Environment Canada

AN EVALUATION OF FLOODING IN STEPHENVILLE, NEWFOUNDLAND

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HALIFAX, NOVA SCOTIA,
DEC. 1975.

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1. SUMMARY AND CONCLUSIONS

1.1 Summary

The town of Stephenville has experienced periodic flooding throughout its history. The predominant cause of this flooding on Blanche Brook and Warm Creek has been excessive rainfall during the spring months leading to rapid snowmelt and ice jams at various man-made constrictions. Floods have frequently occurred during autumn months as well - the two most recent of which were experienced in late August, 1973 and November, 1974.

Subsequent to the 1973 event, the Town of Stephenville requested (through the Newfoundland Department of Environment and Provincial Affairs), that Environment Canada conduct a study of the flooding problem. This report is the result of that study.

A brief description of the local economy, the basic physiographic and climatic forces at work in the area, as well as an account of the most recent floods of record are contained in sections 3 and 4.

The nature and extent of the flood hazard is described in section 5. Water surface profiles for floods of various magnitudes (1:100 year, 1:20 year and Mean Annual events) were determined based on a hydrologic and hydraulic analysis. The areal extent of flooding was determined by applying the profiles resulting from the 1:100 year and mean annual floods to a topographic base map of the floodplain. The base map was compiled from existing maps and adjusted using field survey data. The flood hazard is also discussed in terms of depth of flooding and velocity of flood waters.

The flood damage potential in the Stephenville floodplain is discussed in section 6. Quantitative impressions of the current and future flood damage potential were determined to provide a benchmark for the evaluation of the various potential structural and non-structural adjustments.

The average annual flood damage potential on the Stephenville floodplain has been estimated at about $500,000, most of which would occur at the brewery. This estimate is based on several assumptions, the most important of which are: (1) the existing dyke along the brewery bank would not withstand a flood equivalent in magnitude to the mean annual flood and (2) the damage estimates at the brewery are based on interviews with brewery staff and could be somewhat biased. The implications of potential future development on the level of vulnerability are also discussed.

Various structural adjustments, ranging from regional alternatives such as upstream storage, floodways, and diversions, to more localized alternatives such as dykes and floodproofing are discussed in section 7. What appeared to be the more promising measures were subjected to conceptual design. An analysis of the cost of these measures and their potential to reduce the physical extent of the hazard is also discussed.

Non structural measures are assessed on a similar basis in section 8, although the discussion is substantially more qualitative in nature than the assessments made in section 7.

The various potential structural and non structural solutions are discussed in section 9. Based on arguments summarized in that section, several adjustments emerge as being superior. These suggested adjustments are essentially the conclusions of the report and are presented below.

1.2 Conclusions

1. Because of the topographic features of the Stephenville floodplain, there is no significant difference in the areal extent of the hazard between the 1:100 year flood (Map 1) and the mean annual flood (Map 2). However, the depths of flooding resulting from the above events could differ by up to 3 feet.

2. It is estimated that $500,000 in "average annual flood damages" is the level of vulnerability in the Town. Approximately 96% of this total is located at Labatt's Brewery, where it is estimated that over 5 feet of water will be on the floor of the building in a 1:100 year event.

3. In general, regional solutions to the flooding problem are expensive and generally not as effective as local solutions which are designed to protect critically vulnerable areas on the floodplain.

4. A continuing program designed to clear trees and debris from the channel of both Blanche Brook and Warm Creek, should be initiated by the Town.

5. Any new construction on the floodplain should be required to be floodproofed according to acceptable standards. In the Stephenville case, probably the best way

to accomplish this goal is to require foundations to be built to specified minimum elevations in order to avoid increases in damage potential. Such a regulation should also include all Harmon Corporation land that is currently vulnerable. Recognition should be given in the establishment of these standards to the fact that the 1:100 year flood line as estimated on Map 1 does not necessarily define the entire floodplain.

With the creation of these minimum elevation standards for new development, the onus will be placed on a prospective developer to demonstrate that his concept is compatible with the flood hazard.

6. Certain portions of the floodplain may provide significant flow carrying capacity or a "relief valve" for floodwaters during major events. Because of this, care must be taken to ensure that all new construction is both located and landscaped in such a fashion that flooding at other locations is not aggravated.

7. A rudimentary early warning system could be useful for the area. The possibility deserves a limited amount of further study regardless of which adjustments are adopted. However, if floodproofing is selected as a solution at either the brewery or upstream of Main Street, a detailed assessment of the potential effectiveness of an early warning system should be made.

8. The Town should institute a policy of not permitting any changes to the physical regime of the drainage

area without first considering what effects these changes are likely to have on the flood hazard. This would apply not only to the channels of Blanche Brook and Warm Creek but also in the watershed generally, as in the case of monitoring forest cutting plans and practices.

9. All new public facilities constructed across either Blanche Brook or Warm Creek should be designed to pass the 1:100 year flood without materially affecting upstream flooding. **To help prevent jamming, any new bridge construction should incorporate an open-span design.**

10. The feasibility of altering, reconstructing or removing existing bridges, some of which constrict flow and act as a catalyst for ice or debris jamming, was not evaluated because it would be impossible to justify these strategies on the basis of flood control alone. **It is suggested, however that as bridges become obsolete or require major alteration, consideration should be given to the flood hazard.** One obvious example of this problem exists at the Mississippi Drive bridge. This structure has been subject to periodic damage in the past and will continue to be in the future. The elimination of the bridge would not materially affect flood levels, but it would eliminate the recurring cost of repairing the bridge. Local traffic could be routed up Georgia Drive if the bridge were removed.

11. Bank protection works at T and J's Motel will eventually be required to protect the sleeping unit from damages.

12. Three different regional structural alternatives (floodways, diversions, and upstream storage) were investigated and found to be economically infeasible. One local adjustment (channel realignment near the confluence) was also found to be uneconomical.

13. The existing dyke along Blanche Brook at the brewery is not considered to be structurally competent to withstand the hydrostatic and erosional forces which will occur under major flooding events. Signs of erosional damage and sloughing are already evident.

14. Dredging of the river channel below the brewery was found to be economically and technically feasible in relation to the prevention of flood damages at the brewery. However, the capital cost of this alternative was found to be higher than both dyking and floodproofing both of which would achieve the same level of benefits. A potential benefit of the dredging alternative is that it would provide a larger amount of protection in an event greater than the 1:100 year flood than either dyking or floodproofing.

15. Dyking and floodproofing are sufficiently close to each other in economic terms that further detailed study would have to be made of both possibilities before one could be chosen over the other. Floodproofing appears to be superior on the basis of preliminary cost-benefit comparisons, but risk considerations, the non-universality of the solution, and the potential development benefits of land make the two possibilities of roughly equal attractiveness.

A program of either dyking or floodproofing should be coupled with intelligent land use planning in vulnerable areas to ensure that catastrophes are avoided should the measures fail or should a larger flood than the 1:100 year event occur.

16. Whichever alternative is selected for the brewery, bank protection will be required (see discussion of dyking proposal) and the local drainage system at the brewery should be improved. The existing drainage ditch south of the brewery should be diverted to a point just upstream of the Recreation Centre bridge.

17. It became quite apparent during the resident survey (Appendix A) that the level of public awareness of and concern about the flood hazard was not very high. The only way to ensure that all activity in the drainage area is considered in terms of the flood hazard is for this awareness to be increased. A program to ensure that the population of the area is adequately informed of the flood hazard should be initiated.

18. Restrictive zoning has been used effectively in the recent past to ensure that economic growth is compatible with the flood hazard, and its usefulness should be considered in future development plans. However, there appears to be no sound economic reason for excluding conforming land uses from the floodplain. To do so would be to ignore the potentially high economic utility of the land in question.

2. INTRODUCTION

Parts of the Town of Stephenville, are subject to periodic flooding by both Blanche Brook and its major tributary, Warm Creek. As a result, the implementation of many of the recommendations in the current municipal plan depends on answers to several questions concerning the flood hazard, such as:

1. What can be done to protect existing development?
2. What is the nature and extent of the flood hazard?
3. How often is flooding likely to recur?
4. Should development of the vulnerable areas be permitted?

To obtain answers to these questions, Council sought assistance from the Newfoundland Department of Provincial Affairs and Environment, who in turn requested that the Inland Waters Directorate of Environment Canada (Atlantic Region), investigate all pertinent aspects of the flooding problem in Stephenville.

This report is the result of that investigation. It describes both the nature and extent of the flood problems in the Town of Stephenville. It also provides a preliminary evaluation of alternative means of flood control and suggests measures for reducing flood damage potential that could be considered by the Town.

The Appendices to this report are presented in a separate volume. Included in these Appendices are (A) the results of a resident survey conducted in Stephenville in

October, 1974, (B) the methods used to determine flood magnitudes, (C) the technical aspects involved in both the production of the two flood hazard maps and the evaluations of various structural alternatives, and (D) the text of a press release by the Minister of the Environment for Canada, Mme. J. Sauve, concerning the creation of the National Flood Damage Reduction Program referred to above. The flood hazard maps are located in a separate jacket on the back cover of this report.

The study area encompasses Blanche Brook to a point just upstream of the Hanson Highway Bridge and Warm Creek to the outlet of Noel's Pond. Flooding occurs above Noel's Pond, but consideration of this part of the problem would have required an evaluation of the water supply implications of flooding, which would have been outside the scope of the study.

The study did not consider the possibility of relocating vulnerable assets. Obviously, one alternative would be to move the brewery off the floodplain, but the limited data base available during the study would not have permitted an adequate assessment of this alternative.

To the extent possible, institutional considerations have been reflected in the analysis. For example, if it is projected that growth will occur in a specific location because of the policies embodied in the Development Plan, then this information has been included in the floodplain study. However, this report has been primarily concerned with the solution of the flood problem in Stephenville and the question of responsibility for the problem has not been addressed. It was felt that such a consideration would have been beyond the mandate of this study. As a result, the various options are discussed entirely in terms of the flood problem itself. No opinions are expressed in the report concerning who should pay for work resulting from the report or who should be held responsible for damages resulting from floods.

One recent institutional development that should be considered is that the federal government is at present initiating a Flood Damage Reduction Program through Environment Canada. This will be a federal-provincial program designed to reduce flood damages by various means. Notably, it will seek to restrict and discourage future development in designated flood risk zones which will be defined on special offically approved maps. In considering the options outlined in this report, the authorities concerned should consider also the implications the Flood Damage Reduction Program would have if it were to be applied to Stephenville. (A copy of the Press Release announcing the Program is contained in Appendix D).

3. DESCRIPTION OF THE AREA

Stephenville is located on St. George's Bay on the west coast of Newfoundland. The principal streams flowing through the Town are Blanche Brook and its tributary Warm Creek, which joins it one mile from its mouth.

3.1 Physical Features

The Blanche Brook watershed, as shown on Figure 1, drains an area of approximately 51.2 square miles. Blanche Brook, which drains the western half of the area, rises in the Indian Head Range at an elevation of 1,550 feet and flows southwesterly over a distance of 15.3 miles to its outlet at St. George's Bay. Warm Creek, the major tributary of Blanche Brook, drains the eastern half of the area. It also flows to the southwest from its source in the Indian Head Range and drops 1,350 feet over 12 miles.

At one time Blanche Brook and Warm Creek met near the middle of existing airport runways, but during construction of the Harmon Air Force Base in 1941, the channel was realigned as shown in Figure 2 . Later, airport expansion (circa 1952) precipitated further changes when most of the regime was dredged to its present location. The exception to this was near the mouth where a further change was made in 1955. Since 1955, local marine currents have shifted the mouth southward to its present position.

The principal physiographic properties of the basin as a whole and for the two major branches are given in Table 1.

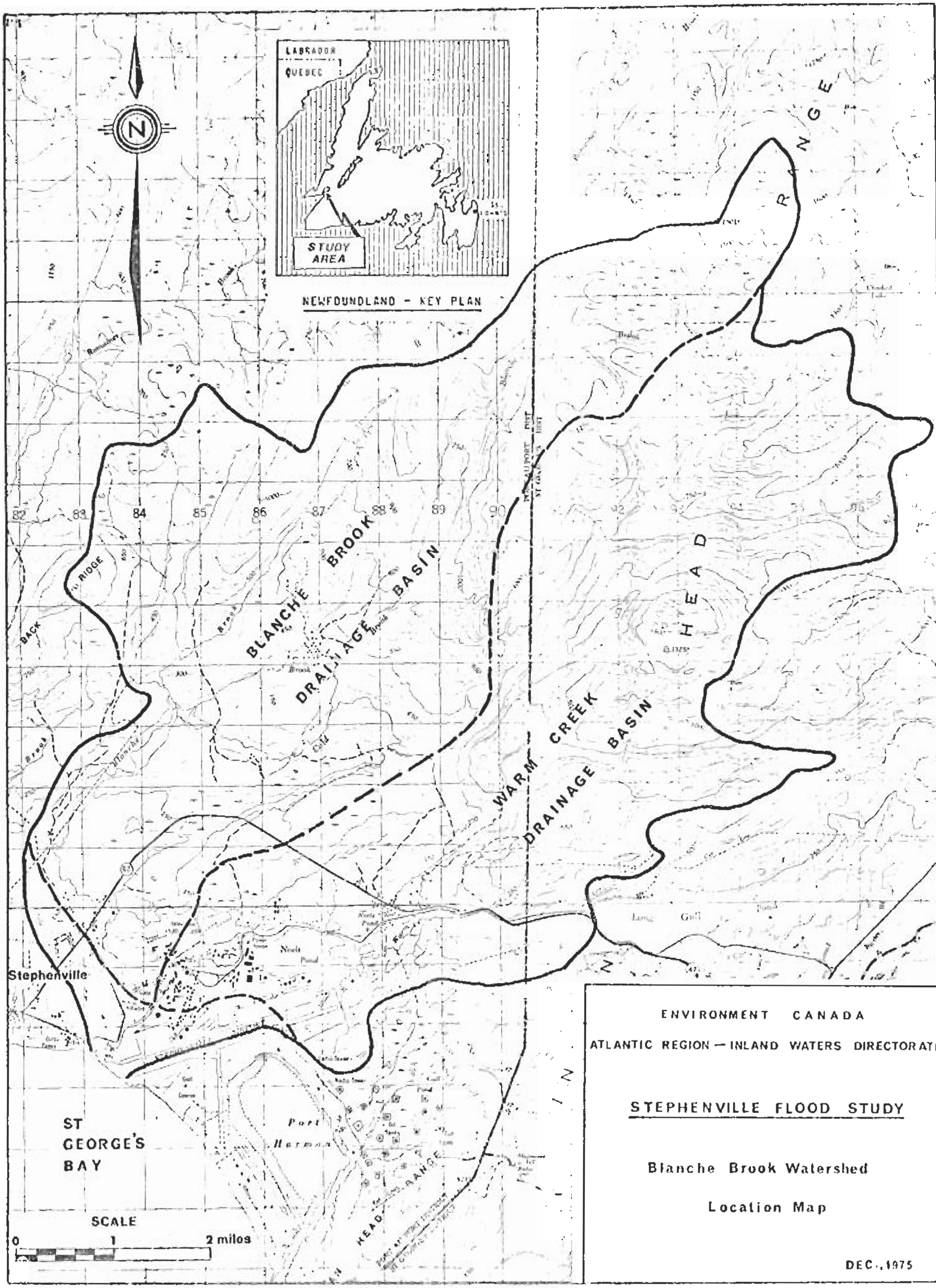

NEWFOUNDLAND - KEY PLAN
LABRADOR
QUEBEC
STUDY AREA
BLANCHE BROOK DRAINAGE BASIN
WARM CREEK DRAINAGE BASIN
BACK RIDGE
INDIAN HEAD RANGE
Stephenville
ST GEORGE'S BAY
Port Harmon
SCALE
0
1
2 miles
ENVIRONMENT CANADA
ATLANTIC REGION — INLAND WATERS DIRECTORATE
STEPHENVILLE FLOOD STUDY
Blanche Brook Watershed
Location Map
DEC., 1975

