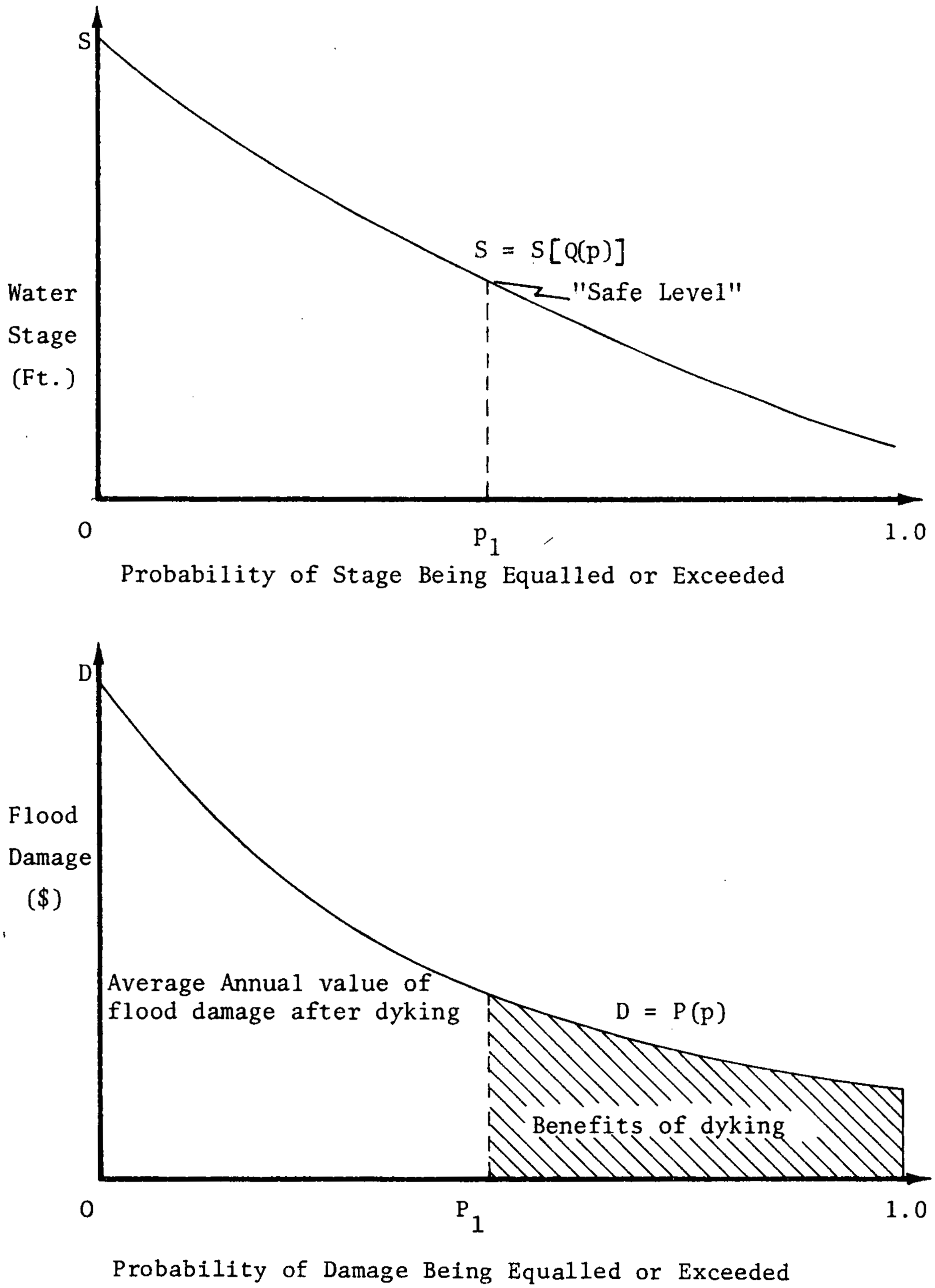
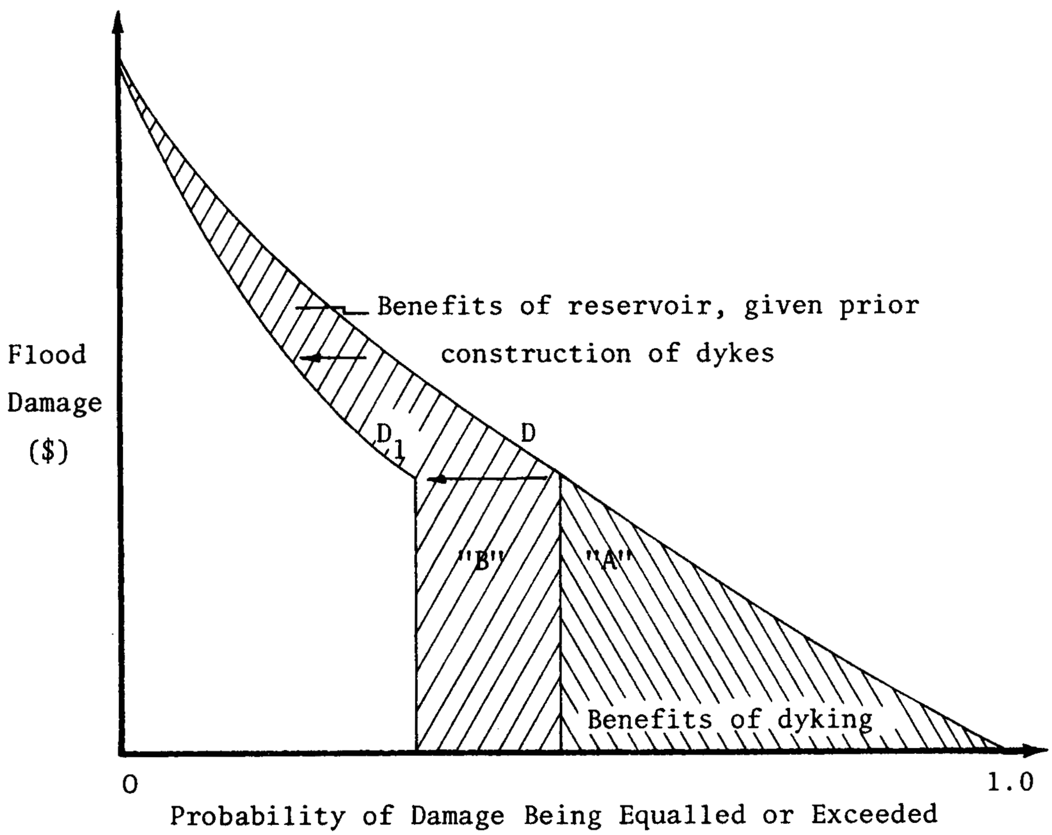


FIGURE 7

ALLOCATION OF FLOOD PROTECTION BENEFITS
BETWEEN DYKES AND DAMS



PROBLEMS AND POSSIBLE MODIFICATION OF STANDARD PROCEDURES FOR ESTIMATING AVERAGE ANNUAL VALUES OF FLOOD CONTROL BENEFITS

This section deals with the following problems and possible procedural modifications: 1) instances where computed damages are greater than actual net returns from floodplain activities; 2) the interpretation of reservoir impacts in terms of damage reductions rather than frequency reductions; 3) attempts to examine simultaneously the benefits due to a system's dykes and dams; 4) the identification of the benefits of risk aversion; 5) the interpretation of maximum "safe" levels; and 6) further procedural modifications.

(1) Attributing the average annual benefits of reducing potential flood damages to specific structures is not without difficulties. One computational problem may occur if the maximum safe level of an existing levee is below the design level of the structure. If the usual economic interpretation (see p.15) of the maximum safe level is accepted and damages predicted for each flood above this level are large, then the estimated average annual value of damages could prove greater than the annual net returns of floodplain activities, and also greater than the maximum benefit of flood protection works.5/

The size of the average annual damages becomes superfluous, since it is illogical to suppose that any economic activities would be carried on in an area where yearly damages exceeded yearly net return.

Under these conditions, the general measure of flood reduction benefits should be taken to be

$$B = (Y_i - D_i)$$

where B = the benefits of flood reduction

Yi= either the net income and payments to fixed factors of activity i (excluding hypothetical damages under present conditions) in a floodable area or the average annual estimated flood damages to activity i prior to project completion, whichever is less. If a new operation can profitably replace an unprofitable activity i even if the flood reduction program is not undertaken,

5/ For an example of such a problem, see Fraser River Board (1963: Plate 4-6).

Y_1 represents the difference between the income of activity i, exclusive of the hypothetical present damages, and the income of the new operation, inclusive of its hypothetical damages (or, again, the average damage to activity i prior to project completion).

D_i= average annual residual damages to activity i after project completion.

(2) A second common problem (mentioned earlier) arises when analysts examine shifts of damage-frequency curves in terms of reductions in damages rather than reductions in frequencies. A typical statement resulting from the first interpretation would be: "A reservoir reduces the design flood of 33 feet to a mere 31 feet. Therefore all damages that would have occurred during the floods ranging from 31 to 33 feet in the absence of any protection should be credited to reservoirs. This should be done even though dykes are upgraded to withstand floods of up to 33 feet". Obviously, since reservoirs diminish damages, not by eliminating 31 to 33 foot flood levels but by reducing their frequency of occurrence, dykes are effective in the 31 to 33 foot range and should be credited with some benefits of damage prevention in this range.

(3) A third related difficulty may occur if analysts attempt to examine a system's dykes and dams simultaneously. If this is done, there is a problem of dividing the benefits of flood protection between dykes and dams over ranges of flood levels in which both structures have some influence. The standard approach in such cases is to assign, arbitrarily, a portion of the benefits to each structure (e.g. Fraser River Board, 1963: 52). However, this method ignores the economic rationale of examining each project on the basis of its marginal contribution to the benefits and costs of the system. As indicated previously, the correct economic assessment of the benefits of a dyke built prior to a reservoir requires that the dyke be credited with the full extent of its flood reduction benefits. If the reservoir does have some positive impact, such as reducing stress on the dykes, its benefits should be measured as the value of decreasing repair costs and lengthening the dyke's economic life.

(4) A fourth and very important problem in calculating reasonable flood reduction benefits derives from the extreme risk-averting characteristics of most flood control studies. In Chapter I, it was suggested that costs of risk-taking may be legitimate and may be included in an analysis. However, reports on flood problems often adopt the objective of providing a

safe system with such single-purposed fervour that they tend to eclipse real economic considerations. They do this without explicitly recognizing the portion of estimated benefits being attributed to the costs of risk-taking. Therefore, distorted or misleading estimates of flood control benefits frequently emerge from such reports.

This failure to present a clear picture of the average annual value of damage-reduction benefits, separate from any imputed benefits of risk-aversion (and intangibles), has had some oblique recognition in the literature. For instance, comments about the significance of the design flood concept have appeared in several articles (e.g. Whipple, 1968: 1509). These articles propose that since a design flood is simply a large flood of some "infrequent" occurrence and is determined via an arbitrary engineering or political decision, it may have no relationship with the principles of marginalism adhered to in economics. Thus, levees may be too high and reservoirs too vast to satisfy economic efficiency criteria.

In the same vein, critics have noted that there is an existing risk-averting practice of topping dykes with two-to-three feet of freeboard and that the effects of this extra protection are excluded from economic analyses of dyking benefits. Since dykes have been known to withstand water levels greater than the design flood, this practice of ignoring the freeboard is purported to violate the "incremental benefit - incremental cost" criteria.[6/]

6/ This is not necessarily a valid argument. The purpose of the freeboard is partly to prevent wave action from breaking down a dyke. If it is to be brought into the economic analysis at all, it should probably be introduced in conjunction with emergency measures like flood-fighting. If flood-fighting is undertaken, the records indicate that freeboard can be used to prevent flooding from discharges greater than those for which dykes are designed.

Also, as an aside on the incremental benefit = incremental cost criterion, it should be pointed out that Whipple (1968: 1511-1513) has noted that both project engineers and their academic critics have actually failed to include residual damages of project-induced growth in their analyses of marginal benefits and costs of flood control measures. He contends that once project-induced residual damages have been incorporated into an analysis, the optimum level of protection may be higher than that indicated when these damages are excluded. Thus, he suggests that early projects that have come under attack for violating economic efficiency criteria have been criticized on an incorrect basis. He further proposes that many that were attacked for exceeding the optimal size were, on the contrary, too small to be optimal.

(5) One other standard procedure used in assessing the benefits of flood control reflects the engineers' conservative approach and obscures the meaning of the average annual value of flood damages. This procedure has escaped criticism to date, even though it has a very significant impact on the size of flood control benefits. It is the act of assigning a maximum safe level to dykes for the purpose of assessing economic gains.

The maximum "safe" level of protection offered by a dyke is determined by engineers who base their conclusion on the physical characteristics of the structure. The level coincides with what the engineers feel is the maximum water elevation the dyke can withstand virtually 100% of the time. It may be several feet below the design level of the structure.

In engineering terms, the maximum safe level is a meaningful statistic. However, when it is translated directly into economic analyses with no modifications, a large bias is injected into the assessment of flood control benefits. The distortion in the economic analysis exists because there is a great difference between the maximum safe and maximum possible level of protection offered by a dyke. Engineers do not expect flooding to occur every time a river exceeds the maximum safe level. Moreover, historical records show that water stages often rise above this level with no resultant flooding. The maximum safe level simply marks the point at which flooding becomes possible. Nevertheless, traditionally the economic interpretation of this engineering datum is based on the implicit assumption that dykes will fail every time the safe level is exceeded. The potential for over-stating the average annual value of flood damages is obvious.

(6) The standard procedure for estimating the mean annual value of flood damage clearly fails to give reliable results when a set of dykes exists in a system. It is not enough to consider stage-frequency functions as the sole basis for constructing frequency-damage curves under such circumstances. Alterations must be made if realistic assessments are desired.

One way of introducing realism into economic analyses of such flood prevention problems is to establish a subjective probability distribution for dyke failure as a function of water stage. This method is best illustrated by example. Figure 8 shows how the technique might be applied to existing dykes in the Lower Fraser. In this figure, the 20 foot level is taken to be the maximum safe level of the existing dykes; there is zero probability of failure at this point. The 25 foot level is assumed to be the maximum possible level of protection offered by the dykes; at this extreme, the probability of failure is 1.0. Probabilities of failure are also associated with intervening stages and it is here that a subjective appraisal of the dykes must be made.[7/] The resulting subjective failure-probability path between the two extremes (0.0 and 1.0) may be concave, linear or convex. In Figure 8 it is assumed to be linear (Path A); in contrast, standard techniques imply that its shape is discontinuously convex downwards (Path B), the most conservative path possible.

By combining "Stage-probability of failure" Path A with the hypothetical stage-damage function[8/] of Figure 9 (developed for illustrative purposes only), a stage-expected damage curve can be constructed (Figure 10). This function describes the expected value of damages for every water stage greater than 20 feet in elevation. ("Expected value" is used loosely here to mean the estimated average value of damage that occurs each time a given water stage is reached.)

Once this intermediate step is taken, the resulting function can be combined with the previously constructed stage-frequency function to obtain an expected damage-frequency function (Function D_1 in Figure 11). The area under this curve, in contrast to the area under the standard curve (Function D_2 in Figure 11), represents the best estimate of the average annual value of the measurable economic benefits that could accrue to flood prevention structures (under the assumption that dyke-failure path "A" is more accurate than "B").

Although hypothetical, Figure 11 clearly illustrates the possibility of distorting flood damage estimates. The premium placed on "risk-taking" and "intangibles" in flood control studies is seen to be potentially large (150% greater than the actual average annual damages in Figure 11). Since such significant quantities may be involved, this premium cannot be ignored in a flood control program that attempts to portray its benefits realistically.

7/ The duration of flooding and its effect on under-seepage are two factors that would have to be considered when the probability distribution is being determined.

8/ Which effectively assumes no dyke protection above 20 feet.

FIGURE 8

POSSIBLE "STAGE-PROBABILITY OF FAILURE PATH" OF DYKES IN THE FRASER VALLEY

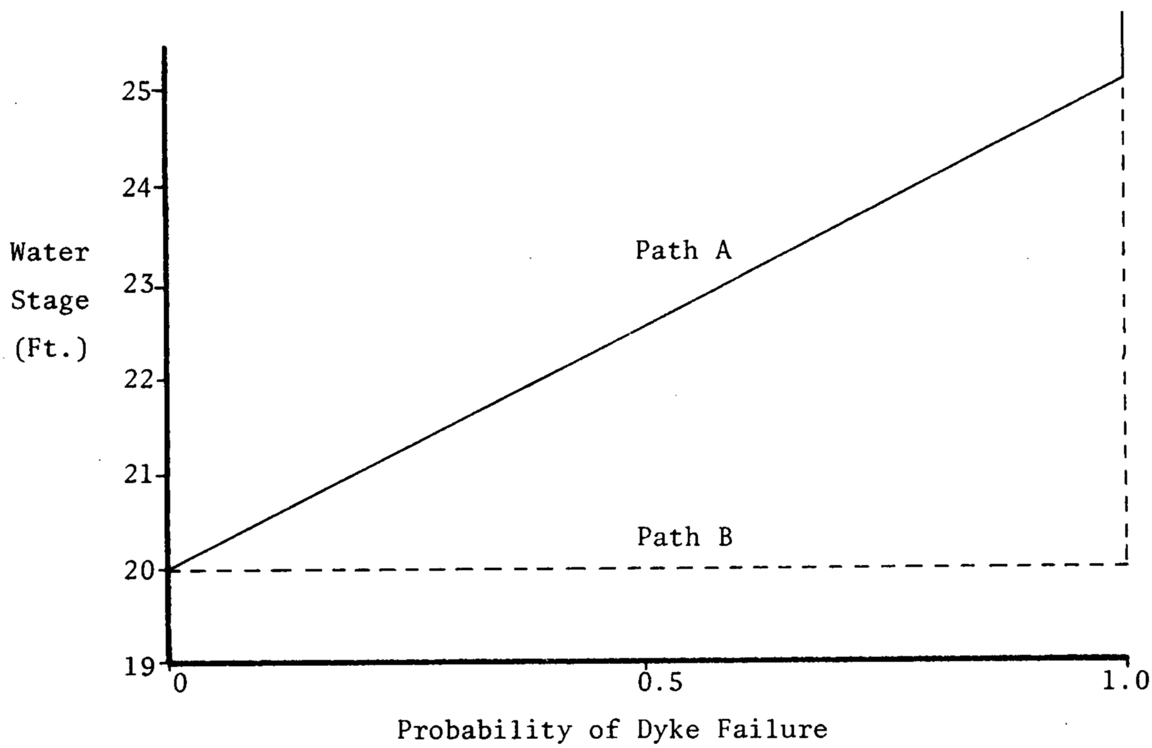


FIGURE 9

HYPOTHETICAL STAGE-DAMAGE FUNCTION REPRESENTING
DAMAGE DURING FRASER RIVER FLOODS

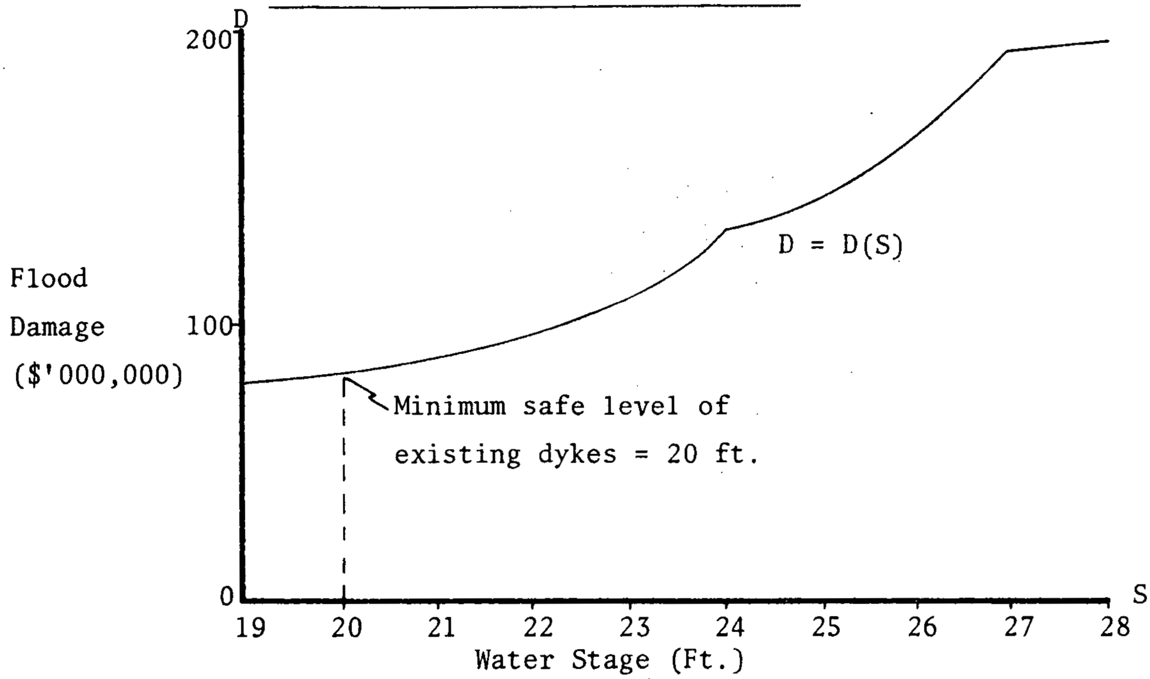


FIGURE 10

STAGE-EXPECTED DAMAGE FUNCTION DEVELOPED
BY APPLYING FAILURE-PROBABILITY PATH "A"
OF FIGURE 8 TO FIGURE 9

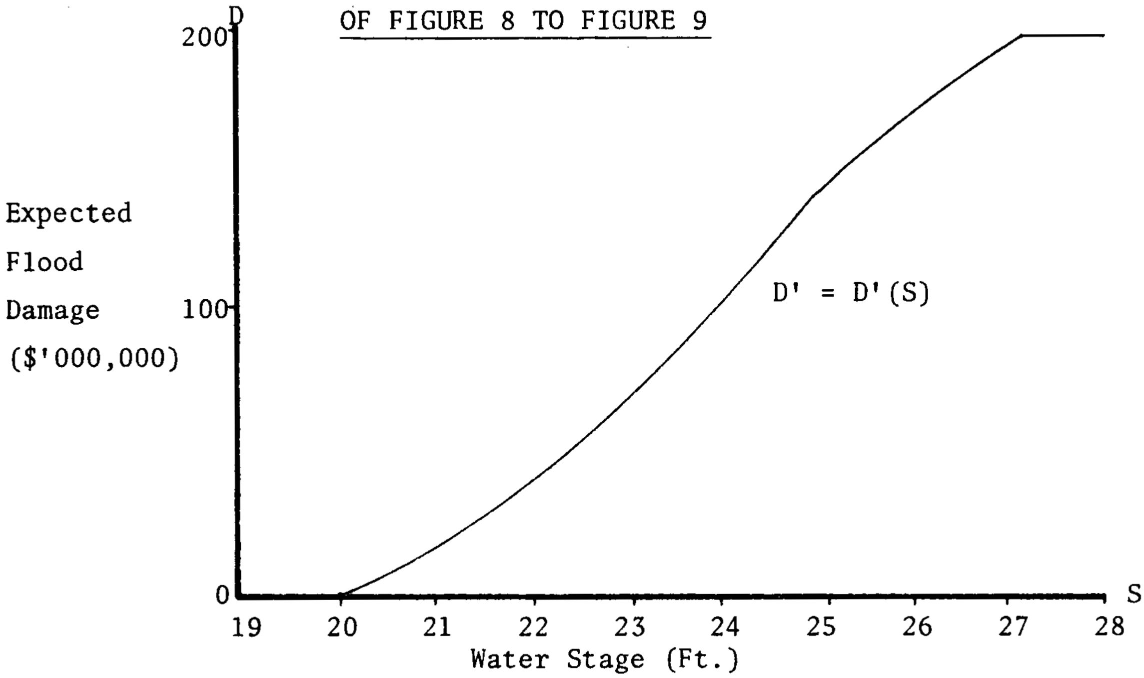
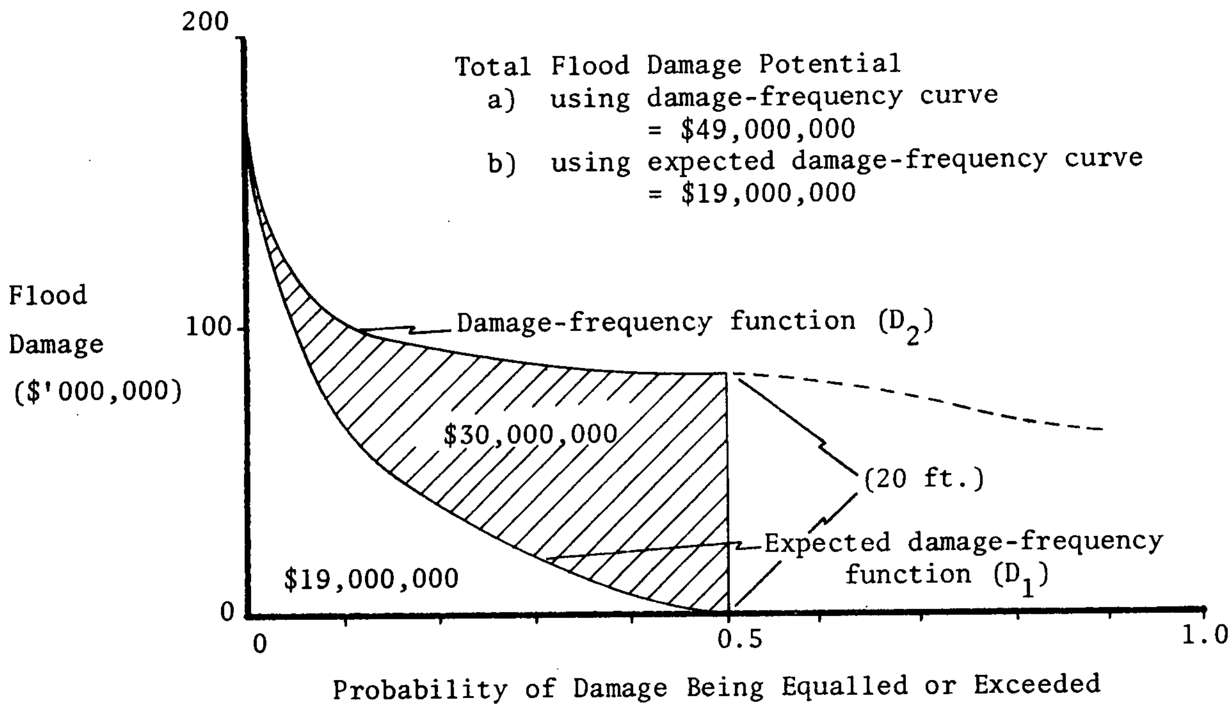


FIGURE 11

DAMAGE-FREQUENCY VS. EXPECTED DAMAGE-FREQUENCY FUNCTION

BASED ON HYPOTHETICAL STAGE-DAMAGE FUNCTIONS

OF FIGURES 9 AND 10



PRESENT STUDY'S METHOD OF COMPUTING AVERAGE ANNUAL VALUES

The Fraser River Program Committee (1971), aware of the possible distortions linked to the average annual value measure, attempted to modify the standard procedures used in damage-prevention studies. Initially, it considered estimating probabilities of failure for both existing dykes and proposed improved structures. However, after investigating the problem, the Committee decided that more meaningful results could be obtained if the benefit estimates were based on a "confidence level" criterion. It therefore identified levels up to which it considered confidence could be placed in existing and up-graded dykes.

These levels are not "maximum safe levels" in pure engineering terms. Rather, they represent the high water stages at which dyke patrols are accelerated, equipment is committed for emergency action, and concern about dyke stability emerges. They are not "safe" levels because there is some chance of dyke failure during lower water elevations. They are merely rough indicators of the stages at which dykes stop providing fairly reliable protection.

With this concept as a base, the Committee adopted the economically rational procedure of allocating flood control benefits among dykes and several proposed upstream storage reservoirs on a "first added" basis. The mechanics of this process have been covered in previous examples. However, to clarify the specific steps adopted, a final, complete interpretation of the Committee's decision is presented in Figures 12 and 13.

Existing dykes are credited with all benefits derived from preventing floods during peak water elevations lower than the established confidence levels (which range between 21 and 23 feet at Mission). These benefits are represented by area A_1 in Figures 12 and 13. Existing reservoirs are then allotted the flood reduction benefits shown as area A_2 in the figures. The damage-frequency function on which the present study is based is therefore D_3, rather than D_1, as it would be under natural flow conditions.[9/]

9/ As noted earlier, the acceptance of maximum safe levels (or, in this case, confidence levels) associated with water elevations that recur frequently creates problems of measurement of flood control benefits if damage-frequency functions are used. These problems are not

FIGURE 12

VALUE OF FLOOD CONTROL BENEFITS CALCULATED
USING CURRENT FRASER STUDY ALLOCATION PROCEDURES
(DYKES FIRST ADDED)

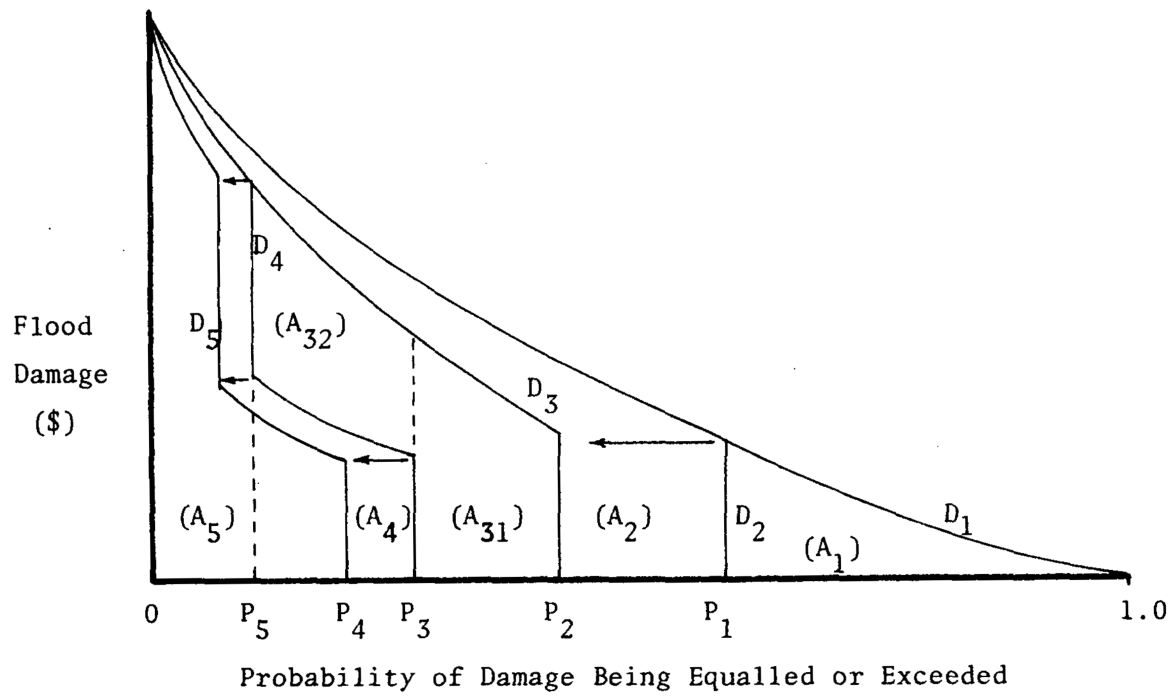


FIGURE 13

VALUE OF FLOOD CONTROL BENEFITS CALCULATED
USING CURRENT FRASER STUDY ALLOCATION PROCEDURES
(RESERVOIRS FIRST ADDED)

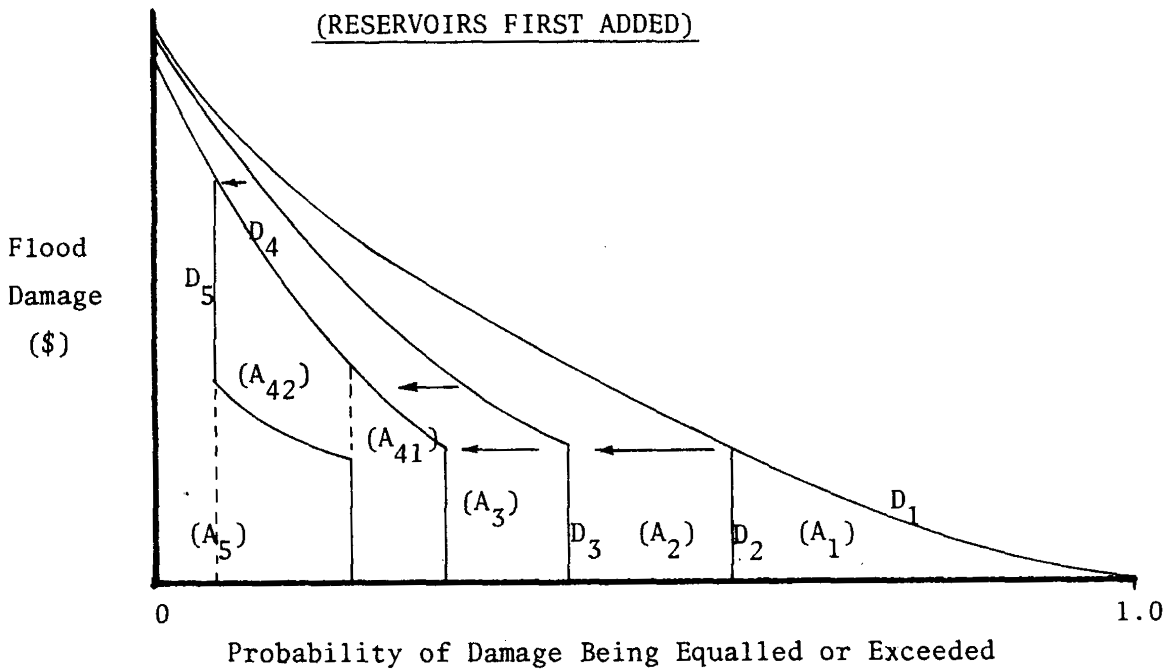


Figure 12 illustrates how benefits are credited to improved dykes and dams if dyke improvements precede reservoir construction. Upgraded dykes supply full protection against all water stages less than 24 feet (i.e. with a probability of occurrence of P_3 under the existing partially controlled river regime). All benefits between P_2 and P_3 are therefore attributed to these dykes (area A_{31} in Figure 12). However, there is some probability that improved dykes will fail if water levels rise to between 24 and 26 feet. Thus, it is assumed that dykes can be credited with only 50% of the benefits of preventing all damages that could occur in flows with probabilities ranging between P_3 and P_5 under the existing river regime. The damage-prevention benefits of the dykes in this range therefore are represented by Area A_{32} in Figure 12; the total benefits of improved dykes are A_{31} plus A_{32}.

The residual damages lying under the new damage function D_4 can be reduced by and credited to upstream storage projects. The impact of the storage projects is to shift D_4 leftwards as is illustrated by the movement of D_4 to D_5 in Figure 12. The damage-reduction benefits that result from this shift are represented by Area A_4.

If reservoirs precede dyke construction, the allocation of flood control benefits between dykes and dams changes. Reservoirs will shift D_3 leftwards to D_4 in Figure 13 and capture damage-reduction benefits equal to A_3. Dyke improvements are then introduced to decrease the size of the residual damages lying under the curve D_4. The benefits attributed to

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9/ (continued) insurmountable as long as the fact that there is a ceiling on the size of the potential damages is brought into the analysis. As stated previously, this ceiling is equal to the value of net incomes and payments to fixed factors that will be lost if the areas must be abandoned for lack of flood protection. In Figure 12, it is assumed that even under natural flow conditions, flooding is not serious or frequent enough to prevent occupation of the floodplain.

In the assessment of reservoirs in the present study, assumptions of frequent floodings posed few problems. The question of a "ceiling" on the benefits did not arise for Lower Fraser areas because a decision was made in 1972 to upgrade all mainstem Lower Fraser dykes. (It should be noted that "ceilings" for individual dyking areas were too high to affect the decision to upgrade the dykes.) In Upper Fraser and Thompson areas, flood frequencies and damages were not large enough to necessitate the introduction of a limit on the size of the benefits.

these dykes are calculated following the same criterion described in the preceding paragraph and are equal to area A_{41} plus A_{42} in Figure 13. In this case, the final residual dykes is represented by Function D_5 (which is the same as D_5 in Figure 12)[10/]

Because a decision was made in 1972 to build most mainstem Lower Fraser dykes, the question of risk-reduction benefits being attributed to up-graded dykes under the Committee's allocation procedure is now irrelevant. However, risk-reduction benefits may be a significant part of the damage-prevention benefits credited to reservoirs under the Committee's procedure. Most of these benefits are based on the assumption that Lower Fraser dykes will be up-graded before dams are constructed. Therefore, it is important to examine the impact of the Committee's assumption about the potential damage that can be prevented by upstream storage regulation, given that dyke improvements precede reservoir construction.

To facilitate the analysis, it is useful to describe the Committee's criterion in terms of "failure-probability paths". In this context, Figure 14 illustrates several possible "stage-probability of failure paths" of up-graded dykes. Path A depicts the Committee's

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10/ One anomaly in the computation of average annual damages in the present study should be noted. Two municipalities in the Lower Fraser (Richmond and Delta) are subject to both tidal and river influences. Each has sea and river dykes and each is cut by Highway 499. This highway would act as a partial dyke protecting the western part of these municipalities if river dykes fail during peak run-offs of 24 feet (Mission) or less. Therefore flood depths (and damages) would be lower than would be the case if this obstruction were non-existent. Because of the unpredictability of factors such as the point during the tidal cycle at which the dyke would break, the speed of dyke repair, and the duration of flooding, it was impossible to determine the exact impact of the highway on flood damages. However, to account for the highway's mitigating effects, western areas were assumed to suffer only half of the damages that would occur if there were no obstruction to water elevations of 24 feet or less.

decision to credit the dykes with 50% of the benefits of preventing damages that could occur during water levels ranging between 24 and 26 feet.[11/] This is likely a conservative estimate of dyking benefits. Path B represents the lowest probability of failure path possible. It rests on the assumption that dykes will withstand all water levels for which they are designed (i.e., all levels up to 26 feet). Paths A and B represent two extremes. Paths C and D are simply hypothetical, intermediate possibilities.

These failure-probability paths must be combined with potential stage-damage functions of the Fraser to determine the risk-reduction portion of the damage-prevention benefits derived using Committee procedures. Appendix H.9 summarizes the Lower Fraser damages computed for 1971 on the basis of the methods presented in Chapters III through VII. These damages are coupled with stage-frequency data and the failure-probability paths of Figure 14. The expected damage-frequency functions of Figure 15 result.

11/ It should be noted that Path A is only one of many possible interpretations of the Committee's decision. The path could be any shape that conforms to the following constraints:
(1) $0 \leq p^*$ at 24 feet ≤ 0.5; (2) $0.5 \leq p^*$ at 26 feet ≤ 1.0;
(3) p^* at 24 feet $\leq p^*$ between 24 and 26 feet $\leq p^*$ at 26 feet;
(4) p^* between 24 and 26 feet is such that area A_{32} in Figure 12 = ½ area under D_3 between P_3 and P_5 (where p^* = probability of failure).

The shape of the selected path has no effect on the benefits allocated to dykes (given the constraints) and no significant impact on the benefits attributable to specific reservoirs. Moreover, if probabilities of failure such as "0" at 24 feet and "1.0" at 26 feet had been assumed, then p^* at 25 feet would have had to be calculated separately for each dyking area as a function of the individual damage-frequency curves. Therefore, the simplest and most practical interpretation of the Committee's decision was to make $p^* = 0.5$ at all three levels.

As an alternative way of recognizing the possibility of dyke failure, the Committee could have assumed probabilities of failure to be 0.0, 0.5 and 1.0 at 24, 25 and 26 feet respectively, and eliminated the fourth constraint listed above. Had this approach been adopted, the resulting estimates of damages and reservoir benefits would have been about 7% lower than those obtained using the criteria established by the Committee.

FIGURE 14

POSSIBLE "STAGE-PROBABILITY OF FAILURE PATHS"
OF UP-GRADED LOWER FRASER DYKES

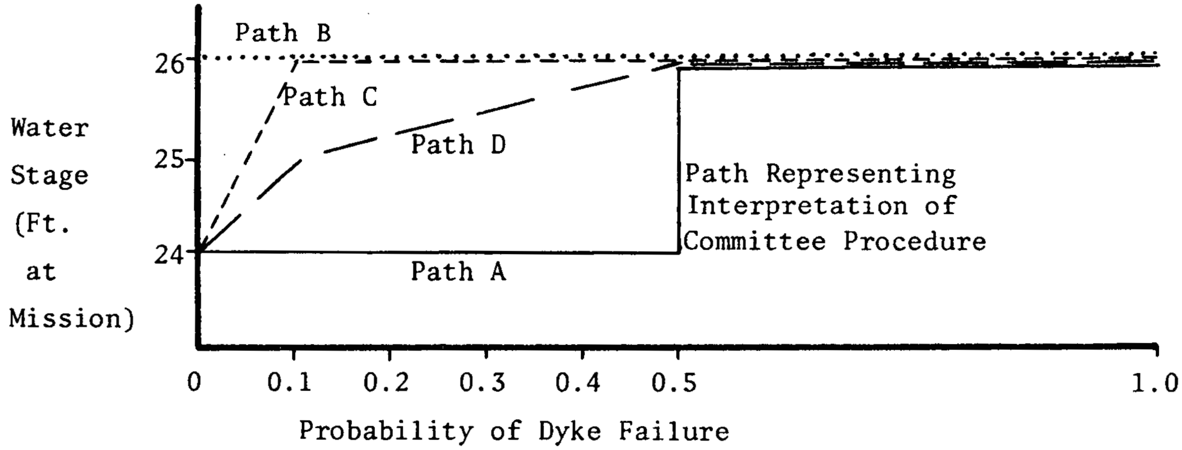


FIGURE 15

POSSIBLE RESIDUAL EXPECTED DAMAGE-FREQUENCY FUNCTIONS
SUBSEQUENT TO UP-GRADING OF LOWER FRASER DYKES

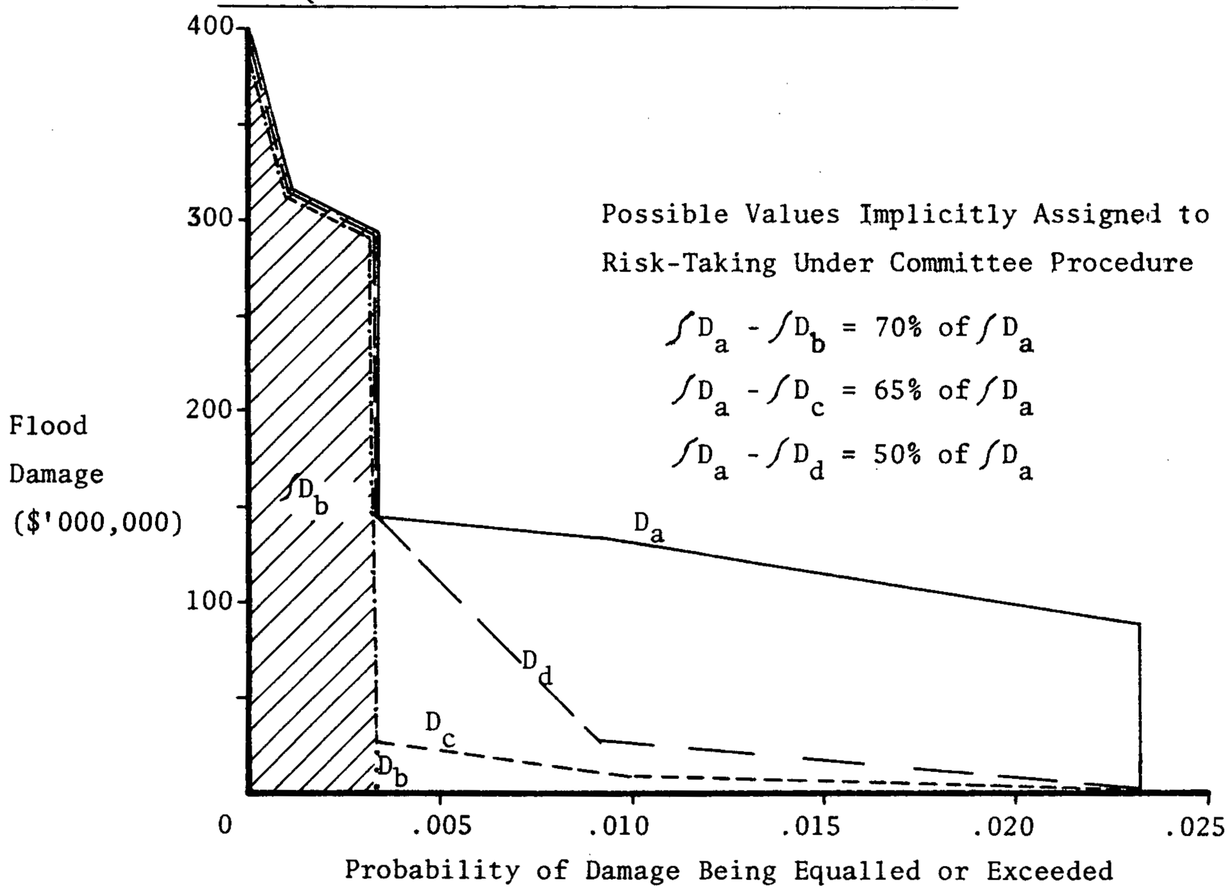


Figure 15 illustrates the size of risk-reduction benefits that could be hidden in the estimates of annual flood damages in the present study. Actual potential property and income losses may be as small as the area under D_b. The Committee estimate is equal to the area under D_a.[12/] The difference between the two represents the maximum likely value implicitly attributed to risk-taking under the Committee procedure.

Since no growth has been incorporated into Figure 15, the absolute values of the average annual damages are not very meaningful. The significance of Figure 15 is that it shows that up to 70% of the residual damages assumed reducible by reservoirs may consist of costs of risk-taking and intangibles. This means that as little as $0.30 out of every dollar of average annual residual flood damages predicted in this study represents actual potential property and income losses.

Unfortunately, nothing can be said about the validity of the remaining $0.70. This figure is based on a physical criterion that may be unrelated to the true value people place on risk-taking and intangibles. However, the explicit separation and identification of the two components of average annual damages is critical. It enables decision-makers to recognize the maximum possible relative weight being assigned to risk-taking and intangibles in the final damage estimate. Therefore, it should provide them with a better understanding upon which they can base a decision.

SUMMARY

One of the most important determinants of the size of potential flood damage estimates is the procedure used to calculate the average annual value of flood damages. The average value of flood damages represents the weighted mean of a specific distribution of potential losses. This distribution defines the statistical probabilities of various magnitudes of flood losses that could occur in any one year for a given state of economic development.

12/ D_b is the expected damage-frequency curve derived from failure-probability Path B. D_a is based on Path A.

Both the average value measure and its underlying probability distribution are susceptible to gross distortions that occur when hydrologic data and engineering criteria, upon which the measure is based, are translated literally into economic terms. Standard procedures fail to acknowledge any difficulties in the translation and have, consequently, led to peculiar results in past reports.

A study of the Fraser River Basin is particularly complex in this aspect because of the river's extensive dyking system. Problems arise when predictions of frequencies of flooding in the Fraser's dyked areas are made. Engineers tend to approach dykes in terms of their maximum safe levels of protection. However, if this tactic is adopted by economists, biased answers emerge. Thus, meaningful estimates of the potential economic impact of floods in a dyked region must be based on some other criterion.

Estimates of potential average annual flood damages in this study rest on a modified version of traditional methods. One modification is that "confidence levels" instead of "maximum safe levels" were assigned to dykes. Another is that each project's damage-reduction benefits were examined on a "first added" basis and arbitrary divisions of benefits among projects were avoided. Still another is that the value assigned to risk-taking and intangibles, implicit in most analyses of flood reduction benefits, was identified explicitly in this analysis.

CONCLUSION

There are many serious problems inherent in analyses of flood control benefits based on the average annual value of damages derived from damage-frequency curves. The method used in the present Fraser Study, although incorporating a potentially large premium for risk and intangibles, is superior to traditional procedures.

This method represents a positive step towards providing realistic estimates of flood control benefits because it allows for a partial blending of economic and engineering criteria. The explicit recognition of the premium placed on risk-taking and intangibles is, in itself, an asset. However, the technique used in this study does not completely eliminate the bias found in most flood control studies. Consequently the existence of the bias must be considered both when methods of assessing damage in the field are being selected and when a decision to accept or reject a proposed project is being made.

PART II

ESTIMATING STAGE-DAMAGE FUNCTIONS

CHAPTER III

ESTIMATING RESIDENTIAL FLOOD DAMAGE

INTRODUCTION

Studies of potential flood damages normally divide residential losses into two components: structural and content damages. Estimates of structural damages are more reliable because there is greater uniformity in the design of houses than in their contents. Nevertheless, most analyses develop unit stage-damage functions for both the contents and structures of houses.

Previous studies have shown residential losses to be highly predictable. This conclusion has been illustrated both in theoretical studies which derived synthetic stage-damage functions for individual houses (White: 1964; Acres: 1968) and in empirical analyses which established linear damage functions on the basis of data collected in the wake of actual floods (Stanford Research Institute: 1960).

The predictability of residential flood losses is particularly important in an analysis of potential damages in the Fraser River Basin. An examination of the data collected for the 1963 Fraser River Report revealed that, in the event of a major flood, residential property losses would make up the most significant portion of total flood damages. It showed that, if there were no river dykes, residential losses would account for approximately 45% of the primary damage likely to occur during a 24-foot flood stage (measured at Mission). Consequently it was considered essential to develop an accurate method for estimating residential damages.

This chapter describes the development of synthetic unit stage-damage functions for high, medium and low quality houses in the Fraser Basin. It outlines the method used to combine these unit-damage functions with variations in structural housing characteristics and flood depths and estimate potential damages for different areas throughout the basin.

GENERAL METHODOLOGY

The original Fraser River Study (Fraser River Board: 1963) based its estimates of residential damage on an assumed "average house" with a single story, no basement, a market value of $7,000[1/] and a main floor elevation of two feet above ground level. The study further developed its stage-damage curves with information from the Winnipeg Flood Cost-Benefit Report (Royal Commission: 1958) which had presented graphs expressing real and personal property damage as a percentage of the equalized assessed values of buildings.

As a first attempt at estimating residential damage, this approach was adequate. However, it was too general to give the level of precision required in the present study and had to be revised.

While the 1963 study established its description of an "average house" largely on the basis of professional opinion, the present research team constructed models of "average houses" by using sound statistical data. House types in the British Columbia Appraisal Manual were grouped into three classes (A, B, and C), primarily according to their value per square foot (Appendix A.2). Then, for the "average" house in each class, component stage-damage curves were derived from information on house characteristics obtained from assessment rolls and field surveys.

The mix of house classes in given areas on the floodplain and the average value of houses in each class were obtained by taking a random sample from assessment rolls of two separate areas of the floodplain: Richmond Municipality and Chilliwack City and Chilliwhack District Municipalities. These areas were selected because they contain about 90% of the houses on the floodplain and account for most house types found in the Fraser River Basin. By sampling both areas, it was possible to construct models capable of describing major variations in house types throughout the study area.

1/ Excluding land value.

STRUCTURAL DAMAGE ESTIMATES

A series of reports on structural flood damage provided the background required for establishing a method for estimating residential losses. Two major studies were particularly useful: the Royal Commission on Flood Cost-Benefit (1958) and the more recent Guidelines to Analysis, Vol. 2: Flood Damages (Acres Ltd.: 1968). Unfortunately, there were large unexplained discrepancies between the reports and no basis existed for deciding which was more relevant to the Fraser River area. Consequently, a new study was undertaken to determine the probable stage-damage relationships for Fraser Valley dwellings.

Initially, all data on potential structural damage were to be obtained from a random field sample of houses from each class. However, because assessment rolls contained all the required information on housing characteristics except elevations of main floors above ground level, and because a larger, more accurate sample could be taken from these rolls than in the field, the survey approach was abandoned. Eventually, only data on ground floor elevations were collected in the field.

Estimates of standard unit costs of replacing and/or repairing high, medium and low quality flood damaged material were obtained from the Federal Department of Public Works. Although this department, with its wide access to information on construction costs, was thought to be the most reliable source of such data, its estimates were checked against information from the Appraisal Manual of British Columbia and from a number of firms contacted about specific items (Appendix A.1). Because the results of the spot-checks compared favourably with the figures provided by Public Works, the latter were modified only slightly (Appendix A.3)[2/] before being combined with information on A, B and C class house characteristics to determine stage-damage relationships.

2/ Note that no depreciation rates were applied to obtain these figures. Only in the case of paint damage could a depreciation rate have been justified and the inclusion of such a rate would have had an insignificant effect on the total structural damage estimate.

Damage relationships were established for three house classes to enable the development of typical unit residential stage-damage functions for all distinct areas on the basis of the proportions of such houses in each area. These functions could have been developed in several ways. One method considered in this analysis involved the following operations: 1) calculating exterior and interior basement and main floor damage per foot of flooding for each sample house; 2) finding the average "per foot" damage for the main floor and basement of all houses within each class; 3) combining the stage-damage curves of the main floors and basements into a composite stage-damage function for each house class in each dyking area; 4) constructing a stage-damage curve of the "typical" house in each area by taking a weighted average of the functions developed for the three house types.

Because this procedure required an excessive number of calculations, a simplified system was adopted in the present study. Before any damage was estimated, the structural characteristics of houses in each class were determined. The first step was to calculate average perimeters, areas of floor and walls, heights of main floors above ground level, and lengths of interior walls. The second was to establish the percentage of A, B and C class houses made of specific materials.[3/] Once derived, this information was combined with the unit-damage estimates provided by Public Works to form stage-damage functions for exteriors, main floor interiors and basements of houses in each of the three classes.

Two exterior damage functions were developed for each house class because exterior damages were found to vary with the heights of main floors above ground level and with the percentage of houses having basements. One function was based on the sample of houses taken in Richmond and the other, on the sample taken in Chilliwack. The two functions were used to represent potential damages in all areas in the Fraser Valley. The selection of a particular function for a given area depended upon whether an area's houses were similar to those in Richmond or to those in Chilliwack.

3/ For instance, it was found that 60% of the B class houses have plaster walls and 40% have gyproc; 12% have wall-to-wall carpeting, 36% have hardwood flooring, 29% are tiled and 23% have fir flooring. Hence, it was possible to describe an "average" house as being 60% plaster and 40% gyproc, etc.

Appendix A.4 shows the characteristics of A, B and C class houses and the computations used to determine their damage functions. The final stage-damage functions for main floors, basements and exteriors are illustrated in Appendices A.4.1.3, A.4.2.3 and A.4.3.3.

CONTENT DAMAGE ESTIMATES

A large field sample would be the most reliable source of data on which to base a description of the average contents (and subsequently, flood damage) of typical A, B and C class houses. However, because a sample would require the use of more resources than were available for the present study, the information had to be acquired through secondary sources.

An attempt was made to obtain a description of house furnishings from the records of the Canadian Underwriters Adjustment Bureau. However, the Bureau[4/] in Vancouver advised that rather than keep detailed records on furnishings for insurance purposes, the Bureau simply assessed the value of the contents of a residence at 40% of the market cost of the building (excluding the property). Since this figure proved to be the only indication of the value (and characteristics) of house contents available, it was used in the present study as a basis from which unit stage-damage functions for house contents could be determined.

Damage to basement contents was assumed to be 10% of the total value of the furnishings of each house. Estimates in the Acres Report (1968) ranged from 7% for "B" and "C" class houses to 20% for "A". However, since "A" class houses on the floodplain are rare, the present study has ignored the possible differences that might exist between houses of different classes. Moreover, because basements tend to have old or discarded furnishings and, because their contents can often be moved upstairs in an emergency, the 10% selected for this report was considered to be a generous figure.

4/ Personal communication

The only other information needed to estimate unit stage-damage functions was obtained from a report on the Squamish River flood problem (Engineering Division: 1967). Figure 16 illustrates that report's estimate of potential damage at various flood depths expressed as a percentage of total content value.5/ This percentage distribution was applied to the previously calculated value of furnishings on main floors and in basements to determine the content damages outlined in Appendix A.5

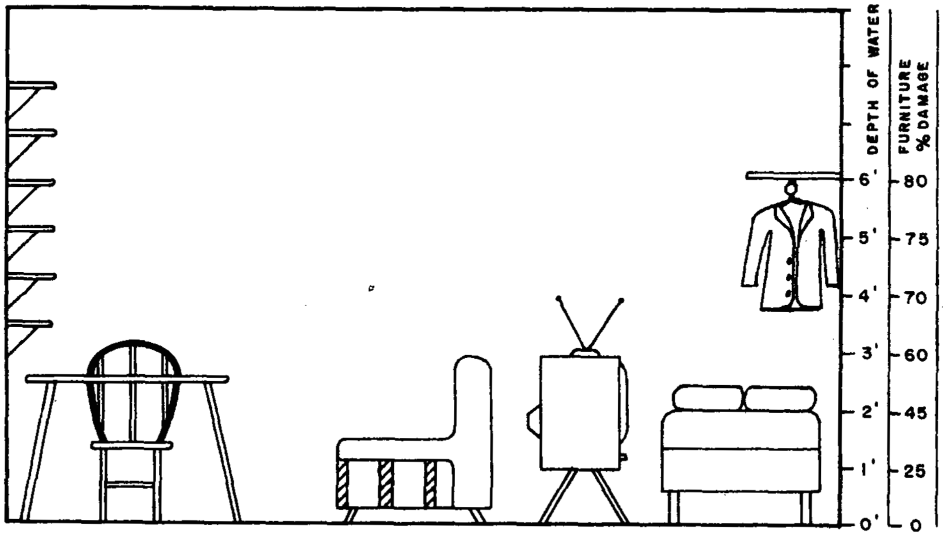


FIGURE 16

POTENTIAL CONTENT DAMAGE EXPRESSED AS PERCENTAGE OF TOTAL CONTENT VALUE

COMBINED STRUCTURAL AND CONTENT DAMAGE

Total structural and content damages estimated for main floors and basements (Appendix A.6) were combined with exterior damage functions (Appendix A.4.2.3(3)) to determine total stage-damage functions for each house class in 22 areas in the Lower Fraser Valley (Appendix A.7.1 and Figure 1 in Appendix A.7).6/ The functions calculated for each house class differed among areas solely because of differences in average heights of main floors above ground level, in the percentage of houses with basements, and in exterior damage functions (Appendix A.7.2).

5/ A similar distribution of content damage was used in the Winnipeg (Royal Commission: 1958) and Fraser River (Robertson: 1963, Dwg. 4433-G) benefit studies.

6/ Housing characteristics and unit stage-damage functions were also determined for 10 areas in Kamloops, Prince George and Quesnel in the upstream reaches of the Fraser system (Figures 2, 3 and 4 in Appendix A.7 and Appendices A.8.1 and A.8.2).

Ultimately, a single unit stage-damage function was developed for each of the 22 areas by combining stage-damage functions of A, B and C class houses weighted according to the numerical importance of these houses in each area (Appendix A.7.2).[7/]

DETERMINING FLOOD DEPTHS

Time and money constraints made it impossible to determine the exact elevation and potential flood depth of every floodplain dwelling. Consequently, specific elevations and flood depths were identified for individual houses only in lightly populated areas. In highly urbanized areas, an averaging technique was adopted as the best way of approximating these data. This technique was effective because it enabled the computation of reasonably consistent and accurate results, eliminated inconsistencies in flood depth estimates that could have resulted from speculation about the level of flooding at each house, and speeded up the process of tabulating the number of residences affected by various flood depths.

In lightly populated areas, flood depths for individual houses were established for various potential floods by subtracting the elevation of each house from anticipated flood elevations. Land elevations were obtained from air photographs containing spot heights, and flood levels, from maps[8/] containing one foot contour lines representing water surface elevations that would occur during various floods (Figure 17b).

In heavily populated areas, several adjustments were made to the basic data before flood depths were determined. First, all spot heights taken from air photographs were rounded to the nearest foot and transferred to overlays. "Zones" of equal land elevation were then outlined on the overlays (Figure 17a). Secondly, average elevations between consecutive one foot water surface contours (Figure 17b) were computed and bands of

7/ The proportions of A, B and C class houses were determined through assessment rolls in Richmond and Chilliwack and in the field in all other areas.

8/ Supplied by the Engineering Division, Water Planning and Management Branch, Department of the Environment.

"equal" flood elevations were drawn on the water surface maps supplied by the Engineering Division (Figure 17c). Thirdly, these bands were transferred to the overlays containing the outlines of zones of "equal" land elevations so that areas of "equal" flood depth could be determined by comparing bands with zones (Figure 17d)[9/] Finally, these areas were drawn on enlarged 1969 air photographs (scale 1:6,000). This made it possible to identify quickly the range of flood depths to which houses would be subjected and enabled the enumeration of dwellings flooded to each depth.

Although the averaging technique used in the present study is adequate for residential areas like those in the Fraser Valley which have relatively uniform distributions of houses, an alternative method should be used in areas which do not have uniform distributions. One such method is to draw topographic and water surface contour lines on a common map or photo (Figure 18b). By marking flood depths at the points of intersection of the two types of lines and contouring the resulting map of "spot" depths, it is possible to create a flood depth map (Figure 18c). Then, if every house lying within any given contour interval on this map is assumed to be flooded by the average flood depth for that interval and if the map contains one foot intervals, there will be less than six inches difference between the true flood depths and the averages computed using this method.

CALCULATING TOTAL POTENTIAL RESIDENTIAL DAMAGES

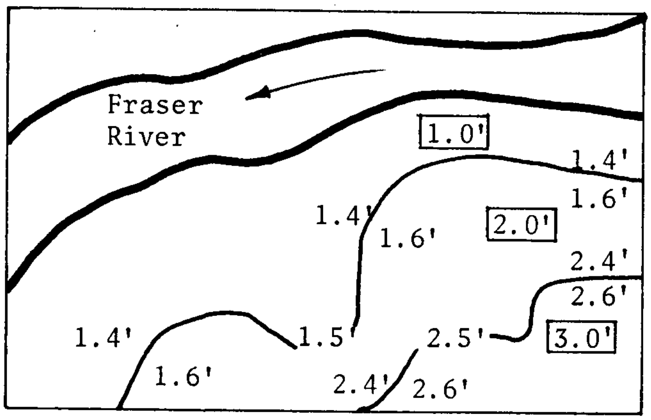
Once the depth of flooding was determined for every house on the floodplain, it was possible to combine this information with the unit stage-damage functions developed for selected areas. This procedure provided an estimate of the total residential damages each selected area would suffer during floods of various magnitudes (Appendix H.1).

9/ This procedure enables the estimation of flood depths accurate to within one foot of true flood depths (if spot heights and water surface contours are accurate).

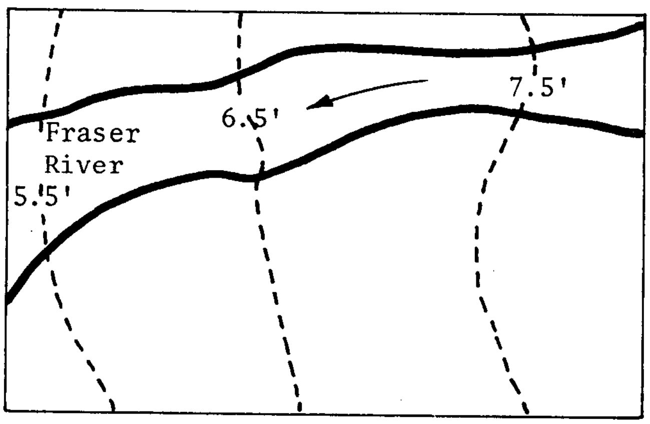
FIGURE 17

STEPS IN ESTABLISHING AVERAGE DEPTHS OF FLOODING

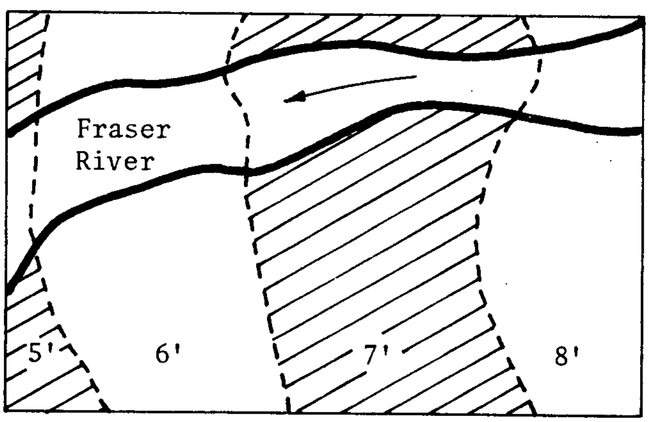
FOR A FLOOD OF A GIVEN FREQUENCY



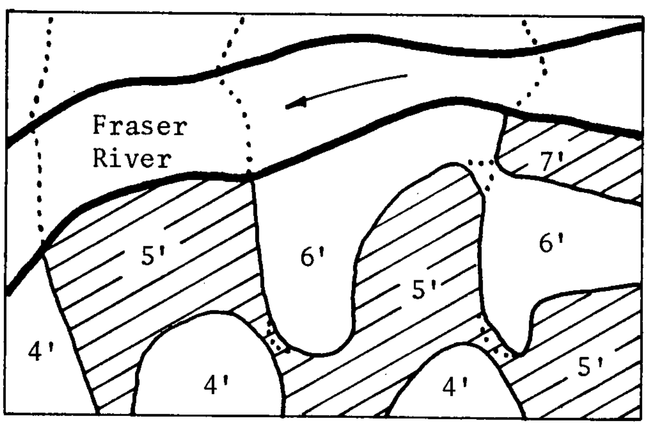
17a. Sample map showing an area for which three "bands" of "equal" elevation are derived from spot heights



17b. Water surface contours of 1/50 yr. flood of area shown in 17a



17c. "Bands" of water levels of "equal" elevation in 1/50 yr. flood

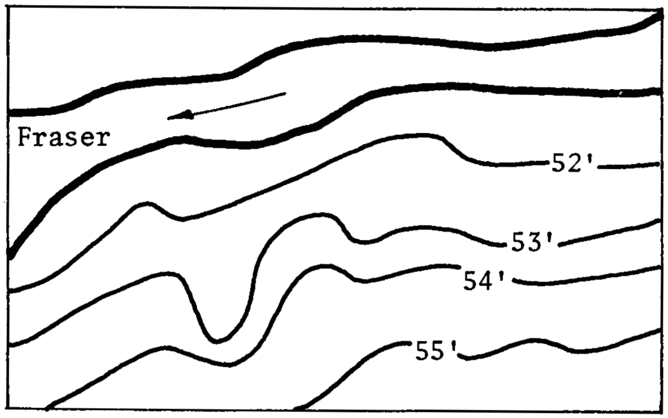


17d. Average potential depths of flooding in 1/50 yr. flood derived by overlaying "17a" with "17c"

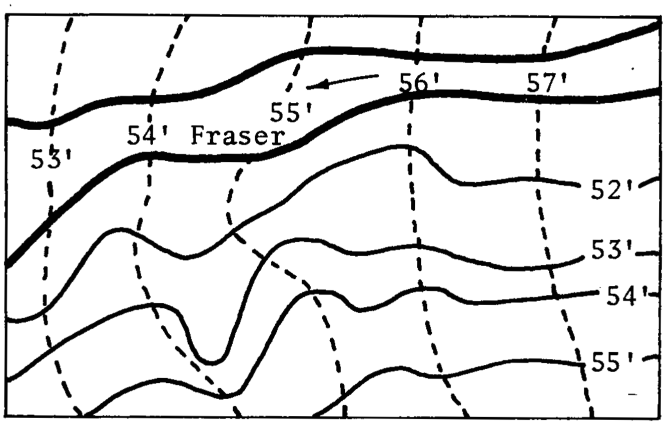
FIGURE 18

MAPS SHOWING DERIVATION OF DEPTH OF FLOODING MAP FROM

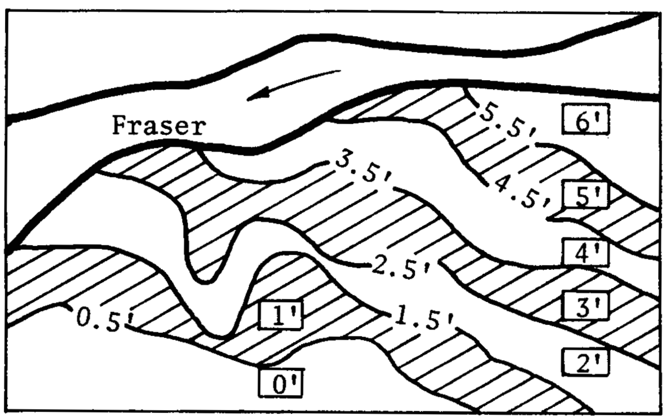
TOPOGRAPHIC AND WATER SURFACE CONTOUR INFORMATION



18a. Topographic Contour Map



18b. Topographic map with water surface contours of a 1/50 flood



18c. Depth of flooding map of a 1/50 flood showing both flood depth contours and shaded areas of roughly "equal" flooding

SUMMARY

A review of previous studies of flood losses in the Lower Fraser Valley showed that the most significant portion of the total damage that would occur in a major flood would consist of damage to residential property. Consequently, it was considered essential to develop an accurate method for calculating residential damages in the interest of attaining a reasonably accurate estimate of total losses.

Municipal assessment rolls proved useful in providing information on the structural characteristics of high, medium and low quality houses in floodplain areas. This source, in conjunction with a field survey and data obtained from the Federal Department of Public Works, formed the basis for determining potential structural damages to houses on the floodplain.

The Canadian Underwriters Adjustment Bureau and earlier studies of flood damages in the Lower Mainland were the sources of information used to compute potential content damages for the three classes of residences identified above.

A separate unit stage-damage curve was constructed for each dyking area in the Fraser Valley to represent the damage that would occur at various flood depths to the "average" house in each.

In urban zones, one-foot contours of depths of inundation were drawn on air photos to help identify residential areas subject to identical depths of flooding during selected floods. The use of these contours enabled a rapid and reasonably accurate estimation of the total damage that would occur to residences during floods of various magnitudes (Appendix H.1).

CONCLUSION

Although there is little empirical evidence with which to compare the residential damages estimated for the Fraser River Dyking areas, several features of the methods used in this study lend credibility to the results. First, the sample of houses is large, the data on structural characteristics are detailed and accurate, and supplementary information on repair costs were obtained from reliable sources. These factors suggest that the unit stage-damage functions are reasonably precise. Moreover, because sound techniques were used to determine the depths of flooding, errors that could have originated in this area were minimized.

Numerous variables, which can affect flood damages significantly, have, however, been excluded from the analysis. Perhaps the most important one lies in the realm of potential "human reactions" to floods. Any evacuation of furniture or emergency measures undertaken during a flood will drastically affect the validity of the estimates of total damages as they have been computed in the present study. Hydrologic variables such as water velocity, duration of flooding, channel changes, sediment loads, and the amount of debris in the water can also influence the size of damages during particular floods. All of these variables are presently unpredictable or else have unknown effects on the houses found in the Fraser Basin. What is certain, however, is that these variables do affect the size of damages and their exclusion in any study of potential flood damages invites criticisms of that study's estimates.

Despite inherent weaknesses in the present analysis, the techniques adopted were the most reliable ones available during the implementation stages of the program. The study offers a level of generality that should, on average, outweigh the advantages that a summary of actual damages inflicted by <u>one</u> specific historic flood might have. Moreover, the data base is sufficiently detailed and accurate to guarantee a high correlation between estimated and actual flood damages in the long run. Thus, regardless of divergences of actual and computed damages that might appear during particular inundations, the residential damage estimates calculated for the Fraser River Basin form a sound foundation upon which total damage estimates can rest.

CHAPTER IV

COMMERCIAL AND INDUSTRIAL DIRECT FLOOD DAMAGE

INTRODUCTION

All flood damages inflicted on the contents, structures and property of commercial and industrial establishments are classified as primary direct damages. They include costs of clean-up and damages to inventory, equipment, raw materials and buildings.

Past methods of measuring these damages have varied considerably.[1/] In some studies, surveys of actual flood damages were carried out. In others, synthetic damage curves were constructed on the basis of field surveys of plant lay-outs and conjecture about the extent of potential destruction. In still others, assumptions were made defining speculative relationships between plant value and damage at different flood levels.

On the basis of a review of the methods used in these previous studies, three fundamental procedural decisions were made in the present analysis. The first was to develop synthetic damage curves from field survey information. The second was to group different types of commercial activities into categories and to compute an average unit-damage curve for each. The third was to determine industrial damages by surveying every industry on the floodplain.

This chapter describes how these three general guidelines were used to estimate potential industrial and commercial damages in the Fraser River Basin. It outlines the techniques applied during the field survey, the development of unit stage-damage functions, and the computation of total damages.

The results of this analysis are to be used with caution. Errors in the final damage estimates may be significant. In studies of this type, the extent of potential flood damage reported by a proprietor during an interview depends upon his ideas of how he thinks he will react in the event of a flood. It fluctuates from person to person and firm to

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1/ For example see: Acres (1968), Kates (1965), Robertson (1963), Royal Commission (1958), Stanford Research Institute (1960), U.S. Corps of Engineers (1965), and White (1964).

firm. In fact, the only relatively consistent factor unifying the data gathered in the interviewing process is the research team. And the accuracy of the entire damage estimate rests on the tenuous premise that each researcher makes a correct subjective decision about the validity of a firm's estimate of its probable damage in a hypothetical flood.

COMMERCIAL PRIMARY DIRECT DAMAGE

1. ASSUMPTIONS

Since all commercial enterprises on the floodplain are located behind dykes and since the type of flooding considered in this analysis would result from a major dyke failure, it was assumed that proprietors would have no time to remove inventory from their establishments in the event of a flood.[2/] Perhaps a few firms located near high ground in areas such as Mission would be able to evacuate some goods. To the extent that this is true, commercial damages are over-stated in this study. Generally, however, little such evacuation is likely to occur and the use of average stage-damage curves based on anything but the assumption adopted could lead to a gross underestimation of commercial damages.

2. DEVELOPMENT OF THE QUESTIONNAIRE AND DAMAGE CATEGORIES

The objective of the field research on commercial[3/] activities was to gather enough information on potential damage to allow the construction of stage-damage curves for several distinct categories of commercial enterprises. To meet this objective, 15 tentative groups were formed on the basis of previous reports on the subject (White, 1964; Acres, 1968). Then, a questionnaire modelled after one used by Acres (1968: V.2, App. B.8) was drawn up and a pilot survey was conducted at Mission, B.C.

2/ This is consistent with the residential content damage estimates.

3/ "Commercial" refers to wholesale, retail and service trades.

The pilot run revealed two very useful facts. First, it proved that poor results were obtained when a questionnaire was presented and explained to a proprietor with the request that it be filled out and returned by mail. Proprietors responded so adversely to this approach that the questionnaire had to be remodelled to enable the researcher himself to take stock of potential damages during the interview (Appendix B.1). Secondly, it revealed the need for constructing stage-damage functions for 20 categories within the commercial sector to account for the diversity of commercial activities on the floodplain.

The final 20 categories for which average stage-damage relationships were determined are the following:

1. Petroleum Services - service stations, bulk oil plant.
2. Financial Services - banks, trust companies, finance companies.
3. Grocery Retail - supermarkets, medium-sized grocery store, corner store, grocery wholesale, confectionery, and liquor stores.
4. Hardware Stores -
5. General Stores - dry goods, feedstuffs (eg. Buckerfields), and variety stores.
6. Retail Stores - essentially large retail establishments.
7. Furniture and Furnishings - furniture, appliances, carpets, draperies; also includes paints, television.
8. Small Retail Trade - jewellers, stationery, music stores, photographic, florist, needlework, sporting goods, book shops, fabric, bicycle and mower stores, etc.
9. Retail Apparel - men's wear, ladies' wear, and footwear.
10. Mechanical Retail - machine shop, (i.e. wreckers, parts, body shop, retail - air-cooled engines).
11. Building Supplies - lumber yard (when associated with "do-it-yourself" type stores), sash and door, glass - often included mirrors.
12. Contractor Services (small) - electrical, plumbing, upholstery.

13. Personal Services - beauty salon, barbers, laundromat, dry cleaners, and funeral homes.
14. Recreation Services - theatres, billiard halls, bowling alleys, ice rinks, bars, etc.
15. Hotel-Motel Services - hotels, motels, autocourts.
16. Transportation and Communication Services - printing, newspaper, publishers, trucking and freight services.
17. Professional Services - doctors, dental surgeons, lawyers and solicitors, veterinarians, optometrists and realtors
18. Institutional Aspects - courthouse, post office, hospital.
19. Food Services - restaurant, drive-in, coffee shop, cafe, delecatessen, specialty foods, butchers, bakers, and similar.
20. Drug Stores - all types and sizes ranging from the very large to quite small.

3. SAMPLE SELECTION AND USE OF ASSESSMENT ROLLS

Two researchers carried out the field survey of potential commercial flood damage during May through August, 1971. Data were obtained for 81 of the 1,150 commercial enterprises located on the Lower Fraser floodplain. From 1 to 10 establishments were sampled for each category, depending upon the diversity anticipated within each. Because of the small sample sizes, random sampling techniques could not be used effectively in the data collection. Instead, representative selections were made on the basis of prior information about the types of commercial establishments in Richmond, Chilliwack and Mission City.

The researchers used two sources to develop a complete list of floodplain establishments and their structural characteristics. In areas with few commercial activities on the floodplain, establishments were identified directly in the field. In the municipalities of Richmond, Chilliwack and Delta, firms were first identified through municipal assessment records. The accuracy of these records was then checked in the field.

Assessment records were useful as a source of data on the type of activity, the address of the firm, the type of structure, its dimensions and interior finish, and the value of machinery, equipment and furniture. They proved unreliable however, because they were seldom up-to-date. Consequently, every listing in the assessment cards had to be checked in the field before a complete inventory could be drawn up for 1971.

4. DAMAGE ASSESSMENT

Prior to the investigation of individual firms, a list of unit costs of repairing and replacing different structural features of commercial buildings was prepared. The information required for this index was obtained from the Federal Department of Public Works, private concerns, and B.C. Appraisal Manuals (Appendix A.3). As the study progressed, the list was expanded to include the values of machinery, furniture and equipment commonly found in stores. This composite list was useful in untangling conflicting information given by different proprietors and acted as back-up data for estimating damage to goods whose values were not known.

During the interviews, the field representatives asked proprietors to cooperate by providing information on the value of their inventories, the percentage damageable at each foot of flooding, possibilities of salvage, and values of equipment and furniture. If such cooperation was not given, the researchers had to obtain the data by sampling the inventory in the stores.

The sampling procedure used in the latter case varied with the type of establishment. However, the general approach was to measure shelves, racks, counters and display cabinets and to record the value of goods found in selected sample areas within each type of display or storage unit. For example, an inventory of all the goods found on a shelf within a number of one foot lengths was taken at regular intervals. The average value per foot of sample shelving was then applied to the entire length of shelving to obtain the total value of goods in the unit. When this information was combined with the proprietor's estimate of the proportion of his inventory that could be salvaged, it was possible to determine the firm's total inventory damage for every foot of flooding.

Structural damages were estimated by applying re-calculated unit costs (adjusted for age and quality of the structures) to statistics on the structural characteristics of the buildings selected in the field survey. These characteristics included the quality, material and area of windows, walls, doors and floors and the flood depths at which the buildings would be damaged. The estimates of structural damage were combined with inventory, equipment and other content damage to form a composite stage-damage table for each sample commercial enterprise.

One of the most difficult problems of the field survey was to determine realistic salvage rates for the many types of goods encountered. Other studies (White, 1964; Acres, 1968) had identified salvage possibilities for certain goods and these were tentatively accepted in the beginning of the analysis. However, they were subsequently abandoned because no establishments in the Fraser Valley could confirm them. The set of salvage rates finally adopted was based on the consensus that the salvage value would usually be negligible and only in the following cases would some degree of salvage be possible:

1.	Liquor Stores	85-100% salvageable
2.	Hardware	35- 40% salvageable
3.	Jewellers	35- 33% salvageable
4.	Sporting Goods	8- 12% salvageable
5.	Drugs (including cosmetics)	8- 10% salvageable

5. UNIT STAGE-DAMAGE RELATIONSHIPS

Once total damages had been tabulated for each sample establishment per foot of flooding, average damage curves were formed for the various commercial categories. This was done by calculating the damage per square foot of floor area per foot of flooding for each establishment. Then the resulting figures were allocated to their appropriate groups and a simple average damage per square foot per foot of flooding was computed for each category (Table 1).[4/]

4/ Category 6 had to be determined by averaging 4, 8, and 9 because none of the stores in this group would cooperate.

TABLE 1

AVERAGE DOLLAR DAMAGE PER SQUARE FOOT OF COMMERCIAL BUILDING AREA

AT ONE FOOT FLOOD DEPTH INTERVALS

CATEGORY OF ESTABLISHMENT	Cumulative Damage ($) per Foot of Flooding									
	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.	10 ft.
1. Petroleum Services	2.6	3.5	4.2	5.0	5.1	5.1	5.1	5.1	5.1	5.1
2. Financial Services	2.3	3.2	5.3	5.8	5.9	5.9	5.9	5.9	5.9	5.9
3. Grocery Retail	2.3	5.6	7.5	8.5	9.2	9.8	10.1	10.1	10.1	10.1
4. Hardware	1.9	3.1	5.2	6.4	7.6	8.7	9.9	10.3	10.3	10.3
5. General Stores	2.2	4.5	5.9	7.0	8.1	9.2	10.0	10.1	10.1	10.2
6. Retail Stores	5.0	10.2	13.0	17.4	19.4	21.1	22.4	23.1	23.1	23.1
7. Furniture & Furnishings	11.3	14.3	18.7	20.5	21.6	22.6	23.2	23.3	23.4	23.5
8. Small Retail Trade	3.9	6.5	9.5	14.4	17.3	20.0	21.1	21.5	21.5	21.5
9. Retail Apparel	9.2	21.1	24.2	31.3	33.2	34.8	36.2	37.4	37.4	37.4
10. Mechanical Retail	2.1	3.1	4.7	6.6	8.0	9.0	10.1	10.1	10.1	10.1
11. Building Supplies	4.4	4.8	5.3	5.7	6.2	6.7	7.2	7.3	7.3	7.3
12. Contractor Services	2.0	2.7	3.5	4.5	5.7	6.3	6.6	6.9	7.1	7.1
13. Personal Services	3.3	6.6	9.7	10.7	11.3	11.4	11.4	11.4	11.4	11.4
14. Recreation Services	1.3	1.8	3.4	3.6	3.7	3.7	3.8	3.8	3.8	3.8
15. Hotel-Motel Services	2.3	2.8	3.5	4.3	4.5	4.6	4.6	4.6	4.6	4.6
16. Transp & Communic. Services	3.4	5.5	7.6	9.6	11.5	13.3	13.3	13.3	13.3	13.3
17. Professional Services	2.6	3.8	4.9	5.9	6.1	6.3	6.4	6.4	6.4	6.4
18. Institutional Services	1.8	5.7	7.7	7.8	7.8	7.8	7.8	7.8	7.8	7.8
19. Food Services	1.7	3.7	7.0	9.6	10.5	10.5	11.5	11.5	11.5	11.5
20. Drug Stores	1.3	3.9	6.9	10.0	14.2	14.9	15.6	15.6	15.6	15.6

This method of calculating stage-damage relationships is superior to alternative methods. It avoids biases towards large stores inherent in techniques in which recorded damages of all sample firms are summed within a given category and divided by the total floor area measured in the sample. Moreover, it does not attribute an unrealistic degree of accuracy to the sample damage estimates. Such would be the case if the individual damage curves had been weighted according to the size distribution of the firms on the floodplain.[5/] For these reasons, the "mean of means" approach was adopted in the present analysis.

6. ESTIMATING TOTAL DIRECT COMMERCIAL DAMAGE BY DYKING AREA

The total potential commercial damage for each dyking area was determined in four steps. First, all establishments were assigned to their appropriate categories. Then, the depth of inundation of each structure was calculated by comparing floor elevations[6/] with water surface contours.[7/] Next, floor areas were multiplied by the unit damage estimates of Table 1 to obtain the total potential damage for each firm. Finally, total damages for each dyking district were computed by summing the damages estimated for the individual establishments (Appendix H.2).

INDUSTRIAL PRIMARY DIRECT DAMAGE

1. ASSUMPTIONS

In assessing industrial damages, generally it was assumed that no evacuation would be possible and no emergency measures would be undertaken in the event of a flood. This assumption was made for two reasons.

5/ The same argument accounts for the failure to weight the damages for each type of activity within each category according to their preponderance on the floodplain.

6/ Spot heights plotted on 1961 air photographs were used to estimate these elevations.

7/ Water surface elevations of different hypothetical flood levels were provided by Engineering Division, Water Planning and Management Branch, Department of the Environment, Government of Canada (1971).

First, the type of flooding considered in this study would result only from a major dyke failure. Secondly, according to the field survey, only 7% of the floodplain firms were concerned about the flood hazard or had developed any kind of emergency program.

The few industries that were prepared to evacuate their equipment and materials were assumed to bear evacuation costs rather than flood damages. These industries were usually located near high ground or could move their goods to elevated parts of their plants.

2. DEVELOPMENT OF THE QUESTIONNAIRE

A study by Acres (1968) proposed that the most effective way of obtaining flood damage information from industries was to use an open-ended interview approach rather than a formal questionnaire. This technique was initially adopted in the present study and tested in a pilot survey at Mission, B.C.

The pilot survey showed that this procedure was inadequate. Not only were important questions omitted in the interviews, but also, direct damages were difficult to record. Therefore, a formal questionnaire and an inventory sheet were drawn up to overcome these problems.

The questionnaire was designed to obtain an industry's structural characteristics, production, wages and salaries, potential to defer production, inputs and outputs, inventory value, and assessed plant and equipment values (Appendix B.2). Answers to all but the input-output questions were used in estimating primary damages. Those related to production, wages, and potential to defer were used for calculating both primary and secondary damages. The input-output data were used for computing secondary losses and for verifying reported production. The assessed values, acreage, employment and production were used for checking the validity of a firm's damage claims and forming a base from which estimates of damages to non-participating firms could be made.

Of the questions asked, those related to assessed values and construction materials proved least useful. Replies to queries on appraised values were inconsistent because different firms reported different types of values for the same items (i.e. depreciated book values, replacement values or value used for tax purposes). Moreover, municipal appraisal records which should have been a good secondary source of information were too outdated to be of any use. As a result, assessed values were excluded from the analysis. Statistics on construction materials were found to be most effectively gathered during the inventory of damage potential and were therefore redundant in the main body of the questionnaire.

3. THE FIELD SURVEY

After all industries on the floodplain had been identified from listings in assessment rolls, from air photos and by field reconnaissance, the field survey of industrial establishments proceeded in two stages. The questionnaire was delivered in the first; an inventory of direct damages was taken in the second.

Initially, the researchers approached a firm with a letter of introduction (Appendix B.3). They arranged an appointment with the management to explain the requirements and usefulness of the questionnaire which they left with the firm to be retrieved at a later date. In the second stage they took an inventory of potential damage to stock and equipment with the assistance of informed personnel.

This two-stage approach enabled the researchers to obtain direct damage estimates from 67% of the firms,[8/] accounting for 82% of the employees on the floodplain. The response to the questionnaire portion of the survey was slightly better at 70% of the industries and 86% of the employees. This success rate was attained only after companies that had failed to return the first questionnaire had been sent a revised and condensed version (Appendix B.4).[9/]

8/ 45 of the 268 floodplain firms contacted were really wholesale and service trades mistakenly assessed as industries in the direct damage survey (Appendix B.5).

9/ Damage estimate for Kamloops, Quesnel, and Prince George were based largely on information collected in the Lower Fraser. Only a few major industrial establishments were actually interviewed to obtain data on primary and secondary industrial losses in these areas.

4. INVENTORY OF DIRECT DAMAGES

The objective of the field survey of direct damages was to record all significant potential flood-induced industrial property losses or the costs of avoiding these losses. In almost every case, the losses were counted either as the cost of repairing damaged equipment or as the depreciated value of that equipment, whichever was less.

Initially, potential damages and repair costs of standard equipment, furniture and structures were listed in an index similar to the one used in the commercial survey. This index included items such as costs of rewinding motors and replacing or repairing windows, doors and furniture. Depreciation rates were not applied to structural items such as doors and windows. Instead, their replacement values were equated to the costs of typical modern structural furnishings.

Unit costs were listed in a form that could be used in the field. For example, the costs of rewinding or replacing motors were associated with motors of various horsepower and RPM, the costs of replacing windows were recorded as dollars per square foot of window area, and the value of chairs (along with depreciation rates) were indexed by type. Thus the interviewers were provided with a "rule-of-thumb guide" to costs that could be used to estimate damages to goods common to most industries and to fill gaps in information that firms were unable to provide.

Because some industries chose not to participate in the study, their potential damages had to be estimated from other data. Wherever possible, these estimates were based on information obtained from industries of like function and size. However, if no similar establishments had been surveyed, damages were computed by using average unit-damage functions.

These average unit-damage functions were determined for several industrial groups classified according to the 110 categories defined in The Input-Output Structure of the Canadian Economy (D.B.S., 1968: V.2)[10/]. Field survey data were used to calculate three different functions. These were: 1) damage per employee, 2) damage per acre of land in use and 3) damage per square foot of plant area.

10/ A list of these industries is presented in Appendix B.5

Unit-damages were sometimes difficult to estimate because damages had not been recorded over the same range of flood depths for all industries. For instance, some industries were expected to be flooded by one foot of water and others by 10 feet in a 26 foot flood. Thus, for some industries, damages were assessed for only 1 foot of flooding while for others, they were estimated for every foot of flooding between 1 and 10 feet. Another problem was that industries located on slopes could not be included in unit-damage estimates because often only a portion of the plant would be subject to flooding; depth-damage relationships were meaningless in such a lay-out. These irregularities, coupled with differences among plant lay-outs, made it extremely difficult to provide consistent estimates of damage that could be applied to non-participating industries. Nevertheless, the tables in Appendix B.6 were constructed from selected statistics to represent "typical" industries in several important categories.

5. ESTIMATING TOTAL DIRECT INDUSTRIAL DAMAGES

Total direct industrial damages were calculated for various flood levels for each dyked and undyked area by summing the damages estimated for individual firms (Appendix H.3). Damages to individual firms in a given flood were determined by combining depth-of-flooding information with stage-damage data gathered in the field survey. The depth of flooding was estimated for each plant by comparing floor elevations with water surface contours.[11/]

SUMMARY

Primary direct commercial and industrial flood damages are damages inflicted on the structures, contents and property of establishments located on a floodplain. In many areas they are the most important source of potential flood losses, but in the Fraser Valley they rank

11/ The water contours were taken from the same 1:25,000 maps that were used in the residential and commercial damage surveys and prepared by the Engineering Division, Department of the Environment. The elevations of the buildings were established by surveyors who related them to benchmarks in the area.

second to residential, comprising about 17% of the total damage potential (Appendix H.9).

The most salient feature about primary direct commercial and industrial flood damages is their diversity. This feature makes predictions of losses in a generalized model difficult and has led to a wide range of results in past analyses.

In the present study, commercial activities were grouped into 20 categories. A 7% sample of floodplain activities was taken to determine the average damage that establishments falling within each category would suffer when subjected to given depths of flooding. The average damage per square foot of floor area was calculated for each category and applied to all firms within the floodplain to obtain the total commercial direct flood damage for selected flood levels.

In the case of industrial damages, all industries on the floodplain were contacted and an inventory of potential damage was taken to provide the basis for estimating total direct industrial damages in selected floods.

CONCLUSION

The inaccuracies of the procedures used in the present analysis to estimate commercial and industrial damages have been stressed frequently. They have been emphasized to impress upon the reader that the resulting "point" estimates really are "best" estimates representing a broad range of damages that could occur during specific floods.

In future, more detailed studies might yield more accurate assessments of damages in the Fraser Valley. A larger number of commercial establishments could be examined and additional categories formed. A meticulous item-by-item inventory of all contents and structural characteristics of industries could be taken. But the final answer would probably not prove significantly more reliable than the one derived in this study.

Many uncertainties inherent in flood damage estimates would remain. Factors such as the probable effects of water on materials and equipment, the depreciated and salvage values of goods, and the responses of entrepreneurs to floods would still require speculative, subjective judgements. Moreover, the host of localized flood conditions listed in Chapter III would continue to defy prediction.

When the results of this analysis are considered in the context of these uncertainties, they appear to be well within the range of accuracy possible in estimating flood damages. In fact, a more extensive survey and greater expenditures on collecting data would be very difficult to justify.

CHAPTER V

AGRICULTURAL FLOOD DAMAGE

INTRODUCTION

Floods can cause severe damages to agricultural operations on a floodplain. These damages can include crop and equipment losses, reductions in the productive capacity of livestock, premature slaughtering of poultry, and extra costs of importing feed to replace that lost during a flood.

Since most of the best agricultural land in the Lower Mainland lies on the floodplain, a major flood could cause significant agricultural production losses in British Columbia. Because these losses could be substantial, an error in estimating them could seriously affect the precision of an estimate of total flood damages in the Valley. This is especially true for some dyking areas in which the agricultural sector accounts for as much as 30 or 40% of the total flood damages. Therefore, accurate assessments of agricultural losses are important in a study of potential damages in the Fraser Valley.

This chapter describes the methods used to derive estimates of potential agricultural damages in the Fraser Basin. Since past studies of agricultural losses are fairly comprehensive, the current analysis draws heavily upon them. The Fraser River Flood Control Benefit Study (Robertson, 1963) was particularly useful in supplying both basic data and methods of analysis. Where 1963 data were inadequate, marketing boards, government agronomists and individual farmers were consulted for additional information.

ASSUMPTIONS

Following the guidelines of the 1963 Benefit Study (Robertson, 1963: App. A, H and J), it was assumed that (1) on average, floods would begin on June 1, (2) all work would proceed normally up to June 1, and (3) all livestock would be safely evacuated in the event of a flood.

AGRICULTURAL FLOOD DAMAGE AND INCOME LOSS

1. CROP LOSS

The most appropriate way of computing total potential crop damages in various floods is to base estimates on the average loss per acre. Although researchers could identify and record damages to crops on individual farm plots in a field survey, these data would be useful only for a specific point in time. By using the average damage per acre for a given floodable area, analysts can allow for annual changes in patterns of land use without placing excessive weight on existing patterns. They also can gather and synthesize data more rapidly than would otherwise be possible. For these reasons, in the present study, the weighted average damage per acre of agricultural land was determined for each dyking area and used as a basis for estimating total potential damages during different floods.

a. Crop Damage Categories

Before average losses per acre could be calculated for specific regions, it was necessary to estimate potential damages for individual crops or crop groups. Where data were available, damages were computed for individual crops which had distinct production functions. Damages were estimated for oats for hay, corn for ensilage, strawberries, raspberries, hops and vegetables (Appendix C.1). However, separate damages were not calculated for every crop type. Where data were inadequate or where crops were expected to suffer damages similar to other crops, they were grouped into categories for which average potential losses were estimated. All cereal grains, for example, were placed under the general heading "grains". Other categories identified were tame hay and legumes, pasture, tree fruit, other small fruit, nursery products, and greenhouse products (Appendix C.1).

b. Crop Damage per Acre

Per acre flood losses were established for annual crops by taking the average gross return per acre for each crop and subtracting the non-labour costs (i.e. machine time, gasoline, fertilizers, insecticides, etc.) avoided when operations are interrupted by flooding (Appendix C.1). The gross return per acre is the income, including returns to land, management, labor and capital, generated by a farming operation. If a flood completely destroys a crop, a farmer loses all income attributable to that crop. However, he will not have realized all of his normal annual costs of materials (fertilizers, sprays, containers, sacks and gasoline) and equipment (wear, repairs and depreciation) before the flood occurs. Therefore, his total loss is less than his normal annual income by the size of the expenditure he fails to incur.

It was more difficult to determine the damage per acre of perennial crops because the annual income needed to retire the initial establishment cost over the life of the plants had to be calculated. Plants, such as raspberries, strawberries, pasture and tree fruits, require an establishment cost before they yield an annual return over a specified number of years. This cost is normally amortized over the expected productive cycle of the plants and specified in annual terms. Therefore, when a field is flooded and perennial plants are destroyed, the loss per acre includes both the normal gross income for the flood year and the unretired establishment cost.

Ideally, the unretired portion of the debt associated with the flooded crop can be determined if the ages of all crops are known. However, since these data were unavailable for the Fraser Valley, the loss was estimated on the basis of the assumption that all plants would be mid-way through their productive cycle when flooded (Appendix C.1).

c. Crop Mix by Dyking District

Agricultural data required to estimate the relative importance of each crop or crop group within individual dyking areas were obtained from Statistics Canada and the British Columbia Department of Agriculture. Statistics Canada supplied information on the number of acres under different crops in all Enumeration Areas (E.A.'s) on the floodplain.[1/] Since Statistics Canada did not provide an adequate breakdown of all crops (eg. vegetables were lumped together), additional data were obtained from the British Columbia Department of Agriculture.