FIGURE 1

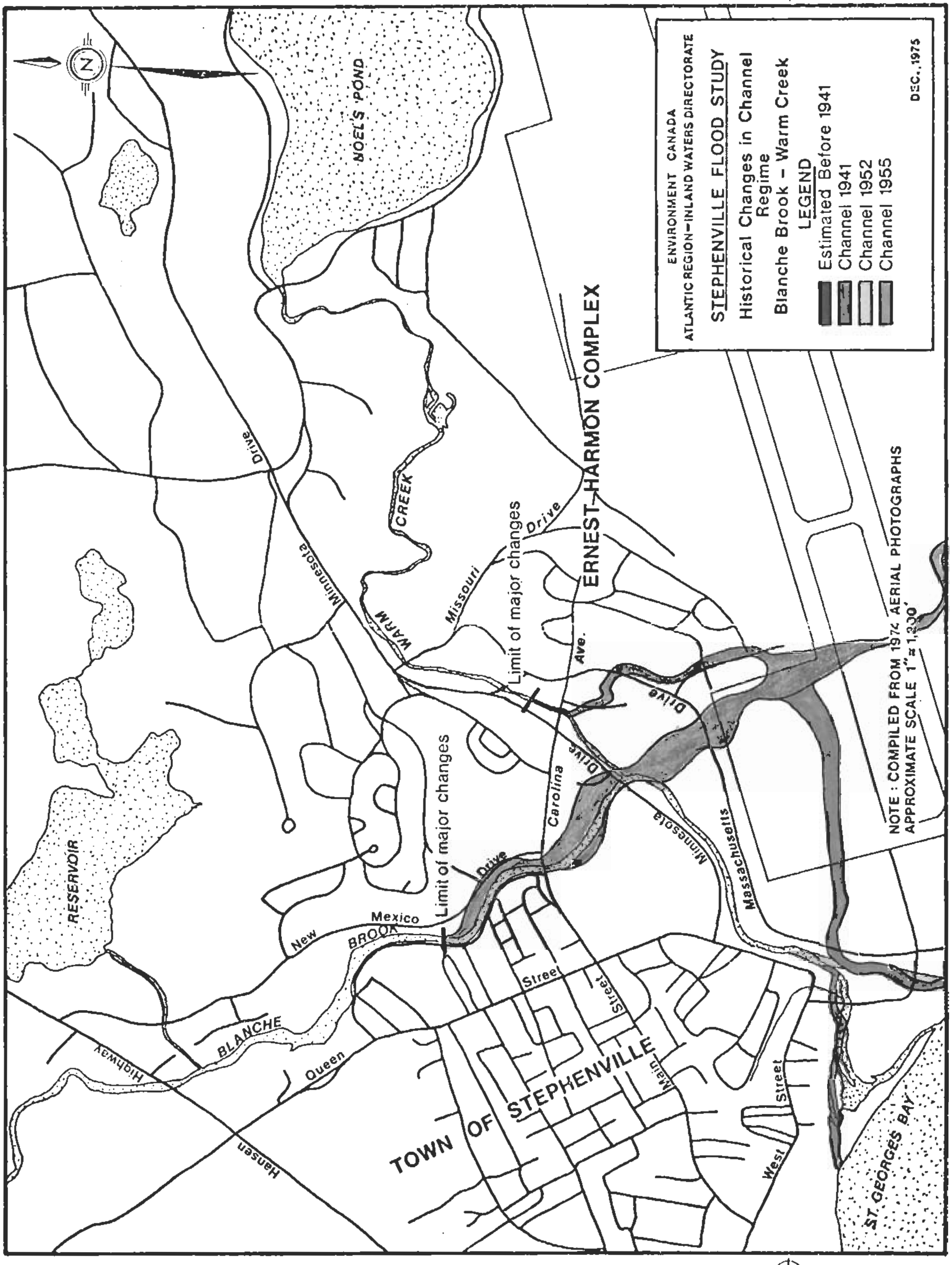

ENVIRONMENT CANADA
ATLANTIC REGION–INLAND WATERS DIRECTORATE
STEPHENVILLE FLOOD STUDY
Historical Changes in Channel Regime
Blanche Brook – Warm Creek
LEGEND
Estimated Before 1941
Channel 1941
Channel 1952
Channel 1955
DEC., 1975
NOTE : COMPILED FROM 1974 AERIAL PHOTOGRAPHS
APPROXIMATE SCALE 1" = 1,200'
N
NOEL'S POND
RESERVOIR
ERNEST HARMON COMPLEX
TOWN OF STEPHENVILLE
WARM CREEK
BLANCHE BROOK
Limit of major changes
Limit of major changes
Minnesota Drive
Missouri Drive
Carolina Ave.
Drive
New Mexico Drive
Massachusetts
Hansen Highway
Queen
Street
Street
Main
West Street
ST. GEORGES BAY

FIGURE 2

TABLE 1

Selected Physiographic Properties

Blanche Brook Watershed

	Total Basin	Blanche Brook[1]	Warm Creek[1]
Drainage Area	51.2 sq. mi.	24.3 sq. mi.	25.2 sq. mi.
Length of Channel	15.3 miles	14.3 miles	12 miles
Difference in elevation source to mouth	1,550 feet	1,530 feet	1,350 feet
Slope	101 ft./mile	107 ft./mile	112 ft./mile
Percent of area controlled by lakes and swamps	57%	21.7%	95%

1. Parameters are given for that portion of the basin upstream of confluence of Blanche Brook and Warm Creek.

For the most part, the basin is forested with extensive swampy areas in its upper reaches. The entire area is the product of intense glaciation with outcrops of granitic and basic rocks of the Precambrian era. The lowlands are covered with glacial drift and outwash deposits. As a result, the streams have developed meanders, are generally shallow, and have coarse gravel and cobble beds.

3.2 Climate

The climate of western Newfoundland is influenced by the same continental air masses as those affecting the rest of eastern North America. Because of this, the entire area generally experiences a wide range between summer and winter temperatures. However, the climate is also affected by the cold Labrador current which has the effect of narrowing this range.

Meteorologic records have been kept at the Stephenville airport since 1942. Although not representative of climatic conditions in the entire basin (because of the station's proximity to the coast), these records represent the best information available. The range in temperature and precipitation in the interior portion of the watershed would of course be more pronounced.

The mean daily temperature in the Stephenville area is approximately 41°F (5°C). The coldest month is February with a mean daily temperature of 22°F (-6°C) while the warmest month is August with a mean daily temperature of 61°F (16°C). The mean daily temperature ranges from -17°F (-27°C) to 87°F (31°C).

The mean annual total precipitation in the Stephenville area is approximately 43 inches (1092 mm) consisting of 31 inches (787 mm) of rain fall and 128 inches (325 cm) of snowfall. Precipitation is well distributed over the year. Autumn is the wettest season, and November is the wettest month (4.5 inches - 114 mm). After November, there is a general decline in precipitation until a minimum is reached in April (2.2 inches - 56 mm). Little is known about the water equivalent of the snowpack during the winter and spring months. The average annual snowpack for the Humber River Basin was estimated[1] to be about 10 inches

1. Shawinigan Engineering Company Ltd. - Waters Resources Study of Newfoundland-Labrador

(254 mm) during mid-march and varied from 0 to 18 inches (457 mm) during the period from 1926 to 1968.

The maximum amount of precipitation recorded at Stephenville airport in a 24 hour period was 3.7 inches (94 mm). This occurred on February 22, 1946, and was primarily in the form of rain. The February date is significant in that if the right conditions were to exist in advance of and during such a storm, a large volume of water could be released from the snowpack as well as the rainfall itself. This could in turn result in extremely high flood waters. Because of the time of year, there is also a high probability that such a flood would be complicated by ice jams.

3.3 Economic Features

Stephenville experienced rapid growth after the establishment of the Harmon Air Force Base in 1941. Growth rates averaged about 5% per annum in the Town and its immediate environs between 1941 and 1961. After 1961, declines were experienced until about 1966 when the Air Force Base was finally closed down. Subsequently, the Town began to grow again, and now the population is estimated at approximately 10,000 for the Town itself. This contrasts with a 1966 census figure of 5,810, so some measure of economic recovery is apparent over the past ten years.

Throughout the period when the Harmon Base was in operation, the local economy was almost entirely dependent on the Base. Since the Base closed, the Harmon Corporation has been encouraging expanded and more diversified economic activity. Though the Town is now heavily reliant on the Linerboard Mill for its prosperity, it now has a much sounder economic base than at any time prior to the departure of the Americans.

The floodplain itself has never figured very prominently in the local economy. The few residential properties located on it represent only a small proportion of existing and planned housing facilities in the Town. Although there is a large absolute amount of commercial and industrial investment in the vulnerable area, proportionately this investment is not particularly significant. Total employment by enterprises within the approximate 100 year flood line is estimated to be only about 50 people Apart from the Labatt's Brewery located at the confluence, there is no major employer likely to be affected by flooding.

Some new construction has taken place on the floodplain in recent years. The Federal Building is one example, and the owner of T and J's Motel was recently granted a building permit which enabled him to expand his facilities even though a flood warning appeared on the permit. Both the brewery and Humber Motors began operations in their current locations after the Harmon Corporation was formed. Virtually no residential construction has occurred on the floodplain since the municipal plan became public knowledge and restrictions were placed on development in the floodplain (See Figure 3).

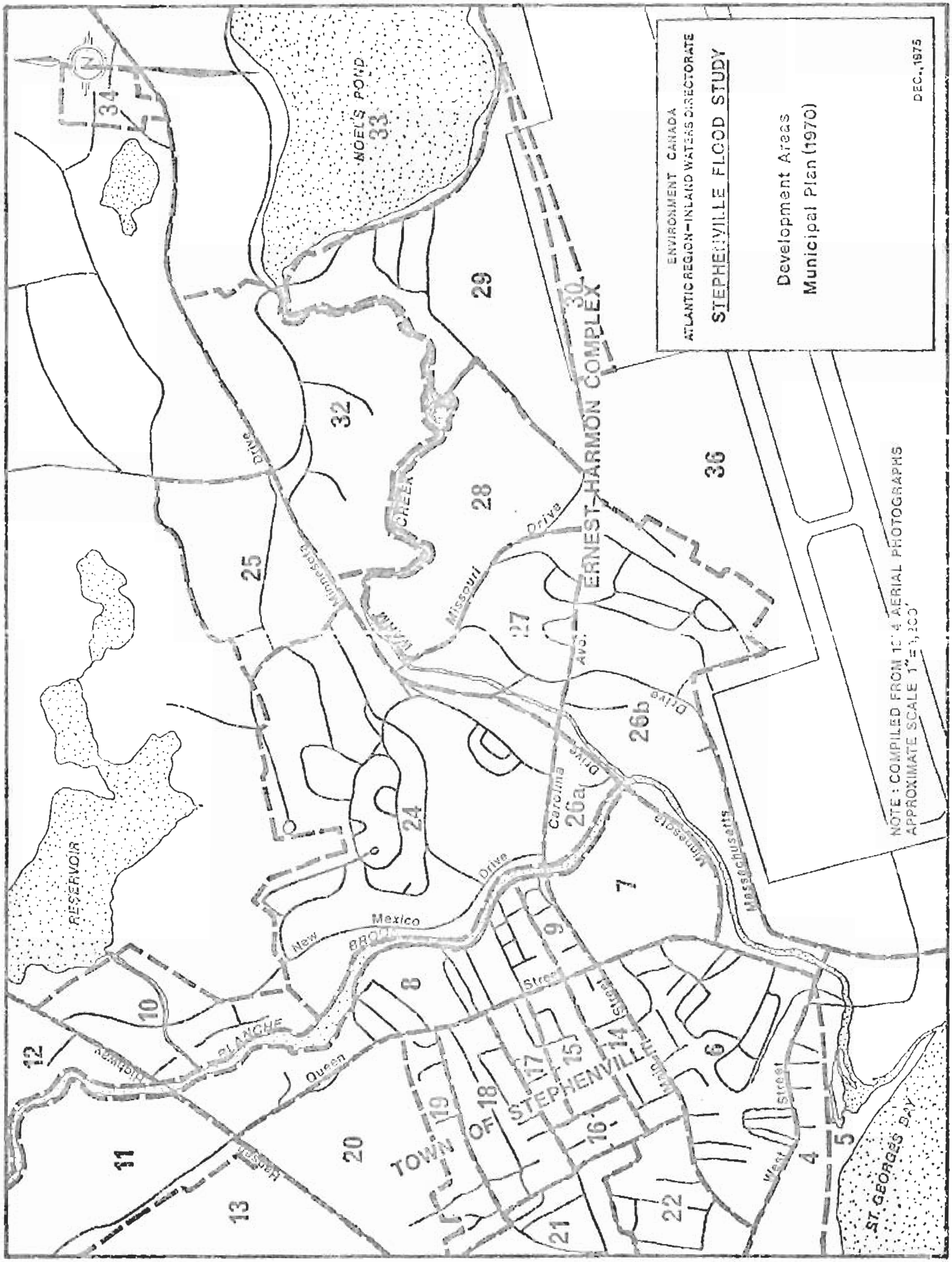

ENVIRONMENT CANADA
ATLANTIC REGION—INLAND WATERS DIRECTORATE
STEPHENVILLE FLOOD STUDY
Development Areas
Municipal Plan (1970)
DEC., 1975
ERNEST HARMON COMPLEX
TOWN OF STEPHENVILLE
NOEL'S POND
RESERVOIR
ST. GEORGES BAY
New Mexico Drive
Missouri Drive
Carolina Ave.
Massachusetts
West Street
Queen
Minnesota
Drive

FIGURE 3

In short, although economic investment on the floodplain is substantial, it does not represent a large proportion of the total industrial or housing stock and much of it was placed on the floodplain after the Harmon Base was closed.

4. REVIEW OF PAST FLOODS

No reliable documentation could be found for any flood prior to 1969. It is known that periodic flooding has occurred but the only available evidence of this is the fact that the N.C.O. Club (where Humber Motors is presently situated) had experienced flooding up to 2 feet on the main floor at different times.

However, it is known that the flooding events described below were not as severe as future floods are likely to be, based on a review of meteorological records.

4.1 Flood of May 19-21, 1969:

Heavy snowmelt combined with severe rain caused high flows in both Warm Creek and Blanche Brook. Ice was apparently not a large factor in this flood.

On Blanche Brook, the residential area upstream of Main Street was flooded as the banks were overtopped at bends in the river located near Mill Place and Maxwell Avenue. Flood waters flowed through local depressions approximately parallel to the river, flooding several basements and some outside property.

Most of the flood waters returned to the Brook just above the Main Street Bridge, but Main Street was also overtopped near the present Federal Building allowing some of the overbank flow to rejoin Blanche Brook several hundred feet below the bridge.

Backup of water at the Mississippi Drive bridge on Warm Creek caused overtopping and erosion of the roadway. Overbank flow occurred west of the bridge between the church and overpass embankment, then under the overpass to the area below the Carolina Avenue Bridge.

Near the confluence of Warm Creek and Blanche Brook, flood waters covered the field near the curling rink and the brewery. Another area flooded was on the airport side of Blanche Brook above the present St. Stephen's Recreation Centre Bridge, but no damage was reported at this location. Various municipal agencies assisted in flood relief, and the Town provided fill at cost to residents who sustained erosion damage.

Following the 1969 flood, the Town initiated a program to alleviate the problem. During the summer of 1970, the channel of Blanche Brook was deepened and materials dredged from the channel were used to form rudimentary dykes. The work was done by the Heavy Equipment School at a minimal cost to the Town. During this bulldozing operation a water line was severed. This line was repaired, but the new cover was insufficient to withstand the ice gouging that occurred during the spring flood in 1973.

4.2 Flood of May 15-17, 1972:

Spring runoff combined with rainfall caused Warm Creek to rise, wash out the causeway at Mississippi Drive, and threaten the bridge on Caroline Avenue. It was necessary to erect temporary dykes along the edge of Warm Creek to protect the low ground around the Harmon gymnasium and the brewery.

Debris carried by the floodwaters clogged the culverts under the bridge on Mississippi Drive, forcing water to flow over the bridge itself and the pavement at both ends (see Figure 4). Before the water washed out the roadway, work crews attempted, unsuccessfully to clear the blocked culverts.

Flood waters backed up behind a culvert bridge on Missouri Drive, the water flowed over the pavement, and formed a waterfall over the edge until a section of earthfill (about 10' - 15' thick) collapsed (see Figure 4). The remains of this structure were later removed to clear the channel. The road has never been rebuilt.

4.3 Flood of February 2-3, 1973:

The worst recorded ice conditions in the history of the Town occurred on Blanche Brook when floating ice piled up across the Main Street Bridge (see Figure 5). The wooden sidewalk on the Bridge had to be replaced, but the bridge itself was not damaged. The Canada Manpower Office and Building 450 on the Harmon Complex were slightly damaged when ice was forced against them.

All buildings close to the Main Street Bridge had their parking lots blocked with ice which was piled up to 10 feet high in places. Water rose almost to the floor level of the Indian Head Co-op, and also flooded Minnesota Drive opposite the brewery. Flooding of the brewery was prevented by the temporary dykes which had been built in the Spring of 1972 when similar, but less extensive flooding occurred in the area.