1/ Unpublished data collected by the Dominion Bureau of Statistics for the 1966 Census of Canada, Agriculture.

The information from the two sources formed the basis for describing the agricultural characteristics of twenty dyking districts listed in Appendix C.2. The percentage crop mix within each district was determined by dividing the acreage under individual crops by the total agricultural acreage in each area (Appendix C.2).

d. Average Crop Loss per Acre by Dyking District

To determine the weighted average damage per acre of agricultural land in each dyking area, estimates of the loss per acre for specified crop types (Column 5, Appendix C.1) were multiplied by the percentage of farmland occupied by these crops in each of these areas (Appendix C.2). The resulting values were summed to obtain a weighted average for each area (last row, Appendix C.2).[2/]

e. Estimating Acres of Floodable Agricultural Land and Total Crop Damage

Air photographs (1969; scale 1:6,000) and 1966 Statistics Canada data were used to estimate floodable acreage. The accuracy of the Statistics Canada data was checked by planimetering several E.A.'s outlined in the air photographs. Since differences between the two sources were insignificant, census data were adopted wherever feasible. However, if census Enumeration Areas did not lie completely within floodable regions or had experienced urban development after 1966, the agricultural acreage had to be determined by planimetering relevant areas. Once the total acreage floodable in each dyking district had been calculated for different flood levels, it was multiplied by the appropriate estimate of damage per acre to derive the total potential crop damage during various floods (Appendix H.2).

2. LIVESTOCK LOSSES

a. Dairy Production

Although it was assumed that all dairy cows would be evacuated safely from floodable areas in the event of a flood, it was

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2/ A sample of the process is illustrated in Appendix C.3.

recognized that their evacuation would cause a substantial reduction in milk production. This reduction would arise as a result of relocation problems including changes in the cows' daily routine, erratic and perhaps reduced feeding, crowded conditions, and lack of milking facilities.

In 1963, officials of the British Columbia Department of Agriculture estimated that evacuated cows would lose 22.2 pounds of milk per day (Robertson, 1963: Appendix J). To obtain the total loss per cow, the 1963 Benefit Study combined this estimate with the assumption that losses would occur for 45 days.

Although dairy specialists (British Columbia Department of Agriculture, 1971) confirmed the 1963 conclusion that milk production would be negligible during the flood period, current estimates of milk losses differ from those of 1963 in several ways. First, the average daily production per milk cow in the lower Fraser has risen by one third,[3/] so that the potential daily flood-induced loss is now 33 pounds per cow. Moreover, the weighted average price of bulk milk paid to producers is $6.10 per hundred pounds (1971).[4/] Finally, present estimated losses are based on the assumption that cows would be relocated whenever farm buildings were inundated and would produce no milk during the flood period (Appendix E.3) and for 30 days thereafter.

Records of the British Columbia Department of Agriculture, Dairy Branch, provided the information required to estimate the number of cows to be evacuated from each floodable area. By combining this information with calculations of the loss per cow, the total value of milk losses was derived (Appendix H.5).

b. Beef Cattle Production

The procedure used to determine losses of beef production in the present analysis closely follows that of the 1963 Benefit Study

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3/ Average annual production was reported to be 12,000 pounds per cow in 1971 (personal communication with Department officials).

4/ 60% of the milk delivered in the Fraser Valley is Class 1, and 40% is Class 3.

(Robertson, 1963: Appendix J). As in 1963, it was assumed that evacuated beef cattle, while absent from their normal feeding areas, would fail to gain 1.5 pounds per animal per day. In 1971 prices, this is the equivalent of $0.48 per head per day.[5/] The total loss per animal for specified flood levels was assumed to be a direct function of the duration of flooding (Appendix E.3) plus a two week allowance for both the movement of stock and the post-flood preparation of fields. To determine the total loss by dyking area, the estimated 6,000 head of beef cattle[6/] on the Lower Fraser floodplain were allocated among dyking areas according to the proportion of cultivated acreage in each (Appendix H.5).

c. Hog Production

Based on the findings of the 1963 Benefit Study (Robertson, 1963: Appendix J), it was assumed that hogs would fail to gain weight only when they were being transported to and from their farms and not during the entire flood period. Therefore, the loss per hog during a flood would be only 17 pounds valued at $0.30 per pound in 1971 (Canada Department of Agriculture, Livestock Division).

The British Columbia Department of Agriculture, Livestock Branch, provided accurate data on the number of hogs in each dyking district. This information was combined with the estimated loss per hog to determine total potential damages by dyking area (Appendix H.5).

3. POULTRY LOSSES

While the 1963 Benefit Study (Robertson, 1963) proved a valuable point of departure for establishing poultry losses, the methods used and the results obtained in the current analysis are distinct. They are the product of extensive consultation with officials of Marketing Boards and the British Columbia Department of Agriculture.

Two general assumptions were adopted and applied to the entire poultry industry. The first is that high costs of transportation and the

5/ Personal communication, Canada Department of Agriculture, Livestock Division.

6/ Personal communications, B.C. Department of Agriculture.

possibility of disease arising from excessive crowding would prevent any evacuation of poultry from floodable areas. The second is that although many birds would be mere chicks, their loss should be measured as the value of mature birds (less any feed costs not incurred) to account for the unretired portion of a farmer's investment and his loss of anticipated income.

a. Broiler Production

A flood would cause only a partial loss of the income normally generated in broiler and fryer operations. Since broilers require only 8 weeks to reach market size, farmers would slaughter and sell all birds older than 5 weeks. In this way, they could recover one-third of their normal gross output (B.C. Department of Agriculture). Birds less than 5 weeks old would be too small to salvage.

Because floods would likely affect production for no more than 8 weeks in any area in the Fraser System, it was assumed that the total loss in any flood would not exceed two thirds of the value of birds on hand at the time of inundation. The 1971 value of the lost production would be $0.63 per bird (B.C. Broiler and Fryer Marketing Boards). Total losses by dyking area are presented as part of "Other Agricultural Damages" in Appendix H.5.

b. Egg Production

Floods would seriously affect egg production on the floodplain. Since hens would not lay during the flood period and for about 8 weeks thereafter,[7/] their evacuation would be uneconomic (B.C. Department of Agriculture, Poultry Branch). Therefore it was assumed that all hens in the inundated areas would be sent to the slaughter house. Because hens do not begin laying until they are six months old and because their average productive life is only one year, it was estimated that a farmer would lose about one half

7/ Poultry officials with the B.C. Department of Agriculture indicated that laying hens would go into moulting for 8 weeks following a relocation.

of his annual egg production.[8/] Estimates of the total value of lost egg production by dyking area are shown in Appendix H.5.

c. Turkey Production

Although it would not be feasible to evacuate turkeys, floods would inflict only small losses on turkey producers for two reasons. First, only part of the normal annual income derived from turkeys would be lost in the event of a flood. Even with a two-month interruption, the seasonal nature of the turkey industry gives farmers the flexibility needed to satisfy all of the Christmas and probably part of the Thanksgiving market demands. Secondly, birds eleven weeks and older could be slaughtered and part of their normal value could be recovered. For these reasons, it was assumed that only three months of production would be lost.

The total loss by dyking area was computed on the basis of Marketing Board production statistics. The 1971 unit loss was estimated to be $2.90 and $1.20 for large and small birds respectively.[9/]

4. EXTRA FEED COSTS

Flooding would destroy stored feed and eliminate a large portion of British Columbia's fodder-producing capacity, thereby causing substantial increases in feed costs in the province. Because B.C. Department of Agriculture officials felt that inundated fodder crops could not be replaced with new production until the year after a flood had occurred, it was assumed that livestock would have to be supplied with feed from alternative sources for one year. Since most of this feed would be imported from out-of-province areas, its cost to farmers would be higher than normal. Department officials[10/] suggested that increased demand from flood-stricken areas would force the normally high price of imported hay even higher by 25%. Therefore, the additional cost of feed to farmers was estimated to be $20 per ton of hay equivalents.

8/ 1971 producer's prices were $9.50 per case of 30 dozen (B.C. Egg Marketing Board).

9/ Producer's prices reported by the B.C. Turkey Marketing Board.

10/ Personal communication.

Estimates of floodable agricultural acreage (Appendix C.2) formed the basis for determining additional feed requirements that would arise in the event of a flood. The total extra cost of feed was computed by combining the acreage under various crops in each dyking district, the physical yields per acre of fodder crops converted to hay equivalents (Table 2), and the additional cost per ton of hay equivalents ($20) that would be incurred when floodplain fodder is destroyed.

TABLE 2

ANNUAL "HAY EQUIVALENT" YIELDS OF VARIOUS FODDER CROPS

(Tons/Acre)

Crop	Hay Equivalent
Grains, Pasture	3 tons
Tame Hay, Legumes	4 tons
Corn	6 tons
Rough Pasture	2 tons

5. DAMAGE TO MILKING EQUIPMENT

Damage to milking equipment was determined by up-dating the results of the 1963 Benefit Study (Robertson, 1963: Appendix C). In the 1963 report, damage and rehabilitation costs for milking equipment were estimated to be $15 per milking cow. This was based on the assumption that damage would be 30% of the capital cost of milking equipment. The 1971 value of damage, therefore, was estimated to be $20 per cow.[11/] This was combined with data on the number of dairy cows (provided by B.C. Department of Agriculture) to obtain the total damage to milking equipment by dyking district.

11/ This was derived by raising the 1963 price by 3% per annum (Appendix G.6).

6. LIVESTOCK EVACUATION COSTS

Three general assumptions underlie the estimates of livestock evacuation costs in this study. First, a flood on the Lower Fraser would cause the complete evacuation of livestock from inundated areas. Secondly, the animals would be moved to the nearest safe and accessible areas available. Thirdly, an equal number of producing and non-producing cows would have to be evacuated.

Probable unit costs of evacuation were taken directly from the report "Flood Control Benefit Study of Fraser River Below Hope" (G.E. Crippen and Associates, 1972: Table F.3). These costs were recorded as follows:

Livestock	Transportation Cost Per Head
Dairy Cattle	$ 6.00
Beef Cattle	$ 1.60
Hogs	$ 1.00

SUMMARY

Since most of the best agricultural land in the Lower Mainland lies on the Fraser floodplain, a major flood could cause significant agricultural production losses in British Columbia. Direct agricultural losses comprise 16% of the total potential flood damage in the Fraser Valley, ranking close to commercial and industrial damage in size (Appendix H.8).

Estimates of potential agricultural losses can be made rapidly and accurately on the basis of generalized unit-damage models. Both the speed and the precision with which estimates can be made are crucial features of the methods used to calculate agricultural losses in the Fraser Valley.

In the present study, the average damage per acre of farmland was determined for individual dyking districts by combining data on the crop mix in each area with estimates of the damage likely to be inflicted on different types of crops. The resulting weighted average was then multiplied by the total acreage floodable in each area during various floods to obtain total crop damage.

Total livestock production losses were derived mainly from estimates of weight losses per animal established in the 1963 Benefit Study (Robertson, 1963). The 1963 figures were updated to account for productivity and price changes.

The British Columbia Department of Agriculture, and Turkey, Broiler and Egg Marketing Boards contributed much towards assessing potential production losses in the poultry industry.

Extra costs of importing feed, repairing damaged milking equipment and evacuating livestock were determined on the basis of earlier reports, and with the assistance of the British Columbia Department of Agriculture.

CONCLUSION

The methods used in this study to estimate agricultural damages are believed to yield reliable results. A greater expenditure of time and elaboration of detail would have dubious benefits.

The technique devised to determine crop damage appears to be particularly effective. Crop damage estimates are probably very accurate.

Appraisals of other potential agricultural damages are more tenuous because they are dependent upon numerous assumptions. However, unless good historical records are available, the application of alternative methods of gathering and synthesizing data is unlikely to produce significantly better estimates.

CHAPTER VI

PERMANENT INCOME LOSSES INFLICTED BY A FLOOD ON THE BRITISH COLUMBIA ECONOMY

INTRODUCTION

Income losses in flood damage studies are normally classified as "primary" or "secondary". The former refers to losses incurred by floodplain activities forced to shut down because of a flood. The latter includes losses born by non-floodplain firms forced to reduce production when a flood destroys their markets or sources of raw materials.

This chapter describes the methods and assumptions used to estimate primary and secondary losses in the present study. Because the problem of identifying such losses is complex, the chapter outlines the rationale underlying the selection of assumptions, reports the qualitative responses of managers of firms that assisted the analysts, justifies the methods used to determine estimates of losses, and indicates the accuracy and significance of the results.

THE REFERENT GROUP AND THE ADMISSABILITY OF INCOME LOSSES

The point of view from which flood-inflicted income losses are assessed is a critical factor affecting the size of such losses. Since the referent group in this study is British Columbia, only the income portion of production losses that can neither be deferred nor transferred to parties within the province is an admissable income loss. Production (and income) transfers between two parties within the province represent redistributions of income and not net losses to B.C.

Mandatory delays and transfers of production can, however, inflict some costs on the economy. One such cost is the hardship suffered by those whose income is transferred to others within the province; but because this hardship is off-set by the benefits accruing to those to whom the income is transferred, no net loss can be recorded. The only costs of production delays and transfers representing a real loss to the economy as a whole are frictional costs.[1/] In this study, these costs have been estimated to be 2% of the value of transferred or deferred production (Kates, 1965: 54).[2/]

True income losses, both primary and secondary, are represented by returns to labour, land and capital permanently lost to the province during a flood. They vary directly with the size of production losses and are confined almost entirely to certain types of industries. They originate in floodplain industries whose productive capacities, markets or raw material sources are so inflexible that British Columbia establishments cannot recoup flood-induced losses by deferring production or by transferring it from one firm to another.

The trade sector would not realize true income losses. The disruption of normal sales of wholesale, retail and service trade establishments located on the floodplain would not constitute a net loss to British Columbia because such sales can be either deferred or transferred to non-floodplain firms.

BIASES IN INCOME LOSS ESTIMATES

In the present study, three upward biases in estimates of income losses arose because of data limitations. These limitations were related to problems in determining the foreign component of income losses, the importance of imports, and the potential of industries to defer or transfer disrupted production.

The first bias was introduced when <u>all</u> permanent losses of British Columbia-based industries were counted as income losses even though returns destined for out-of-province investors should have been subtracted from the total.[3/] This error could have been corrected by

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1/ Frictional costs result because transfers in space involve extra transport costs, and transfers in time (deferrals), increased production costs.

2/ It was functionally convenient to assess transfer costs and income losses simultaneously even though the former are not true income losses.

3/ This is true only to the extent that dividends paid to non-residents would not normally be re-invested in British Columbia.

conducting a complex and costly assessment of the foreign component of income losses. Because the results of such an assessment would have been tenuous, and because they would have had only a minor effect on the estimates of total potential flood damage in the basin, this bias was ignored.4/

The second exaggeration in the estimates of income losses arose because the impact of import leakages was excluded from the analysis of secondary losses. In the publication "The Input-Output Structure of the Canadian Economy, 1961" (D.B.S., 1968), impact tables show that the income-generating capacity of an expenditure of one dollar in final demand varies among industries from $0.80 to $0.90 when allowances are made for import leakages (D.B.S., 1968: Table 16, V.2). While not directly applicable to the British Columbia economy, this information does indicate the magnitude of the import-component of final demand. If it were relevant at the provincial level it would imply that (other things being equal) for every $1.00 of production permanently lost to the province when an industry is flooded, $0.80 to $0.90 would represent the total primary and secondary income loss. Since no such information was available for B.C., however, no allowance could be made for import leakages; net income losses have been overstated accordingly.5/

The third upward bias occurred because the potential of some industries to defer or transfer production was unknown. Since it was possible to identify the transferable and deferable portion of primary losses in the field survey, a large part of this bias was eliminated. However, the ability of indirectly affected industries to find new markets and sources of raw materials was not usually determined so that some exaggeration remained in the estimates.

4/ It should also be noted that there might be an influx of foreign capital to replace industrial property destroyed in a flood. This would mean that industrial property damages have been overstated in Chapter IV in the same way that income losses have been exaggerated in the present chapter.

5/ Foreign industries supplying goods to B.C. firms would suffer losses inadmissible in a net benefit study of the B.C. economy. Nevertheless these losses would be more than simple transfers because they would be felt in Canada's balance of payments accounts.

Because of the incomplete data base and inflationary biases described above, several assumptions were adopted to provide consistent, basic guidelines for determining legitimate income losses. Although, individually, some of these assumptions either inflate or deflate potential income losses, they were selected as a whole to present an accurate picture of potential net income losses in British Columbia.

GENERAL ASSUMPTIONS GOVERNING THE IDENTIFICATION OF INCOME LOSSES

Because of the danger of inflating secondary damages, it usually was assumed that income losses would be incurred only by floodplain industries and their immediate British Columbia suppliers. While permanent potential losses were specifically identified for floodplain industries, all losses of input industries were simply accepted as being permanent. Potential losses of third and subsequent round industries were ignored.

Normally, it was assumed that industries dependent upon floodplain firms for their inputs would not suffer income losses. This was considered reasonable because firms would be able to find alternative suppliers of inputs more easily than markets for their outputs. However, this assumption proved invalid for the dairy, egg processing, and fruit and vegetable processing industries in the lower mainland. Because of their heavy reliance on floodplain agricultural production, these industries would not likely be able to find substitute sources for all produce lost in a major flood. If the necessary agricultural products could not be obtained from other areas, food processing industries and their suppliers would incur sizeable permanent income losses. In such cases, the general assumption that income losses in forward linkages would be negligible was relaxed and specific losses were estimated.

ESTIMATING PRIMARY INCOME LOSSES

1. METHOD

Returns from questionnaires issued in the industrial survey (Appendix B.2) formed the basis for estimating primary income losses. Only 70% of the surveyed industries[6/] provided useful information about the value of their output and their ability to defer or transfer production. The income portion of this production (value added by manufacturing) was determined by combining survey information with other data relating numbers of employees to output in various industries.[7/] In this way, reasonable estimates of production, income and permanent flood-induced losses were obtained for the floodplain.[8/]

The total time lost by each industry as a result of a flood was calculated by adding an allowance for clean-up to the number of days during which each industry would be flooded and inaccessible. It was estimated that five to ten production days would be needed for clean-up operations. The exact time requirement would depend upon the depth of flooding above the main floor and the type of plant.

The period during which industries would be flooded and inaccessible was assumed to be a function of the river hydrograph (Appendix E.3) and road and land elevations. Generally, it was assumed that flooding would begin when the river reached the confidence levels of dykes and that industries would be inoperable as long as they or major roads remained inundated. This general assumption was relaxed in areas of extreme tidal influence (Richmond and Delta). In these areas, it was

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6/ Accounting for 86% of the employment of the significantly affected industries on the floodplain.

7/ The principal sources of these data were: The Input-Output Structure of the Canadian Economy 1961: Vol. 2, Table 14 (D.B.S., 1969); Manufacturing Industries of Canada, Section F, 1968 (D.B.S., 1971); and Key Business Ratios in Canada (Dun and Bradstreet, 1968).

8/ All industries were assessed individually. Their abilities to transfer or defer production were established on the basis of their production capacities, products, and relative importance in the province.

assumed that any breaches that might occur in dykes during floods of less than 24 feet would be repairable during low tide periods and that flooding would last a maximum of ten days.

2. PRIMARY INCOME LOSSES - OVERVIEW

The level of accuracy of estimates of permanent production losses is unknown. According to most company officials,[9/] such losses would depend on too many uncontrollable and extra-provincial factors (including national economic conditions) to be reliably predictable. Many companies, whose markets are local and specialized, expected to be able to defer all production losses not transferred to other British Columbia firms. Others, whose local sales can easily be replaced by imports (eg. meat packers), believed that any disruption would result in a complete loss to the province. Still others, whose products compete in world markets, thought that unfilled out-of-province orders would be transferred to foreign competitors and lost to British Columbia.

In the present analysis, many refinements of estimates of the effects of flooding on production were made for individual firms within each broad industrial class. Some were based on responses of these firms and others were subjectively determined by the analysts. In all instances, however, a high degree of subjectivity was involved and the resulting "best estimates" of primary and secondary income losses are simply rough "order-of-magnitude" approximations of the true losses (Appendix H.6 and H.7).

3. PRIMARY INCOME LOSSES - SPECIFIC INDUSTRIAL GROUPS[10/]

a. Sawmills and Shake and Shingle Mills

Results of the industrial survey indicated that if all vulnerable Lower Fraser lumber mills were inundated simultaneously, an average of 55% of their lost production would be permanently forfeited to out-of-province firms. There are two reasons for this

9/ Personal communication, field survey.

10/ Industrial groupings are listed in Appendix B.5.

loss being permanent. First, the international lumber market is so competitive that foreign sellers would capture most orders unfilled because of minor delays of British Columbia shipments. Secondly, since floodplain industries produce roughly 15 to 20% of the coastal lumber, and since a flood would occur during the peak production period, unaffected British Columbia firms would not likely have the capacity to compensate for lost production on short notice.

Such extensive losses would be sustained only if all dykes in the Lower Fraser were to fail, causing the coincidental inundation of all floodplain lumber industries. This event is very likely to occur when water levels exceed 26 feet. However, when the river peaks at levels much lower than 26 feet, there is little chance that it will happen.

Because no information existed for estimating the probability of total flooding, two arbitrary assumptions formed the basis for determining permanent income losses in the lumber industry. One assumption was that, because upgraded dykes in the Lower Fraser would provide reliable protection to the 24-foot water level, no permanent production losses would occur in floods of less than this magnitude. The other was that all water levels of 24 feet and more would cause permanent losses of the size indicated in the returned questionnaires.

These assumptions, although arbitrary, provided a realistic foundation for the estimates of income losses. The first was appropriate because, even if a dyke were to fail at water levels below 24 feet, it would be protecting only a small portion of the total coastal lumber industry. British Columbia firms could therefore adjust their inventories to compensate for lost production at no extra cost. The second assumption, while tending to exaggerate permanent losses, was also reasonable because the closure of major producers on Lulu Island, the North Bank of the Fraser, or in Surrey would have a serious impact on British Columbia's lumber industry. And the losses caused by their closure would be enhanced by the simultaneous disruption of production of smaller firms in other areas.

b. Paper Box and Bag Industry

Returns from the industrial survey indicated that British Columbia would suffer permanent income losses if paper box and bag industries were forced to halt production. Three reasons were given for the losses. 1) British Columbia's major paper box and bag producers are located on Lulu Island. 2) Markets for their products are typically of a "short-order demand" nature. 3) Producers carry very little inventory. Therefore, it was concluded that B.C. firms would be unable to fill any of the immediate excess market demands created by a flood-originated closure of manufacturers of these paper products.[11/]

Determining time-outage for this industry was very difficult. Although plant managers stated that any damage to their highly specialized equipment could mean cut-backs or shutdowns of six months or more, they also agreed that they might clean and utilize damaged machinery on a temporary basis. Furthermore, it was found that only one major producer was likely to suffer serious flooding. Therefore, although there was a danger of underestimating losses, it was assumed that the paper box and bag industry would require only 10 production days for cleaning up and making repairs once flood waters receded.

c. Plywood Manufacturers

All Lower Fraser plywood manufacturers potentially affected by flooding claimed that most production losses could be either deferred or transferred to B.C. firms. They suggested that the only possible problem would be a loss of foreign markets. Their estimates of permanent losses to out-of-province firms, which ranged from 0 to 10% of the value of the production prevented during a flood, were adopted in this study.

The total time-outage anticipated for these firms was established by combining the expected number of days of inundation with the standard 5 to 10-day clean-up allowance. As in the case of paper products manufacturers, the shut-down period of plywood

11/ Some companies indicated that their diversification would enable them to defer a portion of their gross production losses. These anomalies were accounted for when losses were being estimated.

producers may have been underestimated. However, since no plywood plants would undergo more than a foot or two of flooding, no additional allowance was made for clean-up time.

d. Meat and Fish Processing Plants

Managers of meat processing plants stated that imported meat would immediately fill any market voids created by delays in shipments induced by production set-backs. Consequently, it was assumed that all production and income (value added) losses inflicted by a flood on British Columbia meat processors would be permanent.

A field survey of fish processing plants showed most factories to be sufficiently elevated to escape serious flooding, even during major inundations. Thus, it was assumed that most producers, although surrounded by water, could maintain full production because they would still have access to their wharves during a flood.[12/] Losses of the few minor processors that would actually suffer significant flooding were also discounted because their production could be transferred to other plants in British Columbia.

e. Fruit and Vegetable Processors

Fruit and vegetable processors located on the floodplain would have to shut down their operations during a flood. However, even British Columbia processors not situated on the plain would suffer production losses because their sources of raw materials would be inundated. Therefore, primary income losses inflicted on floodplain factories were not specifically identified. Instead, they were included in estimates of secondary losses resulting from the flooding of agricultural land.

f. Other Industries

No "typical" income losses could be ascribed to other classes of floodplain industries. Even within classes such as

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12/ If electricity were cut off, this assumption would become invalid. However, because June is a slack month, the fish industry could absorb the fish supply even if some firms were to lose their power.

"Sash and Door and Planing Mills", "Boat Building" and "Metal Fabricating" no standard portion of production losses could be identified as being permanent. Therefore, industrial managers and the field team had to estimate losses by examining each establishment individually.

SECONDARY INCOME LOSSES

1. METHOD

Many sources in addition to direct field observations were used in this study to derive secondary losses. Firms accounting for 66% of the total employment of floodable industries did answer questions concerning backward linkages; their responses did reveal many of their purchases and out-of-province sources of materials. However, firms often reported only their major inputs, and not their full range of purchases. Therefore, gaps in field survey information had to be filled with simulated data based upon industrial coefficients listed in Table 14 of The Input-Output Structure of the Canadian Economy - 1961 (D.B.S., 1969: Vol.2). Once the data base was complete, it was possible to calculate the income lost by non-floodplain establishments as a result of the failure of floodplain industries to make purchases from them.[13/]

a. Secondary Effects of Agricultural Crop Damage

(1) Backward Linkages - During a flood, farmers with flooded fields would make fewer purchases of materials and equipment than usual. In Chapter V, the value of these foregone purchases was logically deducted from the gross value of floodable crops to obtain estimates of potential primary agricultural damage. However, such reductions in demand

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13/ See above, "Estimating Primary Income Losses, Section 1 - Method" for general technique and sources of data.

cannot be excluded completely from an analysis of flood damage because they cause secondary losses in the economy.[14/]

In the Fraser Basin, most secondary losses originating in the agricultural sector would result from the flooding of vegetable acreage. Manufacturers of fertilizers, insecticides, sacking, cardboard boxes and wooden crates would be forced to reduce their normal production levels because flooded vegetable farmers would fail to make their usual purchases of these goods. The income portion of this reduced production represents the secondary loss a flood would inflict on British Columbia.

In this study, the scope of the investigation of secondary losses was dictated largely by data constraints. It was possible to estimate the losses that both carton and crate producers and their suppliers would incur as a result of a reduction in demand for their products. This could be done because many carton and crate producers are located on the floodplain and information on their inputs was obtained in the field survey. However, the impact of a reduction in purchases of fertilizers, insecticides and sacking could be traced back only as far as the manufacturers of these commodities.

Because carton producers are located on the floodplain, they would suffer <u>primary</u> income losses for 20 days during a flood <u>irrespective of the state of demand</u> for their products. Therefore, adjustments had to be made in the estimates of <u>secondary</u> losses such producers would suffer as a result of the flooding of vegetable acreage. To accommodate the impact of the primary losses, only 80% of the value of purchases of cartons foregone by vegetable farmers was incorporated into computations of secondary losses. The remaining 20% had already been included in calculations of primary losses of producers.[15/]

14/ Even if farmers had pre-ordered materials, they would have to postpone using them until the year following a flood. At that time, they would fail to make their normal purchases from the British Columbia producers and thereby affect the economy's output level.

15/ Cartons for the agricultural sector are manufactured for 6 months a year, the peak period being the 20 days during which a flood would force producers to shut down their operations.

(2) Forward Linkages - Seven of nine major British Columbia fruit and vegetable canning and processing firms reported that they would suffer severe income losses if their sources of small fruits and vegetable crops were destroyed by a flood. They claimed that the destruction of floodplain crops, for which no substitutes were available, would force them to reduce their total production by $11,366,000 (under 1971 conditions).[16/] Of this total, $3,190,000 would consist of income of the firms and their employees and $1,296,000 would be income lost by British Columbia suppliers of these firms (excluding farmers). Thus, the total "forward linkage" income loss caused by the inundation of all floodplain fruit and vegetable acreage would be about $4,486,000 (or $344 per acre of land under relevant crop types).[17/]

(3) Allocation of Losses Among Dyking Areas - Because differences in the types of crops and flood potential exist among dyking districts, the origins of backward and forward linkage losses had to be established. First, the acreage occupied by crops whose destruction would induce these losses was determined for each dyking district. Secondly, these calculations were combined with estimates of backward linkage losses for individual crop types to compute the total backward linkage loss for each district. Thirdly, because the forward linkage loss was initially estimated only for British Columbia as a whole, it was divided among dyking areas according to the relative number of acres of pertinent crops in each. Fourthly, the forward and backward linkage losses were summed and used to calculate the average loss per acre of farmland for each dyking district. Finally, the average loss per acre was multiplied by the total acreage inundated during floods of different magnitudes to determine total secondary losses for

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16/ Information is based on responses to letters mailed to the companies (Appendix D.2).

17/ The floodplain contains 13,042 acres of vegetables and fruits that could be used in the processing industry.

each area (Appendix H.7).[18/]

b. Egg Processing

Almost all eggs produced in the lower mainland are bought by wholesalers directly from farmers. Wholesalers grade, crate, transport and sell these eggs, adding between $.06 and $.08 per dozen to the farm gate price (Egg Marketing Board, 1971). Of this mark-up, $.04 to $.06 represents income earned by the firms and their employees.

Because wholesalers can import eggs to fill local shortages, a flood that reduces local production would cause only income losses at grading stations and extra freight and handling costs. Since these losses comprise an unknown portion of the normal mark-up, in this analysis, secondary losses associated with a reduction in the local egg supply were simply assumed to be $.03 per dozen.

c. Dairying

Any flood in the Fraser Basin that prevents dairy farmers from producing milk would inflict secondary losses on milk processors. Interviews with managers of major British Columbia dairies revealed that milk processors generate (directly) $.40 of income for every $1.00 of crude milk they purchase. In this study, it was assumed that the entire $.40 would represent the secondary loss induced by a temporary disruption of crude milk shipments. On this basis, it was estimated that secondary losses would be directly proportional to primary losses incurred by flooded farms and would amount to $2.44 per cwt. of milk not produced.

18/ Since the size of the loss depends on the availability of alternative sources of raw materials, significant losses would occur only when major producing areas are flooded. Because this is unlikely in floods of less than 24 feet, in the present study, losses are counted only for floods of 24 feet or greater.

d. Manufacturing Industries

The steps outlined above under the general title "Method" adequately describe the approach used to determine the secondary losses resulting from the temporary closure of manufacturing industries. No further description should be necessary. An example of the calculations of the primary and secondary income losses of a "typical" industry appears in Appendix D.1.

SECONDARY LOSSES RESULTING FROM THE SEVERANCE OF TRANSPORTATION ARTERIES

A study by Pearse Bowden (included as Appendix I) revealed that few permanent losses would be incurred as a result of severances of major transportation arteries. The report suggested that losses would consist of costs borne by transportation industries having to delay or transfer shipments normally scheduled to travel on the Canadian National (C.N.), Canadian Pacific (C.P.), and British Columbia Hydro Railways and on the Trans-Canada Highway. It found that no significant costs would be associated with the flooding of oil and gas pipelines. It also concluded that no British Columbia industry (including the tourist industry) would suffer permanent income losses because of the flooding of transportation arteries.

A range of possible costs of delaying and transferring normal railway and road shipments was presented. Estimates of potential losses caused by the closure of railways varied between $30,000 and $676,000 per flood, depending upon the length of time lines were assumed to be closed and the location of the track failure. For roads, one estimate proved adequate.

1. SECONDARY LOSSES RESULTING FROM THE DISRUPTION OF RAILWAY TRANSPORTATION

There were several problems in using the estimates of railway transportation disruption costs provided in the Pearse Bowden study.[19/] First, there was some uncertainty about the potential size of railway costs and their chance of occurrence during a particular flood. Secondly, secondary losses resulting from breaks in the track at various parts of the rail network would be interdependent and frequently non-additive. Thirdly, it was difficult to allocate costs among different areas in the Basin even though this had to be done before flood prevention benefits could be attributed to alternative flood control measures.

The only apparent solution to these problems was to base the analysis on assumptions that would enable a reasonable (if arbitrary) assessment to be made of potential secondary losses. The following set of assumptions was ultimately adopted.

a. Upper Fraser (Thompson River)

(1) Because of the design of the railroad network, only 50% of the floods in excess of the 1972 level on the Thompson River would cause one-week closures of both the C.N. and C.P. Railway lines south of Basque. The cost of the resulting delays and transfers would be $157,000.

(2) 50% of the floods in excess of the 1972 level would induce one-week closures of both the C.N. and C.P. Railway lines north of Basque on the Thompson River and would cost $116,000 in delays and transfers. 25% of the floods in excess of the 1972 level would inflict one-week closures on only the C.P. line north of Basque at a cost of $30,000. 25% of the floods in excess of the 1972 level would sever the C.N. line, prevent access over the South Thompson Bridge and cost $63,000. The average loss resulting from flooding above Basque would therefore

19/ All gross estimates of the costs associated with the loss of rail access for given lengths of time as a result of breaks in the rail line at different points are presented in detail in Appendix I.

be $81,000 each time water levels exceeded those of the 1972 flood.

(3) Since cases 1 and 2 both refer to the same floods on the Thompson River, the average income loss on the Thompson per occurrence of high water would amount to .5 ($157,000) + .5 ($81,000) = $119,000. The logic underlying this computation is that during 50% of the floods, the <u>maximum</u> loss would be $157,000, while during the other 50%, the maximum average loss would be $81,000.

b. Lower Fraser

(1) A spring run-off of 24 feet (Mission) or higher could flood Delta Dyking District and cause a one-month delay in the shipment of coal over the British Columbia Hydro Railway. This delay would cost the railway $234,000.

(2) The same run-off could sever both the C.N. and C.P. rail lines between Mission Bridge and Hope for one month and inflict costs of $442,000 on British Columbia. However, the net loss resulting from the flooding of areas between Mission and Hope would be only $442,000 less the costs borne in the Thompson River system ($119,000). This subtraction must be made to avoid double-counting the costs incurred as a result of a delay generated simultaneously in the Upper and Lower Fraser.

The $323,000 in delay and transfer costs attributable to flooding in the Lower Fraser were allocated among dyked and undyked areas in direct proportion to the lengths of the dykes and exposed track in each. The percentage contribution of each area is shown in Table 3.

TABLE 3

ALLOCATION OF FRICTIONAL COSTS CAUSED BY SEVERANCE OF RAIL LINES BETWEEN MISSION BRIDGE AND HOPE

Dyking Area	Proportion of Net Cost Allocated to Each Area
Agassiz	17%
Harrison Mills	12%
Dewdney	15%
Hatzic	2%
Chilliwack	32%
Matsqui	17%
Undyked	5%

2. FRICTIONAL COSTS RESULTING FROM FLOODING OF ROADS

Frictional costs incurred during a one-month disruption of road transportation caused by the flooding of the Lower Fraser valley were estimated to be $100,000. To incorporate this estimate into the present analysis, it was necessary to divide it among dyking areas whose flooding could cause the severance of road access to the interior of B.C. Therefore, the $100,000 was allocated among relevant areas in direct proportion to the lengths of the dykes protecting each (Table 4).[20/]

20/ It should be pointed out that the opening of the proposed Vancouver to Lillooet highway would eliminate these frictional costs and that this was considered in the projections of future damages.

TABLE 4

ALLOCATION OF FRICTIONAL COSTS CAUSED BY FLOODING[a] OF ROADS IN THE LOWER FRASER

Dyking Area	$'000 Cost Allocated To Each Area
Agassiz	10
Harrison Mills	7
East Nicomen	10
West Nicomen	22
Dewdney	9
Hatzic	2
Sumas	21
Chilliwack	19

a For floods of 24 feet (Mission) or greater.

SUMMARY

A flood can impose income losses both directly on floodplain industries and indirectly on their suppliers and markets. The losses, in the former case, are primary income losses and, in the latter, secondary.

This chapter describes the procedure used to estimate the size of potential income losses that could occur during a Fraser River flood. Information was gathered both in the field and from secondary sources. Then, on the basis of a series of plausible assumptions, a system was elaborated whereby approximations of potential flood-induced income losses could be established.

It was found that, given certain conditions, estimates of income losses could be determined fairly accurately, although they could never be as precise as assessments of physical damages. However, the problem of identifying a stable set of conditions or even assigning probabilities of occurrences to particular conditions was only partially solved. Consequently, the estimates of flood-induced income losses in this study represent rough approximations of highly unstable potential effects of given floods.

CONCLUSION

Prior to examining primary and secondary income losses, it was thought that considerable time and money would have to be spent to obtain reasonable estimates of true losses. It soon became apparent that, regardless of the detail of the study, these losses would have to be based on many tenuous assumptions. It also became clear that the cost of significantly improving the approach adopted in this analysis greatly exceeded the available budget. Finally, it was realized that secondary income losses represented a very small part of the total potential flood damages. Therefore, it was concluded that the extra cost of obtaining "better" estimates could not be justified.

The weaknesses of the methods used to determine primary and secondary losses have been outlined. The host of assumptions and unstable conditions, upon which these estimates rest, indicate the unpredictable nature of these losses and the potential error inherent in the estimates. Although the results are reliable for calculations of this kind, no claim can be made for their absolute accuracy.

CHAPTER VII

MISCELLANEOUS FLOOD DAMAGES

INTRODUCTION

In the Fraser Basin, about 90% of total potential flood losses consist of damages to residential, commercial, industrial and agricultural activities and income losses. This chapter describes the methods and sources of information used to estimate the remaining damages. These losses include extra costs of food, costs of evacuating people, the value of the loss of use of floodplain dwellings, and damages to roads, railways, schools, apartments, utilities, barns and outbuildings.

Little time was spent estimating miscellaneous damages. In some cases, extensive investigations proved unwarranted because secondary sources were reliable and damages were of minor importance. In others, experts indicated that damages were so unpredictable that further study would add nothing to the analysis.

METHODOLOGY AND FLOOD DAMAGE ESTIMATES

1. ROADS

According to the British Columbia Department of Highways, it is impossible to provide a single estimate that adequately represents average flood damages per mile of road. Apparently, even a mile-by-mile study would give only a rough idea of the potential damage.

The best information the Department could supply was the following general description of the impacts of a flood: 1) good road surfaces and bases would be less severely damaged than poor ones, 2) the greatest problem would be posed by fast-flowing water rushing over the roadway and destroying the shoulder, and 3) depending on the road grade, premature paving might be required because roads would be re-opened before their bases have time to stabilize.

In view of this response, it was decided that damage estimates would have to be based on previous studies of floodable areas. Three studies were selected. A summary of their findings is presented in Table 5.

TABLE 5

AVERAGE ROAD DAMAGE - SELECTED AREAS

Area	Year in which Damage Occurred	Year for which Damage was Estimated	Reported Damage Per Mile ($)	Per Annum Rate of Price Escalation 1/ to 1971 (%)	Value of Damage Per Mile in 1971 Prices ($)
Winnipeg, Man.	1950	1957	6,750	3.0	10,000
Fraser River	1948	1949-50	5,235	2.5	9,000
Squamish, B.C.	various	1965	1,500	5.0	2,000

Sources: Royal Commission (1958: 53); Fraser River Board (1956: 53); Engineering Division (1967)

1/ This, and subsequent rates of price increases used in this chapter, were taken from Engineering News Record 184 (24) : 85

Damage costs for the Fraser and Winnipeg areas are clearly of a much greater magnitude than those estimated for the Squamish basin. The difference might be accounted for by variations in flood duration, road qualities or other factors. However, since there was no basis for deciding which estimate would better reflect the potential damage to existing roads in the Fraser, in the present study it was assumed that the duration of flooding would be the critical variable. Both the Squamish and the Fraser-Winnipeg estimates were then accepted on the following premises: 1) all roads covered by a Fraser River flood for more than one week would suffer $9,000 damage per mile, and 2) all roads covered for one week or less would suffer $2,000 damage per mile.

2. RAILWAYS

Estimates of potential damages to rail lines were based on information obtained from the Canadian National (C.N.) and Canadian Pacific (C.P.) Railway Companies. These companies suggested that, although the extent of the damage in any flood was unpredictable, it would be a function of water velocity, the quality of track bed and the stability of land upon which the line was located. They also anticipated that their major costs would be incurred repairing washouts, dumping riprap, replacing ballast, and raising track.

In 1971, the C.N.R. provided estimates of damages likely to occur to specific lengths of track along the Fraser inside and outside the dykes. These estimates were subsequently modified during a re-assessment of the damage potential in the light of 1972 flood conditions. The final figures are presented in Appendix E.1.

The C.P.R. supplied estimates of the average damage per mile expected to occur over 40 miles of vulnerable track below Hope. It anticipated that repairing 20 miles of lightly affected track would cost $5,000 per mile, and the remaining 20 miles, $13,000 per mile. The company also calculated potential damages for specific points on its line in the Upper Fraser. To do this, it relied heavily on 1972 freshet conditions. All estimates are illustrated in Appendix E.2.

C.P.R. estimates of average damage were applied to several other lines in the Lower Fraser. They were used to compute potential damages to the track of the following companies: British Columbia Hydro and Power Authority, Burlington Northern, British Columbia Harbour Board, and British Columbia Railway (Appendix E.2).

3. UTILITIES

a. Sewage and Water Systems

The Winnipeg Royal Commission (1958: 48) estimated that cleaning the Winnipeg sewage system would cost $1.50 per acre after a 15-day flood and $3.00 after a 30-day flood (1957 prices). The present study based its estimates of sewage damage on this information. Potential damages were assumed to be zero, $2.30 or $4.50 per serviced acre depending upon whether a flood was expected to last less than 8 days, 8 to 30 days, or more than 30 days.[2/]

Winnipeg data were also used to compute the costs of sterilizing and repairing flooded water mains. The Winnipeg estimate of $0.94 per acre of serviced land (Royal Commision, 1958: 48) was updated to $1.40 and applied to the serviced acreage in the Fraser Basin.

b. Major Utilities

Estimates of damage to major utilities were obtained from the Substation, Distribution, and Gas Divisions of the British Columbia Hydro and Power Authority and from the British Columbia Telephone Company (Crippen, 1971: 6-30).

The B.C. Hydro and Power Authority expected that repairing and cleaning power distribution facilities would cost $300 per transformer. It estimated its substation damage would range from $152,000 in a 24-foot flood (Mission) to $715,000 in a 26-foot flood. Finally, it calculated that gas distribution facilities would require cleanup and restarting procedures costing $30.00 per gas-using household flooded.

2/ The 1958 values were updated at 3% per annum to obtain the 1971 estimates.

B.C. Telephone Company provided a lump sum estimate of the potential damage to its installations. It suggested that virtually all of this damage would occur to the Yarrow and Chilliwack exchanges because the Ladner, Steveston and Richmond exchanges would not be inundated to significant depths. Therefore, in the present study it was assumed that only the Chilliwack and Yarrow exchanges would be damaged. Damages were estimated to be $400,000 in a 24-foot flood (Mission) and $450,000 in a 26-foot flood.

4. BARNS AND OUTBUILDINGS

The 1963 Benefit Study (Robertson, 1963: Appendix C) estimated that barns and outbuildings would have to be cleaned and painted following a flood. The costs used in that study were updated to $140 per barn and $40 per outbuilding in the present analysis.

5. APARTMENTS

No differentiation was made between apartment and residential damages. Ground floor apartment suites were simply assumed to suffer the unit residential damages derived in Chapter III, and total damages were calculated accordingly.

6. SCHOOLS

In the 1963 Benefit Study (Robertson, 1963: Appendix E), damages occurring at schools at various flood depths were expressed as a percentage of the assessed market value of school buildings. In the current analysis, the 1963 percentage distribution (Table 6) was applied to 1971 market values to obtain updated damage estimates.

TABLE 6

FLOOD DAMAGE AS A PERCENTAGE
OF ASSESSED VALUE OF SCHOOLS

Flood Depth Above Floor	Per Cent of Market Value Damaged
1	18
2	37
3	44
4	50
5	58
6	65
7	71
8	77
9	86
10	95

Source: Robertson, 1963: Table D-1

Estimates of 1971 market values of schools were provided by the British Columbia Department of Education. The Department supplied these estimates in a form that related classroom values to three variables: 1) level of education, 2) number of classrooms, and 3) costs of offices, libraries and gymnasiums usually found in buildings of specified sizes (Table 7).

TABLE 7

AVERAGE MARKET VALUES OF CLASSROOMS
IN LOWER FRASER SCHOOLS

Primary Schools		Secondary Schools		
Number of Classrooms	Market Value per Classroom ($)	Classrooms	Market Value per Classroom ($) Jr. Secondary	Market Value per Classroom ($) Sr. Secondary
4	45,000	10	80,000	96,000
8	37,000	13	71,000	85,000
9	43,000	17+	65,000	78,000
16	37,000			
23	31,000			

Source: B.C. Department of Education

Once the percentage distribution of damages and values of classrooms had been determined, total potential flood damages were calculated in several steps. First, all flood plain schools were located on maps, and the elevations and number of ground floor classrooms in each school were identified in a field survey. Next, potential flood depths were established using the method described in Chapter IV (Commercial Damages). Then, the total market value of affected classrooms in each school was calculated and multiplied by the percentage damage corresponding to the depth to which each would be flooded. Finally, the results were summed to obtain total potential damages in various floods.

7. LOSS OF USE OF DWELLINGS

The value of the loss of use of dwellings is included in flood damage studies as a measure of the inconvenience, hardship and disutility suffered by people forced from their homes. In the present analysis, it was assumed equal to the rental value of residences over the period of disuse. Since one month's rent was estimated to be one per cent of the market value of a house and its contents, a one-month loss of a house would be worth $400, $210, or $90 for an A, B or C class house respectively.

The duration of the loss of use of dwellings was estimated using a technique similar to the one applied in the 1963 Fraser report (Robertson, 1963: Appendix L).[3/] The true period for which houses would be abandoned was recognized as having a potentially large range with an upper limit of as much as six months. However, past experiences such as the 1950 Winnipeg flood have shown the average evacuation period to be much less. On the basis of this information, the loss of use was defined in terms of average durations of flooding (Appendix E.3) and depths of flooding above main floors (Table 8).

3/ This was an adaptation of the Winnipeg method (Royal Commission, 1958)

TABLE 8

LOSS OF USE OF HOUSES AS A FUNCTION OF FLOOD DEPTH ABOVE THE MAIN FLOOR

Flood Depth above Main Floor	Generalized Total Loss of Use of Dwellings
$<$ 1 foot	Flood Duration only
1 to 2 feet	Flood Duration + 45 days
$>$ 2 feet	Flood Duration + 60 days

Two assumptions had to be made before average duration of flooding could be estimated. One was that flooding would begin once the river reached a dyke's minimum confidence level (described in Chapter II).4/ The other was that flooding would terminate once the river receded to the level of the average land elevation in each dyking area. By plotting these critical levels on schematic hydrographs5/ of various peak flows, it was possible to identify average flood durations in each dyking area.6/

Once losses of use (during and after a flood) had been determined (Appendix E.4), they were combined with data on house rental values and main floor elevations.7/ Appendix E.5 illustrates the resulting unit "depth-value of disuse" functions computed for each dyking area. Total values of disuse for each area were generated with these functions in the same way that total residential damages were derived in Chapter III.

4/ The level at which flooding was assumed to begin was not a very critical variable because flood waters were expected to rise quickly, (see footnote 5).

5/ A hydrograph describes the rise and fall of a given freshet over time. River storage is plotted along the vertical axis and days are plotted along the horizontal. The Engineering Division (Water Planning and Management Branch, Department of the Environment) supplied schematic hydrographs for floods with peaks ranging from 20 to 27 feet (Mission).

6/ This was a rough way of calculating the duration. However, given the unpredictability of such factors as emergency pumping, the size and time of dyke breaches, and even the hydrograph itself, it was considered well within the range of accuracy attainable with the available data.

7/ A sample of the process used in establishing depth-damage curves for the "loss of use" factor is presented in Appendix E.4.