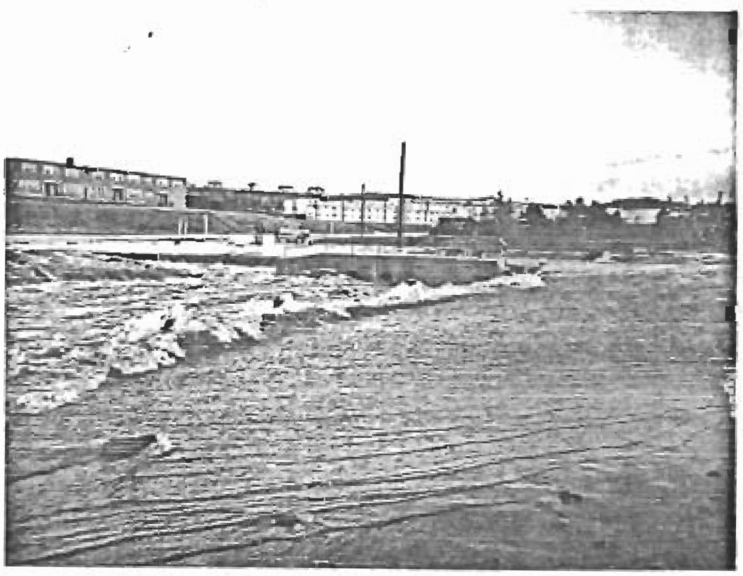
FLOOD OF MAY 15 - 17, 1972
SELECTED PHOTOGRAPHS

The Georgian

The Western Star

The Western Star

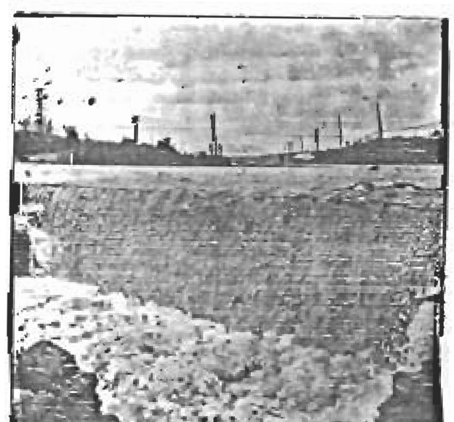
MISSISSIPPI DRIVE



The Georgian

MISSISSIPPI DRIVE

MISSOURI DRIVE



The Western Star

FIGURE 4

FLOOD OF FEB. 2-3, 1973
SELECTED PHOTOGRAPHS

The Georgian

MAIN STREET BRIDGE

The Western Star

The Western Star

FLOOD OF NOV. 1, 1974
SELECTED PHOTOGRAPH

DYKE NEAR LABATT'S BREWERY

FIGURE 5

4.4 Flood of August 2-3, 1973:

The worst recorded flooding in the Town's history occurred when a late summer storm dumped two inches of rain on the area. The main highway into the Town was under water in at least two places and a bridge was washed out near Wheeler's Night Club above Noel's Pond.

Basements in the Mill Place area were flooded as Blanche Brook swelled to several times its normal size. The water line which was damaged during the 1969 flood, and which had been left dangerously exposed by ice gouging in the Spring flood of 1973, was severed again. Many residents were without water for about two days until the line was repaired. The Town then spent approximately $21,000 on encasing the line in concrete and burying it deeply enough to avoid future problems from ice gouging.

Potentially severe damages were averted at the Hanson Highway and Main Street bridges by clearing several truck-loads of trees and other debris from behind the bridges. Even so, the bridges were sufficiently blocked to cause some concern for their safety (see Figure 6).

High water broke through the temporary dykes protecting the brewery and reached a height of about 1.5 feet above flood level. Damages of approximately $70,000 were inflicted on the assets of the brewery (see Figure 7). Interior materials and equipment as well as inventories of both goods in process and finished goods were damaged.

Some damage was inflicted on the residential area north of Main Street (Development Area 8), but by far the most severe effects were felt at the brewery.

4.5 Flood of November 1, 1974:

Heavy rain caused flooding problems at Cold Brook, Noel's Pond and Stephenville. The community of Cold Brook was isolated by the washout of the wooden bridge on the main road connecting that community with Stephenville. Residents of Noel's Pond (Wheeler's area) were also reported to have experienced flooding. The Blanche Brook channel had become swollen and the Town's Works Department was hard pressed to prevent debris from piling up underneath the Hanson Highway Bridge (see Figure 5).

FLOOD OF AUG. 2-3, 1973
SELECTED PHOTOGRAPHS

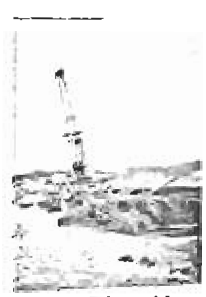
The Georgian

The Western Star

The Western Star

MAIN STREET BRIDGE

The Western Star



The Western Star

HANSON HIGHWAY BRIDGE

PHOTOGRAPHS OF BREWERY
FLOOD OF AUG. 2-3, 1973

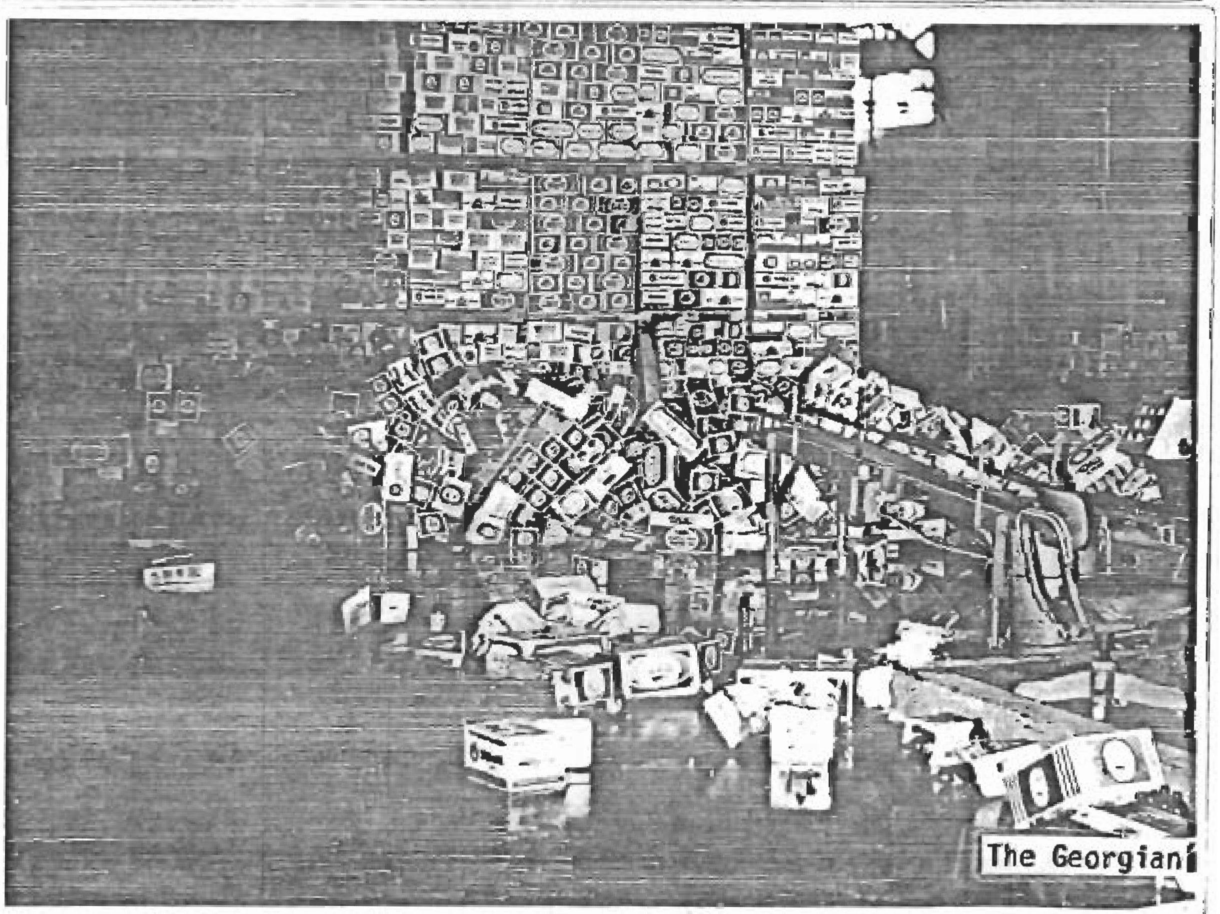


FIGURE 7

5. AREAS SUBJECT TO INUNDATION

This section of the report deals with the delineation of the extent of flooding under 1:100 year, 1:20 year, and mean annual recurrence interval floods. It should be borne in mind that the flood hazard map as developed is based on existing river channel conditions, and a variety of assumptions that are described below. The following paragraphs summarize the various steps taken in the preparation of the flood hazard map. For a more detailed accounting of the procedures followed, the reader is referred to Appendix C.

In this report, the 1:100 year recurrence interval flood is defined to have a 1% chance of occurring in any given year; the 1:20 year flood is defined to have a 5% chance of occurring in any given year and the mean annual flood, which is the arithmetic mean of each annual flood over a long period, is defined to have a 50% chance (approximate) of occurring in any given year. The 1:100 year flood, for example, would occur (statistically) once in a 100 year period. However, there is a chance, albeit small, that the 1:100 year flood could occur two years in a row or even twice within the same year.

5.1 The Base Map

To develop an accurate flood hazard map it is essential to have a suitable and accurate topographic map. Two basic sources were employed in developing the base map used in this study. These were:

1) Basic Layout Plan, Ernest Harmon Complex: Scale: 1" = 400 feet, Contour Interval: 5 feet; Compiled by Henningson, Durham and Richardson Inc., Omaha, Nebraska for the U. S. Department of the Air Force and;

2) Topographic Mapping, Town of Stephenville; Scale: 1" = 200 feet, Contour Interval: 5 feet; Compiled by the Photographic Survey Corporation Ltd. based on 1958 photographs and revised based on May 1963 and September 1966 photographs.

The former map was blown up to a scale of 1" = 200 feet and spliced with the latter to form the base map. The mapping of the Harmon Complex appears in places to be distorted, therefore the final base map is not of uniform quality. However, using information obtained in field surveys, the topographic features of the floodplain were revised and brought up to a consistent and relatively accurate state. However, no changes were made to the basic planimetric map.

5.2 Water Surface Profiles

Water surface profiles were developed for the Mean Annual, 1:20 year and 1:100 year recurrence interval floods under three conditions; (1) no blockage (ice and debris) at constrictions, (2) 50% blockage at each constriction and (3) 100% blockage at each constriction.

5.2.1 Mean Annual Flood

The water surface profile developed for the mean annual flood is shown on Figure 8 and on Table 2 for Blanche

Brook and on Figure 9 and Table 3 for Warm Creek respectively. The solid lines on Figures 8 and 9 represent the estimated water surface profiles under free flowing conditions. The water surface profile for the situation when each of the constrictions would be fully blocked by ice and debris is shown on Figures 8 and 9 by a dashed line and tabulated on Tables 2 and 3 for Blanche Brook and Warm Creek respectively. (Profiles were also developed for the condition when the cross-section would be reduced by 50% at each constriction, but these are omitted here)

5.2.2 1:20 Year Recurrence Interval Flood

The water surface profile developed for the 1:20 year recurrence interval flood is shown on Figure 10 and on Table 2 for Blanche Brook and on Figure 11 and on Table 3 for Warm Creek.

5.2.3 1:100 Year Recurrence Interval Flood

The water surface profile developed for the 1:100 year recurrence interval flood is shown on Figure 12 and on Table 2 for Blanche Brook and on Figure 13 and on Table 3 for Warm Creek.

5.3 Delineation of Flood Hazard Areas

The areal extent of flooding was determined by applying the water surface elevations derived for the Mean Annual and 1:100 year recurrence interval floods to the topographic base map. It must be pointed out that, as available mapping showed only 5 foot contour intervals, the areal extent of flooding in general could be defined

TABLE 2

WATER SURFACE PROFILES[1]

BLANCHE BROOK

STATION	CHAINAGE (feet)	1:100 YEAR RECURRENCE INTERVAL FLOOD		1:20 YEAR RECURRENCE INTERVAL FLOOD		MEAN ANNUAL FLOOD	
		OPEN WATER CONDITION (feet)	100% BLOCKAGE CHANNEL CONSTRICTIONS (feet)	OPEN WATER CONDITION (feet)	100% BLOCKAGE CHANNEL CONSTRICTIONS (feet)	OPEN WATER CONDITION (feet)	100% BLOCKAGE CHANNEL CONSTRICTIONS (feet)
BB-1	0+00						
	0+40	11.0	14.6	9.0	14.4	9.0	13.8
BB-2	5+24	11.2	14.6	10.0	14.4	9.5	13.8
BB-3	19+99	20.0	20.0	19.2	19.2	15.3	16.3
BB-4	32+34	23.9	23.9	22.8	22.8	21.0	21.0
	36+44	24.4	24.4	23.6	23.6	22.3	22.3
	37+04	24.7	25.6	23.9	25.0	22.5	24.8
BB-5	38+44	24.8	25.6	24.0	25.0	22.9	24.8
	44+64	29.1	29.1	28.5	28.5	27.3	27.5
BB-6	47+64	31.5	31.5	31.1	31.1	30.3	30.3
	48+34	33.1	33.1	32.5	32.5	31.9	31.9
BB-7	49+56	35.2	38.1	33.2	38.0	33.0	37.7
BB-8	53+34	38.3	39.0	36.8	39.0	35.2	38.7
BB-9	62+34	51.6	51.6	50.3	50.3	48.0	48.0
	67+24	55.0	58.5	54.2	57.5	53.0	56.7
BB-10	73+24	61.4	61.4	61.1	61.1	60.5	60.5
BB-11	78+84	69.0	69.0	68.4	68.4	67.3	67.3
BB-12	82+34	73.0	73.0	72.6	72.6	71.5	71.5
BB-13	88+24	81.3	81.3	80.7	80.7	79.7	79.7
BB-15	96+14	92.0	92.0	91.4	91.4	90.2	90.2
BB-16a	99+84	96.1	103.0	95.6	102.8	94.8	102.4
BB-17	104+34	102.6	103.7	101.9	103.4	100.3	102.8
BB-18	110+74	109.9	109.9	109.4	109.4	108.5	108.5

[1] ALL ELEVATIONS REFERRED TO GSC DATUM

TABLE 3

WATER SURFACE PROFILES[1]

WARM CREEK

STATION	CHAINAGE (feet)	1:100 YEAR RECURRENCE INTERVAL FLOOD — OPEN WATER CONDITION (feet)	1:100 YEAR RECURRENCE INTERVAL FLOOD — 100% BLOCKAGE CHANNEL CONSTRICTIONS (feet)	1:20 YEAR RECURRENCE INTERVAL FLOOD — OPEN WATER CONDITION (feet)	1:20 YEAR RECURRENCE INTERVAL FLOOD — 100% BLOCKAGE CHANNEL CONSTRICTIONS (feet)	MEAN ANNUAL FLOOD — OPEN WATER CONDITION (feet)	MEAN ANNUAL FLOOD — 100% BLOCKAGE CHANNEL CONSTRICTIONS (feet)
Intersection of Warm Creek with Blanche Bk	0+00	24.4[2]	24.4[2]	23.3[2]	23.3[2]	22.0[2]	22.0[2]
W-16	3+70	25.5	25.5	25.0	25.0	23.7	23.7
W-1	9+47	30.3	31.4	30.3	31.1	29.5	30.8
W-2	12+02	31.0	31.4	31.0	31.5	29.9	30.9
	15+77	31.0	31.0	31.3	31.6	30.5	31.0
	16+17	32.2	32.2	32.0	32.0	31.6	31.6
	16+73	36.5	37.5	36.4	37.3	36.1	35.8
W-4	18+05	36.4	36.4	36.1	36.1	35.8	35.8
W-5	21+10	39.5	39.5	38.6	38.6	37.5	37.5
	26+33	51.4	51.4	50.0	50.0	48.5	48.5
	28+75	55.5	57.5	51.8	57.0	52.5	55.6
	31+76	56.2	56.2	55.4	--	54.5	55.6
W-7	34+20	59.2	59.2	56.2	58.2	56.8	56.9
	40+33	63.0	63.0	62.5	62.5	61.0	63.0
W-8	45+73	67.5	69.0	67.0	68.8	63.6	67.0
W-9	48+35	68.2	69.2	67.5	69.0	64.4	67.2
	55+10	69.6	70.0	69.1	69.7	66.9	68.2
	56+95	73.6	73.9	73.3	73.6	72.5	73.1
W-10	65+25	73.6	73.9	71.3	73.7	72.6	73.1
W-11	76+35	73.8	74.1	73.4	73.8	72.7	73.2
W-12	87+35	75.0	75.1	74.5	74.6	73.7	74.0
	91+75	76.7	75.7	75.9	75.9	74.7	74.7
	92+31	77.2	80.3	76.5	80.1	75.1	79.7
	93+15	77.2	82.0	76.5	81.7	75.2	81.0
Noels Pond		77.7	82.2	77.2	82.0	75.3	81.2

1 ALL ELEVATIONS REFERRED TO GSC DATUM

2 ELEVATIONS TAKEN FROM BLANCHE BROOK FLOOD PROFILES

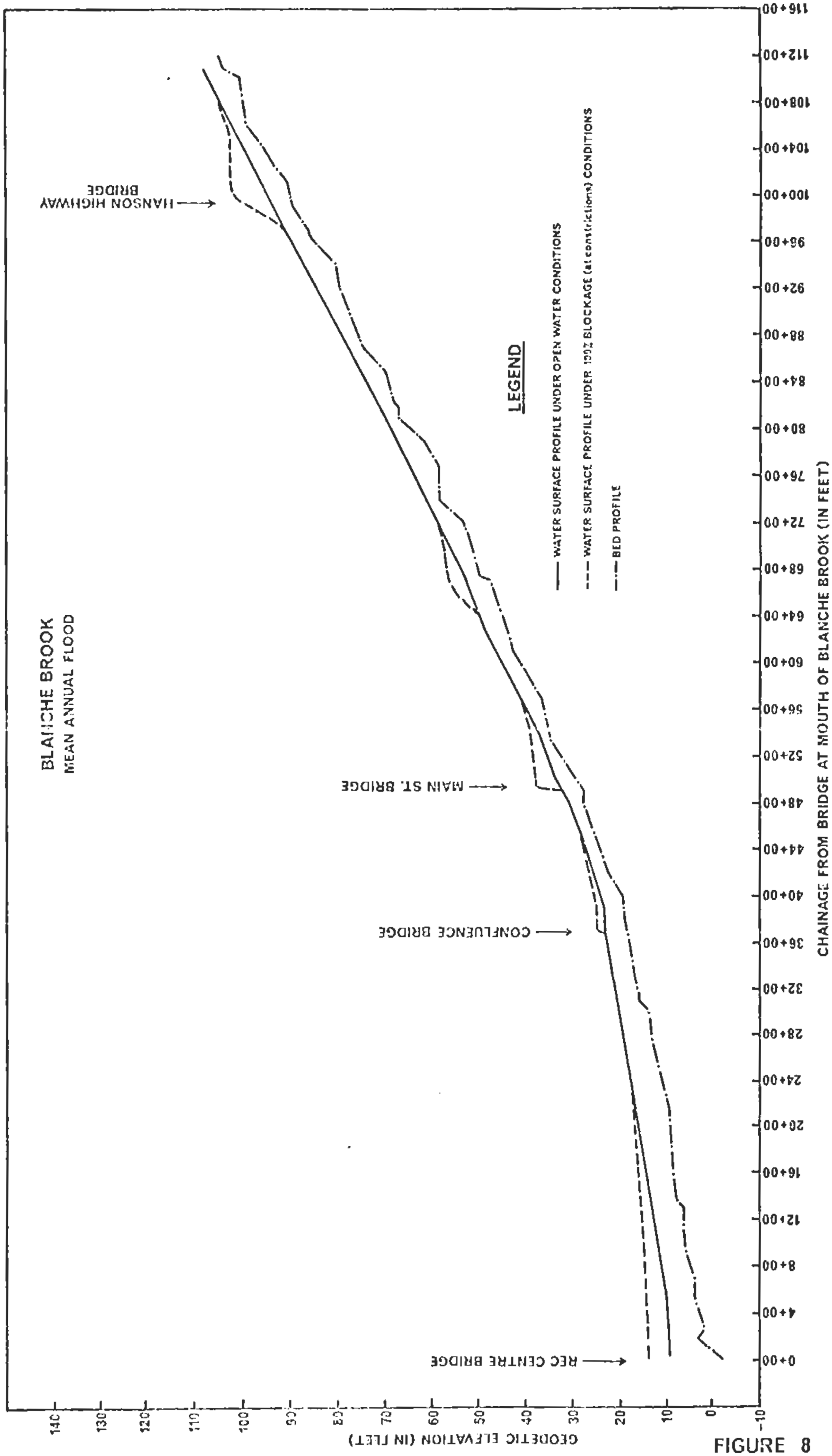

BLANCHE BROOK
MEAN ANNUAL FLOOD
LEGEND
WATER SURFACE PROFILE UNDER OPEN WATER CONDITIONS
WATER SURFACE PROFILE UNDER 100% BLOCKAGE (at constrictions) CONDITIONS
BED PROFILE
HANSON HIGHWAY BRIDGE
MAIN ST. BRIDGE
CONFLUENCE BRIDGE
REC CENTRE BRIDGE
GEODETIC ELEVATION (IN FEET)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
CHAINAGE FROM BRIDGE AT MOUTH OF BLANCHE BROOK (IN FEET)
0+0
4+00
8+00
12+00
16+00
20+00
24+00
28+00
32+00
36+00
40+00
44+00
48+00
52+00
56+00
60+00
64+00
68+00
72+00
76+00
80+00
84+00
88+00
92+00
96+00
100+00
104+00
108+00
112+00
116+00

FIGURE 8

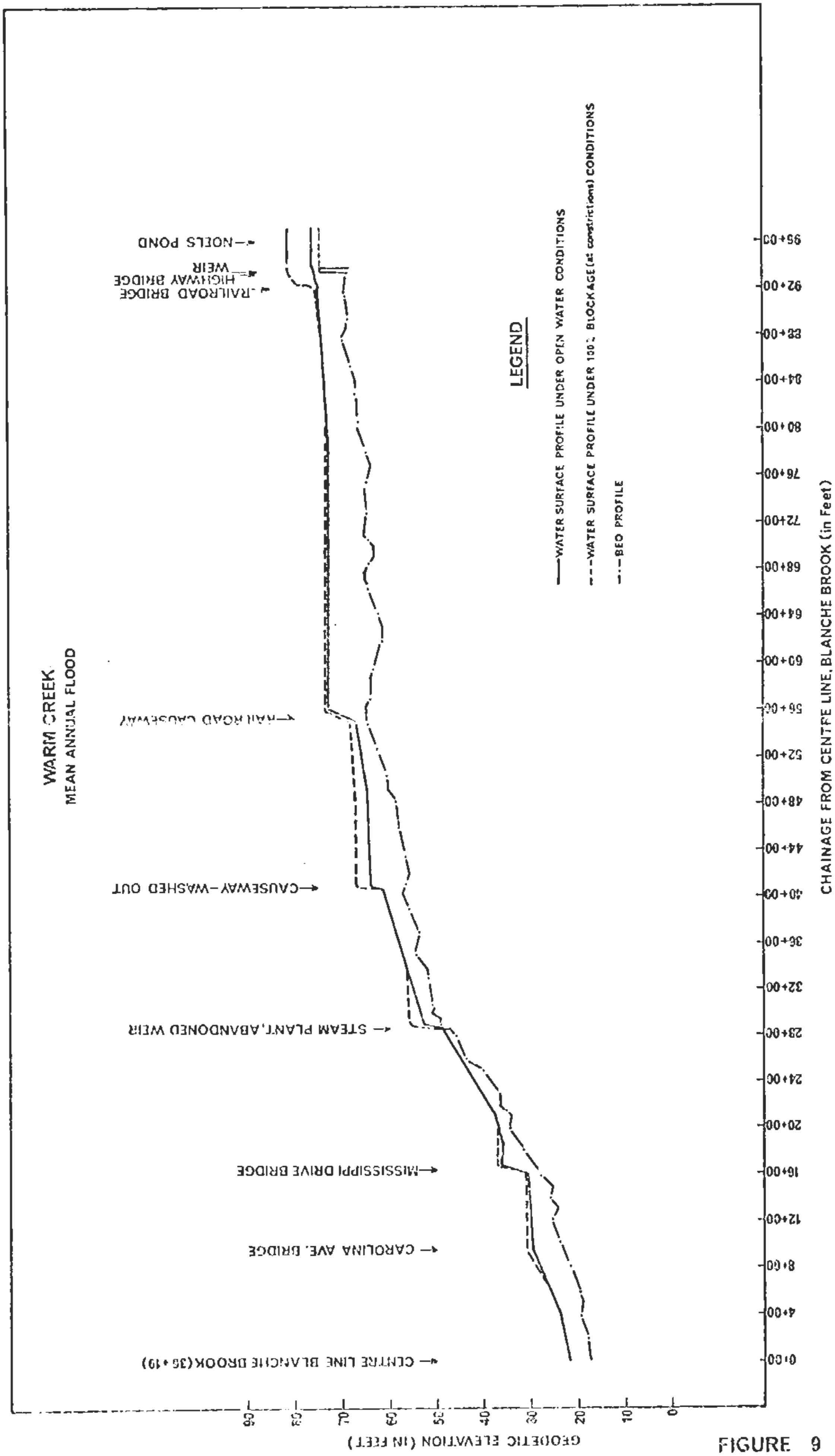
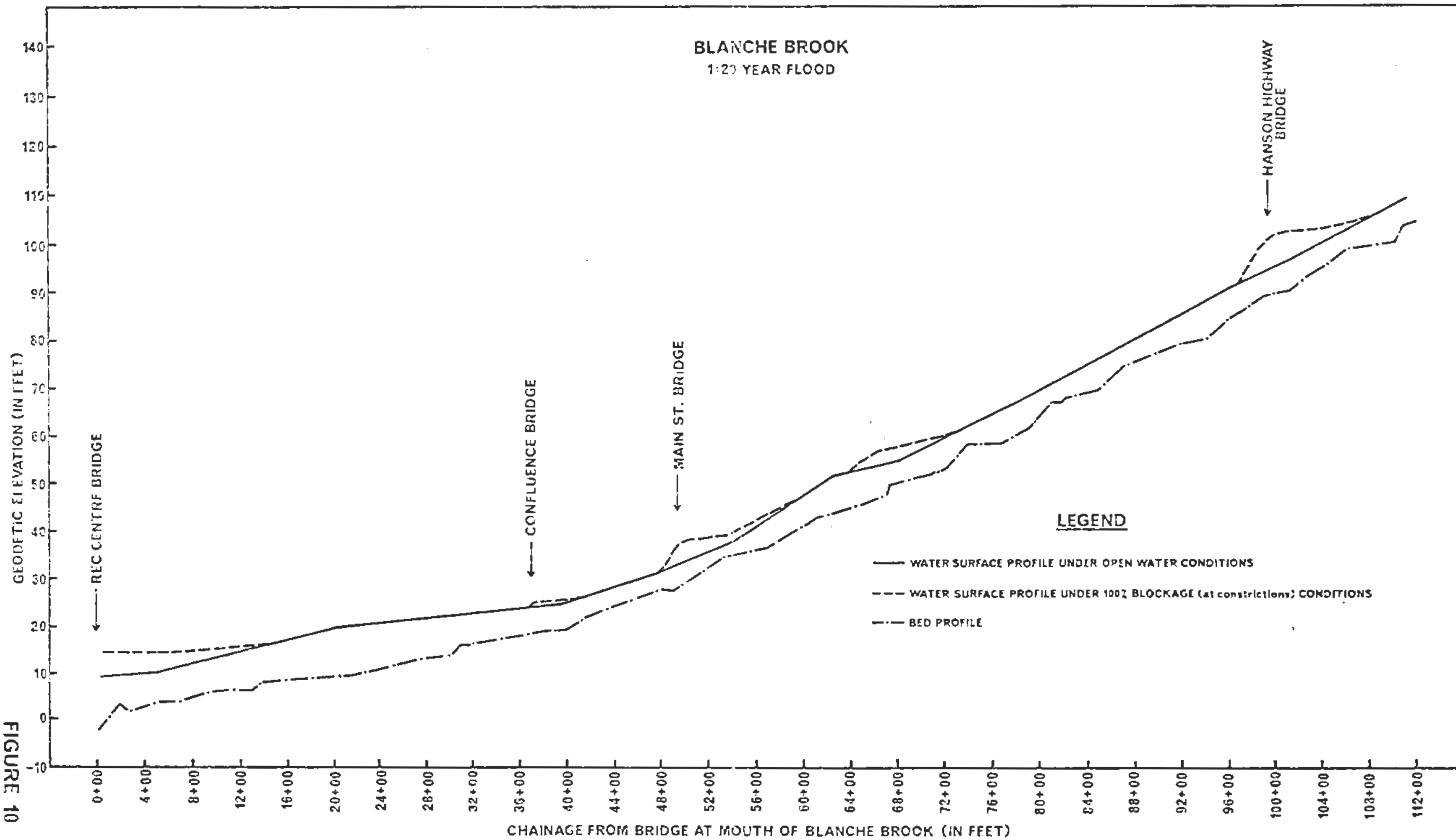

WARM CREEK
MEAN ANNUAL FLOOD
LEGEND
WATER SURFACE PROFILE UNDER OPEN WATER CONDITIONS
WATER SURFACE PROFILE UNDER 100% BLOCKAGE (at constrictions) CONDITIONS
BED PROFILE
NOELS POND
WEIR
HIGHWAY BRIDGE
RAILROAD BRIDGE
RAILROAD CAUSEWAY
CAUSEWAY-WASHED OUT
STEAM PLANT, ABANDONED WEIR
MISSISSIPPI DRIVE BRIDGE
CAROLINA AVE. BRIDGE
CENTRE LINE BLANCHE BROOK (35+19)
0+00
4+00
8+00
12+00
16+00
20+00
24+00
28+00
32+00
36+00
40+00
44+00
48+00
52+00
56+00
60+00
64+00
68+00
72+00
76+00
80+00
84+00
88+00
92+00
96+00
CHAINAGE FROM CENTRE LINE, BLANCHE BROOK (in Feet)
0
10
20
30
40
50
60
70
80
90
GEODETIC ELEVATION (IN FEET)

FIGURE 9



BLANCHE BROOK
1:20 YEAR FLOOD
HANSON HIGHWAY BRIDGE
MAIN ST. BRIDGE
CONFLUENCE BRIDGE
REC CENTRE BRIDGE
LEGEND
WATER SURFACE PROFILE UNDER OPEN WATER CONDITIONS
WATER SURFACE PROFILE UNDER 100% BLOCKAGE (at constrictions) CONDITIONS
BED PROFILE
GEODETIC ELEVATION (IN FEET)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
0+00
4+00
8+00
12+00
16+00
20+00
24+00
28+00
32+00
36+00
40+00
44+00
48+00
52+00
56+00
60+00
64+00
68+00
72+00
76+00
80+00
84+00
88+00
92+00
96+00
100+00
104+00
103+00
112+00
116+00
CHAINAGE FROM BRIDGE AT MOUTH OF BLANCHE BROOK (IN FEET)

FIGURE 10

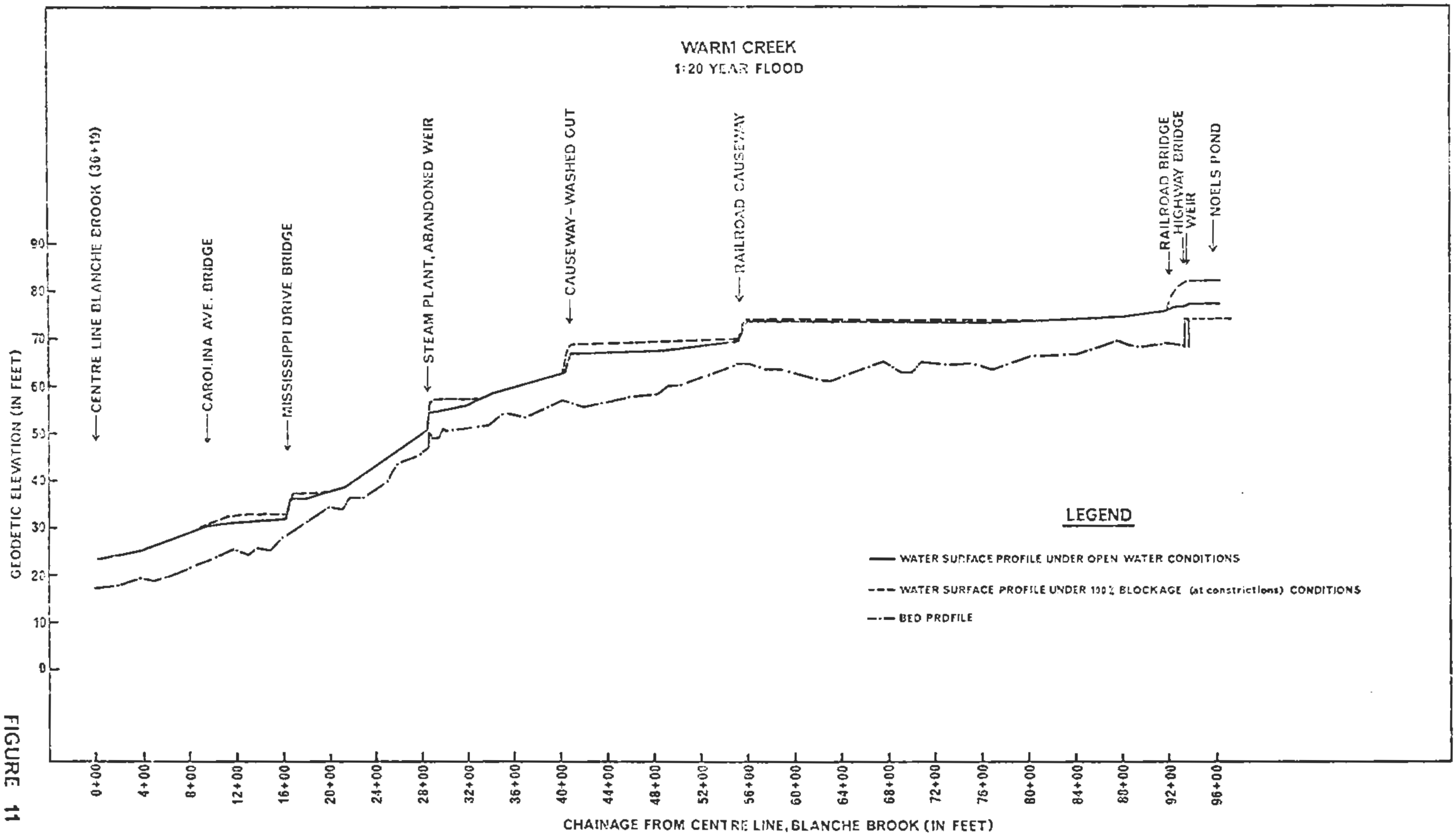

WARM CREEK
1:20 YEAR FLOOD
CENTRE LINE BLANCHE BROOK (36+19)
CAROLINA AVE. BRIDGE
MISSISSIPPI DRIVE BRIDGE
STEAM PLANT, ABANDONED WEIR
CAUSEWAY-WASHED CUT
RAILROAD CAUSEWAY
RAILROAD BRIDGE
HIGHWAY BRIDGE
WEIR
NOELS POND
LEGEND
WATER SURFACE PROFILE UNDER OPEN WATER CONDITIONS
WATER SURFACE PROFILE UNDER 100% BLOCKAGE (at constrictions) CONDITIONS
BED PROFILE
GEODETIC ELEVATION (IN FEET)
0
10
20
30
40
50
60
70
80
90
0+00
4+00
8+00
12+00
16+00
20+00
24+00
28+00
32+00
36+00
40+00
44+00
48+00
52+00
56+00
60+00
64+00
68+00
72+00
76+00
80+00
84+00
88+00
92+00
96+00
CHAINAGE FROM CENTRE LINE, BLANCHE BROOK (IN FEET)