8. EXTRA FOOD COSTS

Following the premise of the Winnipeg report (Royal Commission, 1958), it was assumed that, during a flood, food expenses would be one-third higher than normal. This would occur because people would be forced to buy food in smaller quantities than usual. The per diem extra cost was estimated to be $0.38 per person.[8/] The cost per dwelling was established on the basis of the number of persons per household in different flood plain areas (1966 Census of Canada).

The procedure used to calculate unit depth-damage functions for extra food costs (Appendix E.6) was similar to the one used in the preceding section. The only modification was that a uniform level of expenditure was assumed for all house classes.

9. COSTS OF EVACUATING PEOPLE

In a report by Crippen (1971: 7-2), the cost of evacuating people was assumed to be equal to the average return fare by bus from flooded homes to non-flooded areas ($1.30 per person). This estimate was adopted in the present study.

SUMMARY

The 1963 Benefit Study (Robertson, 1963) showed potential miscellaneous damages to be of minor importance in the Fraser River Basin. Since many of these damages are also unpredictable, in the present analysis estimates were based on sparse historical evidence, secondary sources, and subjective appraisals by informed personnel. In this way, little time was wasted attempting to produce results that would, at best, be questionable.

8/ This was derived from the $28.80 per week average expenditure for feed for a family of 3.8 people in 1969 reported in the August 1971 edition of the Canadian Consumer (page 141). It was updated to 1971 by a factor of 6% to obtain an average expenditure of $1.15 per person per day.

CONCLUSION

The procedures used to assess miscellaneous damages in this study are crude. However, it is doubtful that further refinement would provide more credible results or make the analysis of total damages in the Fraser Basin more meaningful.

CHAPTER VIII

GROWTH ON THE LOWER FRASER FLOODPLAIN

INTRODUCTION

Flood prevention works constructed today will protect both present and future floodplain developments. Therefore, to determine total benefits of flood control schemes, future economic activities and potential damages must be estimated.

This chapter describes the methods used to make projections of growth on the Lower Fraser floodplain between the years 1971 and 2000. It presents forecasts of population, industrial and agricultural changes in individual dyking areas at five-year intervals, and provides estimates of annual rates of growth.

Although flood control projects have been known to cause an intensification of floodplain use, most forecasts in this study are based on the assumption that additional protection will not affect growth in susceptible areas.[1/] This approach was taken because the existing perception of the flood hazard in the Fraser Valley is so low that a reduction of the threat will not likely induce an acceleration of development.

GENERAL METHODOLOGY

It is difficult to estimate future population, residential, commercial and industrial growth accurately. Cohort, gravity and input-output models can be used to make reasonable predictions for large regions with strong internal economic, social and political linkages. However, these projections are likely to be accurate only for a five or ten-year period because their reliability declines as the time horizon increases.

1/ In the Upper Fraser Basin, improved dyking will probably cause growth in some areas. The impact of dykes in these areas is described in reports on Quesnel, Oak Hills, Prince George, and Kamloops (Canada Department of the Environment, 1973 and 1974). Project-induced growth is defined in Chapter I of the present study.

Predicting growth for smaller areas is even more susceptible to error. The smaller the region, the more sensitive it becomes to factors such as changes in transportation routes and the introduction of new industries. Also, external forces, which tend to be of minor importance in larger areas, become increasingly more significant as the area shrinks in size. Under these circumstances, input-output models and other sophisticated techniques of analysis are of little use.

In this study, growth projections were required for small dyking districts. Since these areas are defined primarily in physical terms, many are merely part of larger economic entities and are critically affected by developments outside their boundaries. The rural dyking districts are probably influenced by factors such as migration of youth to cities, farm consolidation and fertility and mortality rates. The non-rural dyking areas are affected by other variables like their proximity to Vancouver, the location of transportation arteries and major non-floodplain developments.

Growth estimates were based primarily on discussions with local planners, analyses of historic trends and investigations of factors that could influence future development (eg. zoning plans, proposed transport systems, port expansion and industrial activities).[2/] Maps, air photos and census data were examined to determine patterns of past growth. These were used to estimate probable future conditions in areas where historically stable trends appeared likely to continue. In areas where growth rates had been erratic or changes were anticipated, projections were based largely on the opinions of planners and information obtained from municipal plans.[3/]

Projections were made for population growth and industrial and agricultural development. Annual percentage changes in population were projected for each dyking area and used to represent probable rates of expansion of activities that grow in direct proportion to population size (eg. residential and commercial). Industrial growth was forecast in

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2/ Projections made by the Lower Mainland Regional Planning Board (1968) and the Greater Vancouver Regional District Planning Division (1971) were used extensively.

3/ This approach has been used in other studies (eg. James, 1964; Royal Commission, 1958).

terms of the number of industrial acres likely to be developed annually in each dyking area. Gross losses of agricultural acreage were predicted at five-year intervals for three areas in which significant amounts of farmland are expected to be lost to residential, commercial and industrial developments.4/

Two alternative growth projections were used in this study. The one described in this chapter predicts the "most likely" future conditions on the floodplain. The other, which requires no description, is the "zero growth" alternative. It was used to estimate the lower limit of possible future damages. Two projections were made to show the maximum effect that <u>major</u> floodplain zoning restrictions could have on the size potential flood damages (Appendix G.7).

ZONING REGULATIONS

Zoning plans for each district, municipality and township in the Lower Fraser Valley were clearly defined in the "Official Regional Plan" (L.M.R.P.B.: 1966).5/ The aim of the plan was to establish guidelines for land use and prescribe a course of action for an orderly development of the Lower Mainland.

In the plan, all land in the Lower Mainland was zoned according to the purpose for which it was considered best suited. Types of land use were classified under the following categories: urban, rural (agricultural), industrial, park and reserve. For each classification, both short and long range plans and maps were produced to provide a blueprint for the development of the area. The short-term plan was designed to establish the patterns of growth in the immediate future.

4/ Because of a lack of data, growth projections for areas in the Upper Fraser Basin had to be estimated using different techniques. A description of the methods used to estimate growth in these areas can be found in individual studies of the benefits of dyking Kamloops, Oak Hills, Quesnel and Prince George (Canada Department of the Environment, 1973 and 1974).

5/ This plan was officially adopted by an order-in-council in August, 1966.

The long-term plan was intended to define the ultimate extent of urban, rural, industrial and park areas.

The general policy towards floodplain areas is outlined on page 3 of the "Official Regional Plan" (L.M.R.P.B., 1966). The "Plan" declares that the enlargement of floodplain areas presently zoned for urban use is contingent on flood-proofing. In addition, it proposes that little floodplain development should be allowed and that, if growth is permitted, it should be directed towards activities that suffer least from flooding.

This policy towards floodplains was adopted to minimize "public and private expenditure for flood protection" and "losses resulting from periodic flooding". However, since the plan commits a large amount of floodplain land to urban and industrial use,6/ the anticipated level of growth in most dyking areas will not likely be affected by land shortages in the near future. A map showing the present extent of floodplain zoning is provided in Figure 5, Appendix F.

With exception of the establishment of an industrial land reserve in Delta and the re-zoning of a few small parcels of land, the overall zoning scheme adopted in the "Official Regional Plan", has changed little since its inception. However, the British Columbia Land Commission, which put a freeze on agricultural land in 1973, could bring about significant changes. The possible effects of these changes are accounted for in this study because it appears that the Commission tends to favour a lower rate of development than is predicted in the "most likely" projections.

POPULATION GROWTH

1. METHOD

To establish a basis for estimating future population, it was necessary to identify historical population trends in each dyking area. The first step in determining these trends was to subdivide each area into the smallest census units for which population statistics were

6/ i.e. The land is either used for urban and industrial purposes or zoned for these uses.

available (i.e. enumeration areas or E.A.'s). The population of each dyking district was then estimated for the years 1951, 1961, 1966, and 1971 by summing census data recorded at the E.A. level. In areas where boundaries of E.A.'s and dyking areas did not coincide, air photographs were used to derive population estimates. By tracing population statistics back to 1951, a clear indication of the pattern of growth was obtained.

Generally, future population growth rates were expected to be similar to those of the past. For this reason, future rates were estimated on the basis of historic trends. However, historic rates were always adjusted to account for changes predicted by regional and municipal planners, the impact of local zoning plans, the effects of municipal and provincial land use policies, and the influence of growth patterns of neighbouring municipalities.

2. POPULATION GROWTH PROJECTIONS

In 1971 about 114,000 people, representing some 10% of the total Lower Mainland population, lived in areas susceptible to flooding. Of that total, about two-thirds was concentrated in the Metropolitan Vancouver area and one-third was dispersed throughout the rest of the Lower Fraser floodplain. Richmond (excluding Sea Island), with 60,000 inhabitants, accounted for 52% of the floodplain population. The dyking district of Chilliwhack (including Chilliwack City) had the second largest population with 23,000 people or 20% of the total.

According to the "most likely" forecasts of population made in this study (Tables 9 and 10), the floodplain's share of the Lower Mainland population will rise to 13% by the year 2000.[7/] This rise will occur mainly because of increases in the number of people in Richmond, Delta, and Chilliwhack Municipalities. These three areas alone are expected to account for 93% of the total floodplain population by the year 2000 compared with 85% in 1971.

7/ A brief outline of the principal reasons underlying the growth projections for each area is provided in Appendix F.1.

Land scarcities in the Vancouver area, coupled with improved access to outlying regions, will cause the population of flood-prone areas near the city to grow rapidly. Because of its proximity to downtown Vancouver, Richmond will likely attract a large part of the population expanding into the floodable area. Delta, which showed a marked jump in its population between 1961 and 1971 primarily because of improved access (George Massey Tunnel (1959) and Highway 499), is also expected to grow rapidly in the future. These two municipalities, together with the Queensborough area of New Westminster, will probably increase their share of the floodplain area's population from 64% in 1971 to 78% by the year 2000.

Because the eastern portion of the Lower Fraser floodplain is mainly agricultural, most of its dyking districts will experience little population growth over the next 30 years. The only notable exception to this will be the dyking district of Chilliwack. Its population will probably double by the year 2000, largely as a result of the growth of agriculturally oriented industries (Tables 9 and 10).

INDUSTRIAL GROWTH

1. METHOD

Estimates of industrial growth on the floodplain were based on projections made by the Greater Vancouver Regional District Planning Department in its report, "Space for Industry" (1971). In that report, the Department predicted that, by the year 2000, the Lower Mainland will have a total of about 20,000 acres of land in industrial use, or about 12,000 more acres than were developed in 1966. In the present study, these 20,000 acres were allocated among floodplain and non-floodplain areas on the basis of an assessment of the factors expected to influence industrial development in each. Estimates of growth at five year intervals between the years 1971 and 2000 were also made on the same basis.

TABLE 9

HISTORICAL AND PROJECTED POPULATION GROWTH - LOWER FRASER 1951 - 2000

Dyking Area	Population									
	1951[a]	1961[a]	1966[a]	1971	1976	1981	1986	1991	1996	2000[e]
Richmond[f]	16,605	40,589	48,577	59,500[b]	72,400	88,000	107,000	130,000	158,600	186,000
Queensborough	2,047	2,327	2,367	2,500	2,600	3,000	3,500	4,050	4,700	5,300
Delta	2,692	5,050	5,400	10,800[b]	13,700	17,300	22,400	28,600	36,500	44,300
Port Coquitlam	1,570	2,295	1,839	1,750	1,670	1,590	1,510	1,430	1,350	1,300
South Westminster	2,945	3,299	2,989	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Maple Ridge	1,651	2,159	2,115	2,220	2,340	2,460	2,580	2,710	2,850	2,970
Pitt Polder	10	100	146	150	160	170	180	190	200	205
Pitt No. 2	133	250	250	250	250	250	250	250	250	250
Albion[c]	200	280	350	370	390	410	430	450	470	490
Silverdale[c]	40	33	28	26	25	24	23	22	21	20
Mission[c]	300	252	200	175	150	130	115	100	85	75
Dewdney	700	798	777	785	795	805	815	825	835	845
Nicomen	440	600	660	675	690	710	730	750	765	780
Barnston Island	90[d]	94[d]	98[d]	100	105	105	110	110	115	115
West Langley	175	182	198	200	205	210	215	220	225	230
Salmon River[c]	-	-	-	20	20	20	20	20	20	20
Glen Valley	230	236	240	245	250	255	260	265	270	275
Matsqui	1,580	1,716	1,722	1,765	1,810	1,855	1,900	1,950	2,000	2,040
Sumas	1,871	1,915	1,728	1,750	1,770	1,790	1,810	1,830	1,850	1,870
Yarrow	-	1,421	1,553	1,715	1,895	2,090	2,300	2,550	2,810	3,040
Harrison Hot Springs	477	475	486	587[b]	615	650	680	715	755	785
Agassiz-Harrison Mills	1,632	1,982	2,246	2,360	2,480	2,610	2,740	2,880	3,030	3,150
Chilliwhack Dis.	7,953	10,667	12,153	14,100	16,350	18,950	21,950	25,450	29,500	33,200
Chilliwack City	5,662	8,323	8,681	8,848[b]	9,300	9,770	10,270	10,800	11,350	11,800

[a] Source: Statistics Canada; [b] Source: 1971 Census Data; [c] Source: estimated from air photos; [d] Population of McMillan Island is included in Barnston Island total; [e] Similar projections would place the Lower Mainland population at 2.3 million people by the year 2000; [f] excludes Sea Island.

TABLE 10

HISTORICAL AND PROJECTED POPULATION GROWTH RATES - LOWER FRASER

1951 - 2000

Dyking Area	1951-61	1961-66	1966-71	1971-76	1976-2000
Richmond	9.0	4.0	4.0	4.0	4.0
Queensborough	1.0	0.0	1.0	1.0	3.0
Delta	6.5	8.0	8.0	5.0	5.0
Port Coquitlam	8.0	-4.5	-1.0	-1.0	-1.0
South Westminster	2.0	0.0	0.0	0.0	0.0
Maple Ridge	2.5	0.0	1.0	1.0	1.0
Pitt Polder	27.0	8.0	1.0	1.0	1.0
Pitt No. 2	6.5	0.0	0.0	0.0	0.0
Albion	4.0	4.0	1.0	1.0	1.0
Silverdale	-2.0	-2.0	-1.0	-1.0	-1.0
Mission	-3.0	-3.0	-3.0	-3.0	-3.0
Dewdney	1.5	-0.5	0.0	0.0	0.0
Nicomen	3.0	2.0	0.5	0.5	0.5
Barnston Island	0.5	1.0	0.0	0.0	0.0
West Langley	0.5	1.5	0.0	0.0	0.0
Salmon River	-	-	-	0.0	0.0
Glen Valley	0.0	0.0	0.5	0.5	0.5
Matsqui	2.0	0.0	0.5	0.5	0.5
Sumas	0.0	-2.0	0.0	0.0	0.0
Yarrow	-	2.0	2.0	2.0	2.0
Harrison Hot Springs	0.0	0.0	4.0	1.0	1.0
Agassiz - Harrison Mills	2.0	2.0	1.0	1.0	1.0
Chilliwhack Dis.	3.0	3.0	3.0	3.0	3.0
Chilliwack City	4.0	1.0	0.5	1.0	1.0

2. INDUSTRIAL GROWTH PROJECTIONS

An analysis of the present dispersion of industrial land in the Lower Mainland reveals that about 80% of the developed acreage lies in non-floodable areas in Vancouver, Burnaby, Port Moody, North Vancouver, Surrey, and New Westminster (Appendix F.3). Of the remaining 20%, over half is located in the Municipality of Richmond; the rest is scattered throughout the Lower Mainland from Delta to Agassiz (Table 13).[8/]

The main build-up of industries has occurred where transport facilities (water, rail and roads) are readily accessible and where the concentration of population (needed to satisfy both labour and market requirements) is greatest. Industries which must have waterfront access are situated mainly near the north and south shores of Burrard Inlet, around False Creek, on the North Arm of the Fraser River, and in New Westminster. The non-water oriented industries are located near the principal arterial routes in the Vancouver-New Westminster urban area.

The major industries in the valley are closely linked to the area's agriculture, lumber and mineral resources. Sawmilling and other wood-related industries that need waterfront property are concentrated along the Fraser, Pitt, Stave and Harrison Rivers. Other industries, such as processors of agricultural and other natural resources, are located near the larger urban communities in the valley.

Industrial growth in the Greater Vancouver area averaged about 180 acres per year between 1960 and 1966 (Table 11). Of the total industrial acreage developed during these years, close to 50% occurred in non-floodable areas near Vancouver. These areas will continue to absorb a large portion of the region's development because of their site advantages. However, rising land costs in the non-floodable areas (due in part to increasing land scarcities) and better transportation to outlying regions will partially counter-balance the advantages of locating near downtown Vancouver. The net effect will probably be a reduction in the absorption rate of central locations and an increase in the development rate of peripheral areas.

8/ Existing and future industrial developments on the Upper Fraser Basin floodplain are described in individual reports on Kamloops, Quesnel and Prince George (Canada Department of the Environment, 1973 and 1974).

TABLE 11

INDUSTRIAL ACREAGE DEVELOPED: 1960 - 1966

Municipality	Acreage Developed 1960 - 1966 (# acres)	Average Annual Growth 1960 - 1966 (# acres)	Each Municipality's % of Total Growth
Vancouver	131	22	12.3%
Burnaby	274	46	25.7%
New Westminster	50	8	4.5%
Coquitlam[a]	25	4	2.2%
Port Coquitlam	27	5	2.8%
Port Moody	7	1	.5%
N. Vancouver (City and District)	115	19	10.6%
Delta	144	24	13.4%
Richmond	202	34	19.0%
Surrey	94	16	9.0%
TOTAL	1,069	179	100.0%

[a] Includes Fraser Mills.

Source: "Space for Industry", Greater Vancouver Regional District, 1971.

Floodplain areas will likely be prime targets of this industrial expansion. Their abundant supply of zoned land (Table 12), combined with improvements in access, should enable these areas to capture much of the future industrial growth. If the "most likely" projections in this study are correct, the number of floodplain acres under industrial use will rise from 1,942 to 6,635 between the years 1971 and 2000 (Tables 13 and 14). Floodable areas will then account for over 30% of all industrial acreage in the Lower Mainland as opposed to the present 20% (Appendix F.3).

Of the total floodplain acreage to be developed between the years 1971 and 2000, probably over 90% lies within the Greater Vancouver Regional District (Table 13). The rest is scattered throughout the Fraser Valley. Richmond, which presently contains the largest developed area, is expected to experience the greatest industrial expansion. Good access to Vancouver and large tracts of flat land zoned for industrial use are likely to attract industries to this municipality. Delta, Port Coquitlam, the Big Bend areas of Burnaby, and the South Westminster area of Surrey also have sizeable areas zoned for industrial use, are reasonably close to Vancouver,

TABLE 12

FLOODPLAIN ACREAGE AVAILABLE FOR INDUSTRIAL DEVELOPMENT (1971)

Area	Acres
Richmond	3,400
Queensborough	140
Delta	5,000[a]
South Westminster	1,600
Brunette Creek	30
Port Coquitlam	1,100
Burnaby (Big Bend)	1,000
Sub-total: Greater Vancouver Area	12,270
Maple Ridge	600
Albion	60
Mission City	300
Barnston Island	N.A.
Langley	N.A.
Harrison Hot Springs	0
Chilliwack City	7
Chilliwhack Dis.	487[b]
Sub-total: East Fraser Valley	1,454
Total	13,724

Source: Municipal Zoning Plans.

[a] Excludes Roberts Bank Port and back-up lands.

[b] G.V.R.D., 1971

TABLE 13

HISTORICAL AND PROJECTED INDUSTRIAL DEVELOPMENT ON THE FLOOD PLAIN: 1960 - 2000

Area	Acres of Industrial Development 1960 - 2000								
	1960[a]	1966[a]	1971[a]	1976	1981	1986	1991	1996	2000
Richmond	525	700	830	980	1,155	1,355	1,580	1,880	2,120
Queensborough	114	114	183	210	240	270	300	320	320
Delta	80	165	210	260	360	510	660	860	1,020
South Westminster	160	168	220	270	345	445	570	720	840
Brunette Creek	107	119	126	135	145	155	155	155	155
Port Coquitlam	32	59	127	200	300	425	575	725	845
Burnaby (Big Bend)	45[b]	75[b]	125	175	325	475	625	775	895
Sub-total: Greater Vancouver Area	1,063	1,400	1,821	2,230	2,870	3,635	4,465	5,435	6,195
Maple Ridge	11	28	30	40	60	85	125	175	215
Albion	13	16	44	59	74	89	104	104	104
Mission	23	28	30	32	34	36	41	46	50
Harrison Hot Springs	2[b]	2[b]	2	2	2	2	2	2	2
Chilliwack City	6[b]	7	7	7	8	10	12	15	17
Chilliwhack Mun.	6[b]	6	8	10	15	20	30	40	52
Sub-total: East Fraser Valley	61	87	121	150	193	242	314	382	440
Total	1,124	1,487	1,942	2,380	3,063	3,877	4,779	5,817	6,635

[a] Source: Municpal records, maps; [b] Estimate based on air photographs.

TABLE 14

HISTORICAL AND PROJECTED RATES OF INDUSTRIAL DEVELOPMENT ON THE FLOOD PLAIN: 1960-2000

Area	Average Annual Number of Acres Developed per Year							
	1960-66	1966-71	1971-76	1976-81	1981-86	1986-91	1991-96	1996-2000
Richmond	29	26	30	35	40	45	60	60
Queensborough	0	14	6	6	6	6	4	0
Delta	14	9	10	20	30	30	40	40
South Westminster	1	10	10	15	20	25	30	30
Brunette Creek	2	2	2	2	2	0	0	0
Port Coquitlam	5	13	15	20	25	30	30	30
Burnaby (Big Bend)	5	10	10	30	30	30	30	30
Average: Greater Vancouver Area	56	84	83	128	153	166	194	190
Maple Ridge	3	.4	2	4	5	8	10	10
Albion	.5	6	3	3	3	3	0	0
Mission	1	0	.4	.4	.4	1	1	1
Harrison Hot Springs	0	0	0	0	0	0	0	0
Chilliwack City	0	0	0	.2	.4	.4	.6	.6
Chilliwhack Mun.	0	.4	.4	1	1	2	2	3
Average: East Fraser Valley[a]	5	7	6	9	10	14	14	15
Flood Plain Average[a]	61	91	89	137	163	180	208	205

[a] Totals may not add due to rounding.

and have well developed transportation networks. They too should experience relatively high growth through to the year 2000. Other floodplain areas offer no special advantages to industries. Therefore, industrial growth in these areas will likely be low over the next 30 years.9/

DEPLETION OF AGRICULTURAL LAND

Most parts of the floodplain will lose little agricultural land as a result of the expansion of urban and industrial areas. However, in the municipalities of Delta, Richmond, and Chilliwack, the rate of industrial and urban development will be high enough to cause a considerable loss of agricultural property and have an important impact on potential damages.

1. ESTIMATING IMPACT OF RESIDENTIAL DEVELOPMENT

Since there is urban sprawl in the Municipalities of Richmond and Delta, it is difficult to predict the amount of farmland that will be absorbed as a result of residential expansion in these two areas. Urban-zoned areas of Richmond, for instance, have an average density of five people per acre. New residential areas, on the other hand, are being developed with a density of 15 persons per acre. Clearly, much of the anticipated population growth can be channelled into existing urban areas without causing farmland to be withdrawn from production.

Based on this observation, it was estimated that Richmond and Delta would lose one acre of cropland for every 30 people added to the population (Table 15). Underlying this estimate is the assumption that half the people will locate in new residential developments in agricultural land and half will move into existing low-density, non-agricultural areas. Implicit in the latter case is the assumption that some people will occupy high density accommodations such as condominiums and apartments.

9/ For a brief description of some of the reasons for the anticipated growth in each dyking district, see Appendix F.2.

In Chilliwack, most of the land zoned for urban use is farmland. Therefore, on the assumption that population densities of new developments in the area will not change over time, it was estimated that one acre of cropland will be lost for every 12 people added to the population (Table 15).

TABLE 15

LOSS OF AGRICULTURAL LAND

Dyking Area	Acres of Land Lost during Specified Periods 1971-76	1976-81	1981-86	1986-91	1991-96	1996-2000
RICHMOND						
1. Loss to Residential	430	520	630	120	-	-
2. Loss to Industrial	150	175	200	225	300	240
Total Acreage Lost	580	695	830	345	300	240
DELTA						
1. Loss to Residential	90	120	150	190	250	-
2. Loss to Industrial	50	100	150	150	200	160
Total Acreage Lost	140	220	300	340	450	160
CHILLIWACK TOWNSHIP						
1. Loss to Residential	190	220	250	290	340	310
2. Loss to Industrial	0	5	10	10	10	10
Total Acreage Lost	190	225	260	300	350	320

2. ESTIMATING IMPACT OF INDUSTRIAL DEVELOPMENT

Virtually all industrial growth on the floodplain will occur on land presently used for agricultural production in Richmond, Delta, and Chilliwack. Therefore one acre of agricultural land will be taken out of production for every acre occupied by new industrial developments (Table 15).

SUMMARY

Because of the long-term nature of most flood control projects, it is essential to incorporate future growth into analyses of the benefits of flood protection. This chapter, therefore, has projected changes likely to occur on the Lower Fraser floodplain between the years 1971 and 2000.

Estimates of rates of population growth in each dyking area were used to represent growth rates of population-oriented activities. Future rates were predicted on the basis of analyses of historical trends, land scarcities, government policies, and zoning plans.

Industrial growth forecasts were based mainly on historical trends, but projections were adjusted to account for the availability of land and changes in industrial demands in the Lower Mainland.

Forecasts show that urban and industrial developments will cause significant amounts of agricultural property to be withdrawn from production in the dyking districts of Richmond, Delta, and Chilliwack. Consequently, losses of agricultural land were estimated for these three areas but were ignored in all other areas in the valley.

CONCLUSION

The primary forecasts presented in this chapter are labelled "most likely" because they are based on projections of historical trends modified to account for probable changes not reflected in history. Since these projections are merely "most likely", they may be higher or lower than actual growth on the floodplain.

The "zero growth" forecast describes an unlikely minimum bound for future floodplain development. Such a forecast makes it possible to assess the maximum impact that stringent zoning regulations could have on the size of potential flood damages. However, it will be approached only if the British Columbia Land Commission retains its freeze on agricultural land.

Although simple projections were used to predict future conditions in this study, the results are sufficient for estimating the effect of growth on potential flood damages. In view of the small size of floodplain areas and the uncertainties inherent in forecasting, the use of more complex procedures is unwarranted.

CHAPTER IX

PROJECTIONS OF FUTURE DAMAGES TO FLOOD PLAIN ACTIVITIES

INTRODUCTION

The value of potential flood damages in an area may change over time because of changes in the level of economic development and variations in the real values of damageable commodities.

If the level of economic activity on a floodplain is expected to intensify in the absence of improved flood protection works, the benefits of raising the level of protection are called normal growth benefits. These benefits are equal to the amount by which a project is able to reduce anticipated increments of growth-induced damages (see Chapter I).

If, however, people devote the floodplain to higher uses in response to higher levels of protection, the benefits of this protection are called project-induced benefits. These are clearly defined in Chapter I.

The present chapter describes the methods used to project changes in damages expected to occur as a result of four factors: the expansion of urban and industrial areas, increases in productivity in agriculture, the conversion of land into higher uses, and fluctuations in the real values of damageable commodities.

This chapter does not outline the procedures adopted for measuring project-induced growth. The variables and general methods involved in such a measurement are presented in a theoretical form in Chapter I. Since only a few small areas were expected to respond to improvements in flood protection works, a more detailed explanation is not warranted.

GENERAL METHODOLOGY

Three principal projections of future potential flood damages were made in this analysis (Appendix G.7). Of these, the first was the most comprehensive and most likely estimate. It was based on predictions or probable changes in growth, productivity, and real values of different floodplain activities. The second estimate provided a minimum (unlikely) limit to the range of possible future damages. It was calculated on the assumption that the 1971 level of damages would remain constant over time.[1/] The final projection was designed to show the sensitivity of damage estimates to minor errors in projections. It was computed simply by raising the "most likely" rates of change for each damage category by 1% per annum.

The "most likely" estimates of flood damages for the period 1971 to 2000 were based on the following general premises: 1) technological developments will not alter the fundamental unit stage-damage functions that presently exist for residential, industrial and commercial properties, 2) the flood hazard perception of floodplain occupants will remain constant, 3) the relationship between direct and indirect industrial losses, barring price fluctuations, will not change, and 4) the relationship between residential direct damage, extra food costs, the value of the loss of use of dwellings, and commercial and school damages will not vary except for adjustments in real values.

No changes in the annual value of damages were predicted beyond the year 2000. It was felt that projections into the distant future would be completely arbitrary because of uncertainties associated with alterations in growth rates, zoning plans, technology and real values. Consequently, holding annual damages constant after the year 2000 was considered at least as realistic as speculating on changes.

PROJECTIONS OF INCREASES IN RESIDENTIAL, COMMERCIAL AND MISCELLANEOUS DAMAGES

Future potential damages to residential and commercial properties were estimated by adjusting the existing level of damages at a rate equal to the projected rate of increase in the population of each dyking area (Chapter VIII). These estimates were based on the assumption that damages would increase in direct proportion to population.

This assumption should prove accurate unless a radical change occurs in the ratio between apartments and single family units and condo-

1/ It is comparable with the 1963 estimate (Fraser River Board, 1963).

miniums. If this happens, the predicted damage estimates for residential dwellings may be distorted. However, the size of the potential damages will be affected seriously only if there is a very large change in the apartment-single family unit ratio. Since this is unlikely, unadjusted rates of population growth were used to estimate future residential damages.

Rates of population growth were also used to predict changes in damage to other types of activities. These activities fall into the following categories: extra food costs, evacuation costs, value of the loss of use of dwellings, school damages, and damages to sewage, water and gas distribution systems.

Road damage was assumed to remain constant over time even though there may be some correlation between population growth and road building in parts of the Fraser. This approach was adopted because of the questionable accuracy of present estimates of road damage.

FUTURE AGRICULTURAL DAMAGES

Two major factors (excluding price changes) will probably have a dominant influence on the size of the potential agricultural flood damages in the future. One is the loss of agricultural land to rapidly expanding urban and industrial areas; the other, changes in agricultural productivity. Both of these factors were incorporated into the assessment of future damages.

In Chapter VIII, it was suggested that only in the municipalities of Richmond, Delta and Chilliwhack would significant amounts of land be converted from agricultural to urban and industrial use during the period 1971 to 2000. To account for the effect of this expansion on the size of future agricultural damages, estimates of 1971 potential crop damages in the three municipalities were reduced over time in direct proportion to the projected decline of farmland (Table 15, Chapter VIII).2/ Estimates of

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2/ On Lulu Island, only pasture and hay acreage was expected to be removed from production as a result of expanding urban and industrial areas; future agricultural damages were adjusted accordingly.

potential losses of animals and animal products were not adjusted because it was assumed that the impact of urban expansion would be reflected only in reductions in agricultural crop damage.

A study of probable increases in the volume of Lower Fraser agricultural products between 1965 and 1985 (Carne, 1966) showed that rising productivity would be important in shaping the characteristics of agricultural conditions (and flood damage) in the whole valley. These productivity changes were incorporated into the present analysis in several steps. First, the estimated increases in the volume of individual products (Appendix G.1) were grouped into six categories. Then, average annual rates of increase were computed for each category for the periods 1971-1975, 1975-1985, and 1985-2000 (Table 16). These average rates formed the basis for measuring the effect of productivity improvements on future agricultural flood damages.

The rates of increase of total production in Table 16 represent projected output changes for the entire Fraser Valley. It was assumed that the rates predicted for dairy, beef, and swine production would hold true for each dyking area. It was also assumed that physical[3/] crop yields in each area would change at the valley-wide rates.[4/] However, since three crop categories were involved, an additional prediction had to be made of the way in which each area would accommodate the crop production increases. This was necessary to enable the calculation of the average annual rate of change in total crop production for each dyking area.

The annual rate for each area was computed by taking an average of high and low estimates of future production. The high estimate was based on the assumption that vegetable and fruit production would increase at the same rate in each area while fodder production would remain constant. This could occur under three conditions. Productivity on existing vegetable

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3/ Physical output was equated to the 1971 dollar value of the products; "products" in this case really refers to "categories of products", i.e. vegetables, small fruits and pasture and fodder.

4/ Initially, projections in all areas were made under the assumption that the acreage under agricultural use would remain constant. The Chilliwhack, Delta and Richmond projections were then reduced to take into account the number of acres lost to urban and industrial expansion.

TABLE 16

AVERAGE ANNUAL PERCENTAGE CHANGE IN PRODUCTION OF SPECIFIC AGRICULTURAL PRODUCTS - LOWER FRASER VALLEY-1971 TO 2000

Agricultural Group	Average Annual Percentage Changes In Production - Lower Fraser Valley		
	1971-1975	1975-1985	1985-2000[a]
Pasture and Fodder	0	0	0
Vegetables	2.4	1.4	1.0
Small Fruits	7.0	3.3	3.0
Dairying (milk)	2.7	2.4	1.0
Beef	1.0	2.4	2.4
Swine	1.0	0.9	0.8

a/ Projected from previous years

Source: Appendix G.1

and fruit acreage[5/] might rise to meet expected increases in output; in this case, productivity on fodder lands would not change. Farmers might convert fodder land into vegetable and fruit production to meet the anticipated increases; fodder production per acre would then have to rise to accommodate the loss of acreage and maintain fodder output at a constant level. A combination of the two previous conditions might occur.

The low estimate was derived on the basis of the assumption that fruit and vegetable production would expand only by displacing fodder crops. Fodder production would then decline at the same rate at which it was displaced.

Little difference was found between the high and the low estimates. Only during the period 1971-75 was the difference significant and, even then, it was significant only in areas expected to undergo major increases

5/ Increases in productivity on existing vegetable and fruit land could occur with improvements of strains or shifts from low to high yield vegetables and fruits.

in vegetable and fruit production. Therefore, although the average rates presented in Table 17 may deviate from the actual, they are probably a good measure of potential productivity changes.

PROJECTIONS OF INCREASES IN INDUSTRIAL FLOOD DAMAGES

Damages to future industrial establishments were calculated by applying estimates of current potential damages per acre of industrial land to projections of annual increases in industrial acreage (Chapter VIII). In this manner, annual increments in damages resulting from given flood levels were determined for each dyking area.

1. CALCULATING AVERAGE STAGE-DAMAGE RELATIONSHIPS PER ACRE OF FUTURE INDUSTRIAL LAND

The average damage per foot of flooding per acre of developed industrial land was found to vary dramatically among different regions on the floodplain. Since such a variation will probably also exist in areas of future industrial development, two distinct stage-damage relationships were computed as a basis for assessing future potential damages. One represents the industrial areas near Vancouver, and the other, the remaining industrial areas in the valley.

The damage function for the Vancouver area was derived from 1971 field survey results for Lulu Island. This was done, first, by computing potential depths of flooding above floor levels for all industries on the island: these depths were found to range from 0 to 5 feet in a 23-foot flood and 0 to 7 feet in a 26-foot flood. Then, average depths of 1.2 and 1.4 ft. were calculated for the respective flood levels. Next, average damages per acre corresponding to the two average flood depths were derived by dividing the estimated total direct industrial damages in the 23 and 26-foot floods[6/] by the island's 1,013 acres of industrial land.

6/ The damages were $6,542,000 and $7,363,000 respectively. Damage to one major industry flooded to a depth of one foot in the 26-foot flood was excluded from the calculations because it was atypical. Its inclusion would have distorted the results.

TABLE 17

AVERAGE ANNUAL PERCENTAGE INCREASE IN

AGRICULTURAL CROP PRODUCTION IN RELEVANT DYKING AREAS

1971 TO 2000

Areas Likely to Experience Significant Increases in Production	Expected Rates of Increase of Production (%/Year)		
	1971-1975	1975-1985	1985-2000
Richmond	4.5	2.5	2.5
Delta	1.5	1.0	1.0
Glen Valley	2.0	1.0	1.0
Matsqui	2.0	1.0	1.0
Sumas	2.5	1.5	1.5
Chilliwack	3.5	2.0	2.0
West Nicomen	1.0	1.0	1.0
East Nicomen	1.0	0.5	0.5
Dewdney-Hatzic	2.0	1.0	1.0
Albion	2.0	1.0	1.0
Maple Ridge	3.0	2.0	2.0
Pitt Polder	2.0	1.0	1.0

These averages were, in turn, divided by 1.2 and 1.4 feet respectively to obtain an estimate of the damage that would occur in a flood having an average depth of one foot. Since the computed estimates of damages at one foot were similar for both calculations (i.e. $5,400 and $5,200 per acre), they were used to construct a stage-damage curve based on the assumption that damages are directly proportional to flood depth.[7/] Thus, the average damage in a one-foot flood (assumed to be $5,200) was extrapolated to form a stage-damage curve representing the existing stage-damage relationship per acre of industrial land on Lulu Island (Appendix G.2).

The predictive capability of this stage-damage curve was tested by applying the curve to the known distribution of the depths of flooding of industries on Lulu Island. The resulting "predictions" were within 4% of the actual damage estimates.

This stage-damage function was adopted as the probable average stage-damage curve of future industrial floodplain developments in Richmond, Queensborough, Delta, and the Big Bend area of Burnaby. However, because of apparent differences between stage-damage curves of Lulu Island industries and those of industries located in the Lower Fraser Valley upstream from Queensborough, a second "valley" function was identified.

A simple method was used to determine the valley function. Existing potential industrial damages recorded during the 1971 field survey in areas above Queensborough were listed for flood depths of up to seven feet. For certain industries, some damages had not been recorded over the entire seven-foot range. For these, the missing information was extrapolated from the available data. Average damages per acre per foot of flooding were then calculated for South Westminster, Brunette Creek, Port Coquitlam, Albion, and Mission, and a composite function was derived to represent the potential industrial damages to future industries located upstream from Queensborough (Appendix G.2).

The composite function was tested in each "valley" area on the floodplain in the same way that the downstream curve was tested on Lulu Island. It proved capable of providing estimates that were within 10% of the measured damage in each area.

7/ For flood depths of from 1 to 7 feet.

There are several reasons for the large discrepancy between the Lulu Island and the Upstream Damage Functions and for the development of separate curves to represent the two different parts of the valley. The most important, are the following:

1. The industrial mix in Richmond is different from that in the valley.
2. Industries tend to use land less intensively in the valley than on the island, i.e. 70% of the total industrial acreage on the island was reported by the industries as being "actively" used; only 40% was reported as such in the valley.[8/]
3. Industrial layouts may differ between the two regions; machinery and inventory components of the industries may have distinctive characteristics in each.

While it is possible to speculate that areas such as Coquitlam and South Westminster lying near Vancouver will eventually exhibit industrial characteristics approaching those currently found on Lulu Island, no such conjectures were made in this study. Growth projections (Chapter VIII) were based on the assumption that relative intensities of land use would remain unchanged because zoning restrictions were known to favour the types of industries currently found in these areas. For this reason, no reconciliation of "Valley" and "Lulu Island" damages appeared necessary: the two-function approach seemed least likely to distort estimates of future industrial damages.

2. CALCULATION OF PROBABLE FUTURE FLOOD DEPTHS

Before the stage-damage curves could be used to predict future damages, depths of flooding above main floors of prospective industries had to be determined. These depths were estimated for Lulu Island, Delta and the Big Bend area on the basis of the characteristics of existing Lulu Island industries. First, flood depths above ground level were calculated for areas on Lulu Island in which industries are presently situated (see Chapter III). Secondly, an average flood depth was computed for each flood

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8/ Industrial Questionnaire results.

level. Thirdly, this average was compared with the average flood depth above floor levels of existing industries (determined in the 1971 industrial field survey) and a ratio was calculated (Appendix G.3). Finally, this ratio was multiplied by the average flood depth above ground level in areas for which industrial development was predicted. In this way, average depths of flooding above floor levels of future industrial complexes were established for the three municipalities.

As control variables, these averages were useful. However before unit stage-damage functions could be introduced into the analysis, further information was required on the range of flood depths upon which these averages were dependent. Therefore, hypothetical distributions of flood depths were estimated on the basis of the distribution of flood depths over existing Lulu Island industries. These distributions were adjusted to suit each area so that when they were averaged, the results were consistent with the averages calculated as control variables. In this way, the percentage of future industries that would be flooded to different depths in various floods was established (Appendix G.3).

For the industries located upstream from Queensborough, the expected depths of flooding above floor levels were determined directly from data on existing industries in each area (Appendix G.3). This was possible because potential flood depths on existing and future industrial land in these districts are similar.

3. AVERAGE DAMAGE PER ACRE OF FUTURE INDUSTRIAL LAND

Primary direct damages per acre of future industrial land were estimated for different flood levels by applying the stage-damage functions of Appendix G.3 to the probable future flood depths in each area (Appendix G.3). The resulting damages per acre in various floods are shown in Appendix G.4.

Primary and secondary indirect losses to future industries were calculated as simple percentages of the projected primary direct damages. The relationship now existing between indirect and direct industrial damages was measured and found to be approximately 0.5 : 1 in Lulu Island and 0.7 : 1 in areas upstream from Queensborough. These ratios were applied to the estimates of direct damages of Appendix G.4 to derive the expected indirect losses per acre in Appendix G.5.

Projections of total increases in industrial damages per year were then made by combining the estimated rates of development of new industrial acreage derived in Chapter VIII with the "per acre" stage-damage curves of Appendices G.4 and G.5.

4. IMPACT OF PRODUCTIVITY CHANGES ON INDUSTRIAL LOSSES

Potential effects of productivity changes on industrial direct and indirect losses initially were excluded from this analysis. However, when it was found that real incomes in the manufacturing sector had risen over the past two decades while prices of manufactured products had remained relatively constant, it was decided that effects of possible productivity changes should be incorporated into the assessment of future losses. Consequently, the "most likely" projections were based on assumptions of positive productivity shifts from 1971 to the year 2000. The impact of these assumptions was subsequently tested by incorporating an assumption of "no productivity changes" into a second projection based on assumptions of "most likely growth" and "zero price changes" (see footnote 10).

The conclusion that significant productivity changes in the manufacturing sector have occurred and could continue to occur was drawn from an assessment of data from two sources. One was a series of studies by the Economic Council of Canada, and the other, crude trend analyses of real wage and price changes in British Columbia.

Economic Council studies of Canadian productivity in the manufacturing sector between 1947 and 1967 showed that, on average, labour productivity rose by about 3.5% per annum and factor productivity by about 3.0% per annum (Economic Council, 1970: 95-96; Postner, 1971). These studies also showed that, in the wood products manufacturing industry, important in British Columbia, labour productivity rose by more than 4.0% per annum during the 1957-1967 period, and factor productivity by more than 3.5% per annum (Postner, 1971). The Economic Council anticipated that similar changes would occur up to at least 1980.

An analysis of wage and price trends in British Columbia done for the present study also showed that significant productivity changes have occurred in the manufacturing sector. Real wages, as indicated by the Industrial Composite Index deflated to account for inflation, rose by more than 3.0% per annum between 1955 and 1971 and by 3.5% from 1966 to 1971. Over the same period, few positive changes in real prices of manufactured products occured (Statistics Canada, 1970, No. 11-505: 63). Moreover, the proportions of the total value of manufactured products consisting of wages and salaries, on the one hand, and total value added by manufacturing on the other, have remained fairly constant in British Columbia over the past 20 years. Such evidence suggests that manufacturing industries have used both capital and labour increasingly more efficiently over time, and, if the trend continues, labour and factor productivity changes could have an important impact on the size of both direct industrial flood losses and income losses.

In an attempt to predict the effect of productivity changes on flood losses, two sets of assumptions were examined. The first was that total production and value added per acre would remain constant, factor and labour productivity would rise by 3.5% per annum, and the prices of manufactured products would not change.[9/] The second was the same as the first except that production was assumed to increase at 3.5% per acre per annum instead of 0.0%.

Clearly, if the first combination of assumptions is to prove realistic, the number of labourers per acre must fall rapidly in the future. Although no accurate statistics on worker densities per acre in the Lower Mainland exist, there is reasonable evidence to suggest that the rapid decrease in density required to meet these assumptions will not likely occur. For instance, in older cities a maximum decline in worker density of only 10% per decade is predicted. Moreover, the crude figures available for the Lower Mainland indicate that a slight increase may occur in this area (de Chiara, 1969; Herman, 1969; G.V.R.D., 1971: 74). From this information it was concluded that the first set of assumptions is probably untenable and therefore its impact on flood damage estimates was not examined further in this study.

9/ It was necessary to include production per acre because of the "areal" characteristics of the flood damage estimates.

The second combination of assumptions would be roughly consistent with a constant worker density in the manufacturing sector. Because of the lack of evidence to indicate a significant deviation from the present density, this was accepted as a reasonable possibility for the "most likely" projection. On this basis, it was assumed that income losses resulting from the flooding of floodplain industries would "most likely" increase by 3.5% per annum from 1971 to 2000. Following from this income loss premise, it was also assumed that direct industrial losses per acre would rise over time. However, the "most likely" rate of change was set at 2.5% per annum, 1.0% lower than the income loss rate. The difference between the two represents an attempt to recognize that factors such as more efficient handling of inventories could cause direct losses to rise at a slightly lower rate than production and income losses.

In making this "most likely" projection of income and industrial property losses, the analysts were well aware of the likelihood that actual conditions would deviate from projected ones. Factors such as a decreasing of worker densities per acre, a slowing of the rate of increase in labour and factor productivity, and a shift in the composition of the manufacturing sector could reduce future changes in damages per acre to zero. It was for this reason that the impact of the "most likely" assumptions was tested in the second projection that included "no productivity changes", "most likely growth" and "no price changes". (See footnote 10, page 132.)

THE EFFECTS OF REAL PRICE CHANGES ON ESTIMATES OF FUTURE POTENTIAL FLOOD DAMAGES

There are two ways of estimating the value of potential flood damages in a given year in the future. One is to assume that the price structure of damageable goods will be the same in the future as it is today. The other is to forecast price structure changes resulting from differential price increases of various flood-damageable commodities. This section describes how the latter method was employed in the present study to determine "most likely" future damages (Appendix G.7).[10/]

Since an inflation-free discount rate was used to obtain the present value of potential damages over time, inflation-free (real) prices had to be used to determine the value of damages in future years. Real changes in the prices of damageable commodities were forecast by projecting historic changes. The 1966-71 performances of the prices of these commodities relative to the consumer price index were assumed to be the prime indicators of future trends (Appendix G.6 and Table 18).[11/] However, rates of real price changes between 1955-1971 were also examined to obtain an idea of long term price trends to provide a better basis for predicting future rates. The real values of potential flood damages in each year in the future were then estimated by compounding the average annual potential damages calculated for 1971 at the rates of price increases listed in Table 18.[12/]

10/ Two forecasts were also made under the assumption that there will be no change in the price structure. One is the "zero growth" alternative mentioned in Chapter VIII. The other couples the "most likely" growth projections with "zero price changes" (Appendix G.7).

11/ The Fraser River Program Committee decided to use this period as the basis for projecting the benefits and costs of providing flood protection. If only the 1966-71 price trends had been used to predict future changes, the computation of the real annual percentage change in prices would have been:

$$100\left(\frac{100\% + \text{annual \% change in price of commodity (1966-71)}}{100\% + \text{annual \% change in consumer price index (1966-71)}}\right) - 100$$

12/ It should be emphasized that the result is, in real terms, in 1971 dollars. It should also be mentioned that another forecast was made to test the sensitivity of flood damage estimates to possible accelerated changes in agricultural prices in the future (Appendix G.7).

TABLE 18

RELATIVE RATES OF PRICE CHANGES 1955 to 1971 AND

PROJECTED RATES OF CHANGES IN REAL VALUES 1971 TO 2000

Items	Average Annual % Change In Real Value of Items 1955-71	Average Annual % Change In Real Value of Items 1966-71	Damage Category	Assumed Future Annual Rates of Change in Real Values By Damage Category[a] 1971-2000
B.C. Residential Const. Costs	1.3%	2.3%	Residential Direct	2.5%
Cdn. Residential Const. Costs	2.0%	3.8%		
B.C. Industrial and Commercial Structural Construction Costs	2.0%	3.8%	Industrial, Commercial and Schools	0 %
Cdn. Wholesale Index Less Animal & Vegetable Products	-0.7%	-0.8%		
B.C. Machinery and Equipment	0 %	0 %		
Canadian Vegetable Products	-1.2%	-2.5%	Agricultural Crop Damage	-1.0%
B.C. Farm Product Prices	-0.6%	-2.1%		
Canadian Dairy Prices	0.4%	0.7%	Dairy Losses	0.5%
Canadian Beef Prices	1.1%	0.5%	Beef Losses	1.5%
Canadian Poultry Prices	-3.4%	-3.9%	Poultry Losses	-3.0%
Canadian Egg Prices	-3.3%	-8.0%	Egg Losses	-3.0%
Vancouver Food Prices	-0.1%	-0.3%	Extra Food Costs	0 %
Canadian Food Prices	-0.1%	-1.2%		
Canadian Housing	0 %	0.3%	Loss of Use of Dwelling	0 %
Cdn. Indstl. Composite of Wkly. Wages	2.7%	3.8%	Income Losses	3.5%
B.C. Indstl. Composite of Wkly. Wages	2.8%	3.6%		

[a]Note: All other damages assumed to change at 0% per annum; real values were assumed to remain constant after the year 2000.

SUMMARY

Two events could cause the value of potential flood damages in the Lower Fraser floodplain to change over time. One is a change in the intensity of development on the floodplain; the other an adjustment in the relative values of damageable activities. Both factors were included in the projections of "most likely" damages in this study.

Changes in the intensity of floodplain development were the first to be investigated. Growth trends of residential, commercial and related activities projected in Chapter VIII were used to predict increases in future damages. The expansion of industrial acreage forecast in that chapter formed the foundations for estimating future industrial damages. Estimates of future agricultural damages were based on both changes in productivity and the loss of land to expanding urban and industrial areas predicted in Chapter VIII.

The impact of the second factor (i.e. changes in the relative prices of damageable activities) was determined mainly on the basis of historic price trends. With few exceptions, it was assumed that "most likely" future changes in the price structure would roughly parallel historic changes and alter the real value of projected damages accordingly.

CONCLUSION

Reasonable estimates of future flood damages were made in this study by including the effects of real price changes and changes in the physical characteristics of floodplain activities. Nevertheless, as with all projections, there are many uncertainties underlying these estimates. Technological innovations, attitude and policy changes, or any number of unpredictable variables can have a significant impact on the size of future damages. Therefore, while the "most likely" estimates of flood damages in this study are the best approximations of actual damages available, their sensitivity to errors in underlying assumptions should be considered in the context of the two principal alternative estimates presented at the beginning of this chapter.

The incorporation of projections of future floodplain conditions into an assessment of flood damages is the final step preceding the synthesizing of stage-damage and damage-frequency functions. By combining this information with data on the protective capacity of flood control works as described in Chapter II, the economic benefits of providing flood protection can be determined.

PART III

CONCLUSION

CHAPTER X

CONCLUSION

This study has two primary functions. It provides estimates of potential flood damages in the Fraser Valley, and presents methods that can be used to estimate flood damages and measure the benefits of flood control in other studies. In addition, it describes the advantages and disadvantages of these methods and the accuracy and meaning of the results.

Perhaps the most important part of this report is the second chapter. Chapter II describes the technique of reducing stage-damage data to a single average annual damage estimate, and explains how minor misuses of damage-frequency functions can cause serious distortions in estimates of potential flood-reduction benefits. But even more important, this chapter emphasizes the significance of some of the assumptions underlying estimates of damage-prevention benefits for an area protected by dykes.

Since engineering and hydrological data traditionally are translated literally into economic terms, a large premium is often unwittingly added to the average annual value of flood damages. This premium represents the value implicitly assigned to intangible costs and risk-taking. It arises because damages are calculated on the basis of the assumption that dykes will provide economic benefits only up to a "maximum safe level".

Such a premium may be a legitimate cost of flooding. People may be willing to pay more for flood prevention than simply the value of property damages. However, the premium, as it is currently calculated, has a physical rather than an economic basis. Therefore, there is not necessarily any relationship between it and the true value people place on risk-aversion and intangibles.

By ignoring the premium inherent in average annual damage estimates, most studies obscure the existence of a potentially large bias in the calculations. The present study departs from the traditional approach by clarifying the meaning of damage estimates derived on the basis of the procedure adopted by the Fraser River Committee (1971). It does this by showing that as much as 70% of the estimated property damage reducible by reservoirs might really represent the value implicitly being assigned to risk-taking and intangibles. In this way, it exposes a possible source of bias that can now be explicitly recognized by those evaluating the economic feasibility of flood control projects.

Although the mere identification of the possible maximum premium is not a perfect solution, it represents an improvement over traditional procedures and a positive step towards providing better flood damage estimates. The size of the premium alone should encourage research into the validity of including such an estimate in future flood damage analyses. Moreover, because the premium is explicitly identified in this study, decision-makers concerned with the Fraser River flood problem will have a better understanding of the flood-reduction benefits being attributed to various proposed protective measures.

Chapters III through IX are less significant than Chapter II in terms of general methodology. However, they do offer a good framework for investigating potential flood damages. They describe some sound techniques for estimating specific types of damages, comment on the accuracy of the results, and record unit-damage functions that might be useful in other studies.

It is easier to estimate potential damages to residences and crops than it is to determine other types of losses. The methods used in this study to calculate these damages should be adequate for most analyses. However, two modifications might make the procedures more effective. One would be to use a computer to process data on residential characteristics and damages. The other would be to calculate backward linkage losses in agriculture as part of primary crop damages. In both cases, a considerable time-saving would be realized.

Estimating commercial and industrial damages by applying the method used in this study is a lengthy and costly process. Nevertheless, it is difficult to conceive of a better way of determining these damages. Calculations of industrial losses might be simplified by collecting information only for major industries in a valley, computing damages per acre, and assuming that the results are applicable to other industries in the region. However, if this procedure is followed, estimates may be highly distorted.

In the same way that a simplification of the procedure used in this study has questionable merits, more detailed assessments are difficult to justify. Little is to be gained from more detailed studies because of the uncertainties and subjective judgements underlying analyses of commercial and industrial damages. Therefore, it is felt that the method described in Chapter IV is a good model for determining stage-damage functions.

Since income losses have not been examined closely in previous studies, Chapter VI provides some valuable insights into problems of estimating these losses. It shows that the most critical variable affecting the magnitude of such losses is the difference in size between the referent area and the area directly affected by a flood: the larger the referent area, the more likely are internal transfers of production to occur, and the less likely are production and income losses to be permanent. Chapter VI also reveals that many assumptions must be made before income losses can be estimated: almost every estimate in this study rests on an elaborate set of assumptions, the validity of which is crucial to the derivation of accurate results. Finally, the chapter demonstrates that a large portion of the total potential income loss in a region can be traced to a few major industries: a region is most likely to suffer a permanent loss if a flood causes the closure of industries that produce commodities whose equivalents are readily available from foreign sources.

A general conclusion might be drawn from the results of this assessment of income losses. The predominant role and critical impact of assumptions has been recognized. Moreover, the fact that most losses can be associated with a few industries has been observed. Therefore, provided that the referent area is large relative to the area affected directly by a flood, the best approach to take in assessing income losses should be to concentrate on major industries and make crude estimates for minor ones. This procedure will enable researchers to speed up the estimating process without sacrificing much in the way of accuracy.

Miscellaneous damages were examined only briefly in the present study. Part of the reason for this is that the types of damages in the miscellaneous category are fairly unpredictable; part is that previous analyses have shown them to be of minor importance. The results of investigations that were undertaken in the present study reinforce the conclusion that more detailed assessments are unwarranted.

The methods used to project growth and real price changes in Chapters VIII and IX are simple but adequate. They were used to derive forecasts that provide decision-makers with a reasonable perspective of the flood problem, and yet they cost little to apply. The range of damages resulting from the application of different growth and price trends (Appendix G.7) gives a good picture of the impact that different future growth patterns and price changes will have on potential damages. Concurrently, the "most likely" future forecast provides an effective point of departure for assessing the economic feasibility of flood control projects.

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APPENDICES

TABLE OF CONTENTS

Page

LIST OF FIGURES

APPENDIX A

RESIDENTIAL FLOOD DAMAGE

A.1 Sources of Information

1. Leddingham Construction
   B.C. Forest Products
   A & B Builders
   Burnstad Hardwood Floors Ltd.
   Floorcraft Ltd.
   Western Gypsum
   Steel Bros. Lumber
   Color-Craft
   ABC Painting
   Clardon Woodworks
   B.C. Sash and Door
   Aluminum Shop
   Edso Plastering
   Starchuk and Sampart Ltd.
   Fred Clarke Ltd.
   Armstrong Heating
   Fraser Lumber Co. Ltd.
   Totem Appliance & Refrigeration
   Pete Mussell's Electric Repair Service
   Nicholson Equipment

2. Department of Public Works (Canada),
   Vancouver, B.C.

A.2 Classification of Houses

Class	Corresponding B.C. Appraisal Manual Type
A	1 storey : 107, 109M*, 110
	1½ storeys: 117, 120*, 121
	2 storeys: 125, 129, 131, 132
B	1 storey : 104, 106, 108*, 109*
	1½ storeys: 112, 113, 115*, 116, 118*, 119
	2 storeys: 124, 127, 128, 130*
C	1 storey : 101, 102, 103, 105
	1½ storeys: 111, 114*
	2 storeys: 122, 123, 126

* indicates most common type of house

A.3 Costs of Replacing Flood Damaged Property (including labour)

Damaged Items	Costs ($)		
	Class A	Class B	Class C
Flooring (per sq. ft.)			
Asphalt tile and plywood	.72	.67	.64
Vinyl asbestos tile	.53	.45	.35
Fir plus finish	1.20	1.18	1.15
Hardwood plus finish	2.60	1.85	1.45
Wall-to-wall carpet	1.11	.89	-
Wall Finish (per sq. ft.)			
Gyproc	.38	.35	.33
Plaster	.74	.73	.72
Kitchen Cabinets (per lin. ft.)			
Counter Units	48.00	44.00	40.00
Upper Units	27.00	25.00	23.00
Windows (per sq. ft.)			
0 - 4 sq. ft.	8.50	8.30	7.80
5 - 8 sq. ft.	7.60	7.10	6.60
9 - 12 sq. ft.	6.50	6.10	5.70
13 - 16 sq. ft.	5.85	5.55	5.25
16 + sq. ft.	5.25	5.00	4.75
Doors	50.00	50.00	50.00
Electrical -			
Rewiring per appliance	100.00	100.00	100.00
Exterior Finish (per sq. ft.)			
Siding	.86	.86	.86
Stucco	-	1.70	1.70
Insulation (per sq. ft.)	.15	.15	.15

A.4 Structural Damage

A random sample of 203 houses was made from the assessment rolls of Chilliwack and Richmond municipalities. Three per cent of the houses in both municipalities were Class "A". Field sampling of other areas in the valley showed that very few Class "A" houses are built on the flood plain. Outside of Richmond and Chilliwack, 75% of the houses sampled from the rolls were Class "B" and about 22% were Class "C".

The following table indicates the size of the sample taken from the rolls and the distribution of houses of different classes.

Sample of Houses Taken from Assessment Rolls

Municipality	Number of Houses			
	Class A	Class B	Class C	Total
Richmond	3	95	12	110
Chilliwack	3	55	35	93
Total	6	150	47	203

Since Class A houses are of such minor importance and an error in the calculation of damage for houses of this class would not significantly affect the total damage estimate of any area, no effort was made to select a larger sample of these houses than that derived from the random sample. The stage-damage curves for Class A houses were formed on the basis of only six houses.

A.4.1 Structural Damage - Class A House

A.4.1.1 Average House Characteristics

1. Average area - 1,589 sq. ft.
2. Average date of construction - 1967
3. Average value - $28,506
4. Average perimeter - 160 feet
5. Average interior walled footage - 480 feet
6. Average interior walled area - 3,840 sq. ft.
7. Average cost of restoring heating system - $28 ($10 service clean-up charge + $18 to replace the motor; the type of furnace is not a major factor).
8. Floor Finish - 75% wall to wall carpet; 25% tile
9. Interior Finish - 66% plaster; 34% gyproc
10. Exterior Finish - 100% siding
11. Basement - 50% of all Class A houses sampled have basements. There are no basements in Class A houses in Richmond. All three of the houses sampled in Chilliwack have basements.

12. Floor levels above ground level:
    Main Floor - Richmond 2 feet
    - Chilliwack 3 feet
13. Heating system - 17% oil; 50% gas; 33% hot water

A.4.1.2 Damage to Structures

1. Walls & Ceilings (Interior Damage):

Structure	Material	Cost of Removing Old Material and Replacement
Walls	plaster	(66% x 3840 sq.ft. x $.74/sq.ft.) = $1,875
	gyproc	(34% x 3840 sq.ft. x $.38/sq.ft.) = $ 496
	Total	$2,371
Ceilings	plaster	(66% x 1589 sq.ft. x $.74/sq.ft.) = $ 776
	gyproc	(34% x 1589 sq.ft. x $.38/sq.ft.) = $ 205
	Total	$ 981

Water 1 ft. above main floor causes $2,371 damage to walls.
Water 8 ft. above main floor causes $3,352 damage to walls and ceilings.

2. Floor Finish

Material	Damage ($) (% of area covered by material x floor area x removal and replacement cost) - (depreciation if applicable.)
Carpet	(75% x 1589 sq.ft. x $1.11/sq.ft.) - 25% dep. = $ 992
Tile	(25% x 1589 sq.ft. x $ .72/sq.ft.) = $ 286
Total	$1,278

3. Doors:
   15 x $50 = $750 damage at one foot of flooding.

4. Cabinets:

Lower: 24 ft. long x $48/ft. = $1152 at 1 foot of flooding.

Upper: 15 ft. long x $27/ft. = $ 405 at 4 feet of flooding.

Total replacement cost at 1 ft. of flooding above floor = $1152

Total replacement cost at 4 ft. of flooding above floor = $1557.

5. Electrical: (Major rewiring at 1 ft. of flooding.)

4 major appliances x $100 each = $400

6. Exterior Finish:

100% of the houses have siding; houses with basements (all in Chilliwack) and those without (all in Richmond) suffer similar exterior damages as listed below.

Flood Depth (Ft. Above Ground Level)		Perimeter (ft.)		cost/sq.ft. ($)		Cumulative Damage ($)
1	x	160	x	0.86	=	138
2	x	160	x	0.86	=	276
3	x	160	x	0.86	=	414
4	x	160	x	0.86	=	552
5	x	160	x	0.86	=	690
6	x	160	x	0.86	=	828
7	x	160	x	0.86	=	966
8	x	160	x	0.86	=	1,104
9	x	160	x	0.86	=	1,242
10	x	160	x	0.86	=	1,380

7. Insulation:

Flood Elevation (Ft. Above Ground Level)	Richmond Damage Perimeter x Depth x Cost = Total	Chilliwack Damage Perimeter x Depth x Cost = Total
1		160 x 1 x .15 = $ 24
2		160 x 2 x .15 = $ 48
3	160 x 1 x .15 = $ 24	160 x 3 x .15 = $ 72
4	160 x 2 x .15 = $ 48	160 x 4 x .15 = $ 96
5	160 x 3 x .15 = $ 72	160 x 5 x .15 = $120
6	160 x 4 x .15 = $ 96	160 x 6 x .15 = $144
7	160 x 5 x .15 = $120	160 x 7 x .15 = $168
8	160 x 6 x .15 = $144	160 x 8 x .15 = $192
9	160 x 7 x .15 = $168	160 x 9 x .15 = $216
10	160 x 8 x .15 = $192	160 x 10x .15 = $240

8. Windows:

Because Richmond houses have no basements and are about 2 feet off the ground and Chilliwack houses have basements but their main floor area is only 3 feet off the ground, the two have been grouped together. Glass areas in the houses in the two districts are approximately equal.

Ft. Above Ground Level at which Damage Occurs	Cost of Removal and Replacement Plus Damage at Lower Elevations		Cumulative Total ($)
4	80 sq. ft. x $ 5.25 + 0	=	$ 420
6	240 sq. ft. x $ 5.85 + 420	=	$1,824

9. Heating:

$28 at one foot above ground level in both Richmond and Chilliwack.

A.4.1.3 Total Damage to Structures

1. Main Floor Damage Data - both Municipalities combined

Flood Depth (Ft. Above Main Floor)	$ Damage to Factors					Total Cumulative $ Damage
	Interior Finish	Floors	Doors	Cabinets	Electric	
0	-	1,278	-	-	-	$1,278
1	2,371	1,278	750	1,152	400	$5,951
2	2,371	1,278	750	1,152	400	$5,951
3	2,371	1,278	750	1,152	400	$5,951
4	2,371	1,278	750	1,557	400	$6,356
5	2,371	1,278	750	1,557	400	$6,356
6	2,371	1,278	750	1,557	400	$6,356
7	2,371	1,278	750	1,557	400	$6,356
8	3,352	1,278	750	1,557	400	$7,337

2. Basement Damage = 25% of Main Floor Damage: (This estimate was derived in consultation with Municipal Appraisers).

(Table on following page.)

Flood Depth (Ft. Above Basement Floor)	0+	1	2	3	4	5	6	7	8
Cumulative Damage ($)	320	1488	1488	1488	1589	1589	1589	1589	1834

3. Exterior Damage

Flood Depth (Ft. Above Ground Level)	$ Damage				Total
	Exterior Finish	Insulation	Windows	Heat	
Richmond					
1	138	-	-	28	166
2	276	-	-	28	304
3	414	24	-	28	466
4	552	48	420	28	1,048
5	690	72	420	28	1,210
6	828	96	1,824	28	2,776
7	966	120	1,824	28	2,938
8	1,104	144	1,824	28	3,100
9	1,242	168	1,824	28	3,262
10	1,380	192	1,824	28	3,424
Chilliwack					
1	138	24	-	28	190
2	276	48	-	28	352
3	414	72	-	28	514
4	552	96	420	28	1,096
5	690	120	420	28	1,258
6	828	144	1,824	28	2,824
7	966	168	1,824	28	2,986
8	1,104	192	1,824	28	3,148
9	1,242	216	1,824	28	3,310
10	1,380	240	1,824	28	3,472

A.4.2 Structural Damage - Class B House

A.4.2.1 Average House Characteristics

1. Average area - 1,077 sq. ft.
2. Average date of construction - 1953
3. Average value - $15,100

4. Average perimeter - 136 ft.
5. Average interior walled footage - 352 ft.
6. Average interior walled area - 2,820 sq. ft.
7. Average cost of restoring heating system - $28.00
   ($10.00 service clean-up charge plus $18.00 to replace the motor; the type of furnace is not a major factor.)
8. Floor finish = 12% wall to wall carpet; 36% hardwood; 29% tile; 23% fir flooring.
9. Interior Finish - 60% plaster; 40% gyproc.
10. Exterior Finish - (see A.4.2.2.(6))
11. Basements - 33% of Class B Chilliwack houses have basements.
    65% of Class B Richmond houses have basements.
    45% of all Class B houses have basements.
12. Floor levels above ground level -

Non-Basement houses - main floor	-	Richmond	2 ft.
		Chilliwack	1 ft.
Basement houses - main floor		Richmond	8 ft.
		Chilliwack	3 ft.
Basement floor levels		Richmond	0 ft.
		Chilliwack	5 ft.

13. For houses which had siding in the lower part of the house and stucco in the upper:
    In basement houses, siding extended up to 9 feet above ground.
    In non-basement houses, siding extended up to 3 feet above ground.

A.4.2.2 Damage to Structures

1. Walls and Ceilings (interior damage):

Structure	Material	Cost of Removing Old Material and Replacing
Walls	plaster	(60% x 2,820 sq.ft. x $.73 sq.ft.) = $1,235
	gyproc	(40% x 2,820 sq.ft. x $.35 sq.ft.) = $ 395
	Total	$1,630

Table continued on Page 9.

1. Continued

Structure	Material	Cost of Removing Old Material and Replacing
Ceilings	plaster	(60% x 1,077 sq.ft. x $.73 sq.ft.) = $ 472
	gyproc	(40% x 1,077 sq.ft. x $.35 sq.ft.) = $ 151
	Total	$ 623

Water 1 foot above main floor causes $1,630 damage to walls.

Water 8 feet above main floor causes $2,253 damage to walls and ceilings.

2. Floor Finish:

Material	Damage ($) (% of area covered by material x floor area x removal and replacement cost) -(depreciation if applicable)	
Carpet	(12% x 1,077 sq.ft. x $ .89 sq.ft.) - (25% Dep.)	= $ 86
Hardwood	(36% x 1,077 sq.ft. x $1.85 sq.ft.)	= $ 717
Tile	(29% x 1,077 sq.ft. x $ .67 sq.ft.)	= $ 209
Fir Flooring	(23% x 1,077 sq.ft. x $1.18 sq.ft.)	= $ 292
Total		$1,304

3. Doors:

11 x $50 each = $550 damage at 1 foot of flooding

4. Cabinets:

Lower: 18 ft. long x $44/ft. = $792 at 1 foot of flooding

Upper: 10 ft. long x $25/ft. = $250 at 4 feet of flooding

Total replacement cost at 1 ft. of flooding above floor = $792

Total replacement cost at 4 ft. of flooding above floor = $1,042

5. Electrical (major rewiring at 1 ft. of flooding):

3 major appliances at $100 each = $300

6. Exterior Finish:

Six categories of houses were identified in the two districts:

(a) Siding basement;
(b) Siding non-basement;
(c) Stucco basement;
(d) Stucco non-basement;
(e) Mixed stucco-siding basement;
(f) Mixed stucco-siding non-basement;

The repair costs of shingle and siding are similar so no distinction was made between the two in the analysis. In Richmond, 20% of the houses are shingles and siding, 17% are stucco, and 63% are mixed. In Chilliwack, 59% are shingles and siding, 30% are stucco, and 11% are mixed.

The various amounts of damage to the different exterior finishes in each area were weighted by the proportion with and without basements. The resulting weighted damage estimates for each of the six classes of houses were then added together for each area. This gave the final exterior finish damage figure per foot of water above ground level for the "average" Class B house in each area.

Calculations were as follows:

(a) Siding Finish - Class B Houses with Basements:

Flood Depth (Ft. Above Ground Level)		Perimeter (ft.)		Cost/sq.ft. ($)		Siding In Area (%)		Basements In Area (%)		Cumulative Damage ($)
Richmond										
1	x	136	x	0.86	x	20	x	33	=	8
2	x	136	x	0.86	x	20	x	33	=	16
3	x	136	x	0.86	x	20	x	33	=	24
4	x	136	x	0.86	x	20	x	33	=	32
5	x	136	x	0.86	x	20	x	33	=	40
6	x	136	x	0.86	x	20	x	33	=	48
7	x	136	x	0.86	x	20	x	33	=	56
8	x	136	x	0.86	x	20	x	33	=	64
9	x	136	x	0.86	x	20	x	33	=	72
10	x	136	x	0.86	x	20	x	33	=	80
Chilliwack										
1	x	136	x	0.86	x	59	x	65	=	45
2	x	136	x	0.86	x	59	x	65	=	90
3	x	136	x	0.86	x	59	x	65	=	135
4	x	136	x	0.86	x	59	x	65	=	180
5	x	136	x	0.86	x	59	x	65	=	225
6	x	136	x	0.86	x	59	x	65	=	270
7	x	136	x	0.86	x	59	x	65	=	315
8	x	136	x	0.86	x	59	x	65	=	360
9	x	136	x	0.86	x	59	x	65	=	405
10	x	136	x	0.86	x	59	x	65	=	450

(b) Siding Finish - Class B Houses with no Basement:

Floor Depth (Ft. Above Ground Level)		Perimeter (ft.)		Cost/sq.ft. ($)		Siding In Area (%)		Basements In Area (%)		Cumulative Damage ($)
Richmond										
1	x	136	x	0.86	x	20	x	67	=	16
2	x	136	x	0.86	x	20	x	67	=	32
3	x	136	x	0.86	x	20	x	67	=	48
4	x	136	x	0.86	x	20	x	67	=	64
5	x	136	x	0.86	x	20	x	67	=	80
6	x	136	x	0.86	x	20	x	67	=	96
7	x	136	x	0.86	x	20	x	67	=	112
8	x	136	x	0.86	x	20	x	67	=	128
9	x	136	x	0.86	x	20	x	67	=	144
10	x	136	x	0.86	x	20	x	67	=	160
Chilliwack										
1	x	136	x	0.86	x	59	x	35	=	24
2	x	136	x	0.86	x	59	x	35	=	48
3	x	136	x	0.86	x	59	x	35	=	72
4	x	136	x	0.86	x	59	x	35	=	96
5	x	136	x	0.86	x	59	x	35	=	120
6	x	136	x	0.86	x	59	x	35	=	144
7	x	136	x	0.86	x	59	x	35	=	168
8	x	136	x	0.86	x	59	x	35	=	192
9	x	136	x	0.86	x	59	x	35	=	216
10	x	136	x	0.86	x	59	x	35	=	240

(c) Stucco Finish - Class B House with Basement:

If stucco is touched with flood water, the entire stucco wall must be replaced.

Richmond: if water reaches a depth of one foot above ground level, 8 feet of stucco must be replaced; if it reaches 9 feet in depth, 16 feet of stucco must be replaced.

- Flood depth of 1 to 8 feet above ground:

8 ft. x 136 ft. x $1.70 x 17% x 33% = $104

- Flood depth of 9 feet or more above ground:

16 ft. x 136 ft. x $1.70 x 17% x 33% = $208

Chilliwack:

11 feet of stucco must be replaced when flood depths reach 1 foot above ground level.

- Flood depth of 1 to 11 feet above ground:

11 ft. x 136 ft. x $1.70 x 30% x 65% = $496

(d) Stucco Finish - Class B House with No Basement:

Stucco on both Richmond and Chilliwack houses will be totally destroyed when water level reach 1 foot above ground level.

Richmond:

- Flood depth of 1 ft. or more above ground:

8 ft. x 136 ft. x $1.70 x 17% x 67% = $211

Chilliwack:

- Flood depth of 1 ft. or more above ground:

8 ft. x 136 ft. x $1.70 x 30% x 35% = $194

(e) Mixed Stucco-Siding Finish - Class B Houses with Basements:

Flood Depth (Ft. Above Ground Level)		Perimeter (ft.)		Cost/sq.ft. ($)		Mixed In Area (%)		Basements In Area (%)		Cumulative Damage ($)
Richmond										
1	x	136	x	0.86	x	63	x	33	=	24
2	x	136	x	0.86	x	63	x	33	=	48
3	x	136	x	0.86	x	63	x	33	=	72
4	x	136	x	0.86	x	63	x	33	=	96
5	x	136	x	0.86	x	63	x	33	=	120
6	x	136	x	0.86	x	63	x	33	=	144
7	x	136	x	0.86	x	63	x	33	=	166
8	x	136	x	0.86	x	63	x	33	=	192
9	x	136	x	0.86	x	63	x	33	=	216
(10 and greater):	(8 x 136 x $1.70 x .63 x .33) + $216 = $600									
Chilliwack										
1	x	136	x	0.86	x	11	x	65	=	8
2	x	136	x	0.86	x	11	x	65	=	16
3	x	136	x	0.86	x	11	x	65	=	24
4	x	136	x	0.86	x	11	x	65	=	32
5	x	136	x	0.86	x	11	x	65	=	40
(6 and greater)[a]:	(6 x 136 x $1.70 x .11 x .65) + $40 = $139									

a: There are 6 ft. of stucco above 5 ft. above ground level.

(f) Mixed Stucco-Siding - Class B Houses with no Basement:

Flood Depth (Ft. Above Ground Level)		Perimeter (ft.)		Cost/sq.ft. ($)		Mixed In Area (%)		No Basement In Area (%)		Cumulative Damage ($)
Richmond										
1	x	136	x	0.86	x	63	x	67	=	49
2	x	136	x	0.86	x	63	x	67	=	98
3	x	136	x	0.86	x	63	x	67	=	147
(4 and greater): (5 x 136 x $1.70 x .63 x .67) + $147 = $635										
Chilliwack										
1	x	136	x	0.86	x	11	x	35	=	5
2	x	136	x	0.86	x	11	x	35	=	10
3	x	136	x	0.86	x	11	x	35	=	15
(4 and greater): (5 x 136 x $1.70 x .11 x .35) + $15 = $60										

(g) Total Exterior Finish Damage ($) to "Average" Class B House:

Flood Depth (Ft. Above Ground Level)	Siding		Stucco		Mixed		Total Damage
	with Basement	with no Basement	with Basement	with no Basement	with Basement	with no Basement	
Richmond							
1	8	16	104	211	24	49	412
2	16	32	104	211	48	98	509
3	24	48	104	211	72	147	606
4	32	64	104	211	96	635	1142
5	40	80	104	211	120	635	1190
6	48	96	104	211	144	635	1238
7	56	112	104	211	166	635	1284
8	64	128	104	211	192	635	1334
9	72	144	208	211	216	635	1486
10	80	160	208	211	600	635	1894
Chilliwack							
1	45	24	496	194	8	5	772
2	90	48	496	194	16	10	854
3	135	72	496	194	24	15	936
4	180	96	496	194	32	60	1058
5	225	120	496	194	40	60	1135
6	270	144	496	194	139	60	1303
7	315	168	496	194	139	60	1372
8	360	192	496	194	139	60	1441
9	405	216	496	194	139	60	1510
10	450	240	496	194	139	60	1579

7. Insulation:

Since 33% of the Class B houses sampled have main floors at 8 feet above ground level (most of those in Richmond), the increase in damage to insulation that would occur at 9 and 10 feet of flooding has been weighted by this factor. Any variation in insulation damage to houses in the two districts is insignificant so no distinction is made between the two areas.

Flood Depth (Ft. Above Ground Level)	Perimeter	x	Depth	x	Cost/sq.ft.	=	Damage ($)
1	136	x	1	x	0.15	=	20
2	136	x	2	x	0.15	=	40
3	136	x	3	x	0.15	=	60
4	136	x	4	x	0.15	=	80
5	136	x	5	x	0.15	=	100
6	136	x	6	x	0.15	=	120
7	136	x	7	x	0.15	=	140
8	136	x	8	x	0.15	=	160
9	.33 (136	x	1	x	0.15)+160	=	167
10	.33 (136	x	2	x	0.15)+160	=	174

8. Windows:

There are similar glass areas in houses in each district. The difference between areas is accounted for by the different heights of the windows above ground level.

(a) Houses with Basements

Ft. above Ground Level at which Damage Occurs	(Cost of Replacement + Removing Old) x (% basements) + (Damage at Lower Flood)	Cumulative Total ($)
Richmond		
2	(72 sq.ft. x 7.10/sq.ft.) x (33%) + 0 =	169
12	(180 sq.ft. x 6.10/sq.ft.) x (33%) + 169 =	531
Chilliwack		
1	(72 sq.ft. x 7.10/sq.ft.) x (65%) + 0 =	332
7	(180 sq.ft. x 6.10/sq.ft.) x (65%) + 332 =	1,046

(b) Houses with no Basements

Ft. Above Ground Level at Which Damage Occurs	(Cost of Replacement + Removing Old) x (% basements) + (Damage at lower flood)		Cumulative Total ($)
Richmond			
3	(32 sq.ft. x $5.00/sq.ft.) x 67% + 0	=	107
5	(76 sq.ft. x $7.10/sq.ft.) x 67% + 107	=	469
Chilliwack			
3	(32 sq.ft. x $5.00/sq.ft.) x 35% + 0	=	56
5	(76 sq.ft. x $7.10/sq.ft.) x 35% + 56	=	245

(c) Total Damage to Windows in "Average" B house in Each Area

Flood Depth (Ft. Above Ground Level)			Damage ($)
Richmond			
2		=	$ 169
3	107 + 169	=	$ 276
5	469 + 169	=	$ 638
12	531 + 469	=	$1,000
Chilliwack			
2		=	$ 332
3	56 + 332	=	$ 388
5	245 + 332	=	$ 577
7	1,046 + 245	=	$1,291

9. Heating:

At one foot above ground level in both Richmond and Chilliwack, damages = $28

A.4.2.3 Total Damage to Structures:

1. Main Floor Damage Data - both Municipalities combined.

Flood Depth (Ft. Above Main Floor)	$ Damage to Factors: Walls + Ceilings	Floors	Doors	Cabinets	Electric	Total Cumulative Damage ($)
0+	-	1,304	-	-	-	$1,304
1	1,630	1,304	550	792	300	4,576
2	1,630	1,304	550	792	300	4,576
3	1,630	1,304	550	792	300	4,576
4	1,630	1,304	550	1,042	300	4,826
5	1,630	1,304	550	1,042	300	4,826
6	1,630	1,304	550	1,042	300	4,826
7	1,630	1,304	550	1,042	300	4,826
8	2,253	1,304	550	1,042	300	5,449

2. Basement Damage = 25% of Main Floor Damage. (This estimate was derived in consultation with Municipal Appraisers.)

Flood Depth (Ft. Above Basement Floor)	0	1	2	3	4	5	6	7	8
Cumulative Damage ($)	326	1144	1144	1144	1207	1207	1207	1207	1362

3. Exterior Damage

Flood Depth (Ft. Above Ground Level)	$ Damage: Exterior Finish	Insulation	Windows	Heat	Total Damage
Richmond					
1	412	20	-	14	446
2	509	40	169	28	746
3	606	60	276	28	970
4	1142	80	276	28	1526
5	1190	100	638	28	1956
6	1238	120	638	28	2024
7	1284	140	638	28	2090
8	1334	160	638	28	2160
9	1486	167	638	28	2319
10	1894	174	638	28	2734

3. Continued.

Flood Depth (Ft. Above Ground Level)	$ Damage				Total Damage
	Exterior Finish	Insulation	Windows	Heat	
Chilliwack					
1	772	20	-	28	820
2	854	40	332	28	1254
3	936	60	388	28	1412
4	1,058	80	388	28	1554
5	1,135	100	577	28	1840
6	1,303	120	577	28	2028
7	1,372	140	1,291	28	2831
8	1,441	160	1,291	28	2920
9	1,510	167	1,291	28	2996
10	1,579	174	1,291	28	3072

A.4.3 Structural Damage - Class C House

A.4.3.1 Average House Characteristics

1. Average area - 760 sq.ft.
2. Average date of construction - 1939
3. Average value - $6,456
4. Average perimeter - 104 ft.
5. Average interior walled footage - 234 ft.
6. Average interior walled area - 1,872 sq. ft.
7. Average cost of restoring heating system:

   $28 for the restoration of a furnace.

   $10 for the restoration of a stove.

   Since 66% of the houses have furnaces and 44% have stoves, the average damage to heating systems, when water reaches one foot above ground, is $23.
8. Floor Finish - 19% tile and linoleum; 81% fir.

   Carpet and hardwood were found in less than 1% of the houses and were therefore ignored.
9. Interior Finish - 73% gyproc; 27% plaster.
10. Exterior Finish - 72% siding (and shingle); 28% stucco (mixed stucco-siding houses represent less than 5% of the total and are included in the stucco category).

11. Basements - 8% of all Class C houses in Richmond have basements.
20% of all Class C houses in Chilliwack have basements.

12. Floor Levels above Ground Level:

Non-basement houses - Main Floor	-	Richmond	1 ft.
	-	Chilliwack	1 ft.
Basement houses - Main Floor	-	Richmond	8 ft.
	-	Chilliwack	3 ft.
Basement Floor Level	-	Richmond	0 ft.
	-	Chilliwack	-5 ft.

A.4.3.2 Damage to Structure:

1. Walls and Ceilings (Interior Damage):

Structure	Material	Cost of Removing Old Material and Replacing		
Walls	plaster	27% x 1872 sq.ft. x $ .72	=	$ 364
	gyproc	73% x 1872 sq.ft. x $ .33	=	$ 451
	Total			$ 815
Ceilings	plaster	27% x 760 sq.ft. x $ .72	=	$ 148
	gyproc	73% x 760 sq.ft. x $ .33	=	$ 183
	Total			$ 331

Water 1 ft. above main floor causes $815 damage to walls.
Water 8 ft. above main floor causes $1,146 damage to walls & ceilings.

2. Floor Finish:

Material	Damage ($) (% of area covered by material) x (floor area) x (removal & replacement cost)		
Tile-Linoleum	(19% x 760 sq. ft. x $ .35/sq.ft.)	=	$ 51
Fir	(81% x 760 sq. ft. x $1.15/sq.ft.)	=	$708
Total			$759

3. Doors:

   7 x $50 = $350 damage at one foot of flooding.

4. Cabinets:

   Lower: 10 ft. long x $40/ft. = $400 at 1 ft. of flooding.

   Upper: 5 ft. long x $23/ft. = $115 at 4 ft. of flooding.

   Total replacement cost at 1 ft. of flooding above floor = $400.

   Total replacement cost at 4 ft. of flooding above floor = $515.

5. Electrical:

   (Major re-wiring at 1 ft. of flooding)

   1 major appliance x $100 each = $100.

6. Exterior Finish:

   Damage was weighted on the basis of the methodology outlined for Class B houses (A.4.2.2 (6))

   Calculations are as follows:

(a) Siding Finish - House with Basement

Flood Depth (Ft. Above Ground Level)		Perimeter (ft.)		Cost/sq.ft. ($)		Siding For Area (%)		Basements In Area (%)		Cumulative Damage ($)
Richmond										
1	x	104	x	0.86	x	72	x	8	=	5
2	x	104	x	0.86	x	72	x	8	=	10
3	x	104	x	0.86	x	72	x	8	=	15
4	x	104	x	0.86	x	72	x	8	=	20
5	x	104	x	0.86	x	72	x	8	=	25
6	x	104	x	0.86	x	72	x	8	=	30
7	x	104	x	0.86	x	72	x	8	=	35
8	x	104	x	0.86	x	72	x	8	=	40
9	x	104	x	0.86	x	72	x	8	=	45
10	x	104	x	0.86	x	72	x	8	=	50
Chilliwack										
1	x	104	x	0.86	x	72	x	20	=	13
2	x	104	x	0.86	x	72	x	20	=	26
3	x	104	x	0.86	x	72	x	20	=	39
4	x	104	x	0.86	x	72	x	20	=	52
5	x	104	x	0.86	x	72	x	20	=	65
6	x	104	x	0.86	x	72	x	20	=	78
7	x	104	x	0.86	x	72	x	20	=	91
8	x	104	x	0.86	x	72	x	20	=	104
9	x	104	x	0.86	x	72	x	20	=	117
10	x	104	x	0.86	x	72	x	20	=	130

(b) Siding Finish - House with no basement.

Flood Depth (Ft. Above Ground Level)		Perimeter (ft.)		Cost/sq.ft. ($)		Siding For Area (%)		Basements In Area (%)		Cumulative Damage ($)
Richmond										
1	x	104	x	0.86	x	72	x	92	=	59
2	x	104	x	0.86	x	72	x	92	=	118
3	x	104	x	0.86	x	72	x	92	=	177
4	x	104	x	0.86	x	72	x	92	=	236
5	x	104	x	0.86	x	72	x	92	=	295
6	x	104	x	0.86	x	72	x	92	=	354
7	x	104	x	0.86	x	72	x	92	=	413
8 & greater	x	104	x	0.86	x	72	x	92	=	472
Chilliwack										
1	x	104	x	0.86	x	72	x	80	=	52
2	x	104	x	0.86	x	72	x	80	=	104
3	x	104	x	0.86	x	72	x	80	=	156
4	x	104	x	0.86	x	72	x	80	=	208
5	x	104	x	0.86	x	72	x	80	=	260
6	x	104	x	0.86	x	72	x	80	=	312
7	x	104	x	0.86	x	72	x	80	=	364
8 & greater	x	104	x	0.86	x	72	x	80	=	416

(c) Stucco Finish - House with Basement:

If stucco is touched by flood water, the entire stucco wall must be replaced.

Richmond:

If flood waters reach one foot above ground level, 8 feet of stucco must be replaced; if it reaches 9 feet, 16 feet must be replaced.

Flood depth of 1 to 8 ft.: 8 x 104 ft. x $1.70 x 28% x 8% = $32

Flood depth of 9 ft. and greater: 16 x 104 ft. x $1.70 x 28% x 8% = $63

Chilliwack:

11 feet of stucco are destroyed in Chilliwack when flood depths reach one foot above ground level.

Flood depth of 1 to 11 ft. above ground:

11 x 104 ft. x $1.70 x 28% x 20% = $109

(d) Stucco Finish - House with no Basement:

Richmond:

Flood depth of 1 ft. or more above ground:

8 x 104 x $1.70 x 28% x 92% = $364

Chilliwack:

Flood depth of 1 ft. or more above ground:

8 x 104 x $1.70 x 28% x 80% - $317

(e) Total Exterior Finish Damage to "Average" Class C House;

Flood Depth (Ft. Above Ground Level)	Siding		Stucco		Total Cumulative Damage ($)
	with Basement	with no Basement	with Basement	with no Basement	
Richmond					
1	5	59	32	364	460
2	10	118	32	364	524
3	15	177	32	364	588
4	20	236	32	364	652
5	25	295	32	364	716
6	30	354	32	364	780
7	35	413	32	364	844
8	40	472	32	364	908
9	45	472	63	364	944
10	50	472	63	364	949
Chilliwack					
1	13	52	109	317	491
2	26	104	109	317	556
3	39	156	109	317	621
4	52	208	109	317	686
5	65	260	109	317	751
6	78	312	109	317	816
7	91	364	109	317	881
8	104	416	109	317	946
9	117	416	109	317	959
10	130	416	109	317	972

7. Insulation:

17% of the Class C houses sampled have main floors 8 feet above ground level. Thus, the increase in damage to insulation that would occur between 9 and 10 feet of flooding has been weighted by this factor. The two areas have been grouped together for this type of damage.

Damage to Insulation

Flood Depth (Ft. Above Ground Level)	Perimeter	x	Depth	x	Cost/sq.ft.	=	$ Damage
1	104	x	1	x	0.15	=	16
2	104	x	2	x	0.15	=	31
3	104	x	3	x	0.15	=	47
4	104	x	4	x	0.15	=	62
5	104	x	5	x	0.15	=	78
6	104	x	6	x	0.15	=	94
7	104	x	7	x	0.15	=	109
8	104	x	8	x	0.15	=	125
9	.17 (104	x	1	x	0.15)+125	=	128
10	.17 (104	x	2	x	0.15)+125	=	130

8. Windows

(a) Total - Richmond (basement and non-basement houses):

Flood Depth (Ft. Above Ground Level)	(Cost of Replacement + Removing Old) + (Damage at Lower Flood)		Cumulative Total ($)
3	30 sq.ft. x (4.75/sq.ft.) + 0	=	143
5	48 sq.ft. x (6.60/sq.ft.) + 143	=	460

(b) Chilliwack

Flood Depth (Ft. Above Ground Level)	(Cost of Replacement & Removing Old) x (% Basement or non-basement) + (Damage at Lower Flood)		Cumulative Total ($)
House with Basement			
2	(48 sq.ft. x (6.60/sq.ft.) x 20% + 0	=	63
7	(120 sq.ft. x (5.25/sq.ft.) x 20% + 63	=	189
House with No Basement			
3	(30 sq.ft. x (4.75/sq.ft.) x 80% + 0	=	114
5	(48 sq.ft. x (6.60/sq.ft.) x 80% + 114	=	367
Total - All Houses			
2	63 + 0	=	63
3	114 + 63	=	177
5	367 + 63	=	430
7	189 + 367	=	556

9. Heating:

$23 at one foot above ground level.

A.4.3.3 Total Damage to Structures

1. Main Floor Damage Data - both Municipalities combined.

Flood Depth (Ft. Above Main Floor)	$ Damage to Factors: Interior Finish	Floors	Doors	Cabinets	Electric	Total Cumulative Damage ($)
0	-	759	-	-	-	759
1	815	759	350	400	100	2424
2	815	759	350	400	100	2424
3	815	759	350	400	100	2424
4	815	759	350	515	100	2539
5	815	759	350	515	100	2539
6	815	759	350	515	100	2539
7	815	759	350	515	100	2539
8	1,146	759	350	515	100	2870

2. Basement Damage - 25% of Main Floor Damage

Flood Depth (Ft. Above Basement Floor)	0+	1	2	3	4	5	6	7	8
Cumulative Damage ($)	190	606	606	606	635	635	635	635	718

3. Exterior Damage

Flood Depth (Ft. Above Ground Level)	$ Damage: Exterior Finish	Insulation	Windows	Heat	Exterior Damage
Richmond					
1	460	16	-	23	499
2	524	31	-	23	578
3	588	47	143	23	801
4	652	62	143	23	880
5	716	78	460	23	1,277
6	780	94	460	23	1,357
7	844	109	460	23	1,436
8	908	125	460	23	1,516
9	944	128	460	23	1,555
10	949	130	460	23	1,562

3. Continued

Flood Depth (Ft. Above Ground Level)	$ Damage Exterior Finish	Insulation	Windows	Heat	Exterior Damage
Chilliwack					
1	491	16	-	23	530
2	556	31	63	23	673
3	621	47	177	23	868
4	686	62	177	23	948
5	751	78	430	23	1,282
6	816	94	430	23	1,363
7	881	109	556	23	1,569
8	946	125	556	23	1,650
9	959	128	556	23	1,668
10	972	130	556	23	1,681

A.5 Content Damage

A.5.1 Class A House

1. Average value - $28,506
2. Total value of contents - 40% x $28,506 = $11,402.
3. Distribution of content value in houses with basements -

   Main Floor value - 90% x $11,402 = $10,262

   Basement value - 10% x $11,402 = $ 1,140.
4. Damage to Contents on Main Floor:

Flood Depth (Ft. Above Main Floor)	$ Damage to Contents: House with Basement	House with no Basement
1	25% x $10,262 = $2,565	25% x $11,402 = $2,850
2	45% x $10,262 = $4,618	45% x $11,402 = $5,131
3	60% x $10,262 = $6,157	60% x $11,402 = $6,841
4	70% x $10,262 = $7,183	70% x $11,402 = $7,981
5	75% x $10,262 = $7,697	75% x $11,402 = $8,552
6 and greater	80% x $10,262 = $8,210	80% x $11,402 = $9,122

5. Damage to Contents of Basements:

Flood Depth (Ft. Above Basement Floor)	$ Damage to Contents
1	25% x $1,140 = $285
2	45% x $1,140 = $513
3	60% x $1,140 = $684
4	70% x $1,140 = $798
5	75% x $1,140 = $855
6 and greater	80% x $1,140 = $912

A.5.2 Class B House

1. Average value - $15,100
2. Total Value of contents - 40% x $15,100 = $6,040
3. Distribution of content value in houses with basements -

   Main Floor value - 90% x $ 6,040 = $5,436

   Basement value - 10% x $ 6,040 = $ 604
4. Damage to contents on main floor:

Flood Depth (Ft. Above Main Floor)	$ Damage to Contents	
	House with Basement	House with no Basement
1	25% x $5,436 = $1,359	25% x $6,040 = $1,510
2	45% x $5,436 = $2,446	45% x $6,040 = $2,718
3	60% x $5,436 = $3,262	60% x $6,040 = $3,624
4	70% x $5,436 = $3,805	70% x $6,040 = $4,228
5	75% x $5,436 = $4,077	75% x $6,040 = $4,530
6 and greater	80% x $5,436 = $4,349	80% x $6,040 = $4,832

5. Damage to contents of basement:

Flood Depth (Ft. Above Basement Floor)	$ Damage to Contents
1	25% x $604 = $151
2	45% x $604 = $272
3	60% x $604 = $362
4	70% x $604 = $423
5	75% x $604 = $453
6 and greater	80% x $604 = $483

A.5.3 Class C House

1. Average value - $6,456
2. Total value of contents - 40% x $6,456 = $2,582
3. Distribution of content value in houses with basements -

   Main Floor value - 90% x $2,582 = $2,324

   Basement value - 10% x $2,582 = $ 258
4. Damage to Contents on Main Floor:

Flood Depth (Ft. Above Main Floor)	$ Damage to Contents	
	House with Basement	House with no Basement
1	25% x $2,324 = $ 581	25% x $2,582 = $ 646
2	45% x $2,324 = $1,046	45% x $2,582 = $1,162
3	60% x $2,324 = $1,394	60% x $2,582 = $1,549
4	70% x $2,324 = $1,627	70% x $2,582 = $1,807
5	75% x $2,324 = $1,743	75% x $2,582 = $1,937
6 and greater	80% x $2,324 = $1,859	80% x $2,582 = $2,066

5. Damage to Contents of Basement:

Flood Depth (Ft. Above Basement Floor)	$ Damage to Contents
1	25% x $258 = $ 65
2	45% x $258 = $116
3	60% x $258 = $155
4	70% x $258 = $181
5	75% x $258 = $194
6 and greater	80% x $258 = $206

A.6 Combined Structural and Content Damage

A.6.1 Class A House

1. Main Floor Damage

Flood Depth (Ft. Above Main Floor)	House with Basement			House with no Basement		
	Structural Damage $	Content Damage $	Total Damage $	Structural Damage $	Content Damage $	Total Damage $
0+	1278	-	1278	1278	-	1278
1	5951	2565	8513	5951	2850	8801
2	5951	4618	10569	5951	5131	11082
3	5951	6157	12108	5951	6841	12792
4	6356	7183	13539	6356	7981	14337
5	6356	7697	14053	6356	8552	14908
6	6356	8210	14566	6356	9122	15478
7	6356	8210	14566	6356	9122	15478
8	7337	8210	15547	7337	9122	16459

2. Basement Damage

Flood Depth (Ft. Above Basement Floor)	Structural Damage $	Content Damage $	Total Damage $
0+	320	-	320
1	1488	285	1773
2	1488	513	2011
3	1488	684	2172
4	1589	798	2387
5	1589	855	2444
6	1589	912	2501
7	1589	912	2501
8	1834	912	2746

3. Exterior Damage (See A.4.1.3 (3))

A.6.2 Class B House

1. Main Floor Damage

Flood Depth (Ft. Above Main Floor)	House with Basement			House with no Basement		
	Structural Damage $	Content Damage $	Total Damage $	Structural Damage $	Content Damage $	Total Damage $
0+	1304	-	1304	1304	-	1304
1	4576	1359	5935	4576	1510	6086
2	4576	2446	7022	4576	2718	7294
3	4576	3262	7838	4576	3624	8200
4	4826	3805	8631	4826	4228	9054
5	4826	4077	8903	4826	4530	9356
6	4826	4349	9175	4826	4832	9658
7	4826	4349	9175	4826	4832	9658
8	5449	4349	9798	5449	4832	10281

2. Basement Damage

Flood Depth (Ft. Above Basement Floor)	Structural Damage $	Content Damage $	Total Damage $
0+	326	-	326
1	1144	151	1295
2	1144	272	1416
3	1144	362	1506
4	1207	423	1630
5	1207	453	1660
6	1207	483	1690
7	1207	483	1690
8	1362	483	1845

3. Exterior Damage (See A.4.2.3 (3))

A.6.3 Class C House

1. Main Floor Damage

Flood Depth (Ft. Above Main Floor)	House with Basement			House with no Basement		
	Structural Damage $	Content Damage $	Total Damage $	Structural Damage $	Content Damage $	Total Damage $
0+	759	-	759	759	-	759
1	2424	581	3005	2424	646	3070
2	2424	1046	3470	2424	1162	3586
3	2424	1394	3818	2424	1549	3973
4	2539	1627	4166	2539	1807	4346
5	2539	1743	4282	2539	1937	4476
6	2539	1859	4398	2539	2066	4605
7	2539	1859	4398	2539	2066	4605
8	2870	1859	4729	2870	2066	4936

2. Basement Damage

Flood Depth (Ft. Above Basement Floor)	Structural Damage $	Content Damage $	Total Damage $
0+	190	-	190
1	606	65	671
2	606	116	722
3	606	155	761
4	635	181	816
5	635	194	829
6	635	206	841
7	635	206	841
8	718	206	924

3. Exterior Damage (See A.4.3.3 (3))

A.7 Lower Fraser Valley

A.7.1 Critical Characteristics of Houses by Area.