FIGURE 11

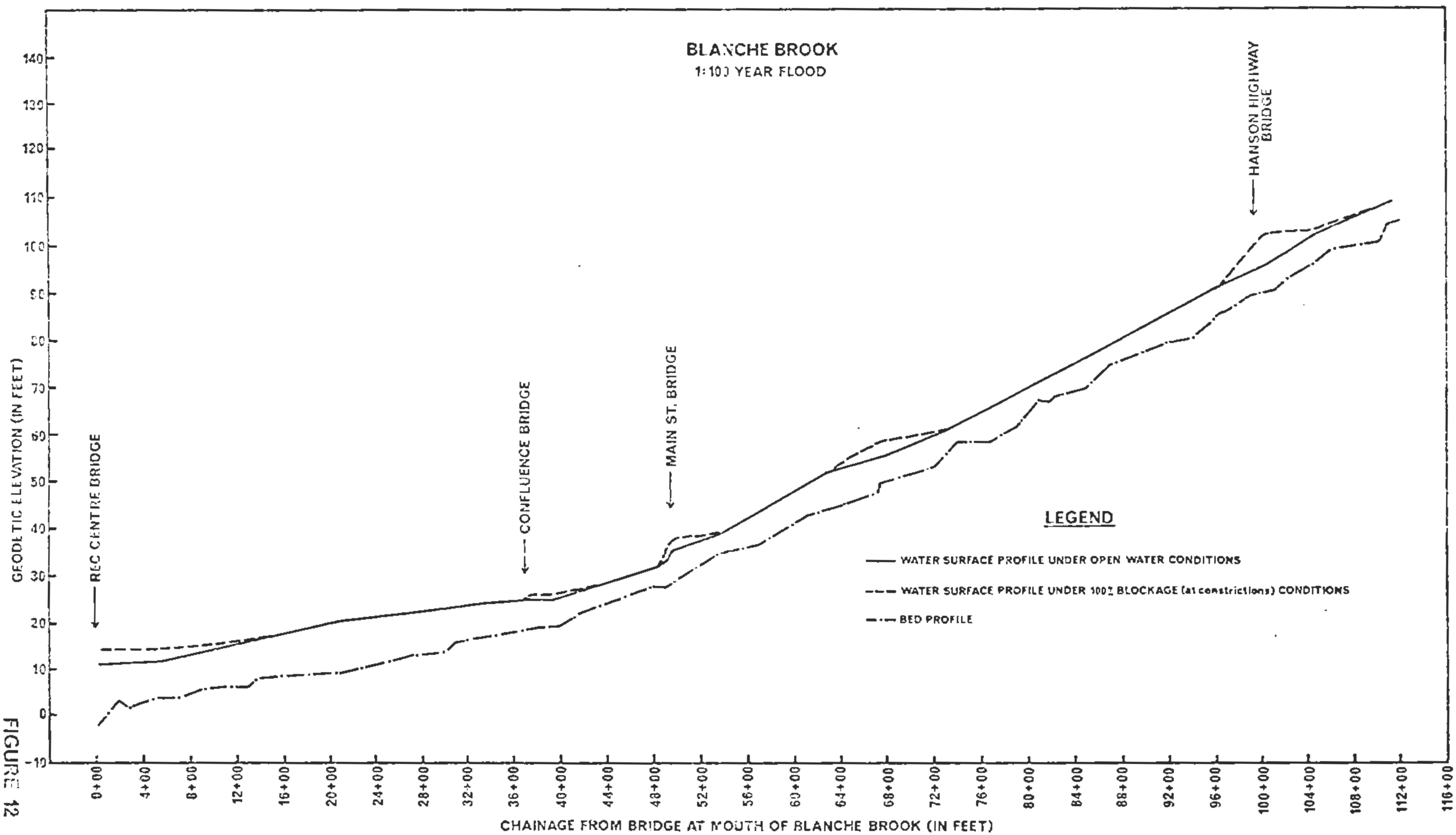

BLANCHE BROOK
1:100 YEAR FLOOD
REC CENTRE BRIDGE
CONFLUENCE BRIDGE
MAIN ST. BRIDGE
HANSON HIGHWAY BRIDGE
LEGEND
WATER SURFACE PROFILE UNDER OPEN WATER CONDITIONS
WATER SURFACE PROFILE UNDER 100% BLOCKAGE (at constrictions) CONDITIONS
BED PROFILE
GEODETIC ELEVATION (IN FEET)
CHAINAGE FROM BRIDGE AT MOUTH OF BLANCHE BROOK (IN FEET)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
0+00
4+00
8+00
12+00
16+00
20+00
24+00
28+00
32+00
36+00
40+00
44+00
48+00
52+00
56+00
60+00
64+00
68+00
72+00
76+00
80+00
84+00
88+00
92+00
96+00
100+00
104+00
108+00
112+00
116+00

FIGURE 12

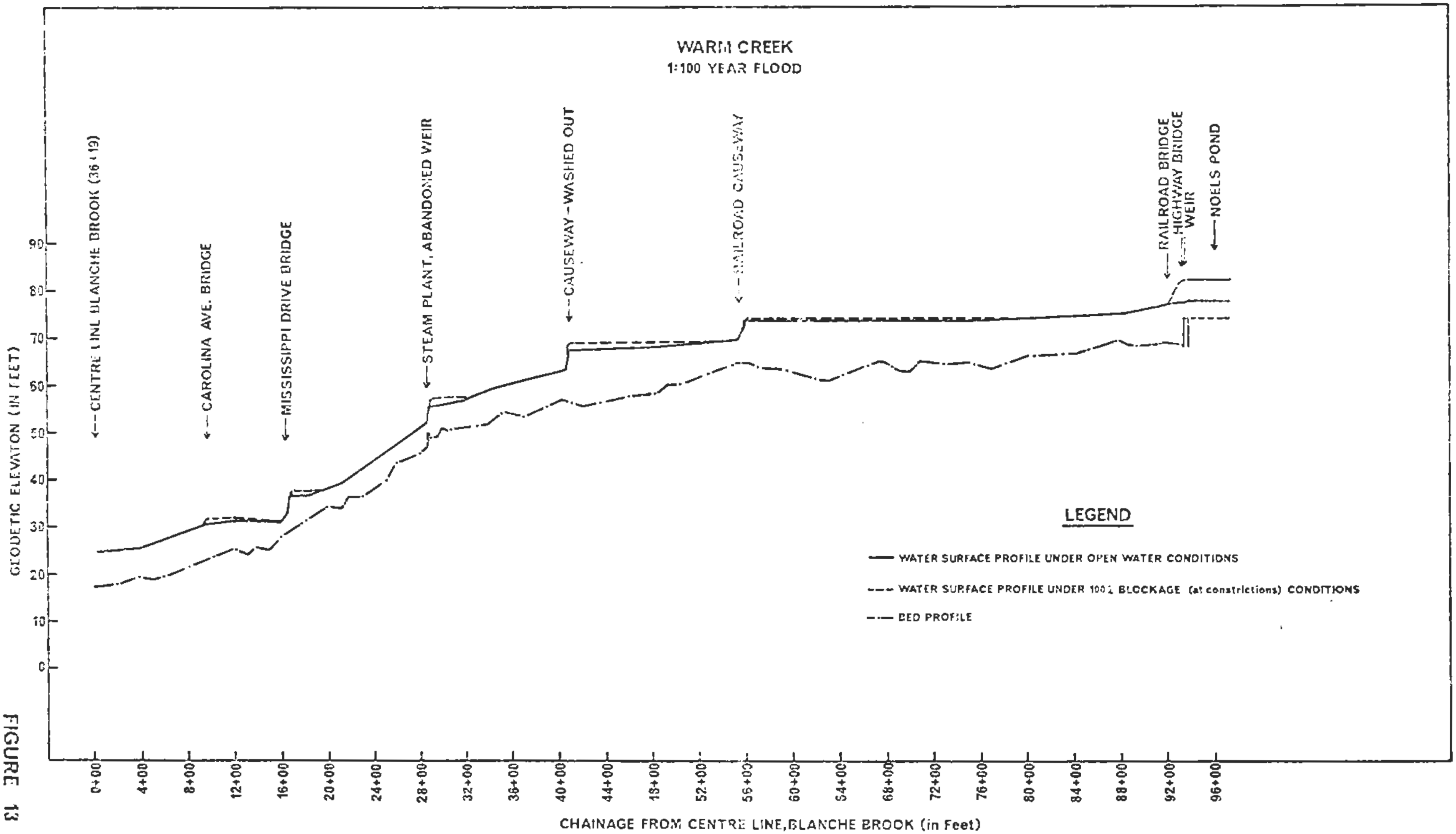

WARM CREEK
1:100 YEAR FLOOD
CENTRE LINE BLANCHE BROOK (36+19)
CAROLINA AVE. BRIDGE
MISSISSIPPI DRIVE BRIDGE
STEAM PLANT, ABANDONED WEIR
CAUSEWAY - WASHED OUT
RAILROAD CAUSEWAY
RAILROAD BRIDGE
HIGHWAY BRIDGE
WEIR
NOELS POND
LEGEND
WATER SURFACE PROFILE UNDER OPEN WATER CONDITIONS
WATER SURFACE PROFILE UNDER 100% BLOCKAGE (at constrictions) CONDITIONS
BED PROFILE
GEODETIC ELEVATON (IN FEET)
90
80
70
60
50
40
30
20
10
0
0+00
4+00
8+00
12+00
16+00
20+00
24+00
28+00
32+00
36+00
40+00
44+00
48+00
52+00
56+00
60+00
64+00
68+00
72+00
76+00
80+00
84+00
88+00
92+00
96+00
CHAINAGE FROM CENTRE LINE, BLANCHE BROOK (in Feet)

FIGURE 13

only within ± 2.5 feet in the vertical. However, it is believed that the ground survey information has improved the accuracy to ± 1 foot. Nevertheless, it was extremely difficult in some instances to discern appreciable differences in areas flooded between the Mean Annual and 1:100 year events. The key element in assessing the actual hazard of a particular flood situation is the depth of flooding and in some instances the velocity of the flood waters. In this study, three factors were considered in defining the flood regime: (1) the areal extent of flooding, (2) the depth of the flood waters, and (3) the velocity of the flood waters.

Certain assumptions, basic to these factors, were necessary in defining the flood hazard areas. These assumptions are explained below.

(1) The existing fill along the banks of Blanche Brook near the brewery will protect the brewery to a certain extent under minor floods. However, in view of the instability of the fill, as well as its relatively erodible nature, it is unlikely to provide substantial protection in a significant flood. It was therefore assumed in this study that the fill was a temporary measure and would not provide protection from even the mean annual flood.

(2) The blockage of the river channel at various constrictions by ice and debris is well documented

in the Stephenville area. Significant ice blockages have developed in the past on Blanche Brook, especially at the Main Street and Hanson Highway Bridges. In general, it was assumed that those bridges with piers would become fully blocked under extreme floods, while bridges with clear spans would become partially (50%) blocked. Because of the low hydraulic capacity of culvert causeways, it was immaterial which assumption was used. Under these assumptions the areal extent and depth of flooding immediately upstream of each major constriction would be similar despite the magnitude of the flood. The velocity of flood waters, however, would be significantly different.

(3) In certain areas, land may be flooded by waters diverted from the river channel upstream and which may not return to the river channel for a considerable distance downstream. An example of this occurs along Blanche Brook, where water at one point overtops Brookside Drive but does not re-enter the main channel for a considerable distance downstream. This has been termed "overland flooding" in contrast to "overbank flooding". The topographic detail available is inadequate to allow the extent of flooding in these areas to be outlined precisely. The flood

hazard maps as developed distinugish between overbank flooding and overland flooding.

5.3.1 Delineation of the Areal Extent of Flooding

Water surface elevations under the Mean Annual and 1:100 year recurrence interval floods were extracted from the water surface profiles (presented in paragraph 5.2) and applied to the topographic base map to determine the areal extent of flooding. Additional topographic detail obtained from the field surveys was also used, but this information was not plotted on the flood hazard map. The shaded areas on Maps 1 and 2 (see foldouts in back cover of report) represent the extent to which overbank flooding occurs under Mean Annual and 1:100 year floods respectively. The cross-hatched areas represent overland flooding. As was noted in the preceding paragraph, in most circumstances not all of the cross-hatched area would be subject to inundation. The exact location of flooded areas within the cross-hatched section would depend entirely on local topographic features. As such, the cross-hatched areas represent an exaggerated estimate of the areal extent of the hazard.

Because topographic detail is limited, and recognizing that design elevations may be more appropriate in terms of floodproofing new construction, water surface elevations are depicted on Maps 1 and 2 at various key locations.

5.3.2 Depth of Flooding

A key variable in estimating existing or future flood damage potential is the depth of flood waters relative to the elevation of damageable assets. The relative depths of flooding at various key locations on the floodplain are shown on Figure 14. For example, it is estimated, bearing in mind the assumption noted above, that the brewery floor would be under 5 feet and 2 feet of water for the 1:100 year and Mean Annual floods, respectively. Or, from another perspective, if a structure were to be constructed on the floodplain northeast of the confluence (Minnesota Drive) bridge, the minimum foundation elevation, to ensure flood protection against a 1:100 year flood, should be between 26 and 32 feet, depending on its location.

5.3.3 Velocity of Flood Waters

Another key parameter in terms of damage potential is the velocity of flood waters over the floodplain. Logically, velocities will diminish away from the river to a point where still water conditions exist. Any development on the floodplain must recognize this fact. For example, a structure on the floodplain northeast of the confluence bridge located in the grey area close to the river bank may impede flow and cause flooding upstream. In general, the cross-hatched areas on Maps 1 and 2 would be relatively low velocity zones with the possible exception of localized areas where the topographic features are riverine in nature. It is anticipated that velocities in the area of the brewery could be relatively damaging under a severe flood.