Area	% of Houses in Each Class			% of House With Basements			Main Floor Level Above Ground (ft.) Houses With Basements			Houses Without Basements		
	A	B	C	A	B	C	A	B	C	A	B	C
1	-	44	56	-	75	25	-	6	3	-	1	1
2	-	48	52	-	36	38	-	6	4	-	2	1
3	-	20	80	-	0	25	-	-	4	-	1	1
4	-	-	100	-	-	0	-	-	0	-	-	1
5	-	30	70	-	30	14	-	3	3	-	2	1
6	-	28	72	-	66	14	-	4	3	-	2	1
7	-	11	89	-	100	57	-	4	3	-	-	1
8	-	20	80	-	100	50	-	5	4	-	-	1
9	-	29	71	-	0	0	-	-	-	-	2	1
10 (A)	3	74	23	100	33	20	3	3	3	-	1	1
10 (B)	3	50	47	100	33	20	3	3	3	-	1	1
11&12	-	48	52	-	50	23	-	3	3	-	1	1
13	-	24	76	-	62	56	-	3	4	-	2	1
14	-	34	66	-	33	0	-	3	-	-	2	1
15	3	46	51	100	59	28	3	8	3	-	1	1
16	-	-	100	-	-	28	-	-	4	-	-	1
17	-	-	100	-	-	35	-	-	6	-	-	1
18 (A)	-	100	-	-	80	-	-	8	-	-	2	-
18 (B)	-	-	100	-	-	0	-	-	-	-	-	1
18 (C)	-	54	46	-	21	33	-	8	6	-	1	1
19 (A)	12	65	23	0	65	8	-	8	8	2	2	1
19 (B)	1	91	8	0	65	8	-	8	8	2	2	1

A.7.2 Unit Residential Stage-Damage Potential by Area

Flood Depth (Ft. Above Ground Level)	$ Damage by Area										
	1	2	3	4	5	6	7	8	9	10 (A) Chilliwack	10 (B) Chilliwack
1	1,500	1,100	1,400	1,300	1,300	1,500	1,500	1,400	1,000	2,000	1,800
2	3,200	2,400	3,800	3,600	3,100	3,200	2,500	2,500	3,200	5,100	4,500
3	3,900	4,200	4,600	4,300	4,800	4,200	3,300	2,900	5,100	6,400	5,600
4	4,700	5,200	5,300	4,800	6,000	5,100	4,800	3,600	5,900	8,400	7,300
5	5,400	6,400	6,500	5,500	6,900	6,600	5,900	5,200	6,800	9,500	8,300
6	6,100	7,100	6,800	5,700	7,300	7,100	6,400	6,400	7,200	10,200	8,800
7	7,900	8,200	7,200	6,000	7,900	7,800	7,000	7,000	7,500	11,200	9,700
8	8,300	8,600	7,300	6,100	8,100	8,100	7,200	7,400	7,700	11,400	9,900
9	8,900	9,000	7,700	6,500	8,400	8,400	7,400	7,800	8,000	11,900	10,300
10	9,300	9,500	7,800	6,500	8,600	8,500	7,500	8,000	8,300	12,000	10,400
10+[a]	14,300	14,800	11,400	9,000	12,600	12,400	10,300	11,400	12,500	18,900	15,800

Flood Depth (Ft. Above Ground Level)	$ Damage by Area										
	11 & 12	13	14	15	16	17	18(A)	18(B) Delta	18(C)	19(A) Richmond	19(B) Richmond
1	1,800	1,400	1,300	1,500	1,300	1,200	1,400	1,300	1,500	1,000	1,200
2	4,000	2,500	3,300	3,400	3,000	2,800	2,100	3,500	4,400	2,300	2,200
3	5,200	3,500	5,000	4,300	3,600	3,300	3,300	4,300	5,300	4,600	4,000
4	7,000	4,800	6,200	5,400	4,200	3,700	4,200	4,800	6,100	5,700	5,000
5	7,900	6,500	7,000	6,200	5,400	4,300	4,800	5,500	7,000	6,600	5,800
6	8,400	7,000	7,500	6,500	5,700	4,800	5,100	5,700	7,400	7,100	6,200
7	9,300	7,700	8,200	6,900	6,100	5,700	5,200	5,900	7,900	7,500	6,400
8	9,400	8,000	8,300	7,400	6,200	5,900	6,500	6,000	8,200	8,400	7,400
9	9,800	8,300	8,600	9,000	6,500	6,300	10,200	6,400	9,300	10,500	10,200
10	9,900	8,400	8,800	9,500	6,600	6,400	11,600	6,400	9,700	11,500	11,500
10+[a]	14,800	11,900	12,900	15,500	9,000	9,000	21,100	9,000	15,500	20,600	20,300

[a] Damage in a flood of 10+ ft. depth = total loss of house and contents.

A.8 Upper Fraser and Thompson Valleys

A.8.1 Critical Characteristics of Houses by Area

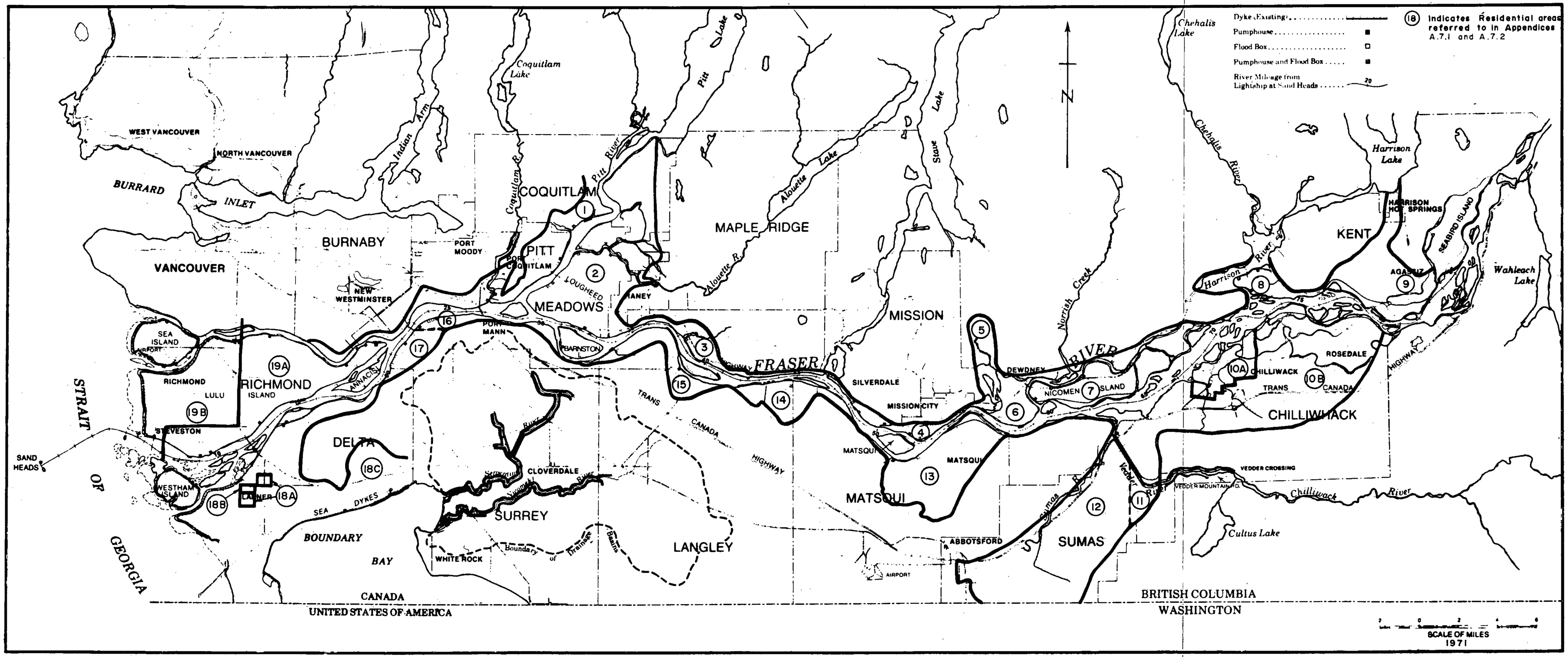
Area	% of Houses in Each Class			% of Houses With Basements			Main Floor Level Above Ground (ft.) Houses With Basements			Main Floor Level Above Ground (ft.) Houses Without Basements		
	A	B	C	A	B	C	A	B	C	A	B	C
Kamloops												
Area (A)	-	85	15	-	77	100	-	3	3	-	1	-
(B)	-	36	64	-	100	56	-	3	2	-	-	1
(C)	-	50	50	-	73	48	-	3	2	-	1	1
(D)	-	75	25	-	66	0	-	3	-	-	1	1
(G)	-	-	100	-	-	28	-	-	4	-	-	1
(H)	-	-	100	-	-	35	-	-	6	-	-	1
(M)	-	100	-	-	100	-	-	3	-	-	-	-
Oak Hills	20	80	-	100	80	-	3	3	-	-	1	-
Quesnel	-	45	55	-	70	10	-	3	3	-	1	-
Prince George												
Area (B)	-	30	70	-	65	15	-	4	3	-	2	2
(C)	-	90	10	-	60	40	-	3	3	-	3	2
(E)	-	-	100	-	-	-	-	-	-	-	-	3

A.8.2 Unit Residential[a] Stage-Damage Potential by Area

Flood Depth (Ft. Above Ground Level)	$ Damage by Area											
	Kamloops									Prince George		
	A	B	C	D	G	H	M	Oak Hills	Quesnel	B	C	E
1	2,000	1,600	1,600	1,800	1,300	1,200	2,100	2,400	1,800	900	1,300	500
2	3,600	2,300	3,200	3,700	3,000	2,800	2,400	3,500	3,700	1,600	1,700	1,300
3	5,300	3,500	4,800	5,100	3,600	3,300	4,000	5,100	4,800	3,700	3,300	3,800
4	9,300	6,300	6,700	8,100	4,200	3,700	9,000	9,700	6,800	4,900	8,000	4,400
5	10,800	7,300	7,700	9,300	5,400	4,300	10,500	11,200	7,700	6,500	9,500	5,100
6	11,500	7,900	8,300	9,900	5,700	4,800	11,400	12,600	8,300	7,100	10,300	5,700
7	12,200	8,400	8,800	10,500	6,100	5,700	12,200	14,000	9,100	7,500	11,100	5,900
8	12,500	8,600	9,000	10,700	6,200	5,900	12,600	14,400	9,300	7,900	11,500	6,000
9	13,000	8,800	9,300	11,200	6,500	6,300	13,000	14,900	9,700	8,000	11,900	6,400
10	13,400	9,000	9,600	11,500	6,600	6,400	13,400	15,000	9,700	8,500	12,300	6,400
10+[b]	19,300	13,400	15,100	18,100	9,000	9,000	21,100	24,900	14,500	12,600	19,900	9,000

[a] Mobile homes located behind dykes were assumed to have the same value and suffer the same damages as C class houses without basements. Those located in non-dyked areas were assumed to be moved and were not expected to suffer damages.

[b] Damage in a flood of 10+ ft. is equal to the total loss of house and contents.



MAP OF LOWER FRASER VALLEY SHOWING AREAS OF DIFFERENT RESIDENTIAL CHARACTERISTICS

FIGURE No. 1

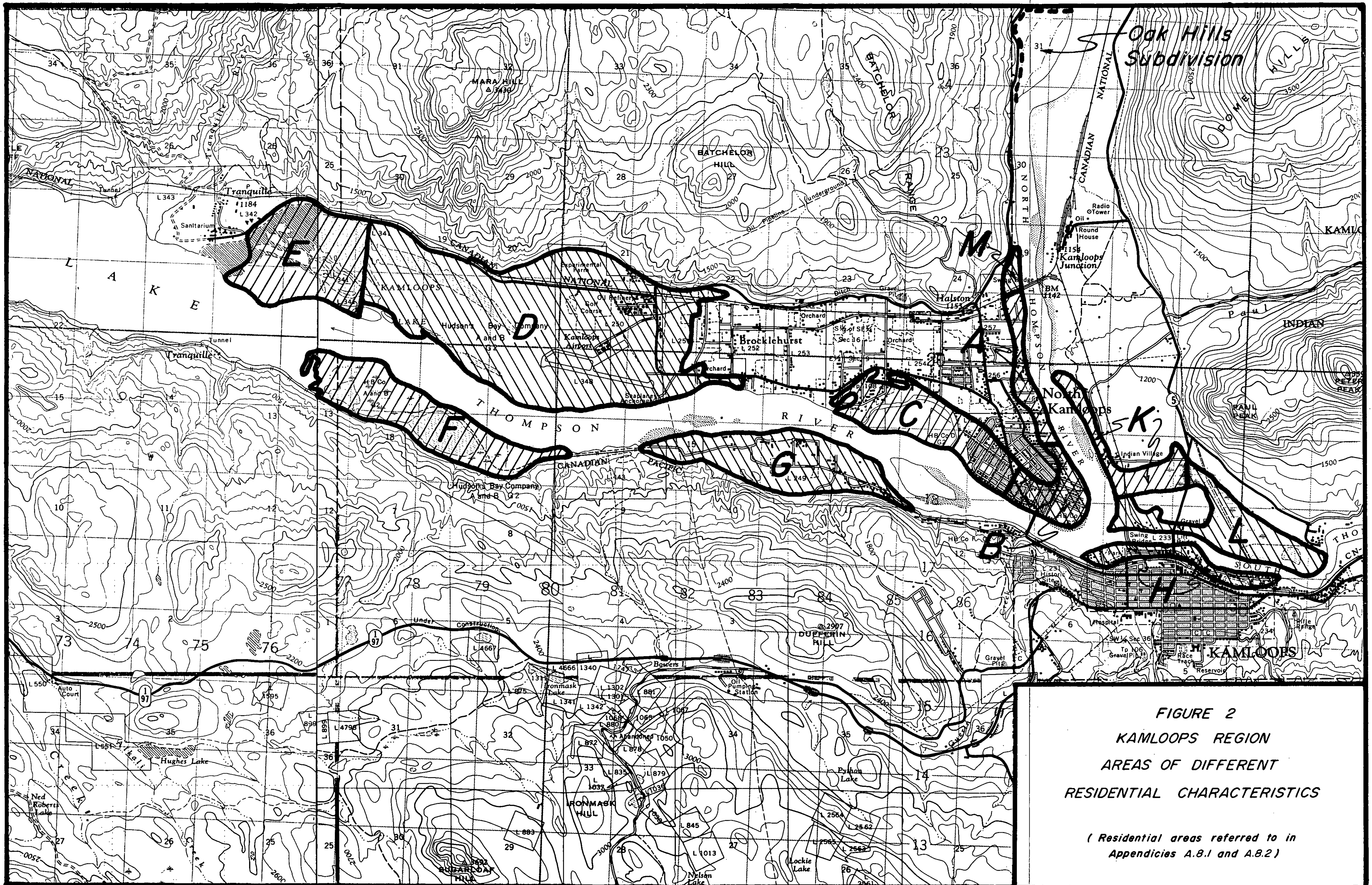


FIGURE 2
KAMLOOPS REGION
AREAS OF DIFFERENT
RESIDENTIAL CHARACTERISTICS

(Residential areas referred to in
Appendicies A.8.1 and A.8.2)

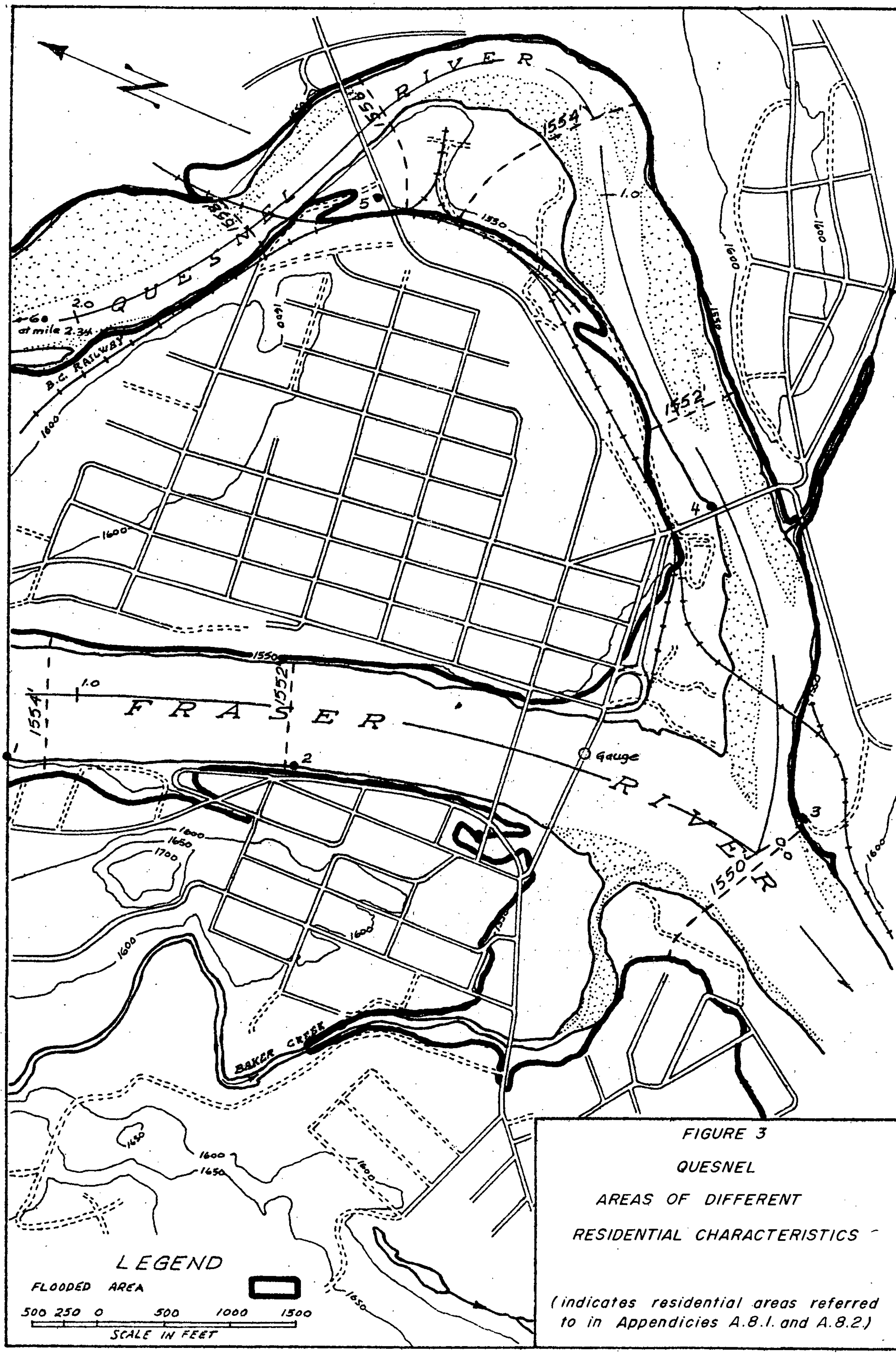


FIGURE 3

QUESNEL

AREAS OF DIFFERENT

RESIDENTIAL CHARACTERISTICS

(indicates residential areas referred to in Appendicies A.8.1. and A.8.2.)

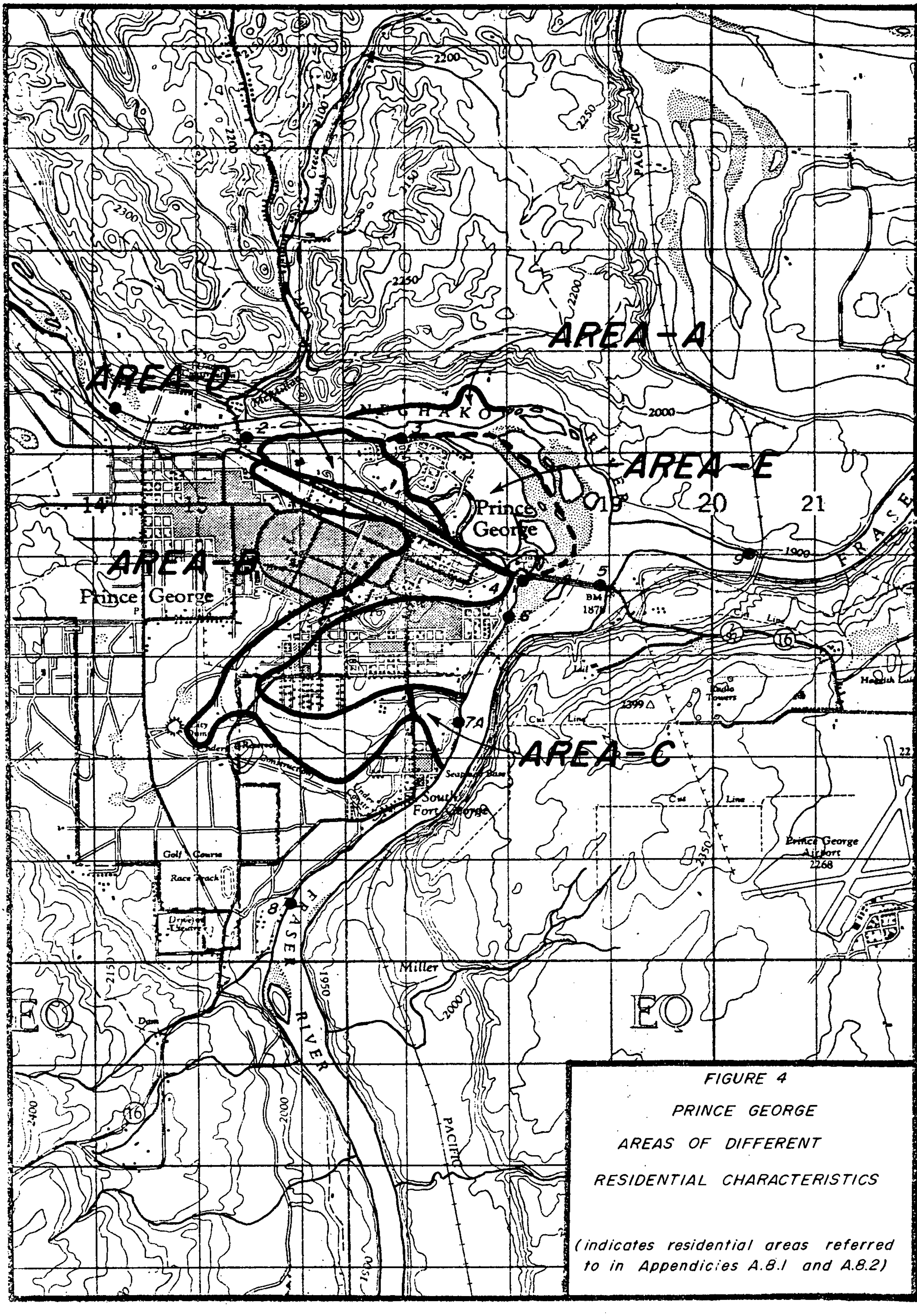


FIGURE 4

PRINCE GEORGE

AREAS OF DIFFERENT

RESIDENTIAL CHARACTERISTICS

(indicates residential areas referred to in Appendicies A.8.1 and A.8.2)

APPENDIX B

COMMERCIAL AND INDUSTRIAL FLOOD DAMAGE

B.1 Commercial Questionnaire Content

Fraser River Joint Programme Committee
Survey of Possible Flood Damages to Commercial Properties

1. Type of Business ____________ 2. Location ____________ 3. Date ____________

EXTERNAL

4. Structural type ____________ 5. Electrical Outlets: No. ______ Av.Height ______ Total Cost ______

6. Walls: Material Length Height Area Repair Cost

Side ______ ______ x ______ = ______ ______ x ______ = ______

End ______ ______ x ______ = ______ ______ x ______ = ______

7. Doors: ______ Size ______ No. ______ ______ x ______ = ______

______ ______ ______ ______ x ______ = ______

INTERIOR

8. Walls: Length Height Area Material Covering Repair Cost Total Cost

Side ______ x ______ = ______ ______ ______ ______ = ______

End ______ x ______ = ______ ______ ______ ______ = ______

9. Floors:

______ ______ x ______ = ______ ______ ______ ______ x ______ = ______

______ ______ x ______ = ______ ______ ______ ______ x ______ = ______

______ ______ x ______ = ______ ______ ______ ______ x ______ = ______

10. Windows: ______ x ______ = ______ Height (above floor level) ______ Sash ______ x ______ = ______

11. Doors: Material ______ Size ______ No. ______ Sash ______ x ______ = ______

12. Damage to Furniture and Machinery:

This figure was calculated as follows for each piece or group of furniture and machinery:

Damage at one foot intervals ($) = (Depreciated value)
x (% of value affected, at one foot intervals)
x (% of affected value unsalvageable, at one foot intervals)

13. Damage to display cabinets and contents:

This figure was calculated as follows:

Inventory value = (No. of display cabinets)
x (Value of inventory per cabinet)

Damage at one foot intervals ($) = (Inventory value)
x (% of inventory value affected at one foot intervals)
x (% of affected value unsalvageable, at one foot intervals)
+ (Cabinet repair or replacement costs)

14. Damage to Shelves and Contents:

This figure was calculated using the same method as in Damage to Display Cabinets and Contents (13)

15. Damage to Racks and Contents:

This figure was calculated using the same method as in Damage to Display Cabinets and Contents (13)

16. Damage Totals:

Total damage figures for nos. 12-15 are summed for each one foot interval; a total damage figure per square foot of building area at each one foot interval is then calculated.

17. Gross Annual Sales ______________________________.

18. Wages lost to employees = (number of full time employees)
x (average weekly wage)
x (number of weeks of work lost due to flood)

19. Comments.

B.2 Industrial Questionnaire Content

CONFIDENTIAL

No. ________

Fraser River Joint Programme Committee
Survey of Possible Flood Damages to Industrial Properties

1. Type of industry________________ 2. Date ________ 3. Address ________________
4. Acres of Property: (A) in use ____________ (B) idle ____________ 5. Acres of roof-coverage__________
6. Buildings: (A) Total No. ________(B) Function and area (in sq.ft.) (1) __________(area: ____________) (2) __________(area: __________). (3)__________(area)__________). (4)__________(area:____________) (5) List other buildings on extra sheet provided.
7. Assessed value of buildings(s) (less contents) (1)__________(2)__________(3)__________(4)__________
8. Total value of building(s) ____________________.
9. Construction material of building(s) (by no. of bldgs.): Wood__________, Concrete Blk.__________, Brick______
10. Floor material (by no. of bldgs.): Wood______, Concrete ________, Linoleum/tile________, Hardwood________
11. Assessed total value of fixed machinery ____________________.
12. Approximate value of inventory: (A) Finished product for the month of May __________and June__________ (B) Raw material for the month of May ______________, and June ______________.
13. Estimated cost of moving inventory to safer location on the premises ____________________and/or to an unaffected area in the immediate vicinity (1 mile radius)____________________.
14. Average monthly/weekly/or daily production in ($) ____________________.
15. Is there any part of the year when operations are at less than normal capacity?__________; if yes, when does this occur ______________, for how long __________(we are chiefly interested in the months of May and June).
16. Total number of employees: (A) Full time ______________ (B) Part Time ______________.

17. Total Monthly Pay-roll ______________.

18. List 10 most important suppliers by value and location.

No.	Name of Supplier	Address	Name of Material	Total Costs (Less Transportation)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
Other				

Total Value of Material Purchased:
(including pay roll, fuel and electricity and all current operating expenses excluding investment expenditures) ______________

19. List your 10 most important products by value and location of purchasers.

No.	Name of Purchaser	Address	Product	Value of Shipments (Less Transportation)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
Other				

Total Value of Shipments (Less Transportation Costs) ____________

20. Damages to Equipment

Description of Equipment	Machine Damage or Repair Costs (at 1 ft. invervals)							
	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.

B.3 Letter of Introduction

Dear Sir:

The Planning Division of the Federal Department of the Environment is currently undetaking a study to evaluate the flood damage potential in the Lower Fraser Valley. The major purpose of this study is to determine the damages that would occur at various water levels during flood periods. The damage estimates will be used to determine the damage potential that may be reduced by constructing dykes and upstream storage reservoirs which will benefit you as a property owner.

In order that damage estimates be calculated, it is necessary to conduct a two-part survey.

Part one of the survey involves a questionnaire (see enclosed) designed to provide general information that is required for the study. The questions are of a straight-forward nature; at all times the replies will be treated in a confidential manner, and none of the information provided by you will be used on an individual basis. The replies will be grouped with other data to produce the required statistics.

The questionnaire will be at your disposal for a period that will allow adequate time for you to provide the information requested. In the near future, we will contact you by phone to clarify any problems that may have arisen in answering the questionnaire, and to arrange an appointment with you to complete part two of the survey.

In the second part, we will require estimates of damage that would occur to your buildings, equipment, and inventory in the event of flooding to various depths. For example, we will have to determine the damage that may occur at one, two, and three foot depths. This analysis will require an inventory of machinery and other fixed features found at these intervals to determine their repair or replacement costs. Further explanation of this second part of the survey will be given when contact is made as mentioned earlier.

The nature of the study requires that all industries located in the immediate proximity of the Fraser River be interviewed, hence your co-operation and assistance will be of the utmost importance and greatly appreciated.

The names of those conducting interviews in your area are:
______________________________ : ______________________________ ___.

______________________________ is in charge of the study and if there are any problems or if you have any questions at this time, please do not hesitate to write or call him (telephone).

I hope that this letter will serve as an introduction to our study and that your co-operation will be forthcoming.

B.4 Condensed Industrial Questionnaire for Firms that had Failed to Return Initial Questionnaire

Dear Sir:

Recently we sent a representative of the Planning Division of the Federal Department of the Environment into your area to assess potential industrial flood damage. At the time of the assessment, we left with every firm a questionnaire containing questions related to industrial damage potential.

Upon examining our records, we find that we do not as yet have a reply from your company. If we do not obtain the necessary information from you, the accuracy of our study will suffer and this could affect you both as a tax payer and a flood plain resident.

An evaluation of the potential losses to every industry is extremely important if we are to determine the most economical method of providing flood protection for the Fraser Valley.

It would be appreciated, therefore, if you would mail in your completed questionnaire as soon as possible. Should you require another copy, you will find, attached to this letter for your convenience, a simplified and somewhat shorter version, along with a self-addressed envelope.

Once again, if you have any problems, do not hesitate to call Mr. ________________________________ at (telephone).

Thank you for your co-operation,

Date ____________________

No. ____________________

FRASER RIVER JOINT PROGRAMME COMMITTEE

SURVEY OF POSSIBLE FLOOD DAMAGES TO INDUSTRIAL PROPERTIES

1. Type of industry ____________________
2. Acres of property: (A) In Use ____________ (B) Idle ____________
3. Square feet of roof coverage ____________________
4. Construction material of bldg.(s): Wood _____ Concrete Blk. _____ Brick _____
5. Average value of finished products on hand at any one time during the month of June $____________________
6. Average value of raw materials on hand at any one time during the month of June $____________________
7. Average monthly production $____________________
8. Total number of employees ____________________
9. Total monthly payroll $____________________
10. List your most important products by value and location of purchasers.

Product	Annual $ Value of Shipments (less transportation costs)	Destination % to B.C.	% out of province
Total value of all Shipments			

11. List most important material used in production by value and location.

Material	$ Total Cost per Annum	% Purchased from Firms Located in B.C.	% Purchased from Firms Out of Province
Total Annual Cost of Production			

B.5 Classification of Industries located on the Flood Plain - Lower Fraser Valley

Indust. I.D. Number[b]	Industrial Type	Number of Industries by Area									
		Lulu Island	Delta and S. Westminster	Brunette Creek	Pt. Coq. and Pitt Meadows	Albion	Trapp Road	Mission	Chilliwack	Other Undyked	Total
2	Forestry	–	–	–	–	1	–	–	–	–	1
11	Other Non Metal Mines (SIC-079)	5	–	1[a]	–	–	–	–	–	–	6
12	Slaughtering & Meat Processing	3	–	–	–	1	–	–	1	–	5
16	Fish Products Industries	5	–	–	–	–	–	–	–	–	5
17	Fruit and Vegetable Canners	2	–	–	–	–	–	1	1	–	4
21	Biscuit Manufacturers	–	–	–	1	–	–	–	–	–	1
26	Miscellaneous Food (SIC-139)	3	–	–	–	–	–	–	–	–	3
27	Soft Drink Manufacturers	2	–	–	–	–	–	–	–	–	2
44	Other Text. (Rope and Cordage)	1	–	1[a]	–	–	–	–	–	–	2
48	Saw, Shake and Shingle Mills	2	4,3[a]	1[a]	3	3	–	5	1[a]	10[a]	32
49	Veneer and Plywood Mills	3	1	–	–	–	–	–	–	–	4
50	Sash & Door, and Planing Mills	13	–	1[a]	2	–	–	–	1	–	17
51	Misc. Wood Ind. (SIC-259,258,256)	5	–	1[a]	–	–	–	–	–	–	6
53	Other Furniture (SIC-266,264,261)	5	–	–	–	–	–	–	1	–	6
56	Paper Box, Bag Manufacturing	3	–	–	–	–	–	–	–	–	3
57	Miscellaneous Paper Converters	1	1	–	–	–	–	–	–	–	2
58	Printing, Publishing & Engraving	1	–	–	–	–	–	–	–	–	1
59	Iron and Steel Mills	1	–	–	1	–	–	–	–	–	2
62	Smelting and Refining	2	–	–	–	–	–	–	–	–	2
63	Alum. Rolling, Cast. & Extrud.	1	–	–	1	–	–	–	–	–	2
67	Fabricated Structural Metal	2	1	1[a]	–	–	1	–	–	–	5
68	Ornamental & Architectural Metal	3	–	–	2	–	–	–	–	–	5
69	Metal Stamp., Pressing & Coating	1	–	–	–	–	–	–	–	–	1
70	Wire and Wire Products	5	–	–	–	–	–	–	–	–	5
71	Hardware, Tool & Cutlery Mfg.	1	–	–	–	–	–	–	–	–	1
72	Other Metal Fabricating (SIC-307,308,309)	10	–	1[a]	5	–	1	1	3	1	21
73	Misc. Machin. & Equip. Mfg. (SIC-311,315)	8	–	–	–	–	–	–	–	–	8
75	Aircraft and Parts Manufacturing	3	–	–	–	–	–	–	–	–	3

B.5 Continued

Indust. I.D. Number[b]	Industrial Type	Number of Industries by Area: Lulu Island	Delta and S. Westminster	Brunette Creek	Pt. Coq. and Pitt Meadows	Albion	Trapp Road	Mission	Chilliwack	Other Undyked	Total
76	Truck Body & Trailer Mfg.	9	-	-	2	-	-	-	-	-	11
77	Motor Vehicle Parts Mfg.	1	-	1[a]	-	-	-	-	-	-	2
78	Boat and Ship Manufacturing	9	-	-	1	-	-	-	-	1[a]	11
81	Elec. Industrial Equipment Mfg.	3	-	-	-	-	-	-	-	-	3
82	Other Elec. Mfg. (SIC-339)	1	-	-	-	-	-	-	-	-	1
84	Concrete Products Manufacturing	3	-	-	-	1	-	-	2	-	6
87	Non-Metal Mineral Prod. (SIC-359,357,355,354)	1	4	-	-	-	-	-	-	-	5
88	Petroleum & Coal Prod. Ind.	-	-	-	-	1	-	-	-	-	1
93	Paint & Varnish Manufacturing	2	-	-	-	-	-	-	-	-	2
96	Ind. & Other Chemical Mfg. (SIC-378,379)	8	-	-	-	-	-	-	-	-	8
97	Misc. Mfg. Ind. (SIC-393,395,397,399, & 381 to 385)	5	-	-	1	-	-	-	-	-	6
98	Building Construction (SIC-404,406,409,421)	11	-	-	-	-	-	1	-	-	12
Other Establishments Surveyed in the Industrial Survey											
99	Wholesale and Retail Trade	35	-	-	1	-	-	-	1	-	37
100	Transportation and Storage	2	-	1	-	-	-	-	-	-	3
105	Engineering & Sc. Services	1	-	-	-	-	-	-	-	-	1
107	Personal and Other Services	4	-	-	-	-	-	-	-	-	4
	TOTAL	186	14	9	20	7	2	8	11	11	268

[a] Firms unprotected by Dykes of Dyking Districts

[b] From the 110 Categories Listed in Table 14, Vol. 2 of The Input-Output Structure of the Canadian Economy-1961 (D.B.S., 1968)

Source: Field Survey, 1971.

B.6 Average Unit Stage Damage Estimates for Selected Industrial Categories

Industrial Category Number	Damage per Acre of Land Used[a] ($1000) Flood Depth in Feet[b]						Acres of Land Used per Employee	Acres of Land Used per Sq.Ft. of Plant Area
	1'	2'	3'	4'	5'	6'		
17	47	50	55	391	393	395	.0284	.00005
44	45	45	-	-	-	-	.0556	.00003
48	1	1	2	5	12	15	.1508	.00019
50	25	37	-	-	-	-	.0416	.00010
51	1	1	6	-	-	-	.6725	.00020
56	40	248	-	-	-	-	.0402	.00004
59	1	3	7	13	-	-	.0392	.00006
63	4	5	43	44	70	71	.0798	.00012
67	3	4	-	-	-	-	.4286	.00012
68	1	1	2	2	2	4	.0897	.00013
69	13	26	-	-	-	-	.0250	.00008
70	13	24	33	-	-	-	.0496	.00007
72	6	12	12	13	19	22	.0546	.00010
73	8	14	24	29	33	-	.0467	.00011
75	8	15	15	-	-	-	.0909	.00008
76	2	6	6	-	-	-	.1759	.00026
77	1	2	-	-	-	-	.0877	.00006
78	2	6	6	-	-	-	.0378	.00006
81	5	9	-	-	-	-	.0199	.00004
93	49	50	58	-	-	-	.0544	.00005
96	19	-	-	-	-	-	.0862	.00009
98	3	4	4	4	-	-	.1327	.00028

[a] Note: These figures are presented only to illustrate the relative magnitudes of the damages estimated for various industries; their usefulness is severely limited due to extreme fluctuations in changes observed from firm to firm.

[b] Flood Depth refers to feet above floor level except for industry No. 48 in which case it refers to feet above ground level.

Source: Field Survey, Lower Fraser, 1971

APPENDIX C

AGRICULTURAL FLOOD DAMAGE

C.1 Per Acre Crop Damage

	Type of Crop Or Crop-Group	Gross Returns Per Acre ($)	Other Income Loss by Flood ($)	Non Labour Costs Not Incurred By Flood ($)	Per Acre Damage ($)
A.	Perennial Crops				
1)	Tame Hay & Legumes	140	50	10	180
2)	Pasture	120	50	10	160
3)	Other Fodder Crops	140	50	10	180
4)	Strawberries	1,600	500	50	2,050
5)	Raspberries	2,000	900	50	2,850
6)	Other Small Fruit	1,500	-	-	1,500
7)	Tree Fruit	1,000	2,000	100	2,900
8)	Nursery Products				
	a. Christmas Trees	2,500	-	100	2,400
	b. Mixed Varieties	3,000	2,000	-	5,000
9)	Hops	1,550	1,100	50	2,600
B.	Annual Crops				
10)	Greenhouse Products	-	-	-	43,560
11)	Grain Crops	130	-	5	125
12)	Oats for Hay	130	-	15	115
13)	Corn for Ensilage	300	-	30	270
C.	Vegetables				
14)	Potatoes	660	-	60	600
15)	Green Beans	300	-	30	270
16)	Wax Beans	270	-	30	240
17)	Beets (Bunched)	2,700	-	200	2,500
18)	Broccoli	550	-	150	400
19)	Brussel Sprouts	800	-	350	450
20)	Cabbage (Early)	1,120	-	180	940
21)	Cabbage (Mid & Late)	690	-	160	530
22)	Cabbage (Savoy)	1,220	-	200	1,020

Table continued on Page 52

C.1 Continued

	Type of Crop Or Crop-Group	Gross Returns Per Acre ($)	Other Income Loss By Flood ($)	Non Labour Costs Not Incurred By Flood ($)	Per Acre Damage ($)
23)	Cabbage (Chinese)	1,875	-	200	1,675
24)	Carrots (Bunched)	2,390	-	190	2,200
25)	Cauliflower	820	-	240	680
25)	Celery	1,475	-	375	1,100
27)	Sweet Corn	190	-	40	150
28)	Cucumbers (Slicing)	875	-	350	525
29)	Cucumbers (Pickling)	725	-	125	600
30)	Lettuce (Head)	1,430	-	300	1,130
31)	Lettuce (Butter & Red)	900	-	160	740
32)	Onions (Bunched)	2,750	-	150	2,600
33)	Parsley	2,640	-	140	2,500
34)	Parsnips	840	-	140	700
35)	Peas	230	-	30	200
36)	Peppers	440	-	40	400
37)	Pumpkins	390	-	70	320
38)	Radishes	1,840	-	200	1,640
39)	Rhubarb	1,380	-	80	1,300
40)	Rutabagus	930	-	100	830
41)	Spinach	870	-	100	770
42)	Squash	540	-	200	340
43)	Miscellaneous	440	-	90	350

C.2 Percentage of Acreage Under Different Crops and Average Damage by Dyking District

Crop Type or Group	% Each Crop of Total Acreage by Dyking District			
	(1) Richmond	(2) Delta	(3) Burnaby Trapp Rd.	(4) Coquitlam
A. Perennial Crops				
1) Tame Hay, Legume & Other Fodder Crops	20.0	26.9	-	30.0
2) Pasture	28.9	22.2	-	54.0
3) Strawberries	8.0	-	-	-
4) Raspberries	.2	-	-	.2
5) Other Small Fruit	7.2	-	-	2.7
6) Tree Fruit	.1	.4	-	-
7) Nursery Products				
a. Christmas Trees	.5	-	-	-
b. Mixed Varieties	1.7	-	.7	-
8) Hops	-	-	-	-
B. Annual Crops				
9) Greenhouse Prod.	.07	.01	.07	-
10) Grain Crops	7.0	14.4	-	5.1
11) Oats for Hay	1.0	.7	-	6.6
12) Corn for Ensilage	1.2	.6	-	-
13) Potatoes	12.9	14.7	-	-
C. Vegetables (Weighted Average For Each Area)	11.3	20.1	99.3	1.4
	Damage Per Acre by Dyking District			
Average Crop Damage	$650.00	$265.00	$1525.00	$205.00

Continued on Page 54

C.2 Continued

Crop Type or Group	% Each Crop of Total Acreage by Dyking District			
	(5) Pitt Meadows Maple Ridge	(6) Pitt Meadows No.1, No.2 Pitt Polder	(7) Barnston Island	(8) Albion + Road 13
(A) Perennial Crops				
(1) Tame Hay, Legume & Other Fodder Crops	40.8	68.8	45.4	29.4
(2) Pasture	44.6	20.1	38.2	60.0
(3) Strawberries	-	-	-	-
(4) Raspberries	-	-	-	-
(5) Other Small Fruit	2.2	-	-	-
(6) Tree Fruit	-	-	-	1.9
(7) Nursery Products				
(a) Christmas Trees	-	-	-	-
(b) Mixed Varieties	1.5	1.3	-	-
(8) Hops	-	-	-	-
(B) Annual Crops				
(9) Greenhouse Prod.	-	-	-	-
(10) Grain Crops	1.8	-	1.8	1.2
(11) Oats for Hay	6.2	9.5	8.1	4.2
(12) Corn for Ensilage	2.6	.3	5.2	2.8
(13) Potatoes	-	-	.6	.5
(C) Vegetables (Weighted Average For Each Area)	.2	-	.7	-
	Damage Per Acre by Dyking District			
Average Crop Damage	$270.00	$230.00	$175.00	$220.00

Continued on Page 55

C.2 Continued

Crop Type or Group	% Each Crop of Total Acreage by Dyking District			
	(9) West Langley	(10) Salmon Arm	(11) Glen Valley	(12) Matsqui
(A) Perennial Crops				
(1) Tame Hay, Legume & Other Fodder Crops	39.9	35.0	45.2	40.9
(2) Pasture	58.1	58.9	41.1	41.1
(3) Strawberries	-	.4	1.1	.8
(4) Raspberries	.1	-	.6	1.0
(5) Other Small Fruit	.1	.3	.2	1.0
(6) Tree Fruit	.1	.8	.4	.1
(7) Nursery Products				
(a) Christmas Trees	-	-	-	-
(b) Mixed Varieties	-	.2	1.1	-
(8) Hops	-	-	-	-
(B) Annual Crops				
(9) Greenhouse Prod.	-	-	-	0.0
(10) Grain Crops	-	1.9	1.4	1.7
(11) Oats for Hay	1.0	1.1	6.5	6.5
(12) Corn for Ensilage	.4	.3	.6	2.5
(13) Potatoes	-	.5	.9	-
(C) Vegetables (Weighted Average For Each Area)	.2	.4	.9	4.5

	Damage Per Acre for Dyking District			
Average Crop Damage	$175.00	$200.00	$220.00	$235.00

Continued on Page 56

C.2 Continued

Crop Type or Group	% Each Crop of Total Acreage by Dyking District			
	(13) Silverdale	(14) South Dewdney	(15) Sumas Including Yarrow	(16) West & North Nicomen
(A) Perennial Crops				
(1) Tame Hay, Legume & Other Fodder Crops	37.5	43.0	38.2	52.9
(2) Pasture	58.3	46.3	25.4	37.5
(3) Strawberries	-	} 2.0 (items 3–6 combined)	.1	.3
(4) Raspberries	-		2.0	.3
(5) Other Small Fruit	-		.1	.3
(6) Tree Fruit	-		.3	.3
(7) Nursery Products				
(a) Christmas Trees	-	1.0	-	-
(b) Mixed Varieties	-	-	.4	-
(8) Hops	-	-	-	-
(B) Annual Crops				
(9) Greenhouse Prod.	-	-	-	-
(10) Grain Crops	.9	.2	2.4	1.0
(11) Oats for Hay	3.3	6.2	3.2	4.6
(12) Corn for Ensilage	-	.2	1.9	2.2
(13) Potatoes	-	.3	-	-
(C) Vegetables (Weighted Average For Each Area)	-	.8	25.9	.6

	Damage Per Acre by Dyking District			
Average Crop Damage	$165.00	$220.00	$265.00	$200.00

Continued on Page 57

C.2 Continued

Crop Type or Group	% Each Crop of Total Acreage by Dyking District			
	(17) East Nicomen	(18) Chilliwack	(19) Harrison Mills	(20) Aggassiz
(A) Perennial Crops				
(1) Tame Hay, Legume & Other Fodder Crops	44.8	37.7	47.5	43.4
(2) Pasture	26.4	37.5	40.4	42.0
(3) Strawberries	-	}	}	}
(4) Raspberries	.3	}	} .3	} .3
(5) Other Small Fruit	-	}	}	}
(6) Tree Fruit	-	} 2.5	}	}
(7) Nursery Products		}		
(a) Christmas Trees	-	}	-	-
(b) Mixed Varieties	-	}	-	-
(8) Hops	-	3.1	-	-
(B) Annual Crops				
(9) Greenhouse Prod.	-	.005	-	-
(10) Grain Crops	-	1.9	4.6	2.4
(11) Oats for Hay	12.7	2.9	4.1	5.7
(12) Corn for Ensilage	4.1	4.3	3.1	5.4
(13) Potatoes	.1	1.2	-	-
(C) Vegetables (Weighted Average For Each Area)	11.6	8.9	-	.8

	Damage Per Acre by Dyking District			
Average Crop Damage	$200.00	$325.00	$170.00	$180.00

C.3 Method Used to Calculate Average Per Acre Crop Damage: Dyking District - Sumas (Including Yarrow)

Type of Crop or Crop Group	Avg. Per Acre Damage ($)	Tot. Acres in Crop	% Ea. Crop Tot. Acres (%)	Weight Val. Ea. Crop ($)
A. Perennial Crops				
1) Tame Hay, Legumes, & Other Fodder Crops	180	8,093	38.2	68.76
2) Pasture	160	5,375	25.4	40.64
3) Strawberries	2,050	30	.1	2.05
4) Raspberries	2,850	423	2.0	57.00
5) Other Small Fruit	1,500	27	.1	1.50
6) Tree Fruit	2,900	68	.3	8.70
7) Nursery Products				
a. Christmas Trees	2,400	-	-	-
b. Mixed Varieties	5,000	87	.4	20.00
8) Hops	2,600	-	-	-
B. Annual Crops				
9) Greenhouse Products	43,560	0.0344	0.00016	.07
10) Grain Crops	125	513	2.4	3.00
11) Oats for Hay	115	682	3.2	3.68
12) Corn for Ensilage	270	401	1.9	5.13
C. Vegetables				
13) Potatoes	600	-	-	-
14) Green Beans	270.	400	1.9	5.13
15) Wax Beans	240.	65	.3	.72
16) Beets (Bunched)	2,500.	-	-	-
17) Broccoli	400.	400	1.9	7.60
18) Brussel Sprouts	450	150	.7	3.15
19) Cabbage (Early)	940.	-	-	-
20) Cabbage (Mid & Late)	530.	-	-	-
21) Cabbage (Savoy)	1,020.	-	-	-
22) Cabbage (Chinese)	1,675.	-	-	-
23) Carrots (Bunched)	2,200.	-	-	-

Continued on Page 59

C.3 Continued

Type of Crop or Crop-Group	Avg. Per Acre Damage ($)	Tot. Acres in Crop	% Ea. Crop Tot. Acres (%)	Weight Val. Ea. Crop ($)
24) Cauliflower	680.	143	.7	4.76
25) Celery	1,100.	-	-	-
26) Sweet Corn	150.	2,657	12.6	18.90
27) Cucumbers (Slicing)	525.	-	-	-
28) Cucumbers (Pickling)	600.	-	-	-
29) Lettuce (Head)	1,130.	-	-	-
30) Lettuce (Butter & Red)	740.	-	-	-
31) Onions (Bunched)	2,600.	-	-	-
32) Parsley	2,500.	-	-	-
33) Parsnips	700.	-	-	-
34) Peas	200.	1,650	7.8	15.60
35) Peppers	400.	-	-	-
36) Pumpkins	320.	-	-	-
37) Radishes	1,640.	-	-	-
38) Rhubarb (Field)	1,300.	-	-	-
39) Rutabagas	830.	-	-	-
40) Spinach	770.	-	-	-
41) Squash	340.	-	-	-
42) Miscellaneous	350.	-	-	-
TOTAL		21,164	100.0	266.39

APPENDIX D

PRIMARY AND SECONDARY INCOME LOSSES

D.1 Example of Method Used in Calculating Primary and Secondary Income Losses and Transfer Costs

A "Typical" Industry

A Value of Flood-Disrupted Production ($'000)	B Production that can be Deferred or Transferred ($'000)	C Transfer Cost ($'000)	D Value of Production Permanently Lost to Out of Prov. Firms ($'000)	E Primary Income Loss: Income Permanently Lost to Out-of-Prov. Firms ($'000)	F Value of Production Reductions of Input Industries From: O-of-P ($'000)	G B.C. ($'000)	H Secondary Income Loss: Income Lost by B.C.'s Input Firms ($'000)
440	240	240.0 x .02 = 4.8	200	50.0	1) Forestry 0.0	60.0	60 x .5 = 30.0
					2) Other Textiles 10.0	4.0	4 x .3 = 1.2
					3) Miscel.Machinery 0.0	30.0	30 x .4 = 12.0
					4) Metal Stamping 0.0	20.0	20 x .4 = 8.0
					5) Industrial Chem. 10.0	6.0	6 x .4 = 2.4
					6) Other 10.0	0.0	0.0
		4.8		50.0			53.6

Total Income Loss to B.C. = "C" (Transfer Cost) + "H" (Secondary Income Loss)

Description of Terms used in Table D.1

A) Value of flood-disrupted production =

$$\text{Value of annual production} \times \frac{\text{No. of Days Shut Down}}{\text{Total Number of Production Days per Annum}}$$

B) Value of production transferred or deferred =
(A) x portion deferred or transferred to provincial firms

C) Transfer cost = (B) x .02

D) Value of permanently lost production = A - B

E) Income permanently lost to out-of-province firms (primary income loss) =

$$D \times \frac{\text{Annual income}}{\text{Annual production}}$$

F) Value of reduction of production of out-of-province firms was obtained directly from the reporting industries

G) Value of reduction of production of provincial firms was obtained directly from the reporting industries.

H) Income lost by B.C.'s input firms (secondary income loss) =

G x income/production ratio of input firms

D.2 Request for Secondary Loss Data

Dear Sir:

The Planning Division of the Federal Department of the Environment is completing a study of the effect that a major flood would have on the Lower Fraser Valley. We are concerned about the possible loss of production that might be suffered by food processors that depend on fruit and vegetables produced on the Fraser flood plain. In this light, we would very much appreciate a brief response to the following questions:

If the fruit and vegetable crops in Burnaby, Delta, Richmond, Sumas and Chilliwack were destroyed for one year,

(a) Would the production of your Company be affected?________________

(b) What is the annual value of the vegetables and fruit that you would normally purchase from these areas (1971)? $______________

(c) Would you be able to substitute some of your loss of local vegetables and fruit with produce from other sources (foreign or national)? _______________. If so, what per cent?___________%

(d) If you expect to lose production because you will be unable to substitute all of the loss of your local vegetables and fruit with produce from other sources,

  (i) What would be the dollar sales value of your production loss for one year (1971)?____________________________

  (ii) What percent of one year's (1971) production does this represent? ________________________%

APPENDIX E

MISCELLANEOUS FLOOD DAMAGE

E.1 C.N.R. - Flood Damage

Lower Fraser Dyking Area	Miles of track affected / $'000 Damage at the following flood levels (ft. at Mission) 22 ft.	23 ft.	24 ft.	25 ft.	26 ft.
Lulu Island			10/130	10/130	10/130
Matsqui			6/300	6/300	6/300
Outside Dykes 61 - 62 (miles from			1/10	1/75	1/75
Boston Bar) 81			-/2	-/2	-/2
91 - 94.5			3.5/20	3.5/250	3.5/250
100.9 - 101.5			.6/25	.6/25	.6/25
112.5 - 113.8			1.3/25	1.3/25	1.3/25
Pt. Mann Yard			-/37	-/37	-/37
TOTAL			22.4/549	22.4/844	22.4/844

Upper Fraser (1972 Freshet)	
Blackpool to Kamloops	$ 79,000
Kamloops to Lytton	$180,000
Lytton to Hope	$ 15,000
TOTAL	$274,000

Source: Discussions with CNR Engineering Division - Telex of 1972 Flood activities and expenditures

E.2 Other Railways Flood Damages[a]

Dyking Area	Miles of Track Affected / $'000 Damage Flood Levels (Feet at Mission) 22	23	24	25	26
Agassiz	-	-	-	7.4/96	7.4/96
Harrison Mills	-	-/0	2.0/10	2.0/26	2.0/26
Dewdney	-	-/0	4.5/22	4.5/59	4.5/59
Mission	-/0	0.2/1	0.2/1	0.5/3	1.0/5
Silverdale	-/0	0.9/12	1.1/14	1.2/16	1.6/21
Albion	-	-	-/0	1.0/5	2.0/10
Pitt Meadows-Maple Ridge	-	-/0	2.0/10	2.0/10	2.4/12
South Westminster	-	-	-/0	1.7/22	1.7/22
Delta	-	-/0	7.0/91	8.0/104	9.0/117
Matsqui	-	-/0	4.0/52	4.0/52	4.0/52
Sumas	-	-/0	4.0/52	4.0/52	4.0/52
Big Bend	-	-	-/0	1.5/8	1.5/8
Other Undyked Areas	-/0	3.0/16	3.0/32	19.3/145	19.3/145

CPR Flood Damage - Upper Fraser and Thompson - 1972 Freshet

Kamloops to 72 miles west - $121,000

Source: Discussions with CPR Engineering Division

[a] CPR, BCR, BNR, B.C.H.B.R., and B.C.H. and P.A.R. Railways.

E.3 Average Flood Duration Per Flood by Dyking Area

Dyking Areas	Days Duration Per Flood Level at Mission		
	23 ft.	25 ft.	26 ft.
Richmond-Queensborough, Delta (Areas 18 and 19):	10 days	24 days	29 days
West Langley and Fort Langley, Albion, Colony Farm, Barnston (Areas 15, 3, Non-residential area, Minor Part of 2):	41	44	44
South Westminster, Yarrow and Sumas, Pitt Meadows (Areas 16 and 17, 11 and 12, Part of 2):	39	43	43
Glen Valley, Hatzic-Dewdney, Port Coquitlam (Areas 14, 5 and 6, 1):	42	45	45
Chilliwack, Agassiz, Harrison Mills (Areas 10A and 10B, 9, 8):	27	34	34
Matsqui (Area 13):	33	38	38
Nicomen Island (Area 7):	30	37	37
Silverdale (Minor Part of Area 4):	29	35	38
Mission (Major Part of Area 4):	20	31	34
Trapp Road (Undesignated Residential Area):	10	18	24

Note: (a) In relevant areas, the duration of a 21 or 22 foot flood was found to be significantly different from that of a 23 foot flood.

(b) The numbers listed under "Dyking Areas" refer to the residential areas outlined in Fig. 1, APPENDIX A.7.

Source: Schematic Hydrograph supplied by Engineering Division, Water Planning and Management Branch, Department of the Environment.

E.4 Sample Computation of Relationship between Depth of Flooding and Value of Loss of Use of Dwellings (Flood Level = 26 Feet at Mission)

1) Value of Loss of Use per House Class and Depth of Flooding Above Main Floor in Sample Areas

House Class	Flood Depth Above Main Floor (Ft.)	Flood Duration-Days	Total Loss of Use-Days	Total Loss of Use per House ($)
A	<1	29	29 @ $400 per 30 days	387
	1 and 2	29	74 @ $400 per 30 days	987
	>2	29	89 @ $400 per 30 days	1187
B	<1	29	29 @ $210 per 30 days	203
	1 and 2	29	74 @ $210 per 30 days	518
	>2	29	89 @ $210 per 30 days	623
C	<1	29	29 @ $ 90 per 30 days	87
	1 and 2	29	74 @ $ 90 per 30 days	222
	>2	29	89 @ $ 90 per 30 days	267

2) Housing Characteristics in Sample Area:

% of Houses in Each Class			% of Houses with Basements			Main Floor Level Above Ground (Ft.) Houses with Basements			Without Basements		
A	B	C	A	B	C	A	B	C	A	B	C
0	54	46	-	21	33	-	8	6	-	1	1

3) Computation of Value of Loss of Use Per Average House by Depth of Flooding Above Ground (Depth-Damage Relationship) for Sample Area:

Flood Depth (ft.)	B Class Houses	+	C Class Houses	= Total Loss ($)
<1	.54 [$203]	+	.46 [$87]	= 150
2	.54 [(.21 x $203) + (.79 x $518)]	+	.46 [(.33 x $87) + (.67 x $222)]	= 326
3	"	+	"	= 326
4	.54 [(.21 x $203) + (.79 x $623)]	+	.46 [(.33 x $87) + (.67 x $267)]	= 385
5	"	+	"	= 385
6	"	+	"	= 385
7	"	+	.46 [(.33 x $222)+ (.67 x $267)]	= 405
8	"	+	"	= 405
9	.54 [(.21 x $518) + (.79 x $623)]	+	.46 [$267]	= 448

E.5 <u>Relationship between Depth of Flooding Above Ground Level and Unit Value of Loss of Use of Dwelling by Area</u>[a]

1) 23[b] Foot Flood Level at Mission:

Flood Depth Above Ground (ft.)	Unit $ Loss per Average Dwelling by Area																					
	1	2	3	4	5	6	7	8	9	10A	10B	11& 12	13	14	15	16	17	18A	18B	18C	19A	19B
1	200	192	155	60	NA	173	103	103	112	169	143	192	130	181	211	NA	NA	NA	NA	52	68	67
2	292	235	NA	195	NA	256	155	157	208	350	288	322	175	272	319	214	204	NA	NA	226	96	77
3	292	332	"	195	NA	286	155	157	300	350	288	322	204	342	319	214	204	133	165	226	239	183
4	341	347	"	240	NA	327	240	175	331	511	418	456	266	406	393	247	234	NA	NA	286	248	187
5	341	406	"	NA	399	396	275	NA	362	511	418	456	334	429	NA	285	234	"	"	286	296	222
6	348	406	"	"	413	401	317	"	362	555	446	486	349	441	"	NA	NA	"	"	NA	296	NA
7	452	468	"	"	413	420	328	"	362	555	446	486	368	441	"	"	"	"	"	"	296	"
8	NA	468	"	"	413	420	328	"	362	555	446	486	368	441	"	"	"	"	"	"	NA	"
9	"	487	"	"	413	420	328	"	362	555	446	486	368	NA	"	"	"	"	"	"	"	"
10 and up	"	487	"	"	413	420	328	"	362	555	446	486	368	"	"	"	"	"	"	"	"	"

[a] Areas are outlined in Fig. 1, Appendix A.7.

[b] 21 and 22 foot levels were found to have the same potential depth-damage relationships as the 23 foot flood in relevant areas.

2) 25 and 26 Foot Flood Levels at Mission:

Flood Depth Above Ground (ft.)	Unit $ Loss per Average Dwelling by Area													
	1	2	3	4		5	6	7	8	9	10A	10B	11&12	13
				25'	26'									
1	NA	211	168	93	102	336	185	127	NA	141	213	190	341	151
2	NA	255	311	228	237	405	269	178	183	237	394	336	341	196
3	NA	252	311	228	237	427	299	178	183	329	394	336	476	225
4	355	366	360	273	282	440	340	264	201	361	562	476	476	286
5	355	425	NA	273	282	440	408	299	255	401	562	476	507	353
6	361	425	"	NA	NA	440	412	322	318	401	588	498	507	890
7	465	490	"	"	"	440	432	334	336	401	588	498	507	980
8	465	490	"	"	"	440	432	334	357	401	588	498	507	980
9	499	507	"	"	"	440	432	334	NA	401	588	498	507	980
10 and up	499	507	"	"	"	440	432	334	"	401	588	498	507	980

continued on Page 70

2) 25 and 26 Foot Flood Levels at Mission (Cont'd)

Flood Depth Above Ground (ft.)	Unit $ Loss per Average Dwelling by Area													
	14	15	16	17	18A		18B		18C		19A		19B	
					25'	26'	25'	26'	25'	26'	25'	26'	25'	26'
1	194	226	NA	NA	NA	NA	NA	NA	124	150	164	197	167	196
2	285	335	NA	NA	NA	NA	NA	NA	300	326	192	222	172	205
3	355	335	226	217	231	NA	207	NA	300	326	335	366	278	311
4	419	409	258	217	NA	266	NA	267	358	385	345	379	281	315
5	442	409	296	246	"	NA	"	NA	358	385	394	427	317	351
6	454	421	296	246	"	"	"	"	358	405	394	427	317	351
7	454	421	309	293	"	"	"	"	NA	405	394	427	317	351
8	454	NA	NA	NA	"	"	"	"	"	NA	394	427	NA	NA
9	454	"	"	"	"	"	"	"	"	"	529	563	"	"
10 and up	454	"	"	"	"	"	"	"	"	"	NA	NA	"	"

E.6 Relationship between Depth of Flooding Above Ground Level and Unit Extra Costs of Food per Residence by Area.[a]

1) 23[b] Foot Flood Level at Mission

Flood Depth Above Ground (ft.)	Unit Extra Cost of Food per Residence by Area ($)																			
	1	2	3	4	5	6	7	8	9	10A& 10B	11& 12	13	14	15	16	17	18A	18B	18C	19A& 19B
1	60	58	53	26	62	62	46	40	40	35	64	49	59	63	52	52	NA	NA	13	15
2	94	79	100	85	102	103	72	67	88	62	110	71	101	97	96	57	NA	NA	57	21
3	94	99	100	85	116	110	72	67	107	62	110	77	115	97	96	64	25	73	57	35
4	113	107	115	104	142	130	115	75	122	103	152	95	137	119	110	64	NA	NA	71	37
5	113	127	NA	NA	147	145	123	NA	128	103	152	125	141	NA	126	85	"	"	71	42
6	116	127	"	"	151	147	134	"	128	113	161	128	144	"	NA	NA	"	"	NA	42
7	140	143	"	"	151	151	137	"	128	113	161	138	144	"	"	"	"	"	"	42
8	140	143	"	"	151	151	137	"	128	113	161	138	144	"	"	"	"	"	"	NA
9	147	147	"	"	151	151	137	"	128	113	161	138	144	"	"	"	"	"	"	"
10 and up	147	147	"	"	151	151	137	"	128	113	161	138	144	"	"	"	"	"	"	"

[a] Areas are outlined in Fig. 1, Appendix A.7

[b] 21 and 22 foot levels were found to have the same potential depth-damage relationships as the 23 foot flood in relevant areas.

2) 25 and 26 Foot Flood Levels at Mission:

Flood Depth Above Ground (ft.)	Unit Extra Cost of Food per Residence by Area ($)												
	1	2	3	4	5	6	7	8	9	10A& 10B	11& 12	13	14
1	64	64	57	40	NA	66	56	50	50	44	70	56	63
2	98	85	104	99	NA	107	82	77	98	70	116	78	105
3	98	105	104	99	120	114	82	77	117	70	116	85	119
4	117	113	115	118	146	134	125	86	133	112	159	102	141
5	117	133	NA	118	151	149	133	113	139	112	159	132	145
6	120	133	"	NA	155	151	145	126	139	122	168	136	148
7	144	149	"	"	155	155	147	134	139	122	168	145	148
8	144	149	"	"	155	155	147	139	139	122	168	145	148
9	151	153	"	"	155	155	147	NA	139	122	168	145	148
10 and up	151	153	"	"	155	155	147	"	139	122	168	145	148

Continued on Page 73

2) 25 and 26 Foot Flood Levels at Mission (Cont'd)

Flood Depth Above Ground (ft.)	Unit Extra Cost of Food per Residence by Area ($)													
	15	16	17	18A		18B		18C		19A		19B		
				25'	26'	25'	26'	25'	26'	25'	26'	25'	26'	
1	67	57	57	NA	NA	NA	NA	32	38	36	43	36	43	
2	111	101	62	NA	NA	NA	NA	76	82	42	49	42	49	
3	111	101	62	44	NA	92	NA	76	82	56	63	56	63	
4	123	115	69	NA	44	NA	118	90	96	58	65	58	65	
5	NA	131	69	"	NA	"	NA	90	96	63	70	63	70	
6	"	NA	NA	"	"	"	"	90	96	63	70	63	70	
7	"	"	"	"	"	"	"	NA	106	63	70	63	70	
8	"	"	"	"	"	"	"	"	NA	63	70	NA	NA	
9	"	"	"	"	"	"	"	"	"	84	91	"	"	
10 and up	"	"	"	"	"	"	"	"	"	NA	NA	"	"	

APPENDIX F

GROWTH IN THE DYKING DISTRICTS IN THE LOWER FRASER VALLEY

F.1 Rationale for Projected Population Growth Rates in Different Dyking Areas

Dyking Area	Reasons for Growth Trends and Projections
Richmond	Growing because of good access and proximity to Vancouver and availability of urban-zoned land. Projected growth rate is only 4% because it reflects recent trends. Also, Municipal Council is increasingly concerned about uncontrolled sprawl.
Delta	Growth between 1961 and 1971 was high due to improved access to Vancouver (the George Massey Tunnel (1959) and Highway 499 were built). Since land values did not immediately rise to reflect this improved access, a building boom resulted. Projected growth rate is lower than 1961-71 because land values have risen in response to increased demand; although urban-zoned areas in Ladner will be fully developed by 1981, North Tsawwassen will develop and counteract any tendency for the rate of increase to fall before 2000.
Queensborough	Growth projections were based on detailed development plans of New Westminster Municipality (about 300 acres will be high density residential). The first phase of development is expected to begin in 1976.
Port Coquitlam	Most land is zoned industrial; little is available for residential use. Therefore, the population decline experienced in 1961-1966 is expected to continue at a reduced rate.
South Westminster	There is no urban land available for expansion.
Maple Ridge	Most of the floodable area is zoned rural. Only a small part of Port Hammond and Maple Ridge is available for urban use.

Dyking Area	Reasons for Growth Trends and Projection
Pitt Polder and Pitt No. 2	Both are areas of large agricultural holdings. Pitt No. 2 is fully developed. Pitt Polder still has some virgin land and will therefore experience small population increase.
Albion	No urban land is available; land is zoned rural or industrial.
Silverdale	Population decline continues because of consolidation of small holdings.
Mission City	Zoned industrial: the historic decline in population will continue as industries expand.
Dewdney-Nicomen	Zoned rural.
Barnston Island	Zoned industrial but is presently rural; no immediate changes are anticipated.
West Langley	Zoned rural and industrial; no immediate changes in land use are anticipated.
Salmon River	Zoned rural.
Glen Valley	Zoned rural.
Matsqui	Zoned rural.
Sumas	Zoned rural.
Yarrow	Zoned urban and land is available; the historic rate should continue.
Harrison Hot Springs	Expansion of resort and recreation facilities will encourage moderate growth.

Dyking Area	Reasons for Growth Trends and Projection
Agassiz-Harrison Mills	Zoned rural, except for a small portion around Agassiz.
Chilliwack City	Little growth because of land scarcity within city limits.
Chilliwhack Township	Large tracts of land zoned urban (near Chilliwack City); historic rate of growth expected to continue.

Sources: Richmond Planning Department (1961); L.M.R.P.B. (1968)

F.2 Rationale for Projected Industrial Growth Rates in Different Dyking Areas

Dyking Area	Reasons for Growth Rates
Richmond	Has shown the highest growth rate over the past 10 year period and has large areas available for future development. Its close proximity to downtown Vancouver will encourage a high growth rate in the future.
Delta	Has the largest block of land available for industrial development of any area in the Lower Mainland. It is presently developing at a modest rate because of availability of land closer to Vancouver. As land closer to Vancouver becomes scarcer and transportation improves, growth in Delta is expected to rise.
Brunette Creek	There is only a small area available for industrial development which is expected to grow at the historic rate. Land will be fully developed by 1986.
Queensborough	Has good land, strategically located for industrial development which is expected to grow at the historic rate. Land will be fully utilized by 1993.
Port Coquitlam	Has a sizeable piece of land, fully serviced and ready for occupancy. Well developed transport facilities and good access to Vancouver will likely encourage moderate to high growth in this area over the next 30 years.
Burnaby (Big Bend)	Has a large area zoned for industrial use. It is favourably located for industrial development with respect to transportation systems and the population concentration.
South Westminster	Approximately 1600 acres of land are available for industrial expansion. Good transportation facilities, road, rail and water, and reasonable distance from major population centre is expected to encourage a moderate to high level of industrial development to the year 2000.

Dyking Area	Reasons for Growth Rates
Maple Ridge	About 600 acres are available for industrial use. The distance from Vancouver and availability of land closer to the central business district is expected to retard growth in this area.
Albion	Has a limited amount of land available for industrial use. Future development is expected to occur at the historical rate. Land will be fully developed by 1991.
Mission	Has a limited amount of land available for industrial use. Very little development is expected over next 30 years.
Harrison Hot Springs	No additional industrial development expected.
Chilliwack City	Limited amount of land is available for industrial expansion. A low rate of growth is expected.
Chilliwhack	A large area is zoned for industrial use but very little is used. Limited growth of local resource industries is anticipated.

F.3 Historical and Projected Industrial Development in the Lower Mainland: 1960 - 2000

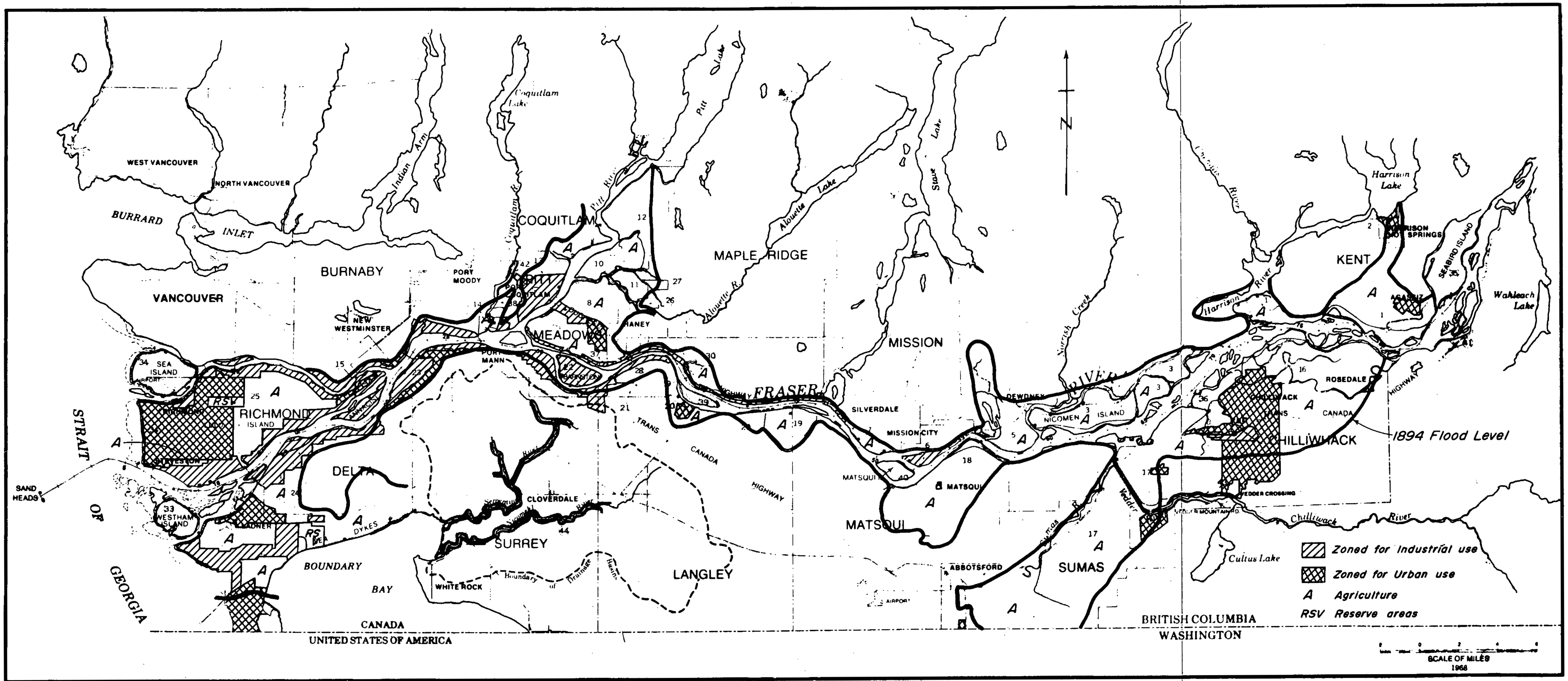
Area	Acres of Industrial Development								
	1960[a]	1966[a]	1971[a]	1976	1981	1986	1991	1996	2000
GREATER VANCOUVER									
Floodplain	1,063	1,400	1,821	2,230	2,870	3,635	4,465	5,435	6,195
Non-Floodplain:									
Vancouver	1,661	1,791	1,890	1,990	2,090	2,140	2,190	2,240	2,280
Burnaby	1,275	1,519	1,720	1,920	2,120	2,370	2,620	2,920	3,160
Coquitlam	505	530	555	605	680	780	905	1,055	1,175
Port Moody	640	647	670	695	720	770	870	970	1,070
North Van.	374	489	565	640	715	790	865	940	1,000
Annacis Is.	20	80	155	255	380	530	680	880	1,040
Surrey	196	282	360	460	560	685	835	985	1,125
New West.	124	162	170	180	190	200	210	220	230
Mitch.-Twigg Is.	60	90	110	160	210	260	310	310	310
Buntzen	321	321	321	345	370	420	470	570	650
SUBTOTAL	6,239	7,310	8,336	9,480	10,905	12,580	14,420	16,525	18,235
EAST FRASER VALLEY									
Floodplain	61	87	121	150	193	242	314	382	440
Non-Floodplain:									
Maple Ridge	47[b]	57	67	77	87	107	127	152	172
Langley	30[b]	40	50	70	90	120	150	200	240
Matsqui	45[b]	55	65	75	85	105	125	155	180
Sumas	100[b]	109	120	130	140	150	170	190	206
SUBTOTAL	283	348	423	502	595	724	886	1,079	1,238
TOTAL	6,522	7,658	8,759	9,982	11,500	13,304	15,306	17,604	19,473

Source: [a] Municipal records, maps; [b] Estimate based on air photographs.

F.4 Historical and Projected Rates of Industrial Development in the Lower Mainland: 1960 - 2000

Area	Average Number of Acres Developed per Year							
	1960-66	1966-71	1971-76	1976-81	1981-86	1986-91	1991-96	1996-2000
GREATER VANCOUVER								
Floodplain	56	84	83	128	153	166	194	190
Non-Floodplain:								
Vancouver	22	20	20	20	10	10	10	10
Burnaby	41	40	40	40	50	50	60	60
Coquitlam	4	5	10	15	20	25	30	30
Port Moody	1	5	5	5	10	20	20	25
North Van.	19	15	15	15	15	15	15	15
Annacis Is.	10	15	20	25	30	30	40	40
Surrey	14	15	20	20	25	30	30	35
New West.	6	2	2	2	2	2	2	2
Mitch.-Twigg Is.	5	4	10	10	10	10	-	-
Buntzen	-	-	5	5	10	10	20	20
SUBTOTAL[a]	179	205	229	285	335	368	421	427
EAST FRASER VALLEY								
Floodplain	5	7	6	9	10	14	14	15
Non-Floodplain:								
Maple Ridge	2	2	2	2	4	4	5	5
Langley	2	2	4	4	6	6	10	10
Matsqui	2	2	2	2	4	4	6	6
Sumas	2	2	2	2	2	4	4	4
SUBTOTAL[a]	11	15	16	19	26	32	39	40
TOTAL[a]	189	220	245	304	361	400	460	467

[a] Totals may not add due to rounding.



MAP OF LOWER FRASER VALLEY SHOWING ZONING PLANS FOR FLOOD PLAIN AREAS

Figure No. 5

APPENDIX G

FUTURE DAMAGES

G.1 1965 Agricultural Production and Projected Production: Fraser Valley Area

Commodity	1965 Value ($'000)	Estimated Physical Incr. % Over 1965 1975	1985	Total Future Value Assuming No Price Changes ($'000) 1975	1985
Dairying (Milk)	23,500	30	65	30,550	38,775
Beef	4,000	10	40	4,400	5,600
Swine	850	10	20	935	1,020
Vegetables - Total	6,570	27[a]	46[a]	8,333	9,608
Potatoes	2,000	0	0	2,000	2,000
Mushrooms	1,190	60	80	1,904	2,142
Peas	970	30	50	1,261	1,455
Beans	450	35	35	608	608
Corn	525	45	65	761	866
Carrots	340	30	50	442	510
Cauliflower	310	10	50	341	465
Lettuce	340	10	40	374	476
Tomatoes (greenhouse)	260	40	140	364	624
Cucumbers (greenhouse)	185	50	150	278	462
Small Fruits - Total	6,000	96[a]	171[a]	11,792	16,247
Raspberries	2,850	50	100	4,275	5,700
Strawberries	1,380	95	170	2,691	3,726
Hops	860	90	180	1,634	2,408
Blueberries	610	165	230	1,617	2,013
Cranberries	300	425	700	1,575	2,400

[a] These percentage figures have been rounded off.

Source: Carne, I.C. et al. Second Approximation Report, Agriculture in the Fraser Valley, 1964 - 1965 - 1974 - 1989. Victoria, B.C.: Department of Agriculture, 1966.

G.2 Average Unit Stage-Damage Relationship Per Acre of Future Industrial Land

Area	Direct ($) Damage Per Foot of Flooding Above Floor Level Per Acre						
	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.
Lulu Island, Delta and Big Bend	5,000	10,000	16,000	21,000	26,000	31,000	36,000
Upstream from Queensborough	1,000	1,000	2,000	2,000	3,000	4,000	5,000

[a] Rounded to the nearest thousand.

Source: Synthesis of 1971 Field Data.

G.3 Flood Depths of Future Industries

G.3.1 Probable Average Depths of Flooding of Future Industries

1. Existing Average Flood Depths: Lulu Island (26 Foot Flood at Mission)

   a) $\frac{\text{Flood Depth above Floor Level East of Freeway}}{\text{Flood Depth above Ground Level East of Freeway}} = \frac{1.6 \text{ feet}}{3.5 \text{ feet}} = .46$

   b) $\frac{\text{Flood Depth above Floor Level West of Freeway}}{\text{Flood Depth above Ground Level West of Freeway}} = \frac{1.2 \text{ feet}}{3.2 \text{ feet}} = .38$

2. Average Flood Depths of Future Industrial Areas on Lulu Island:
   (26 Foot Flood at Mission)

   a) Average Flood Depth above Ground East of Freeway = 4 feet;
   Range = 0 to 7 feet
   Estimated Average Depth above Floors = 4 x .46 = 1.8 feet

   b) Average Flood Depth above Ground West of Freeway = 3.6 feet;
   Range = 3 to 3.6 feet
   Estimated Average Depth above Floors = 3.6 x .38 = 1.4 feet

3. Average Flood Depths of Future Industrial Areas in Delta:
   (26 Foot Flood at Mission)

   a) Average Flood Depth above Ground East of Freeway = 5.2 feet;
   Range = 1 to 6 feet
   Estimated Average Depth of Flood above Floors = 5.2 x .46 = 2.4 feet

   b) Average Flood Depth above Ground West of Freeway = 2 feet;
   Range = 0 to 3 feet
   Estimated Average Depth of Flood above Floors = .8 feet

4. Average Flood Depths of Future Industrial Areas in Big Bend:
   (26 Foot Flood Mission)

   a) Average Flood Depth above Ground = 2 feet;
   Range = 0 to 3 feet
   Estimated Average Depth of Flood above Floors = .8 feet.

G.3.2 Flood Depths Above Floors of Future Industries

1) 26 Foot Flood at Mission

Flood Depth Above Floors (Ft.)	Percentage of Industries with Given Floor Depth by Industrial Area											
	Lulu Is.		Delta									
	East[a]	West[a]	SW[a]	NE[a]	Big Bend[a]	South Westminster[b]	Brunette Creek[b]	Port Coquitlam[b]	Pitt Meadows[b]	Albion[b]	Mission[b]	Chilliwack[b]
0	24	26	48	13	60	0	0	0	0	0	0	0
1	24	26	26	18	32	10	10	0	0	10	0	0
2	24	26	26	19	7	10	80	0	0	10	15	0
3	15	22	0	30	1	10	10	0	0	10	40	0
4	7	0	0	11	0	10	0	0	0	35	15	25
5	4	0	0	6	0	40	0	0	0	35	15	25
6	2	0	0	3	0	10	0	100	100	0	15	25
7	0	0	0	0	0	10	0	0	0	0	0	25

[a] Based on data on distribution of elevations of existing industries on Lulu Island, and differences in extent of areas subject to various depths of flooding above ground.

[b] Based on observed flood depths in each area.

2) 25 Foot Flood at Mission

Flood Depth Above Floors (Ft.)	Percentage of Industries with Given Flood Depth by Industrial Area												
	Lulu Is.		Delta		Big Bend	South Westminster	Brunette Creek	Port Coquitlam	Pitt Meadows	Albion	Mission	Chilliwack
	East	West	SW	NE								
0	36	26	48	31	76	10	10	0	0	10	0	0
1	24	26	26	19	20	10	80	0	0	10	15	0
2	20	26	26	30	4	10	10	0	0	10	40	0
3	11	22	0	11	0	10	0	0	0	35	15	25
4	5	0	0	6	0	40	0	0	0	35	15	25
5	3	0	0	3	0	10	0	100	100	0	15	25
6	1	0	0	0	0	10	0	0	0	0	0	25
7	0	0	0	0	0	0	0	0	0	0	0	0

3) 24 Foot Flood at Mission

Flood Depth Above Floors (Ft.)	Percentage of Industries with Given Flood Depth by Industrial Area											
	Lulu Is.		Delta		Big Bend	South Westminster	Brunette Creek	Port Coquitlam	Pitt Meadows	Albion	Mission	Chilliwack
	East	West	SW	NE								
0	48	26	48	50	96	20	90	0	0	20	15	0
1	22	26	26	30	4	10	10	0	0	10	40	0
2	16	26	26	11	0	10	0	0	0	35	15	25
3	8	22	0	6	0	40	0	0	0	35	15	25
4	4	0	0	3	0	10	0	0	0	0	15	25
5	2	0	0	0	0	10	0	100	100	0	15	25
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0

4) 23 Foot Flood at Mission

Flood Depth Above Floors (Ft.)	Percentages of Industries with Given Flood Depths by Area[a]				
	Big Bend	Brun-ette Creek	Port Coqui-tlam	Pitt Meadows	Albion
0	100	100	0	0	30
1	0	0	0	0	35
2	0	0	0	0	35
3	0	0	100	100	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
7	0	0	0	0	0

[a] Areas excluded from this table do not apply to floods of less than 24 feet.

5) 22 Foot Flood at Mission

Flood Depth Above Floors (Ft.)	Percentage of Industries with Given Flood Depth by Area				
	Big Bend	Brun-ette Creek	Port Coqui-tlam	Pitt Meadows	Albion
0	100	100	0	0	65
1	0	0	0	0	35
2	0	0	100	100	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
7	0	0	0	0	0

G.4 Average Direct Damage Per Acre of Future Industrial Land for Different Flood Levels

Area	Average ($) Damage Per Acre					
	Flood Level at Mission (Ft.)					
	21	22	23	24	25	26
Lulu - East	-	-	NA	5,000	7,000	9,000
- West	-	-	NA	7,000	7,000	7,000
Delta - N.E.	-	-	NA	4,000	8,000	12,000
S.W.	-	-	NA	4,000	4,000	4,000
Big Bend	0	0	0	0	1,000	2,000
South Westminster	0	0	NA	2,000	2,000	3,000
Brunette Creek	0	0	0	0	1,000	1,000
Port Coquitlam	1,000	1,000	2,000	2,000	3,000	4,000
Pitt Meadows	1,000	1,000	2,000	2,000	3,000	4,000
Albion	0	0	1,000	1,000	2,000	2,000
Mission	-	-	NA	1,000	2,000	2,000
Chilliwack	-	-	NA	2,000	3,000	4,000

G.5 Average Indirect Primary and Secondary Damages Per Acre of Future Industrial Land for Different Flood Levels

Area	Average ($) Damage per Acre					
	Flood Level at Mission (Ft.)					
	21	22	23	24	25	26
Lulu - East[a]	-	-	NA	2,500	3,500	4,500
- West[a]	-	-	NA	3,500	3,500	3,500
Delta - N.E.[a]	-	-	NA	2,000	4,000	6,000
S.W.[a]	-	-	NA	2,000	2,000	2,000
Big Bend[a]	0	0	0	0	500	1,000
South Westminster[b]	0	0	NA	1,400	1,400	2,100
Brunette Creek[b]	0	0	0	0	700	700
Port Coquitlam[b]	700	700	1,400	1,400	2,100	2,800
Pitt Meadows[b]	700	700	1,400	1,400	2,100	2,800
Albion[b]	0	0	700	700	1,400	1,400
Mission[b]	-	-	NA	700	1,400	1,400
Chilliwack[b]	-	-	NA	1,400	2,100	2,800

[a] 1971 - Field studies of Lulu Island industries indicated that the indirect damages were 50% of the direct and this proportion has been adopted to represent total losses to future industries.

[b] Indirect losses of industries in the rest of the valley proved to be 70% of the direct damages and this has been applied to projected industrial growth in these areas.

G.6 Average Annual Compounded Percentage Increase in Prices of Selected Goods 1955 to 1971

Items for Which Price Changes are Given	Average Annual Percentage Increase of Prices per Period				
	1955 -'71	1961 -'71	1955 -'61	1961 -'66	1966 -'71
1. Consumer Prices					
Cdn. Consumer Price Index	2.5	2.9	1.8	2.2	3.6
Cdn. Food Prices	2.4	2.8	1.7	3.1	2.4
Cdn. Housing Costs	2.5	3.1	1.4	2.1	3.9
Cdn. Dairy Prices	2.9	3.5	1.8	2.7	4.3
Cdn. Beef Prices	3.6	3.8	3.6	3.4	4.1
Cdn. Poultry Prices[a]	-1.0	0.9	-4.1	2.2	-0.4
Cdn. Egg Prices[a]	-0.9	-0.7	-1.3	3.3	-4.7
Van. Consumer Price Index	2.1	2.4	1.6	1.4	3.5
Van. Consumer Food Prices	2.4	2.9	1.7	2.6	3.3
2. Wholesale Prices					
Cdn. General Wholesale Index	1.8	2.2	1.1	2.1	2.3
Cdn. Vegetable Products Prices	1.3	1.6	0.8	2.1	1.0
Cdn. Animal Products Prices	2.3	2.5	2.0	2.6	2.3
Cdn. General Wholesale less Animal & Vegetable Products	1.8	2.3	1.0	1.9	2.8
3. Other Prices					
Cdn. Feed Prices	0.8	1.1	0.4	2.2	0.1
Cdn. Farm Animal Prices	2.3	2.7	1.6	3.5	1.8
B.C. Farm Products Prices	1.9	2.1	1.5	2.9	1.4
Cdn. Ind. Composite-Weekly Earnings	5.3	5.9	4.1	4.3	7.5
B.C. Ind. Composite - Weekly Earnings	5.4	6.0	4.5	4.8	7.3
Canadian Residential Constr. Prices (including Labour)	4.6	5.9	2.7	4.5	7.5
B.C. Residential Constr. Prices (including Labour)	3.9	4.9	2.4	3.9	6.0
B.C. Industrial & Commercial Concrete & Steel Constr. (including Labour)	4.6	5.1	3.8	4.4	6.0
B.C. Machinery & Equip. Prices	2.5	2.4	2.6	1.1	3.8

[a] These represent averages of the percentage increases calculated for each year within the given periods; this measure was used because large price swings made the standard compounding technique very unstable.

Sources: Prices and Price Indexes, Cat. No. 62-002, Monthly, Statistics Canada. Monthly Bulletin of Index Numbers of Farm Prices of Agricultural Products, Cat. No. 62-003, Statistics Canada. Annual Reports, B.C. Department of Labour. Structural, Machinery & Equipment Conversion Multipliers, Office of Assessment Commission, Victoria, B.C.

G.7 Total Present Worth[a] (1971) of Damages Under Five Different Assumptions of Future Development, Lower Fraser Valley 1971-2031[b]

1. Upgraded Dykes

Projection	Damage Per Flood Level					
	24 ft.		25 ft.		26 ft.	
	$'000	As % of Most Likely	$'000	As % of Most Likely	$'000	As % of Most Likely
1) Most Likely Growth and Price Change	4,478,889	100	6,969,104	100	7,634,401	100
2) Zero Growth and Zero Price Change	2,581,399	58	3,806,295	55	4,176,691	55
3) Changes 1% Higher Than Most Likely	5,214,117	116	8,145,463	117	8,924,421	117
4) Most Likely Growth and Zero Price Change	3,592,050	80	5,516,462	79	6,026,827	79
5) Most Likely Growth With Real Agricultural Price Changes of 3%	4,722,021	105	7,232,585	104	7,904,523	104

[a] Present worth value includes 61 years of damages: from year zero (1971) to year 60 (2031). The present worths are calculated under the assumption that each flood stage occurs every year; they become meaningful only when they are integrated under a "total present worth of damage" frequency curve.

[b] Annual damages were assumed to be constant after the year 2000. Estimates are based on damages by area listed in Appendix H. Discount rate used is 7%.