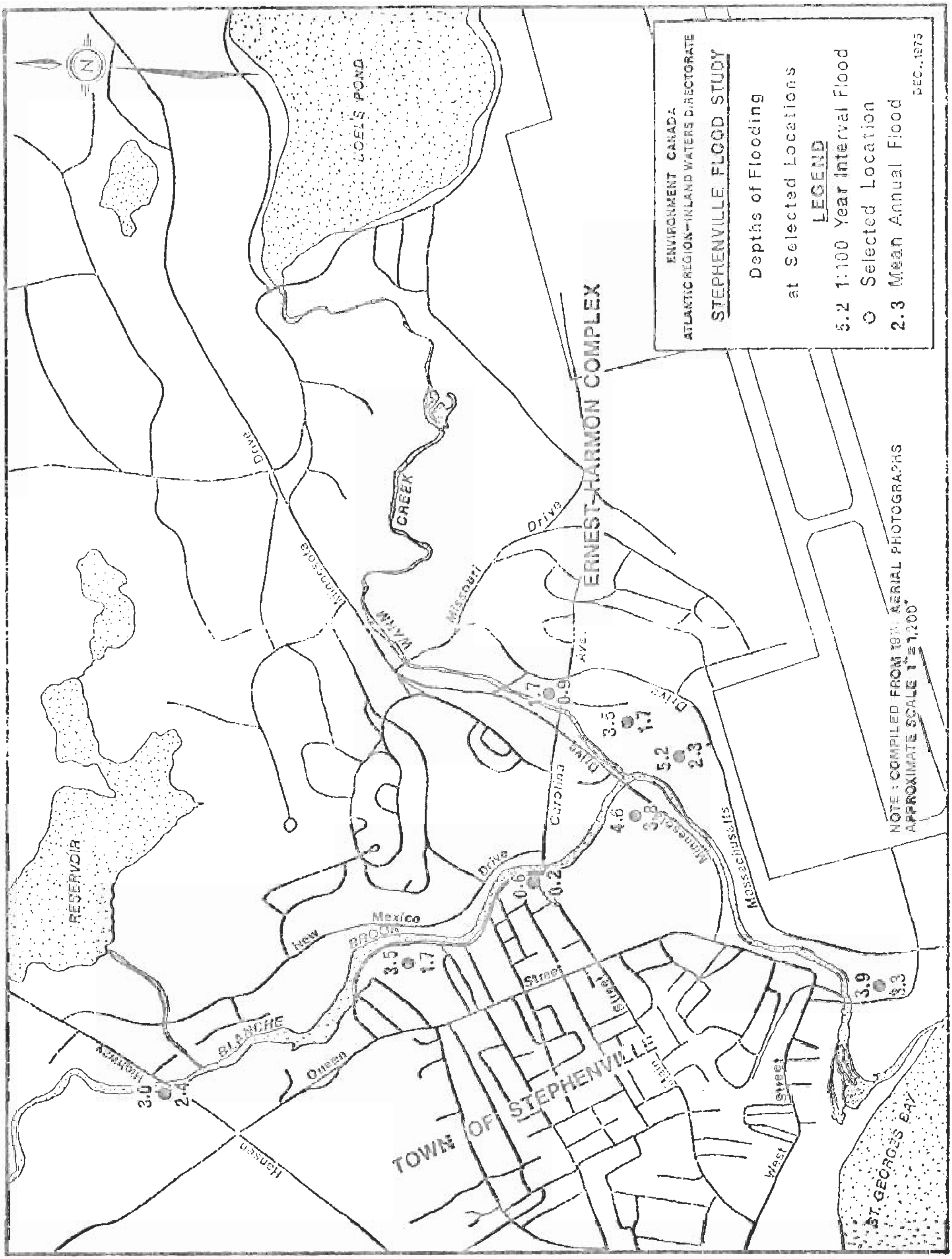

ENVIRONMENT CANADA
ATLANTIC REGION—INLAND WATERS DIRECTORATE
STEPHENVILLE FLOOD STUDY
Depths of Flooding
at Selected Locations
LEGEND
5.2 1:100 Year Interval Flood
O Selected Location
2.3 Mean Annual Flood
DEC., 1975
N
JOELS POND
ERNEST HARMON COMPLEX
CREEK
Drive
Minnesota
WARM
Missouri
Drive
Ave.
Drive
Carolina
Drive
Massachusetts
Massachusetts
RESERVOIR
New
Mexico
Drive
BROOK
BLANCHE
Street
Street
Queen
Hansen
Hansen
TOWN OF STEPHENVILLE
Main
Street
West
ST. GEORGES BAY
1.7
0.9
3.5
1.7
5.2
2.3
4.6
3.8
0.6
0.2
3.5
1.7
3.9
3.3
3.0
2.4
NOTE: COMPILED FROM 1971 AERIAL PHOTOGRAPHS
APPROXIMATE SCALE 1"=1,200'

FIGURE 14

6. FLOOD DAMAGE POTENTIAL

Prior to evaluating possible adjustments to the flood hazard, it is necessary to estimate the damages that would be caused by flooding at different stages, so that any proposed adjustments can be seen in their proper perspectives. Accordingly, this section of the report presents a discussion of flood damage potential in the Stephenville area.

The term "flood damage potential" may be defined in different ways. In this report it is defined as the degree to which physical assets of the residents of Stephenville are exposed to the flood hazard at any given moment in time. An attempt is made to quantify this degree of exposure in monetary terms, but it should be noted that most of these values are gross estimates only. This is so because the objective of the study was mainly to acquire impressions of the magnitude of the total problem rather than to attempt a detailed appraisal of the vulnerability of each asset located on the floodplain. These quantitative impressions are used as benchmarks for evaluating the various possible adjustments to the hazard.

Aside from its spatial aspects, flood damage potential has temporal dimensions to be considered as well. Since economic activity is a dynamic phenomenon, it may be assumed that current damage potential will differ from future damage potential. To the extent possible, future changes in the level of total vulnerability are discussed on the basis of current plans. The first priority however, is to acquire a suitable benchmark, represented by an estimate of current flood damage potential.

6.1 Current Damage Potential

The total potential for flood damage may be broken down into several sub-headings. Floods may cause direct damages to physical assets, as when water actually ruins electrical circuits, etc. Indirect damages are caused by the flood, but are not directly related to the water. Avoidance effort in anticipation of a flood and the inability of employees to perform their normal duties because their place of work has been flooded are both examples of indirect damages. Flooding can also have redistributive effects such as occur when one person's property is flooded (this person thereby incurring an expense) and another man profits from that expense by being in a position to repair or replace damaged items. In this section of the report, emphasis is placed upon direct damages, although both indirect and re-distributive effects are briefly discussed. Intangible damages are ignored.

6.1.1 Direct Damages

During the study, two flood hazard maps were produced. One illustrates the areal extent of flooding under mean annual flood conditions and one depicts the 100 year event. Both these maps are discussed elsewhere in the report as to assumptions made in their prpearation and the possible limitations of information presented on them. In this section, these maps are used to illustrate existing vulnerability under two different sets of assumptions. By investigating the level of this vulnerability implied by each map it is possible to obtain an impression of what the stage-damage function might look like in the Town, given the existing economic structure. Thus, the potential costs of various adjustments may be seen in the perspective of the level of benefits they would be likely to yield.

In Stephenville both residential and non-residential structures are exposed to the hazard. Both types are discussed below. It should be re-emphasized that all quantitative values estimated in this section are developed only to give an impression of the overall magnitude of the flood problem.

Since there are two flood hazard maps, a description of the level of vulnerability suggested by each is in order.

The 100 Year Event:

The Stephenville floodplain contains residential and non-residential structures. Parts of both types are vulnerable to damages.

In the case of residential structures, there are various methods suggested in the literature for estimating direct damages, but none is entirely applicable to the Stephenville case. The estimating functions selected for use here are those developed by Acres Ltd. for Galt, Ontario in 1968[2]. These functions have been adjusted to allow for

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2. Acres, H. G. Ltd., Guidelines for Analysis - Streamflows, Flood Damages, Secondary Flood Control Benefits, Vol. 2 prepared for the Governments of Canada and Ontario Joint Task Force on Water Conservation Projects in southern Ontario, 1968.

inflation. As the significance of residential damage potential in Stephenville is minor, it is believed that the somewhat arbitrary application of the Acres functions to the situation will not materially detract from the general validity of the estimates.

The houses that would be affected by flooding are all located on Blanche Brook, where there are approximately twenty-five homes in the higher hazard (overbank) zone. Of these, most are low to medium quality structures. The depth of flooding on the first floor would appear to be a maximum of about two feet under 1:100 year conditions. Since the first floors of many houses have been raised off the ground by foundations or mounds, a conservative estimate of average level of water over the first floor would be one foot. Using the Acres Ltd. functions, the average damage to contents on the first floor in homes of similar quality to those which exist in the Stephenville floodplain would be about $396[3]. Spread over 25 homes, the total potential for first floor contents damage is therefore estimated at $9,900.

Contents damages in basements may be estimated in a similar fashion at $28 per home for a total of $700. This figure does not account for furnaces or hot water heaters located in the basements. If an average damage per home to these items of $50 is assumed, the total basement damage

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3. Unless otherwise specified, all values are given in 1974 dollars.

potential becomes roughly $1,950.

Structural damage is not expected to be very significant. The shallow depths above the first floor imply that very little water pressure damage would be caused and the apparently short duration of most Stephenville floods would mean that minimal damages would be inflicted on wallboards, panelling, etc. An arbitrary estimate of about $2,500 is used for homes in the overbank areas.

There are approximately 52 units located inside the low-hazard (overland) zone. Since damages in this area vary significantly with topographic characteristics, estimation of their magnitudes is virtually impossible. Historical data indicate, however, that damages in these low-hazard areas are not very significant so in the absence of better data, the potential for direct damages will be assumed to be nil.

Combining the first floor and basement estimates derived above, the total direct damage potential is approximately $14,350 or $575 per home.

Direct damage estimation for non-residential structures is even more difficult because of the specialized uses made of these buildings. In Stephenville, non-residential buildings subject only to low damage potential are T and J's Motel, the Federal Building, the Cormack School, the Co-op and Warehouse and the gymnasium. No attempt is made here to quantify the dollar vulnerability of most of these places, but it is probably safe to say that damages will normally be quite minor even in the assumed flood conditions.

T and J's Motel is subject to damage not from the water itself, but from erosion which will cause slumping of its foundation supports. Evidence of slumping on the banks was seen during field trips in October 1974. This erosion potential is especially acute under the assumed flood conditions since the water would overtop the Hanson Highway and re-enter the brook over the erodable bank on the corner of the sleeping section of the motel. Undermining of the foundation could bring significant structural problems. The magnitude of these problems is difficult to determine, but it is estimated that about $2,500 could be required to restore the foundation to pre-flood conditions should a 1:100 year flood actually occur.

Within the high hazard zone there are five non-residential buildings susceptible to damage: Stephenville Building Supplies, Labatt's Brewery, Humber Motors, the Curling Rink, and the Wesmount Realty Building.

The Humber Motors building is located in a hollow and during periods of heavy rain or flooding, water collects in a low spot behind the building. Under 1:100 year flood conditions, the floor of the building would be flooded to a depth of approximately 1.7 feet. The showroom would likely suffer damage to its interior walls and flooring, but beyond that it is anticipated that most of the automobiles could be moved to higher ground in the event of a flood. In the repair shop behind the showroom, some items, such as tools or electrical equipment might be damaged. Overall, it is not anticipated that there would be much damage beyond some minor structural problems. Accordingly, $1,500 is estimated for the building in the 1:100 year event.

The Curling Rink is located on the periphery of the hazard zone. It is anticipated that about two feet of water would inundate the building under the assumed conditions, and it is quite possible that significant damages could occur here. No investigation of the building was undertaken during the study, but it is probable that most of the damage would occur to the cooling plant. A value of $5,000 is arbitrarily assumed here for estimation purposes.

The Wesmount Realty office is located upstream of an assumed blockage point (Main Street bridge). The water level here would be between 38 and 39 feet. The floor of the building has been surveyed at 39.7 feet, so no water would be inside the structure in the 1:100 year event. However, should ice be associated with the flood, it could block at the bridge and fetch up on the outside bank of the Brook, thereby causing structural damage to the building. Given the uncomplicated nature of the structure, it is estimated that only about $1,000 in damage would be inflicted.

The ground level at the Stephenville Buildings Supplies structure is about 37.5 feet. The building itself may be assumed to have a first floor elevation of at least 38.0. At that point in the stream the flood line is situated at approximately the same height, so it may be assumed that the building would experience only insigificant damage from the water. Possibly, debris backup (ice, trees, etc.) could cause minor damage to the exterior of the building. $500 is arbitrarily estimated under that assumption. The ice problem would not likely be as severe here as at the Wesmount Realty Office since the latter is on the outside bank and would therefore probably be subject to greater ice pressure.

The Labatt's Brewery is the most vulnerable structure in Stephenville. The brewery process involves exacting standards of both automation and cleanliness. Brewery employees were interviewed in an effort to obtain quantitative impressions of the degree of vulnerability to flood damages, and the following facts came to light.

First, if the dyke fails there is, at present, virtually no time to react. The water has normally entered the building from the rear loading doors (facing the brook). The current dyke was built after the August 1973 flood and almost no one in the Town expects this dyke to withstand a major flood in the future. Significant slumping was visible after even the relatively minor November 1974 flood.

Floodwaters affected virtually all aspects of the business in the 1973 storm. Water reached a level of 18 inches inside the building, causing damages to walls and office equipment in the administration sections. Sludge was introduced into most of the beer processing rooms, and the water also caused spoilage of finished products in the rear of the building.

Six inches is judged to be a significant inflection point on the stage damage function (see Figure 15). At this point, some expensive capital installations begin to be damaged. Several of these installations are floodproofed up to six inches. Much of the equipment is such that, once flooded, it cannot be reused because of either dirt or rust. Those items that are damaged above a six inch level are not numerous, but they are the most crucial to the process and the most expensive to replace. Once damaged, the goods-in-process inventory must normally be totally discarded because of quality control and sanitation requirements. At a level of two feet another inflection point is reached. At this point, vital electric panel control boards would be rendered useless. Once inundated, some very expensive items must be replaced since repair is virtually impossible.

With the above comments in mind, an attempt to quantify the existing damage potential at the brewery may be made.

To begin with, the floor of the brewery is situated at level 18.7 and the flood level at that point is estimated at about 23.9 feet. Therefore, the 1:100 year flood will mean about 5.2 feet of water inside the brewery. The 1973 flood reached a level of 1.5 feet and caused an estimated $76,000 worth of damages adjusted to current prices. This figure is used as a basis for estimating current vulnerability at higher stages, as shown in Table 4. Figures given are arbitrary, being essentially based on conversations with

TABLE 4

ESTIMATED FLOOD DAMAGE POTENTIAL AT LABATT'S BREWERY[1]

Component of Total Vulnerability	.5	Feet Above Brewery Floor: 1.5 (1973 Level)	2.3 (Mean Annual)	4.1 (1:20 Year)	5.2 (1:100 Year)
1. 1973 Damages at Current Prices. Activity levels assumed constant.	$5,000	$ 76,000	$ 76.000	$ 76,000	$ 76,000
2. Shut Down Time involving loss of profit at an estimated $7,500 per week. Number of weeks is estimate only.		(1 week)	(8 weeks)	(10 weeks)	(12 weeks)
	-	$ 7,500	$ 60,000	$ 75,000	$ 90,000
3. Loss of Stock - Capacity Approximately 6,000 barrels @ $90 per barrel. Average stage of completion estimated @50% for goods in process.		(30% destroyed)	(80% destroyed)	(100% destroyed)	(100% destroyed)
	-	$ 81,000	$216,000	$270,000	$270,000
4. Estimated equipment damaged above what was destroyed in 1973.	-	-	$ 50,000	$ 60,000	$ 75,000
5. Totals	$5,000	$164,500	$402,000	$481,000	$511,000

1. Estimates for various flood conditions, assuming current levels of production.

FIGURE 15

ESTIMATED STAGE–DAMAGE FUNCTION AT LABATT'S BREWERY

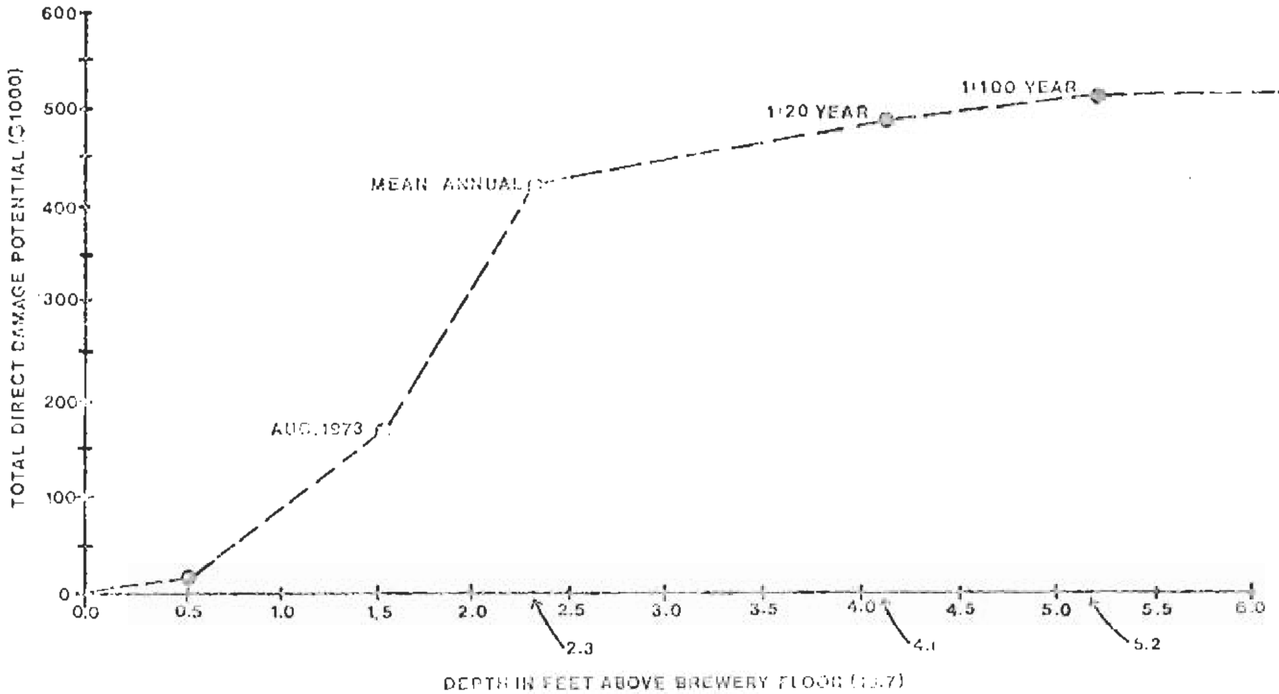
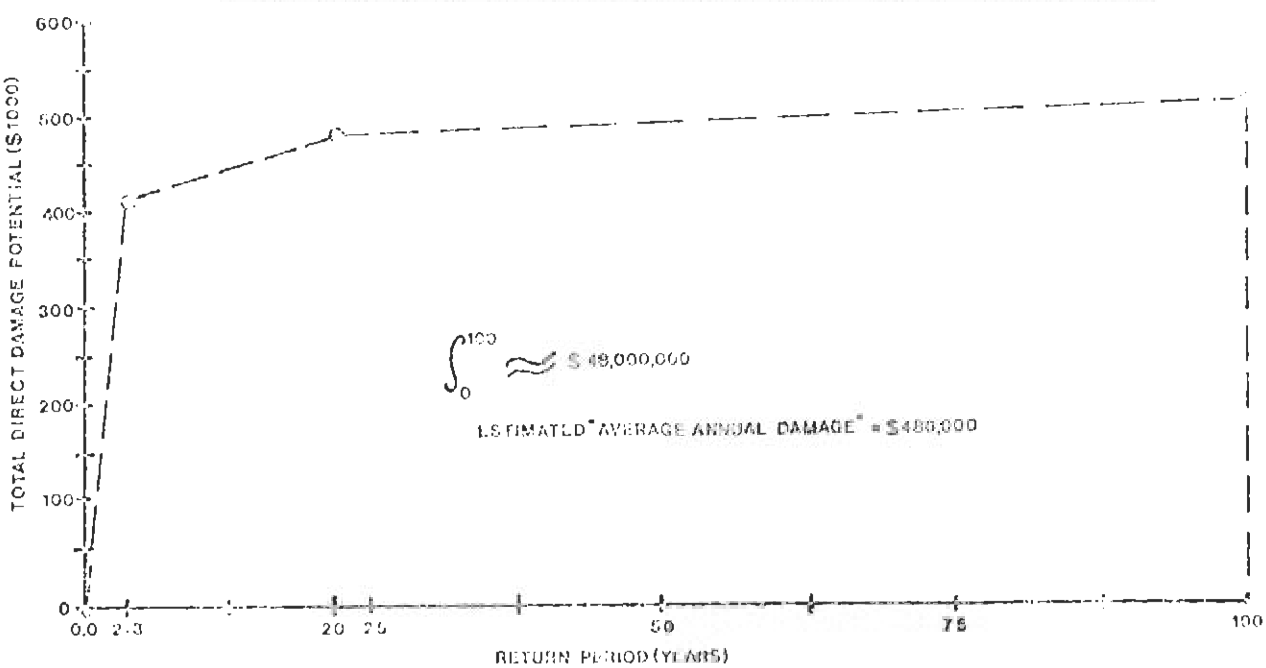


FIGURE 16

ESTIMATED DAMAGE–FREQUENCY FUNCTION AT LABATT'S BREWERY



brewery staff. As such, biases of opinion have probably influenced the estimates. The total of about $510,000 in damage potential under 1:100 year conditions is, however, considered to be grossly representative of the brewery's overall flood vulnerability. If over five feet of water were to inundate the building, there is no question that damages would be very extensive.