2. Non-Upgraded Dykes

Projections	Damage Per Flood Level											
	21 ft.		22 ft.		23 ft.		24 ft.		25 ft.		26 ft.	
	$'000	As % of Most Likely	$'000	As % of Most Likely	$'000	As % of Most Likely	$'000	As % of Most Likely	$'000	As % of Most Likely	$'000	As % of Most Likely
1) Most Likely Growth and Price Change	55,757	100	70,456	100	84,888	100	95,283	100	104,300	100	111,675	100
2) Zero Growth and Zero Price Change	51,750	93	65,135	92	76,534	90	84,731	89	91,047	87	96,521	86
3) Changes 1% Higher Than Most Likely	63,405	114	80,156	114	96,776	114	108,653	114	119,080	114	127,596	114
4) Most Likely Growth and Zero Price Change	56,759	102	70,892	101	84,154	99	92,751	97	99,673	96	105,455	94
5) Most Likely Growth with Real Agricultural Price Changes of 3%	82,720	148	102,410	145	118,487	140	129,548	136	139,112	133	146,986	132

3. Undyked Areas

Projection	22 ft.		23 ft.		24 ft.		25 ft.		26 ft.	
	$'000	As % of Most Likely	$'000	As % of Most Likely	$'000	As % of Most Likely	$'000	As % of Most Likely	$'000	As % of Most Likely
1) Most Likely Growth and Price Change	110	100	3,994	100	14,841	100	48,788	100	62,572	100
2) Zero Growth and Zero Price Change	105	95	3,439	86	11,911	80	35,974	74	45,854	73
3) Changes 1% Higher Than Most Likely	124	113	4,529	113	16,277	110	52,871	108	67,629	108
4) Most Likely Growth and Zero Price Change	105	95	3,588	90	12,390	83	37,430	77	48,192	77
5) Most Likely Growth With Real Agricultural Price Changes of 3%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

APPENDIX H

POTENTIAL FLOOD DAMAGES FOR MAJOR CATEGORIES

LOWER FRASER VALLEY - 1971

H.1 Potential Residential Flood Damage: Lower Fraser Valley - 1971

Area	$'000 Damage					
	Flood Elevation - Feet at Mission					
	21	22	23	24	25	26
Dyked Areas						
(a) Upgraded Dykes						
Richmond & Queensborough	-	-	-	32,647	61,831	61,831
Delta	-	-	-	4,661	9,080	10,650
South Westminster	-	-	-	2,572	2,801	3,098
West Langley	-	-	-	6	7	7
Ft. Langley (Salmon River)	-	-	-	19	27	31
Matsqui	-	-	-	2,732	2,967	3,248
Sumas (Including Yarrow)	-	-	-	6,744	7,110	7,406
Chilliwack	-	-	-	24,756	33,623	43,938
Aggassiz (Incl.H.H.Springs)	-	-	-	2,259	2,668	3,529
Harrison Mills	-	-	-	67	94	106
South Dewdney	-	-	-	1,838	2,057	2,215
Mission	-	-	-	90	120	179
Maple Ridge & Pitt No. 2	-	-	-	2,173	2,529	3,379
Port Coquitlam	-	-	-	1,800	2,001	2,488
Trapp Road	-	-	-	35	80	119
Sub Total	-	-	-	82,399	127,005	142,224
(b) Non Upgraded Dykes						
Barnston Island	-	24	32	52	70	86
Glen Valley	69	124	178	200	226	243
North Nicomen	6	12	17	29	41	48
East Nicomen	16	25	30	50	70	82
West Nicomen	139	202	265	367	468	509
Silverdale	-	4	5	10	16	30
Albion (Incl. Road 13)	-	-	50	114	176	208
Pitt Polder	72	82	92	98	103	163
Tretheway	-	-	-	-	9	19
Pitt Meadows	7	8	8	14	19	36
Sub Total	309	481	677	934	1,198	1,424
Total Dyked Areas	309	481	677	83,333	128,203	143,643
Total Undyked Areas	-	1	60	144	212	236

H.2 Potential Flood Damage to Commercial Establishments: Lower Fraser Valley - 1971

Area	$'000 Damage					
	Flood Elevation - Feet at Mission					
	21	22	23	24	25	26
Dyked Areas						
(a) Upgraded Dykes						
Richmond & Queensborough	-	-	-	8,814	17,905	17,905
Delta	-	-	-	671	1,472	1,497
South Westminster	-	-	-	308	355	462
Matsqui	-	-	-	143	143	143
Sumas (Incl. Yarrow)	-	-	-	567	621	646
Chilliwack	-	-	-	6,736	10,479	12,206
Agassiz	-	-	-	359	383	416
South Dewdney	-	-	-	8	9	9
Mission	-	-	-	185	248	311
Maple Ridge - Pitt No. 2	-	-	-	25	25	25
Port Coquitlam	-	-	-	54	56	56
Sub Total	-	-	-	17,870	31,696	33,676
(b) Non Upgraded Dykes						
Glen Valley	4	7	10	10	10	10
West Nicomen	3	6	8	8	8	8
Albion (Incl. Road 13)	-	-	20	32	44	56
Sub Total	7	13	38	50	62	74
Total Dyked Areas	7	13	38	17,920	31,758	33,750

H.3 Potential Flood Damage to Industrial Establishments: Lower Fraser Valley - 1971

Area	$'000 Damage					
	Flood Elevation - Feet at Mission					
	21	22	23	24	25	26
Dyked Areas						
(a) Upgraded Dykes						
Richmond & Queensborough	-	-	-	5,109	6,946	8,888
Delta	-	-	-	13	13	21
South Westminster	-	-	-	236	237	623
Chilliwack	-	-	-	173	2,209	2,260
Mission	-	-	-	114	136	158
Maple Ridge and Pitt No.2	-	-	-	5	7	7
Port Coquitlam	-	-	-	400	530	671
Trapp Road	-	-	-	-	8	92
Sub-Total	-	-	-	6,050	10,086	12,720
(b) Non Upgraded Dykes						
Albion (Incl. Road 13)	-	6	39	42	45	63
Total Dyked Areas	-	6	39	6,092	10,131	12,783
Total Undyked Areas	0	1	21	157	330	662

H.4 Potential Agricultural Crop Damage: Lower Fraser Valley - 1971

Area	$'000 Damage					
	Flood Elevation - Feet at Mission					
	21	22	23	24	25	26
Dyked Areas						
(a) Upgraded Dykes						
Richmond & Queensborough	-	-	-	4,228	5,603	5,661
Delta	-	-	-	2,549	4,505	4,505
South Westminster	-	-	-	7	8	9
West Langley	-	-	-	64	66	67
Ft. Langley (Salmon River)	-	-	-	200	203	205
Matsqui	-	-	-	2,024	2,035	2,049
Sumas (Incl. Yarrow)	-	-	-	5,236	5,374	5,454
Chilliwack	-	-	-	6,890	7,239	7,681
Agassiz (Incl. H.H.Springs)	-	-	-	879	990	1,008
Harrison Mills	-	-	-	120	126	127
South Dewdney	-	-	-	749	767	773
Maple Ridge & Pitt No.2	-	-	-	1,382	1,390	1,396
Port Coquitlam	-	-	-	167	168	168
Colony Farm	-	-	-	132	132	132
Trapp Road	-	-	-	11	15	18
Sub-Total	-	-	-	24,638	28,621	29,253
(b) Non Upgraded Dykes						
Barnston Island	-	184	193	200	205	207
Glen Valley	293	307	322	335	343	359
North Nicomen	66	69	72	72	72	72
East Nicomen	168	176	184	184	184	184
West Nicomen	649	692	735	741	746	750
Silverdale	-	44	52	52	53	54
Albion (Incl. Road 13)	-	42	44	45	46	47
Pitt Polder	290	291	292	292	292	292
Tretheway	48	50	53	53	53	53
Allouette	23	31	40	40	40	40
Pitt Meadows No. 1	243	243	243	243	243	243
Addington Point	72	74	76	77	78	78
Sub-Total	1,852	2,203	2,306	2,334	2,355	2,379
Total Dyked Areas	1,852	2,203	2,306	26,972	30,976	31,632

Note: Undyked areas are included in a report by Preston (1973).

H.5 Potential Other Agricultural Damage: Lower Fraser Valley - 1971

Area	$'000 Damage					
	Flood Elevation - Feet at Mission					
	21	22	23	24	25	26
Dyked Areas						
(a) Upgraded Dykes						
Richmond & Queensborough	-	-	-	404	548	561
Delta	-	-	-	601	1,052	1,074
West Langley	-	-	-	35	38	38
Ft. Langley (Salmon River)	-	-	-	69	70	71
Matsqui	-	-	-	1,264	1,285	1,289
Sumas (Including Yarrow)	-	-	-	2,377	2,469	2,493
Chilliwack	-	-	-	2,974	3,135	3,302
Agassiz (Incl.H.H.Springs)	-	-	-	820	860	867
Harrison Mills	-	-	-	81	84	84
South Dewdney	-	-	-	456	479	481
Maple Ridge & Pitt No.2	-	-	-	613	623	624
Port Coquitlam	-	-	-	24	24	24
Colony Farm	-	-	-	79	80	80
Sub Total	-	-	-	9,797	10,747	10,988
(b) Non Upgraded Dykes						
Barnston Island	-	125	134	138	141	141
Glen Valley	178	194	209	225	236	263
North Nicomen	31	33	37	37	37	37
East Nicomen	95	106	118	120	123	123
West Nicomen	379	432	485	498	511	513
Silverdale	-	26	41	44	45	45
Albion (Incl. Road 13)	-	12	13	14	14	14
Pitt Polder	139	144	150	153	155	155
Tretheway	22	23	25	25	25	25
Alouette	8	10	13	13	13	13
Pitt Meadows No. 1	77	78	79	79	79	79
Addington Point	22	22	23	24	24	24
Sub Total	951	1,205	1,327	1,370	1,403	1,432
Total Dyked Areas	951	1,205	1,327	11,167	12,150	12,420

Note: Undyked Areas are included in a report by Preston (1973)

H.6 Potential Primary Industrial Income Losses: Lower Fraser Valley - 1971

Area	$'000 Losses Flood Elevation - Feet at Mission 21	22	23	24	25	26
Dyked Areas						
(a) Upgraded Dykes						
Richmond & Queensborough	-	-	-	1,401	2,144	2,378
Delta	-	-	-	57	70	78
South Westminster	-	-	-	192	198	221
Chilliwack	-	-	-	9	9	10
Mission	-	-	-	42	64	72
Maple Ridge & Pitt No. 2	-	-	-	2	5	5
Coquitlam	-	-	-	607	643	643
Sub Total	-	-	-	2,310	3,133	3,407
(b) Non Upgraded Dykes						
Albion (Incl. Road 13)	-	-	6	12	37	50
Sub Total	-	-	6	12	37	50
Total Dyked Areas	-	-	6	2,322	3,170	3,457
Total Undyked Areas	-	-	-	73	468	623

H.7 Potential Transfer Costs and Secondary Income Losses: Lower Fraser Valley - 1971

Area	$'000 Losses					
	Flood Elevation - Feet at Mission					
	21	22	23	24	25	26
Dyked Areas						
(a) Upgraded Dykes						
Richmond & Queensborough	-	-	-	1,486	2,207	2,408
Delta	-	-	-	1,261	1,781	1,795
South Westminster	-	-	-	171	177	229
West Langley	-	-	-	3	3	3
Ft. Langley (Salmon River)	-	-	-	1	1	1
Matsqui	-	-	-	408	414	415
Sumas (Incl. Yarrow)	-	-	-	2,737	2,821	2,859
Chilliwack	-	-	-	1,615	1,692	1,778
Agassiz (Incl. H.H.Springs)	-	-	-	233	239	239
Harrison Mills	-	-	-	70	70	70
South Dewdney	-	-	-	179	185	185
Mission	-	-	-	48	74	83
Maple Ridge & Pitt No.2	-	-	-	132	136	137
Port Coquitlam	-	-	-	376	387	387
Colony Farm	-	-	-	11	12	12
Trapp Road	-	-	-	1	11	14
Sub Total	-	-	-	8,732	10,210	10,615
(b) Non Upgraded Dykes						
Barnston Island	-	1	18	18	19	19
Glen Valley	2	2	46	52	55	64
North Nicomen	-	-	2	2	2	2
East Nicomen	8	8	28	39	40	40
West Nicomen	3	3	88	115	120	120
Silverdale	-	-	6	7	7	7
Albion (Incl. Road 13)	-	1	2	11	29	43
Pitt Polder	-	-	21	22	22	22
Tretheway	-	-	2	2	2	2
Pitt Meadows No. 1	-	-	5	5	5	5
Sub Total	13	15	218	273	301	324
Total Dyked Areas	13	15	218	9,005	10,511	10,939
Total Undyked Areas	-	-	26	137	656	794

H.8 Potential Miscellaneous Damages: Lower Fraser Valley - 1971

Area	$'000 Damage					
	Flood Elevation - Feet at Mission					
	21	22	23	24	25	26
Dyked Areas						
(a) Upgraded Dykes						
Richmond & Queensborough	-	-	-	7,365	14,465	15,034
Delta	-	-	-	1,697	3,580	4,262
South Westminster	-	-	-	593	659	708
West Langley	-	-	-	11	11	11
Ft. Langley (Salmon River)	-	-	-	20	22	22
Matsqui	-	-	-	1,197	1,336	1,366
Sumas (Incl. Yarrow)	-	-	-	1,959	2,085	2,196
Chilliwack	-	-	-	5,110	7,185	8,822
Agassiz (Inc. H.H.Springs)	-	-	-	479	670	715
Harrison Mills	-	-	-	75	109	114
South Dewdney	-	-	-	421	480	511
Mission	-	-	-	44	49	59
Maple Ridge & Pitt No. 2	-	-	-	603	617	667
Port Coquitlam	-	-	-	264	298	309
Colony Farm	-	-	-	4	5	5
Trapp Road	-	-	-	9	26	40
Sub Total	-	-	-	19,851	31,597	34,841
(b) Non Upgraded Dykes						
Barnston Island	-	53	72	74	76	77
Glen Valley	83	100	102	104	105	106
North Nicomen	8	9	10	11	12	12
East Nicomen	14	15	17	18	19	20
West Nicomen	165	186	204	211	217	218
Silverdale	-	3	18	20	27	34
Albion (Incl. Road 13)	30	33	45	49	58	65
Pitt Polder	8	8	8	87	88	88
Tretheway	-	-	-	29	33	33
Pitt Meadows No. 1	1	1	2	16	18	19
Sub Total	309	408	478	619	653	672
Total Dyked Areas	309	408	478	20,470	32,250	35,513
Total Undyked Areas	-	5	121	281	726	734

H.9 Total Potential Damages in Various Floods in Dyked Areas of the Lower Fraser Valley - 1971

Damage Category	Damage per Flood Depth ($'000)		
	24 feet	25 feet	26 feet
Residential	83,333	128,203	143,648
Commercial	17,920	31,758	33,750
Industrial	6,092	10,131	12,783
Agricultural Crop	26,972	30,976	31,632
Other Agricultural	11,167	12,150	12,420
Primary Income	2,322	3,170	3,457
Transfer Costs and Secondary Income Losses	9,005	10,511	10,939
Miscellaneous	20,470	32,250	35,513
Total	177,281	259,149	284,142

APPENDIX I

SECONDARY FLOOD LOSSES DUE TO BREAKS IN MAJOR TRANSPORTATION ARTERIES

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November 17, 1972

I.1 Introduction

The purpose of this study is to estimate the magnitude of the potential secondary flood losses which would result from a disruption of road, rail and pipeline facilities which lie within the floodplain of the Fraser River, and to project these losses to the year 2000, taking into account foreseeable changes in the transportation network. Secondary flood losses can be defined as permanent income losses to firms and individuals located off the floodplain, but which incur production or sales losses due to floods which disrupt transportation links with suppliers and/or consumers. Typically, losses can occur as a result of interruptions in the interindustrial flow of intermediate goods which cause production delays, or as a result of interruptions in final sales of goods to consumers.

In order for such losses to be countable, they must be permanent in that sales and production can neither be delayed nor transferred to other producers within the referent area, which is in this case to be the province of British Columbia.

It is considered that industries most vulnerable to secondary flood losses are those which export bulk commodities, such as grain, coal, sulphur, etc., to competitive world markets. All of these industries are heavily dependent on rail transportation, and for some, serious delays in shipping might result in lost sales.

No significant secondary losses are likely to occur as a result of the short term disruption of interindustrial input flows. Attention during this study has therefore been focused on the shipment of bulk commodities to Vancouver area ports, in order to determine the effect road or rail disruptions of specified lengths would have on sales. The effect of flooding on tourism has also been investigated.

Because of the short term, forced nature of production losses due to flooding, it is appropriate to calculate as the loss, the sales value of the product, minus any returns to labor or capital accruing to out-of-province sources.

Some of the basic assumptions used in this study are as follows:

- No federal aid in the form of flood relief payments has been assumed. While substantial federal aid is generally provided to firms and individuals located within flooded areas, secondary losses are of a much more tenuous nature than property damage, and federal aid to offset secondary losses is therefore considered unlikely.

- Shipments transferred to other B.C. carriers are considered to represent transfer payments, thus involving no net loss to B.C.

- Estimates of frictional costs have been confined to the transportation industry. It is assumed that producers would continue production and build up inventories of finished products, and that extra storage costs would be minor.

- British Columbia Railway is assumed to be open under all flood conditions. In addition, it is assumed that road access between the Lower Mainland and the interior would be possible by rerouting traffic through the U.S. at Huntingdon.

The analysis of secondary losses has been made for the following cases:

Railways:

During flood conditions in the Fraser and Thompson Valleys:

1. (a) The B.C. Railway line between Prince George and Vancouver is never severed.

   (b) The CNR track between Prince George and Jasper is never severed for a significant length of time.

2. (a) The CNR and the CPR simultaneously lose their lines for one week in June on the Thompson River System as far downstream as Basque (10 miles S.W. of Ashcroft); the bridge linking the two lines on the South Thompson is destroyed.

   (b) The CNR and the CPR lose their tracks for one week between Basque and the Chilliwack and Agassiz Dyking Areas.

3. (a) The CN, CP and B.C. Hydro Railways lose their lines for the entire month of June due to the flooding of the following dyking Districts: Matsqui, Sumas, Chilliwack, Mission, Dewdney-Hatzic, Harrison Mills and Agassiz.

   (b) The B.C. Hydro Railway is flooded periodically during the entire month of June, i.e. during high tides in Delta.

   (c) The CNR yards in Port Mann are forced to moderate their activities due to minor tidal flooding but are not forced to close; access over the Fraser at Port Mann remains open to all railway companies during the flood period.

During flood conditions in the Fraser and Thompson Valleys:

1. (a) and (b) - same as 1.(a) and (b) above.

2. (a) Either the CNR or the CPR loses its track for one week within the following track subdivisions: (i) Upstream of Basque as far as Blackpoool (CN) or Kamloops (CP) (also the bridge over the South Thompson at Kamloops is lost); (ii) Between Basque and the Agassiz and Chilliwack dyking areas.

(b) Either the CNR or the CPR loses its track for one month between Mission Bridge and the upstream ends of the Chilliwack and Agassiz dyking areas.

(c) Delta is flooded and the B.C. Hydro Railway is affected as in 3.(b) above.

Roads:

The Trans Canada Highway is lost for one week near Spences Bridge.

The roads in the dyking areas in the Lower Mainland are flooded for one month, thereby making access into the interior via Chilliwack and Kent Municipalities impossible.

Interviews were held with officials of the CN, CP, BCR and B.C. Hydro Railways, major bulk commodity terminals and the trucking industry, to determine the sensitivity of shipments and sales to short term delays caused by flooding.

Of major interest during the interview program was the ability of the CN and CP to either delay shipments and make them up later or to transfer trains to the B.C. Railway at Prince George, since it is not susceptible to flood damage. Oil and gas pipeline officials were also contacted to determine the effect flooding would have on their operations.

I.2 Railways and Port Terminals

Rail access from the Lower Mainland and to the interior and Eastern Canada is provided by the CN and CP, which follow the Thompson and Fraser Rivers, and by the B.C. Railway which provides an alternate route to the interior and does not follow the Thompson or Fraser Rivers below Williams Lake. In addition to these railways the BC Hydro and Burlington Northern Railways provide rail service within the Lower Mainland. Of these railways, only the BC Railway is free of flood danger. Both the CN and CP are vulnerable to inundation, slides and bridge washouts during the Fraser's spring freshet. Several vulnerable areas within the Fraser Canyon and Thompson Valley have been identified and in addition, all railways but BC Railway are subject to inundation within the lower Fraser Valley.

In the event that one or both of the national railways' tracks are inundated, three possible effects may occur. First, shipments may be delayed until service can be restored. Second, shipments may be transferred to another railway. Third, where commodities are sold on a "spot" basis and where inventories at port terminals and points of consumption are low, delay may result in permanent sales losses.

During the interview program, an attempt was made to obtain the opinion of railway officials regarding the general ability of the railways to cope with outages of up to one month. In addition, specific attention was paid to the likely effect outages would have on the shipment of bulk items, especially coal. Port terminal officials were also contacted to determine the general level of inventories which could be utilized during a flood, and the ability of terminals to increase throughout following a flood. Again, bulk commodities were of major interest.

Generally, it was found that B.C.'s railways have sufficient experience and flexibility to cope with short term outages. The three major railways, BCR, CP and CN annually experience delays of varying lengths due to winter snow conditions, rockslides and derailments. During 1972, CN tracks were closed and 23 trains were rerouted over BCR's trackage during one week.

In addition, both the CN and CP lines are vulnerable to flooding, and both railways have developed emergency measures to deal with flood problems. These include the placement of ballast and riprap materials in cars which are held on sidings, placement of bridge material in cars, and preparation measures; although the Fraser and Thompson posed a severe flood threat in 1972 and caused numerous bank slippages and inundation, no serious delays occurred in rail shipments.

As well as delays caused by snow and flooding, rail shipments are often affected by strikes involving railway workers, dockworkers and seamen.

As a result, the railways have a great deal of experience in dealing with delays. The CN and CP have a reciprocal track agreement which allows free access to each other's tracks in the event of outages. CN and the BCR have a similar agreement, and although the CP and BCR do not have a formal agreement, BCR officials were confident that this would present no problem should the need arise for the CP to utilize BCR trackage.

Because of the reciprocal agreement between CN and CP, it can be concluded that no serious delays would occur if one line were closed and access was maintained between the two railways via the bridge over the South Thompson River.

In the event that both the CN and CP were put out of service by flooding, the only remaining alternatives would be to delay shipments or to transfer them to the BCR via Prince George, or to reroute shipments through the U.S.

BCR officials indicated that they could handle up to about 20 trains daily under short term emergency conditions, especially once planned modifications are made to their plant. The main problem in diverting shipments is not rolling stock, but the availability of trained crews. Generally, track conditions such as grade and curvature are similar for the CP and BCR, and CP crews could easily be used over BCR trackage. However, CN does not have grades exceeding 1 percent or curves exceeding 6 percent, compared to the BCR with grades up to 2 percent and curves up to 12 percent. Consequently, CN crews are not used over BCR tracks, although during an emergency such as a major flood, some use could be made of CN crews.

Nevertheless, it can be concluded that a substantial portion of CP and CN's trains could be successfully rerouted through Prince George to the BCR track in the event of a major flood.

Trains could also be rerouted through the U.S. over the Great Northern Railway via Sweetgrass, in Alberta, or either Kingsgate or Troop Junction in B.C. CP coal and grain shipments would appear to be possible candidates for rerouting in this manner. However, railway and terminal officials doubted that much use would be made of this alternative, especially if access to Roberts Bank were cut off. Seattle area ports would not receive coal due to the time required to assemble a shipload and the lack of adequate bulk handling facilities.

It was found also that Vancouver area terminal facilities would be adequate under forseeable demands for increased throughput. Prince Rupert could be utilized to ship grain and forest products. It was estimated that Prince Rupert could, with its present facilities, triple grain shipments. During July, 1972, 70,000 tons of grain were shipped from Prince Rupert.

Vancouver area terminal facilities are also capable of greatly increased throughputs on a short term basis. Since these terminals normally do not operate three shifts, under emergency conditions throughput could be more than doubled simply by working overtime.

Thus, it can be concluded that even if floods disrupted both the CN and CP tracks, a substantial proportion of their traffic could be rerouted to North Vancouver over BCR track via Prince George, and that port terminals could easily handle this extra traffic. When North Vancouver's terminals were fully utilized, bulk commodities could be transferred to Vancouver via the CN tunnel.

Since rerouting over BCR track, especially for the CP, would involve inconvenience and extra costs, an attempt was made to determine under what conditions rerouting would be used, and which commodities would be most likely to be rerouted.

All railway officials interviewed stated that they would prefer to merely delay shipments rather than reroute them. They also indicated that even a closure of one month could be made up over the course of one year, by full employment of rolling stock. Even CP's unit train system for coal shipped to Roberts Bank would be capable of making up a one month shortage, since both the railway and the mine allow for approximately one month's disruption in production and shipping annually in their plans of operation.

Consequently, it was determined that the railways have sufficient capacity to make up for a month's shutdown caused by flooding, so that no permanent sales losses need occur due to transportation bottlenecks.

While it was found that all normal shipments could be delayed for one month and made up later, railway officials noted that in all likelihood certain commodities would nevertheless be transferred to other railways. The conditions under which commodities would be transferred to other lines are as follows:

1. Where competition exists with other transportation modes, especially trucking. Piggyback containers are a good example of intermodal competition where customers might be lost to the trucking industry if substantial delays were encountered.

2. Commodities which generate relatively high profits would likely be transferred. Most general merchandise such as manufactured goods would fall in this category.

3. Bulk commodities which are often sold on a "spot" basis, such as potash, and which were in low supply at port terminals, would be transferred. In these cases, and where ships were waiting to take on specific cargoes, the possibility of permanently lost sales would induce the railways to maintain shipments.

4. Political or other pressure might be exerted to give specific commodities preferential treatment. Grain shipments might be at least partially maintained due to political pressure (or decree in the case of CN).

It was felt that, in general, coal would not be transferred, since shipments could be made up later and since coal sales are on a contract basis so that permanent sales losses would be unlikely. Since the railways have a "captive" market on bulk shipments of such things as sulphur and coal, and since many of these commodities are sold on a contract basis, there would be very little natural inducement to transfer shipments. However, as mentioned above, special circumstances could easily prevail which would induce the transfer of selected commodities.

All rail officials were hesitant to estimate which bulk commodities would be transferred or would receive priority once the tracks were reopened. They indicated, however, that perishables, piggyback and general merchandise would be most likely to be transferred rather than delayed. They also indicated that of the bulk commodities, coal destined for Roberts Bank would be the least likely to be transferred.

It appears therefore that inventories on hand at port terminals and cargoes for waiting ships would determine which bulk commodities would be given priority treatment by the railways. Interviews with terminal representatives indicated that as a general rule, inventories equal to one month's shipments were commonly on hand, but that these inventories varied widely over time and could not be predicted with accuracy.

The following conclusions can be drawn from the information obtained on rail and port terminal facilities and shipments. First, given a severe flood which forced closure of the CN and CP railways for up to one month, all perishables, piggyback and most general merchandise would be transferred over BCR tracks rather than delayed. Secondly, since substantial inventories of bulk commodities such as coal, potash, sulphur, grain and phosphate rock are generally on hand at port terminals and since many bulk commodities are sold on a "contract" basis, no permanent sales losses are foreseen as a result of rail disruptions which delay bulk shipments. The railways and the port terminals would be capable of recovering shipments delayed for one month over the course of the following year. Thirdly, where "spot" sales of bulk commodities were threatened, or where ships were waiting for specific cargoes, bulk commodities would be transferred to the BCR line. Generally, however, railway companies would prefer to delay bulk shipments since they have a "captive" market and since profit rates per unit shipped are low. Transfer of Roberts Bank coal to the BCR would, for example, be very unlikely due to the long detours required and the large volume of material involved.

Since no permanent sales losses are envisaged, no production losses or even delays are likely to occur. Instead, firms would be likely to continue full production and build up their inventories.

I.2.1 Frictional Costs

Where economic activity is either transferred to other establishments or deferred to the future, extra "frictional" production and transportation costs may occur. Where normal production is at less than full capacity, these frictional costs may be offset wholely or in part by economies of scale.

For secondary losses caused by disruptions in the transportation system, the only admissable frictional costs are extra transportation and storage costs, since flooding would not cause production delays.

Generally, flood loss studies which include estimates of frictional costs simply use an estimate based on a percentage of the gross value of production. An estimate of between 2 and 3 percent is commonly used in these cases, due to the extreme difficulty of precisely determining the nature and magnitude of frictional costs.[1]

Since secondary frictional costs in the case of Fraser River floods are restricted to extra transportation costs, and since some railway officials were quite co-operative in providing "rule of thumb" cost estimates, a more detailed methodology for determining frictional costs has been developed for this study.

As was mentioned earlier, railway officials were extremely hesitant to estimate exactly which commodities would receive priority treatment given a disruption of their track. Decisions on which commodities to transfer and which to delay would depend on inventories at port terminals, political pressures, etc. Generally, perishables and profitable items such as piggy-back and general merchandise would be transferred, and where possible, bulk cargo would be delayed.

Accordingly, this study presents estimates of the percentages of broad commodity groups which would be transferred or delayed. Cost estimates for commodities delayed or transferred have been made as follows:

[1] R.W. Kates, Industrial Flood Losses: Damage Estimates in the Lehigh Valley, Chicago, 1965.

Delay Costs:

Railways would recover delayed shipments by making fuller use of available rolling stock. With large inventories of commodities waiting at production sites, and low inventories at port terminals, loading and unloading times might be reduced somewhat, so that fuller use could be made of equipment and labor. In addition to this, shipments would also be increased by working overtime, and this would involve extra costs. Since no extra mileage would be involved, the main component of frictional costs for delayed shipments would be the overtime portion of wages paid.

Railway officials estimated that total operating or variable costs amount to approximately $.003 per ton mile, and that the majority of these costs represent labor charges. For the purposes of this report, the following assumptions have been made.

- It is assumed that 75% of variable operating costs represent wages and salaries.

- It is assumed that in order to recover delayed shipments, half of these shipments would require the use of overtime labor.

- Overtime rates are assumed to be 150% of regular rates.

Based on the above assumptions, the average extra costs for all delayed shipments would be approximately $.0005 per ton mile. If the average trip length is 700 miles, the extra costs incurred due to delay would be about $.35 per ton.

Transfer Costs:

Since transferring freight from either CP or CN onto the BCR via Prince George involves increased travel distance, the extra costs for transferred freight are equal to the full variable costs of $.003 per ton mile. It is assumed that no delay other than the time required to travel the extra distance would occur.

The actual amount of extra mileage generated by transferring to the BCR would depend, of course, on the origin of the freight and which railway it is travelling. Freight travelling on CN via Edmonton would incur about 150 extra miles, while freight which usually moves through Calgary via CP would incur detours of from 200 to 400 miles, depending on origin. For example, freight originating in the southern areas of Alberta would incur the maximum detour mileage, since it would have to be routed through Calgary to Edmonton. Freight originating in Saskatchewan or east of there would incur shorter detours in order to reach Edmonton, while freight originating approximately 100 miles northwest of Edmonton would not incur extra costs, since it could be readily transferred to BCR via the North Alberta Railway, at Dawson Creek.

For purposes of analysis, it can be assumed that the average detour distance is about 270 miles, so that the extra costs incurred due to the transfer of freight to BCR is about $.80 per ton.

These frictional costs, both for delay and transfer, would be borne by the railways rather than passed on to their customers. In connection with this, two points deserve mention here. First, since these losses would occur due to the inundation or damage to tracks within the flood area, the railways' losses are actually primary, not secondary losses. Second, since neither of the national railways are owned or based in B.C., only a small portion of their losses would actually accrue to B.C. residents. However, these points are considered to be somewhat academic, and neither has been included in the following analysis.

Since no published data are available on the amount of freight carried in B.C. by each railway, or by origin and destination, it has been necessary to generate estimates of the amount of freight which could be affected by flooding. Data published in Railway Freight Traffic, Second Quarter, 1971, has been used as a basis for estimation. This publication lists the total tonnage of freight loaded and unloaded in B.C. by commodity groups. Since flooding would mainly affect freight destined for export, only data on freight unloaded in B.C. has been included in this analysis. Certain commodities such as some processed foods, gravel, bauxite, etc., have been deleted since such commodities are either imported into B.C. for local consumption, are not shipped over vulnerable lines, or are produced on the flood plain and would suffer permanent production losses.

In addition, the percentage of total exports shipped via Vancouver and New Westminster ports was obtained from Shipping Report, 1972, and applied to the adjusted tonnages previously derived. Finally, it was assumed that of the remaining tonnage, 75% was shipped via the CN and CP.

Tables 1 - 6 present estimates of the frictional costs incurred by railways under various flood conditions. Based on information obtained from the railways regarding their probable reaction to closure, and on information obtained from port terminal authorities regarding the average inventories of bulk commodities on hand for shipment, it has been estimated that 25% of all foods (mainly grain), crude materials (mainly coal and other materials), and fabricated products (mainly potash and lumber products), would be transferred to the BCR or to CP's southern route (when possible). In addition, it is estimated that all end products and piggyback freight would be transferred. The balance of cargo would be delayed.

Table 1 presents an estimate of the frictional costs which would result from a one week closure of both the CN and CP lines north of Basque. Under these conditions all CN freight would either be delayed or transferred to the BCR or CP lines. Since CP's southern route would be unaffected, it is further assumed that half of its freight could be carried on this line at no extra cost. Based on these conditions, total frictional costs are estimated at $116,000.

Table 2 presents an estimate of frictional costs given a one week closure of both the CN and CP lines below Basque. Under these conditions, CP's southern route could be affected so that both CN and CP would have to either delay shipments or transfer them to the BCR line via Prince George. Losses amount to $157,000 under these conditions.

Table 3 presents an estimate of frictional costs given a one month closure of the CN, CP and BC Hydro Railway below Hope. Again, the only alternatives open to the CN and CP under these conditions are delay or transfer to BCR. Losses would amount to $676,000 under these conditions.

Table 4 presents an estimate of frictional costs generated by a one month closure of the B.C. Hydro Railway in Delta. In order to minimize damages to the roadbed, it is likely that B.C. Hydro Railway would substantially suspend its shipments during the entire month, particularly of Roberts Bank coal. The resulting loss estimate of $234,000 is based on a normal shipment rate equal to present contract volumes of 8 million tons per year.

As can be seen in section I.1 3.(c) of the flood conditions presented in the introduction, the CNR yards at Port Mann are susceptible to intermittent flooding during high tides but would not be closed for any appreciable time. While tidal flooding would cause additional delays, these are not felt to be large enough to warrant attention. The generally reduced total volume of shipping which would occur during a major flood would in part compensate for the delays caused to remaining freight.

Table 5 presents an estimate of the frictional costs which would be incurred by the CN during a one week closure of its line above Basque and the simultaneous loss of the bridge over the South Thompson River at Kamloops. Under these conditions CN would not be able to reroute freight via CP at Kamloops and would therefore have to delay or transfer freight to the BCR via Prince George. Some freight originating in eastern B.C., Alberta and east could be transferred to the CP line for shipment over its southern B.C. route. Since CN freight can transfer to the BCR line with a minimum of difficulty and a detour of only 150 miles, transfer costs are estimated only $.45 per ton. Losses under these conditions would amount to an estimated $63,000.

Table 6 presents an estimate of the frictional costs incurred by CP during a one week closure of its line north of Basque. Under these conditions, CP could retain use of its southern B.C. route and could transfer other freight originating outside of B.C. to the CN line via Calgary and Edmonton. It is estimated that half of its normal freight would utilize the CP track at no estra costs, and that for freight transferred to CN, the average detour distance would be about 150 miles. Under these conditions losses would amount to about $31,000.

If either the CP or CN lost its track for periods up to one month below Basque, freight could be easily transferred to the other railway via Kamloops. While these transfers would involve some delay, it is unlikely that these delays would represent substantial economic loss. Again, however, CP would in all likelihood suspend its coal shipments, especially if the B.C. Hydro Railway connection to Roberts Bank were closed, so that frictional costs would vary from $54,000 to $234,000, for closures varying from one week to one month.

Under all foreseeable flood conditions then, frictional costs would vary from about $30,000 to $680,000 with the latter estimate based on a one month closure of CN, CP and the BC Hydro Railway.

Table 1

Frictional Costs with One Week Closure of CN and CP Lines North of Basque

Commodity Group	Tons Affected[1]	Percent Trans-ferred	Frictional Costs
Food, feed, beverages, tobacco	71,000	25	$ 33,000
Crude materials, inedible	120,000	25	55,000
Fabricated materials, inedible	52,000	25	24,000
End products, inedible	2,000	100	1,000
Piggyback and other	4,000	100	3,000
Total	249,000		$116,000

[1] Assumes CP could reroute 1/2 of normal freight over its southern route connecting at Spences Bridge at no extra cost.

Table 2

Frictional Costs with One Week Closure of CP and CN Lines Below Basque

Commodity Group	Tons Affected	Percent Trans-ferred	Frictional Costs
Food, feed, beverages, tobacco	95,000	25	$ 44,000
Crude Materials, inedible	160,000	25	74,000
Fabricated materials, inedible	69,000	25	32,000
End products, inedible	2,000	100	2,000
Piggyback and other	6,000	100	5,000
Total	332,000		$157,000

Table 3

Frictional Costs with One Month Closure of CN, CP and BC Hydro Railways below Hope.

Commodity Group	Tons Affected	Percent Trans-ferred	Frictional Costs
Food, feed, beverages, tobacco	413,000	25	$190,000
Crude materials, inedible	695,000	25	321,000
Fabricated materials, inedible	301,000	25	139,000
End products, inedible	9,000	100	7,000
Piggyback and other	24,000	100	19,000
Total	1,610,000		$676,000

Table 4

Frictional Costs with One Month Closure of the B.C. Hydro Railway in Delta.[1]

Commodity Group	Tons Affected	Percent Trans- ferred	Frictional Costs
Food, feed, beverages, tobacco	---	---	---
Crude materials, inedible[2]	670,000	---	$234,000
Fabricated materials, inedible	---	---	---
End products, inedible	---	---	---
Piggyback and other	---	---	---
Total	670,000		$234,000

1 It is assumed that periodic flooding during high tides would force closure for the entire month.

2 Includes only coal shipments from Kaiser and Fording fields, based on contract volumes.

Table 5

Frictional Costs with One Week Closure of CN Line North of Basque

Commodity Group	Tons Affected[1]	Percent Trans-ferred	Frictional[2] Costs
Food, feed, beverages, tobacco	48,000	25	$ 18,000
Crude materials, inedible	80,000	25	30,000
Fabricated materials, inedible	35,000	25	13,000
End products, inedible	1,000	100	) 2,000
Piggyback and other	3,000	100	)
Total	167,000		$ 63,000

[1] It is assumed that CN and CP carry approximately equal tonnages.

[2] The average detour for transferred freight would be approximately 150 miles, or $.45 per ton. Delay costs remain at $.35 per ton.

Table 6

Frictional Costs with One Week Closure of CP Line North of Basque

Commodity Group	Tons Affected[1]	Percent Transferred	Frictional Costs
Food, feed, beverages, tobacco	24,000	25	$ 9,000
Crude materials, inedible	40,000	25	15,000
Fabricated materials, inedible	18,000	25	6,000
End products, inedible	) 2,000	100	) 1,000
Piggyback and other	)		)
Total	84,000		$ 31,000

1 Assumes CP could reroute 1/2 of normal freight over its southern route connecting at Spences Bridge at no extra cost. Other freight would be either delayed or transferred to CN line via Calgary and Edmonton, with an average detour distance of 150 miles, or $.45 per ton. Delay costs remain at $.35 per ton.

It is interesting to compare these estimates with those which would result from the use of a standard frictional loss coefficient. As was mentioned earlier, the costs are often assumed to be about 2% of the gross value of production, or in the case of railways, the gross revenue received for affected freight. Assuming the worst flood conditions analysed in this report, about 1,610,000 tons of freight would be affected.

If the average haul is about 700 miles and the average revenue is $.007 per ton mile, then a 2 percent of gross return frictional cost would be $158,000, in contrast to the frictional cost estimate of $680,000 developed in this report for identical flood conditions. It is considered that this large discrepancy results from the fact that the standard loss coefficients were developed mainly for primary industrial losses due to production delays and inefficiencies in transferring production to plants located off the floodplain. Since this study is concerned with secondary losses, and since these losses are confined to the transportation industry, higher frictional costs appear logical in that the transportation industry, by its nature, must be profoundly affected by stoppages or transfers.

I.2.2 Future Secondary Losses

Information was obtained from railway representatives regarding the probable future rail transportation network and terminal facilities, especially with regard to the effect such changes would have on the magnitude of future flood losses.

Overall, it was found that in future, growth and expansion both of rail and terminal facilities will increase the flexibility of the transportation industry, and substantially reduce the dependence on Vancouver and New Westminster ports. Some of the forecast changes are as follows:

- Construction of the Clinton-Ashcroft connection between the BCR and CN would effectively link these railways as well as the CP, thus substantially reducing detour distances. The connection would be particularly beneficial to the coal industry, but all commodity shipments would benefit with the provision of an alternative route to coastal and export markets via BCR. Given flooding of both CN and CP lines below Basque for one month, use of this connection would almost entirely eliminate transfer costs, making transfer more attractive than delay.

- Port expansion is likely at Prince Rupert, Kitimat and possibly Squamish, while Vancouver area ports offer little potential for expansion. CN officials were confident that a substantial proportion of bulk shipments would be rerouted via Prince Rupert in the relatively near future, thus removing this freight from the possibility of delays due to floodings. Similarly, development of bulk handling facilities at Squamish would provide another flood free route for bulk commodities. Therefore, while shipments to Vancouver area ports are likely to continue and even increase to some extent, much of the future bulk traffic will not be susceptible to flooding, and when flooding does occur, transfers to these ports will be both possible and economical.

- As the volume of cargo increases, additional rolling stock will be required, thus increasing the amount of equipment available to make up delayed shipments.

- Roadbed improvements are likely to be made by CP, CN and the BC Hydro Railways. All of these railways recognize the danger posed by floods, and have plans underway designed to improve flood proofing through track elevation, tunnel relocation and other improvements. The feasibility of flood proofing is indicated by the fact that at present the railways are only susceptible to flooding in a few scattered areas.

- Creation of a single "terminal" railway for the Lower Mainland would greatly increase the efficiency of operations in the Lower Mainland, which would be reflected in shorter delays under flood and post-flood conditions.

- Construction of a railway track through the Elk Valley to the U.S. would provide another flood free route, especially for coal shipments.

It is difficult, if not impossible, to determine the probability of timing of these changes. There is little doubt, however, that as the volume of freight increases, various changes will occur which will serve to reduce losses due to flooding. Accordingly, the following assumptions have been made in estimating future losses:

- Overall railway shipments as measured by ton-miles will increase at the historical rate of 4 percent.[1] Of this amount, half will be shipped to Vancouver area ports, and Vancouver area ports will reach capacity by 1990, by which time shipments will have increased by 50 percent.

- Costs per ton-mile will remain constant in 1971 dollar terms.

- A discount rate of 7 percent is assumed.

Under these conditions, the 1972 present value of losses occurring in the year 2000 will range from about $150,000 to $7,000, depending on the duration and location of track disruptions. Table 7 summarizes the present value of frictional costs under the 6 flood conditions presented in Table 1 - 6, at 5 year intervals.

[1] Statistics Canada, Railway Transport, Part IV, 1970. p. 9.

Table 7

1972 Present Value of Frictional Costs to the Year 2000 Under Various Flood Conditions:

Year	As in Table No.: RR Affected: Duration: Location:	1 CN, CP One Week North of Basque	2 CN, CP One Week South of Basque	3 CN,CP,BCH One Month South of Hope	4 BCH One Month Delta	5 CN One Week North of Basque	6 CP One Week North of Basque
1972		$116,000	$157,000	$676,000	$234,000	$ 63,000	$ 31,000
1977		93,000	126,000	541,000	188,000	50,000	25,000
1982		73,000	99,000	426,000	148,000	40,000	20,000
1987		58,000	78,000	338,000	116,000	32,000	16,000
1992		44,000	60,000	257,000	90,000	24,000	12,000
1997		31,000	42,000	183,000	64,000	17,000	8,000
2000		26,000	35,000	149,000	52,000	14,000	7,000

I.3 Roads

If flood conditions either in the Lower Fraser Valley or elsewhere resulted in the blockage of all road traffic, secondary losses could occur both to the transportation industry and to firms cut off either from their source of supply or markets.

Loss of the Trans-Canada Highway in the vicinity of Spences Bridge would not represent a significant disruption, since access between the Lower Mainland and the Interior would be rerouted via Highways 3 and 5. Since these detours are short, no extra costs are envisaged.

Flooding in the Lower Mainland which prevented access to Hope via the Trans-Canada Highway, however, would present more serious problems. Given such flooding, access to the Interior would only be possible by detouring through the U.S. Therefore, while no permanent sales losses to firms located off the floodplain are envisaged, certain road freight would have to be either delayed or transferred over U.S. roads, which represents a substantial detour distance. Since detouring could easily double operating expenses in terms of wages and fuel, it is felt that most affected freight would be delayed. In this case, only the overtime portion of wages would represent extra or frictional costs.

It is estimated that one month's revenue in the trucking industry for inter-city and rural cargo amounts to about $10,000,000 in B.C.[1]

Of this amount, approximately $2,000,000 represents wages and $1,000,000 represents fuel costs. Only a small portion of total freight represents Interior traffic and of this, only a portion would incur secondary frictional losses. For purposes of analysis, it is assumed that 10% of this freight would be delayed for one month, and that all of this delayed freight would require use of overtime labor. Under these circumstances, frictional costs due to a one month closure of the Trans-Canada Highway in the Lower Mainland would generate frictional costs of about $100,000.

It is estimated that if all the affected freight were transferred via U.S. roads, operating costs would double, for a total loss of $300,000. In view of this discrepancy, it is considered likely that most affected freight would be delayed.

For the future, the most important road development will be completion of a major highway from Lytton to Vancouver via the North Shore, Squamish and Lillooet. This route involves mileage similar to the Trans-Canada route and is entirely flood free. All secondary losses to the trucking industry will be eliminated when this road is completed. For purposes of analysis, it has been assumed that this road will be completed in 1987.

1 D.B.S., Motor Carriers - Freight, 1968. A growth rate of 5% used to estimate 1972 revenues.

The present 1972 values of these losses, assuming a 5 percent annual growth in traffic, is given below in 5 year intervals. A 7 percent discount rate is used.

Year	Present Value
1972	$100,000
1977	92,000
1982	83,000
1987	75,000
1992	---
1997	---
2000	---

I.4 Oil and Gas Pipelines

Both oil and gas pipelines are located on the floodplain, and closure of these pipelines due to flooding would result in substantial permanent sales losses.

Westcoast Transmission delivers natural gas to B.C. Hydro and to El Paso Natural Gas at Huntingdon, which is located at the southern end of Sumas Prairie. Gas deliveries to El Paso amount to about 800 million cu.ft. per day, with an export value of about $270,000 per day. B.C. Hydro receives about 200 million cu. ft. per day, with a gross value of about $170,000 per day.

Control and metering facilities at Huntingdon could be inundated by flooding but could be operated underwater. In addition, flood protection could easily be provided at these facilities during an emergency.

In addition to these control facilities, the main gas line traverses the floodplain at Sumas Prairie, so that some danger of line flotation exists. However, much of this line has been weighted, and officials of Westcoast Transmission doubted whether disruption due to line rupture would occur.

Consequently, no secondary losses are envisaged as a result of disruptions in gas pipelines.

Trans Mountain has a pumping station on the Sumas floodplain as well, and without emergency flood protection this station would be vulnerable to flooding. Of the average daily throughput of approximately 350,000 barrels of oil, some 250,000 barrels are exported to the U.S. Trans Mountain receives about $130,000 daily for transmission services.

Considering the potential magnitude of flood losses and the small area which would require flood protection by dyking, it is considered that flood protection could be provided during an emergency, and no secondary losses are envisaged.

I.5 Tourism

Because June is not a peak tourist month, and since alternate routes to Vancouver and the Interior are available for both U.S. and other Canadian visitors, no secondary losses would accrue to the tourist industry as a result of flooding on the Lower Mainland. Tourist accommodations in the Vancouver area would, in fact, realize substantial income from displaced floodplain residents during and after flood conditions.

I.6 Conclusion

In order to assess the potential for secondary flood losses due to breakages in the transportation network, a number of interviews were held with rail and port terminal officials to determine their ability to either transfer or delay shipments following track disruptions. Generally, it was found that both the railways and port terminals have sufficient capacity and experience to make up delayed shipments of up to one month. Short term disruptions are quite common annually due to snow conditions and labor disputes, and the railways annually activate a flood emergency program aimed at minimizing delays following track disruptions.

Port terminals generally carry substantial inventories of bulk commodities, and can more than double throughput by operating extra shifts.

Because of these factors, it can be concluded that no permanent sales losses for bulk or other commodities would occur due to flooding which caused rail disruptions.

Rail officials stated that while they would prefer to merely delay all shipments during flood conditions, they would transfer commodities which generate high profits, perishables and sufficient bulk commodities to prevent permanent sales losses. Generally, all piggyback and general merchandise would be transferred to B.C. Railway, as would a portion of bulk shipments.

Delayed shipments would be made up by using overtime labor, so that the extra cost to the railways for delayed shipments would be confined to the overtime portion of wages paid. If half of the delayed shipments required the use of overtime labor, extra costs of about $.35 per ton would result.

Since transferring freight from either CN or CP to the BCR would involve detours of from 150 to 400 miles extra, costs would include the extra labor and fuel required. These costs are estimated at about $.003 per ton mile, or $.80 per ton transferred.

Frictional costs under various flood conditions would range from about $30,000 to $680,000, as shown in Tables 1 - 6. Losses would vary depending on the location and duration of track disruptions.

Future frictional costs were determined on the basis of foreseeable changes in the transportation network, as well as in past growth rates in rail traffic. Generally, it can be concluded that as changes are made in the rail network, the potential for secondary losses due to flooding will decline.

The present value of these losses was projected to the year 2000, based on a growth rate of 2 percent annually until 1990 in freight destined for Vancouver area ports, and a discount rate of 7 percent.

Thus, it is estimated that the maximum possible secondary loss to the rail transport industry would amount to about $680,000, and that over time, the potential for secondary losses will decline relative to the expected growth in traffic.

Much the same situation exists with regard to the road transport industry. Losses would be confined to the frictional costs caused by delay or detouring shipments through the U.S. at Huntingdon. Only a small portion of total truck traffic in B.C. would be susceptible to such losses, and where disruptions occurred, it is likely that the majority of shipments would be delayed. Under these conditions, secondary flood losses would amount to $100,000. In the event that all freight were detoured, losses of about $300,000 would result.

While oil and gas pipelines lie within the floodplain, it is considered that the companies involved would protect their control and pumping facilities with local dyking, and no secondary losses would occur.

Tourism would probably not be significantly affected by flooding, since alternate routes both to the Lower Mainland and the Interior are available. Vancouver area hotels, restaurants, etc., would probably be at full capacity in any case, servicing flood victims.

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