An estimate of the potential for damages at the brewery at different stages is shown in Table 4. This illustrates the sensitivity of the stage-damage relationship at the two inflection points mentioned above - i.e. 6 inches and 2 feet.

The Town of Stephenville itself is also vulnerable to damages from a flood of the assumed magnitude. Bridges could wash out or become damaged; dykes could slump; and water lines could be broken. The current study assumes that the existing bridges would in fact withstand the 1:100 year flood. To assume otherwise would necessitate detailed engineering studies of these structures. Nonetheless, it is possible to say that cleanup and minor repair could quite possibly cost the Town an estimated $2,000 in the event of a 1:100 year flood.

The estimated direct damage potential under 1:100 year conditions is summarized in Table 5. The relative importance of the brewery is evident and measures to alleviate the flood hazard should recognize this imbalance.

TABLE 5

SUMMARY OF ESTIMATED DIRECT DAMAGE POTENTIAL[1]

TOWN OF STEPHENVILLE

Location	Mean Annual Flood	1:100 Year Flood
Residential Structures	2,300	14,350
Curling Rink	-	5,000
Town of Stephenville	1,000	2,000
Humber Motors	1,000	1,500
Wesmount Realty	1,000	1,000
T & J's Motel	-	2,500
Stephenville Building Supplies	-	500
Labatt's Brewery	402,000	511,000
Totals	407,300	537,850

1. Does not include potential damage to roads or bridges.

The Mean Annual Flood Event:

Table 5 summarizes the estimated direct damage potential caused by a 100 year return flood. In order to make an evaluation of the relative severity of the 1:100 year flood, the mean annual event was mapped and an estimate of damage potential was made using procedures similar to those used for the 100 year flood.

In the mean annual case, there are 30 overland and 4 overbank homes affected. Using the same estimating procedure as above, residential damages under mean annual conditions become roughly $2,300.

In the case of the five non-residential structures noted above, neither the Curling Rink nor T and J's Motel would be vulnerable to mean annual flooding. The water level on the floor at Humber Motors would be reduced to .9 feet. It is estimated that not more than $1,000 worth of damage would likely occur here. The Wesmount Realty building is vulnerable more to ice than to the water itself so water levels do not affect the damage potential. The $1,000 previously estimated applies as well in the mean annual case. The estimated direct damage potential under mean annual flood conditions at the brewery is about $402,000. The breakdown of this figure is found in Table 5 along with the assumptions used to develop it. The Town of Stephenville would also suffer some damages in the mean annual event, but probably not more than an estimated $1,000. Damages at Stephenville Building Supplies are estimated to be nil under the assumed flood conditions.

General

From Table 5 it is apparent that the major damage potential in the Town accrues to the brewery. An estimate of the average annual value of flood damages has been calculated for the brewery (see Figure 16) since more points on the function are known for the brewery than for the rest of the Town. This estimate is approximately $480,000. A rough estimate of the average annual figure for the whole floodplain would be slightly higher than this, say $500,000.

When interpreting this value, two points must be remembered. First, it does not mean that ½ million dollars worth of damages will occur every year; damages in this analysis are assumed to depend on water depths, which are no more cyclical than the occurrence of major floods. The estimate represents the average annual loss which might be expected to occur over a 100 year period.

Second, the estimate is totally dependent on flood depths. Since assumptions made in estimating the areal extent of flooding will often materially affect the flood stage, these assumptions also affect the estimated damage levels. In the Stephenville case, the brewery accounts for virtually all the vulnerability. Therefore, assumptions concerning flood stages at this location are vital. Specifically, an assumption was made that the current dyke would fail at the brewery under even mean annual conditions. Furthermore, the worst possible combinations of events have been ascribed to both the mean annual and the 1:100 year floods. The net effect of these assumptions is that the estimate of flood depth at the brewery is probably over-estimated. The damage estimate should therefore be interpreted in the same way. Another reason that the ½ million dollars annual estimate should be interpreted carefully is that the only source of data used for the estimate was interviews with brewery staff, hence the estimates probably reflect some biases.

While the total vulnerability in the Town is extremely high because of the brewery situation, the average annual estimate should be viewed only as a maximum approximation of that vulnerability. Although it does provide an indication of the magnitude of the damage potential in the Town, it should not be used for rigid cost-benefit analysis when potential adjustments are considered.

6.1.2 Indirect Damages

The stronger the economic linkages between installations on the floodplain and those located in the economic unit, but not on the floodplain, the greater will be the level of indirect damages. This is so because the disruptions caused by flooding to the general economy will be more pronounced where greater economic ties exist. It is customary practice in damage estimation exercises, to add on a percentage of direct damages and label it indirect damages. However, as mentioned earlier in this report, the linkages in the Stephenville case are not strong. With the exception of the brewery, it may be realistically assumed that indirect damages are negligible. In the brewery's case, the major indirect costs would be in the form of lost man days for workers at the plant. If we further assume that workers normally employed in the brewing process would simply transfer their (paid) effort to helping with cleanup, then indirect damages become relatively insignificant in the brewery's case as well.

As for transportation disruptions, the airport would be virtually unaffected by the assumed flood and any road arteries that became impassable could be quite easily circumvented. Therefore, the total potential for indirect damage will be assumed to be insignificant.

6.1.3 Redistributive Effects

The major effects here would emanate from problems at the brewery. Should the brewery be closed down for three months as assumed, their agents would either have to do without beer or obtain it elsewhere. The redistributive nature of this eventuality is obvious. Also, damaged equipment would have to be purchased (probably from Ontario or Quebec). Therefore suppliers in those provinces would likely benefit from a severe flood in Stephenville. Should bridges become damaged or even washed out, local or regional construction contractors would probably become the beneficiaries of the Town's flooding problem. No attempt is made in this report to quantify the redistributive effects of either the mean annual or the 1:100 year flood.

6.2 Future Damage Potential

To ascertain how significantly flood damage potential in Stephenville might grow, the current development plan was reviewed, and the following points emerged.

It is anticipated that the population of the Town and its immediate hinterland will grow to approximately 20,000 within the next decade. Most of the employment to support this population will have to come from a significantly expanded industrial base. This industrial base will be attracted to the area by existing facilities at the Harmon Complex, and it will hopefully serve a provincial and possibly a national market. In accordance with the Stephenville Municipal Plan, most of the necessary housing stock additions will become available in Development Area 13 as the DREE funded project expands. It is expected that units built in this area will satisfy most increases in local housing requirements in the foreseeable future. Queen Street will probably become a major link between residential districts, (especially Area 13 and the West Street region) and employment locations (Harmon and Area 6) The trailer park in Area 6 is being relocated and most of Area 6 will eventually be given over to commercial enterprises according to the current development plan.

The floodplain itself encompasses essentially Development Areas 7, 8, 9 and 10 (see Figure 3). Within Area 7, a substantial amount of development has already occurred in the form of a new shopping mall, a new school complex and a new federal building. Plans exist for the construction of a two million dollar motel downstream of the federal building. Since Minnesota Drive has been extended to the Hanson Highway, it is anticipated that this road will be the major access route for incoming traffic to the Town in the future. In this case, the bridge on Minnesota Drive near the brewery will be a vital link in the Town's transportation system. This bridge is periodically buffeted by both ice and high water, and the possibility of its eventual loss cannot be ignored.

In Area 8 there have been only two new houses constructed since the Town adopted the Municipal zoning plan. For the most part, the current zoning classification of restricted development has been adhered to. The only other instance of recent new construction has been the expansion at T and J's Motel.

Possibly because the dykes have been built to help alleviate the flooding problem in Area 8, it has now been suggested that available lots in the area might be infilled to take advantage of existing water and sewer trunk lines. Accordingly, the Provincial Planning Office has drawn up lot plans for the Town with regard to the expansion of housing stock in both Areas 8 (74 sites) and 10 (34 sites). The northernmost section of Area 8 is currently zoned as commercial highway, and it is expected that the Queen Street-Hanson Highway connection will be upgraded as the Queen Street arterial function grows. Thus, no residential or industrial development is anticipated for this section of Area 8.

The section of Area 10 most exposed to flooding is presently zoned for "open space amenity" (see Figure 17) and no plans apparently exist to alter this classification. North of the Hanson Highway no evidence was found to suggest that expansion of any significance might occur in the foreseeable future.

On the Harmon bank of Blanche Brook, the only recent development has been the construction of Humber Motors and the renovation of the brewery. The study team found nothing to indicate that significant capital investment would soon be made in this area. The current efforts of the Harmon Corporation appear to be directed more toward the utilization of existing capacity than toward its expansion.

In general, some future development on the floodplain might occur in Development Area 8 where housing is apparently desired. It might also occur below Main Street east of Queen where commerical expansion appears to be imminent. Before permitting this growth on the floodplain, it is important that the Town's history of flood vulnerability be taken into consideration in planning any new facilities.

Although it is difficult to speculate about the future with much certainty, there are a few points about current plans that should be made. First of all, the existing municipal development plan calls for infilling in residential areas on both sides of the Blanche Brook above

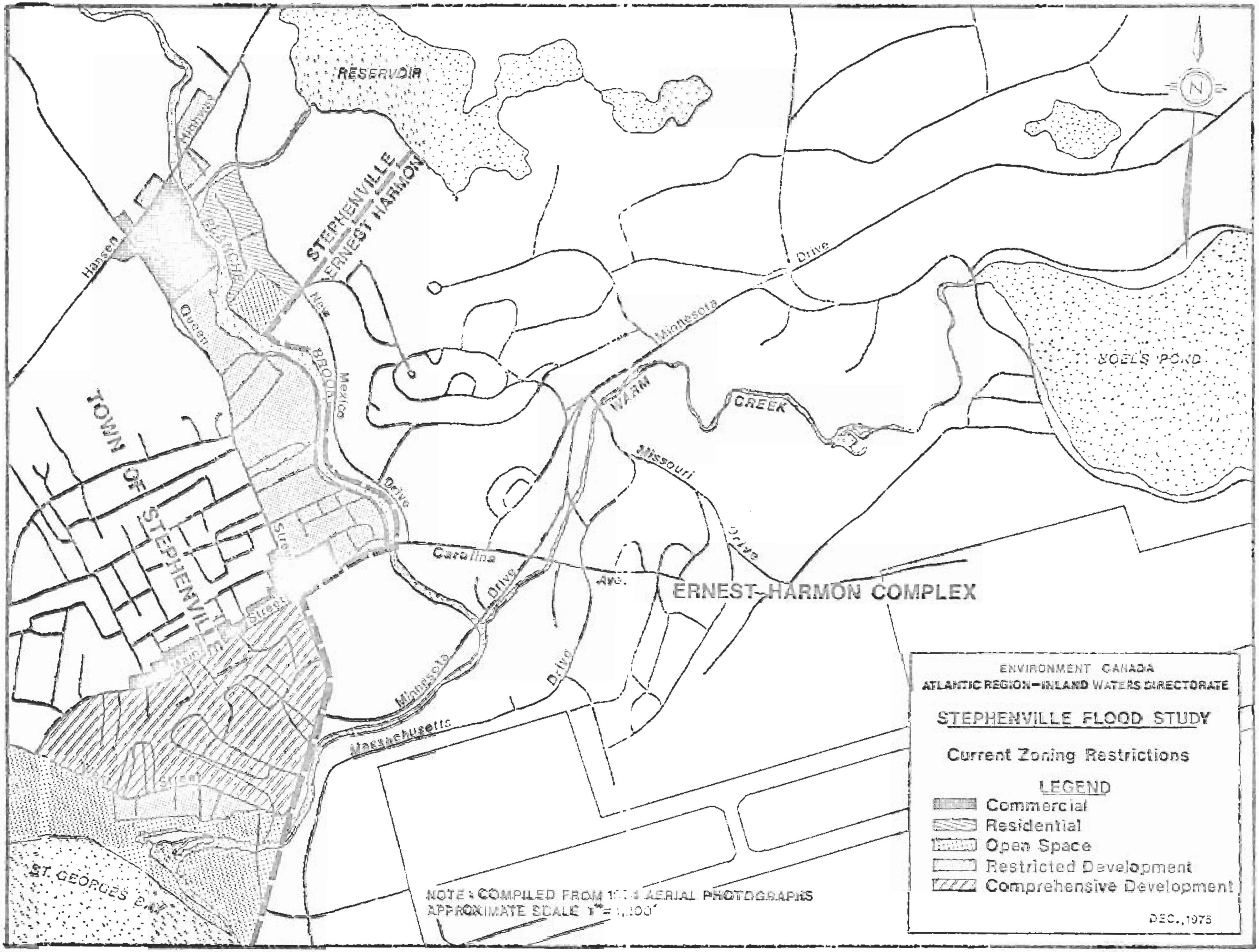

ENVIRONMENT CANADA
ATLANTIC REGION—INLAND WATERS DIRECTORATE
STEPHENVILLE FLOOD STUDY
Current Zoning Restrictions
LEGEND
Commercial
Residential
Open Space
Restricted Development
Comprehensive Development
DEC., 1975
NOTE: COMPILED FROM AERIAL PHOTOGRAPHS
APPROXIMATE SCALE
RESERVOIR
STEPHENVILLE
ERNEST HARMON
TOWN OF STEPHENVILLE
ERNEST-HARMON COMPLEX
NOEL'S POND
WARM CREEK
BROOK
BLANCHE
ST. GEORGES BAY
Hansen
Queen
New Mexico Drive
Minnesota Drive
Missouri Drive
Carolina Ave.
Drive
Massachusetts
Street

FIGURE 17

Main Street. Of about 108 units planned, approximately 27 will be inside the 1:100 year flood line and another 18 will be in the overbank zone.

If the planned motel is in fact built downstream of the Federal Building, it would probably have to be built in either a medium or high flood hazard zone. Unless suitable precautions are taken (e.g. in the form of floodproofing), the Town's overall susceptibility to the flood hazard would increase with its construction.

Given the overwhelming dominance of the brewery problem in estimates developed so far, it is not likely that the percentage increase in total vulnerability to flooding in Stephenville as a result of these plans will be very great. However, the absolute level of this increase could be quite large, especially as the downtown land becomes more highly developed.

It has been estimated that the average annual flood damage potential in Stephenville is in the order of .5 million dollars. While care must be used in interpreting this figure, it does provide what was originally intended-a rough impression of the magnitude of the problem.

The sensitivity of this magnitude to changing conditions does not appear to be very great, mainly because of the prominence of the brewery's damage potential in the total estimates and because of underlying assumptions made in the estimating process.

In short, the flood problem in Stephenville is economically quite extensive. However, the above analysis shows that the problem has more local than regional solutions, and the following discussion of possible adjustments to the hazard reaffirms this conclusion.

7. STRUCTURAL MEASURES FOR FLOOD DAMAGE REDUCTION

The terms of reference for this study call for "a preliminary evaluation of alternative measures of flood control". This section of the report describes the various design concepts, and their associated costs, of those structural measures judged to be technically feasible. It must be emphasized that the level of design does not go beyond the conceptual stage; much of the data employed in the design investigations were very judgemental. Similarly, the unit costs, which were derived from various sources including contractors and consulting engineering firms in Western Newfoundland and other parts of Atlantic Canada, used to provide cost estimates must be considered "order of magnitude" in nature. Should serious consideration be given to any structural alternative, detailed design investigations will have to be carried out by a recognized professional consulting engineering firm. In view of the adverse environmental effects that could result from the construction of many of the structural measures investigated herein, a thorough environmental impact assessment should be carried out in conjunction with the design investigations. This will allow the incorporation of environmental protection features in the design concept.

A number of structural alternatives ranging from regional flood control measures such as upstream storage, floodways, etc. to more localized measures such as dykes, channel improvements, floodproofing, etc. were considered.

All alternatives were not considered in the same light. For example, structural measures, such as the floodway concept, which were viewed as economically infeasible at the outset were not considered in detail. However, the rationale for their rejection is provided.

The approach taken in this section of the report is to outline the concept of each structural measure, its associated cost and its effectiveness, in terms of the physical reduction of the flooding problem. The overall comparison of benefits and costs and the detailing of specific suggestions is reserved to section 9.

7.1 Regional Alternatives

Consideration was initially given to three possibilities which were regional in nature in that, if constructed, they would provide relief to the entire floodplain or a large part of it. These included upstream storage, the provision of a floodway (s) and stream diversion(s). The latter two were discarded, at the outset, as being economically infeasible. The former, because of its dual purpose possibilities (i.e. water supply-flood control) was subjected to a more thorough analysis.

7.1.1 Floodway

Conceptually, a floodway would consist of a relatively large artificial channel which, under flood conditions, would convey the flood waters through the town of Stephenville without causing significant flooding. This could range from improvements to the existing channel to a separate channel which would divert the flood water around the flood hazard areas. To be effective, from a regional perspective, two such floodways would be required in the Stephenville area - one for each stream. This alternative did not receive detailed consideration principally because of the high cost involved. Apart from the large volumes of excavation involved, several highway bridges/tunnels would have to be constructed and/or reconstructed/relocated.

7.1.2 Diversion

Conceptually, a diversion involves the conveyance of water from one watershed into another. This normally involves diversion works, usually a small dam, and an artificial canal into an adjacent watershed where presumably additional flood waters would not present a problem. There are several small scale diversion possibilities on Warm Creek while none are apparent on Blanche Brook. However, the cost of these small-scale diversion works would far outweigh potential flood control benefits.

Two large scale diversions, one for each stream, were examined in somewhat more detail. The selection of both routes was based on an analysis of available topographic mapping and interpretation of aerial photographs. A plan view of each route is shown on Figure 18. The diversion channel for Warm Creek would divert floodwaters from Noel's Pond, into Muddy Pond and eventually into Port Harmon. The diversion channel for Blanche Brook would divert water from Blanche Brook upstream of Stephenville into

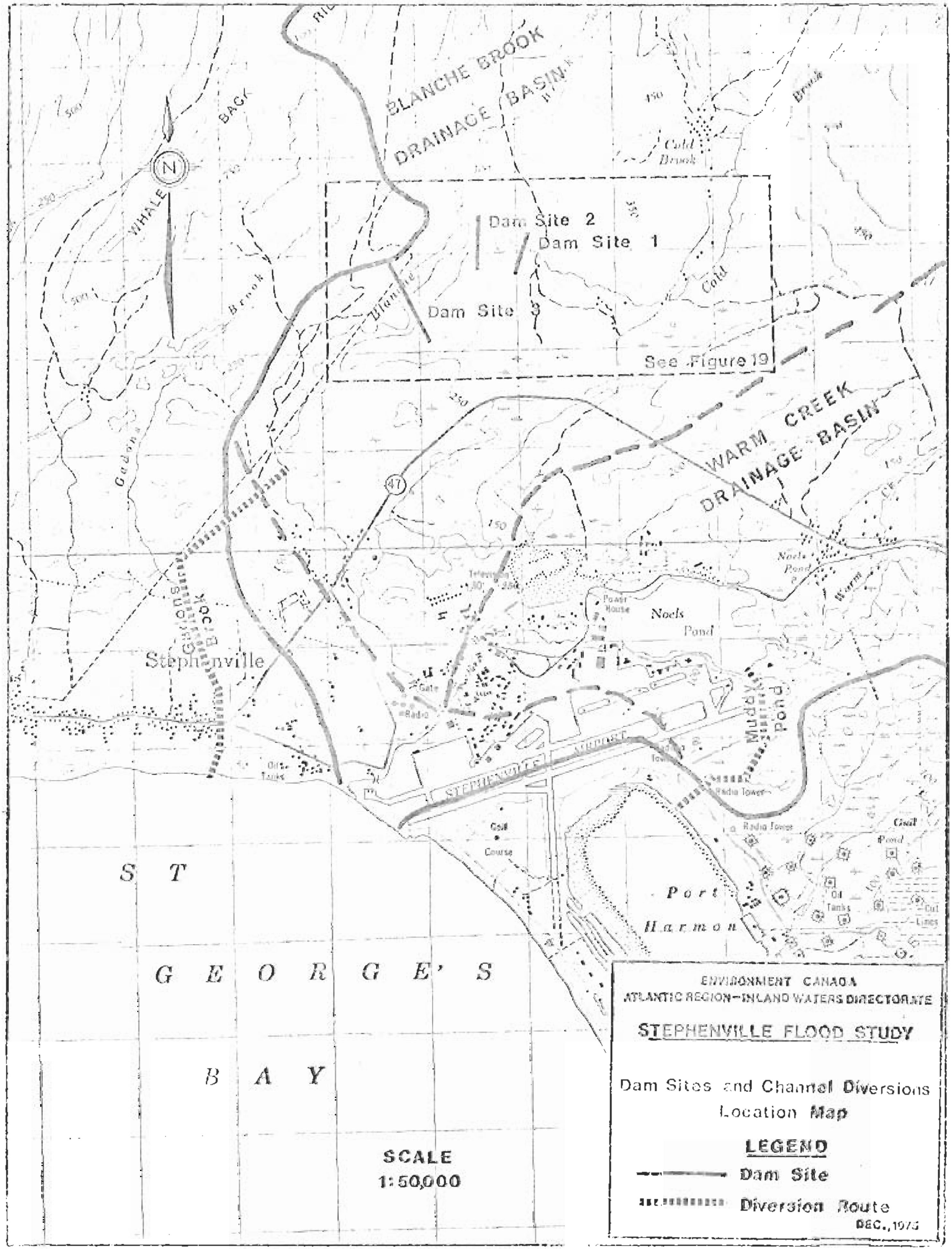

BLANCHE BROOK DRAINAGE BASIN
WHALE BACK
Dam Site 2
Dam Site 1
Dam Site 3
See Figure 19
Cold Brook
WARM CREEK DRAINAGE BASIN
Noels Pond
Stephenville
Gravels Brook
Muddy Pond
STEPHENVILLE AIRPORT
Port Harmon
S T G E O R G E ' S B A Y
SCALE 1:50,000
ENVIRONMENT CANADA
ATLANTIC REGION—INLAND WATERS DIRECTORATE
STEPHENVILLE FLOOD STUDY
Dam Sites and Channel Diversions Location Map
LEGEND
Dam Site
Diversion Route
DEC., 1975

FIGURE 18

the Gadons Brook watershed. The cost of the diversion channels alone was estimated to be close to $2 million. The cost of diversion works (dam), channelization of Gadons Brook, construction and/or relocation of multiple bridges along the Noel's Pond - Port Harmon route, the loss of valuable land (development area 13) associated with the Blanche Brook diversion, etc. when combined with the cost of the basic diversion channels, would undoubtedly make this alternative unattractive relative to other structural measures. It was therefore decided not to develop this alternative further.

7.1.3 Upstream Storage

The provision of a dam(s) and attendant reservoir(s) for the purpose of storing flood waters for later release downstream is a well recognized structural method of flood control. If properly designed, constructed, and operated, this method will normally contain all flood waters up to the design flood. One very serious disadvantage associated with this method, however, is the fact that complete protection can never be provided and because investment on the floodplain is often accelerated after upstream storage has been provided, catastrophic damages may result. Of course there are some additional benefits associated with this type of endeavor if multiple uses such as water supply, recreation, etc. can be incorporated.

Three sites (Figure 18) in the Blanche Brook watershed were identified through an analysis of available topographic mapping. It was decided to investigate the cost of the largest site (Dam 3). No prospective sites were found on Warm Creek.

Description of the Site: Dam site 3 is strategically located on Blanche Brook below four major tributaries and is considered to be the closest site to the Town of Stephenville that would be technically feasible. The location of the dam is shown on Figure 18 and in more detail on Figure 19. A profile of the existing ground elevation along the axis of the dam is shown on Figure 20. The site is limited to an elevation of 350 feet (Lockwood, Kessler and Barltett Inc. Mapping) by topographic features. At that elevation, the maximum height of the dam would be about 70 feet, while the length would be about 2,700 feet including a small dyke section. The area of the reservoir at an elevation of 350 feet would be approximately 420 acres.

Information on the surficial and bedrock geology of the area is relatively sparse. The information that is available suggests that the bedrock is overlain with a relatively thick layer of glacial drift consisting of minor gravels, sands, silts and clays. It has been assumed that the foundation for the dam would be competent for an earthfill dam. However, the surficial deposits would probably be relatively pervious and of such a thickness that a positive cutoff wall would be impractical.

Hydrologic Considerations: A hydrograph (Figure 21), representative of the 1:100 year flood at dam site 3, was selected

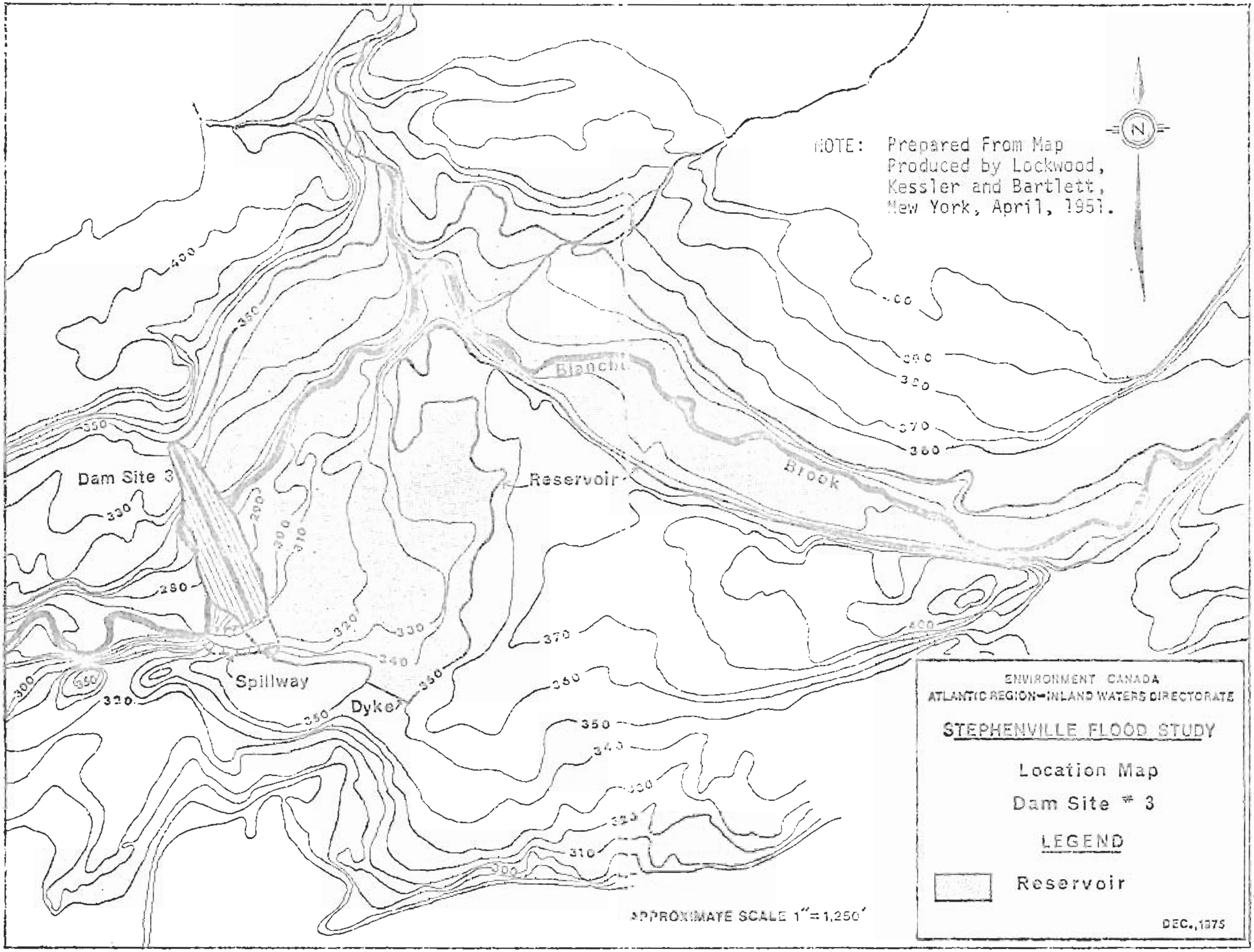
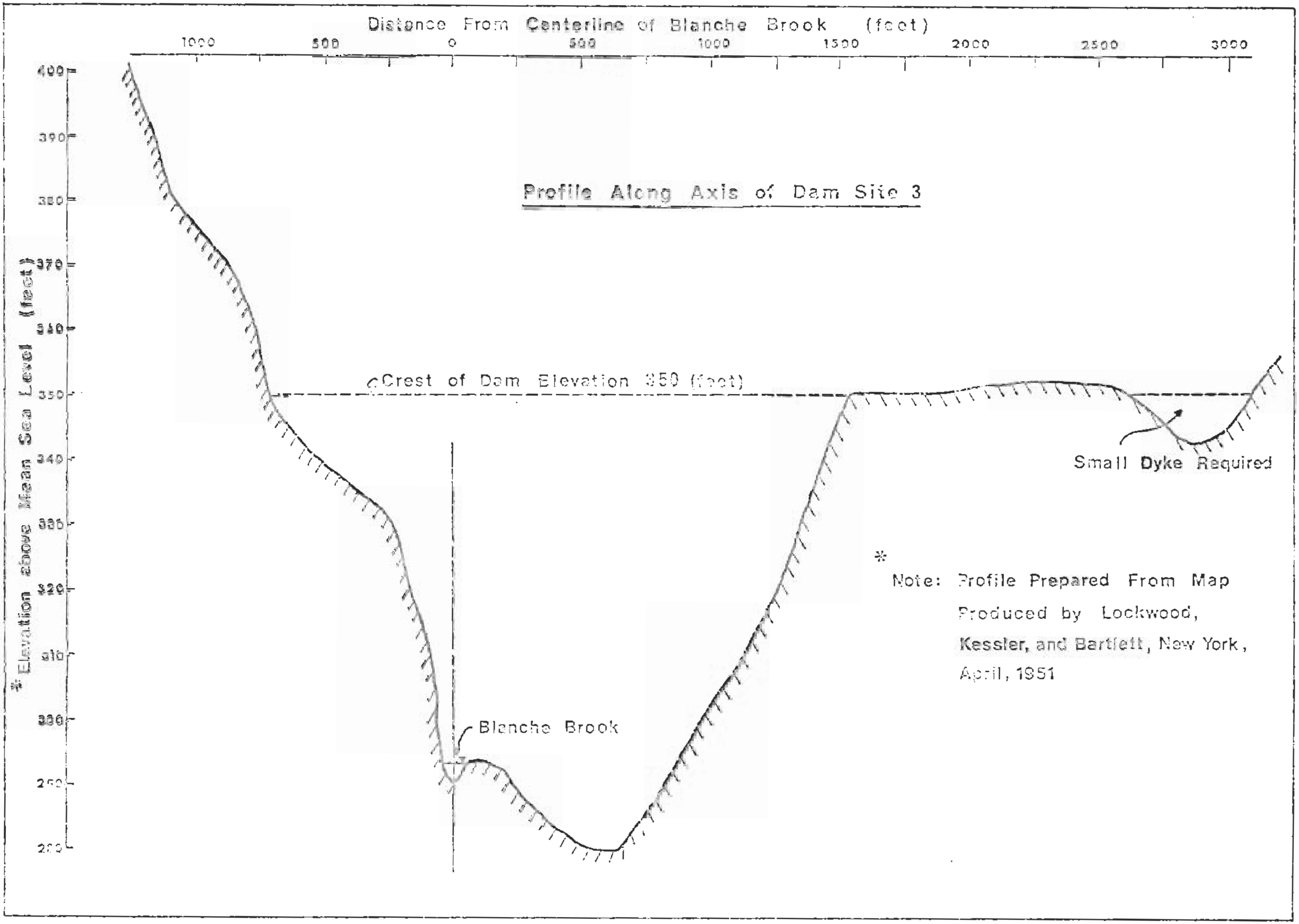
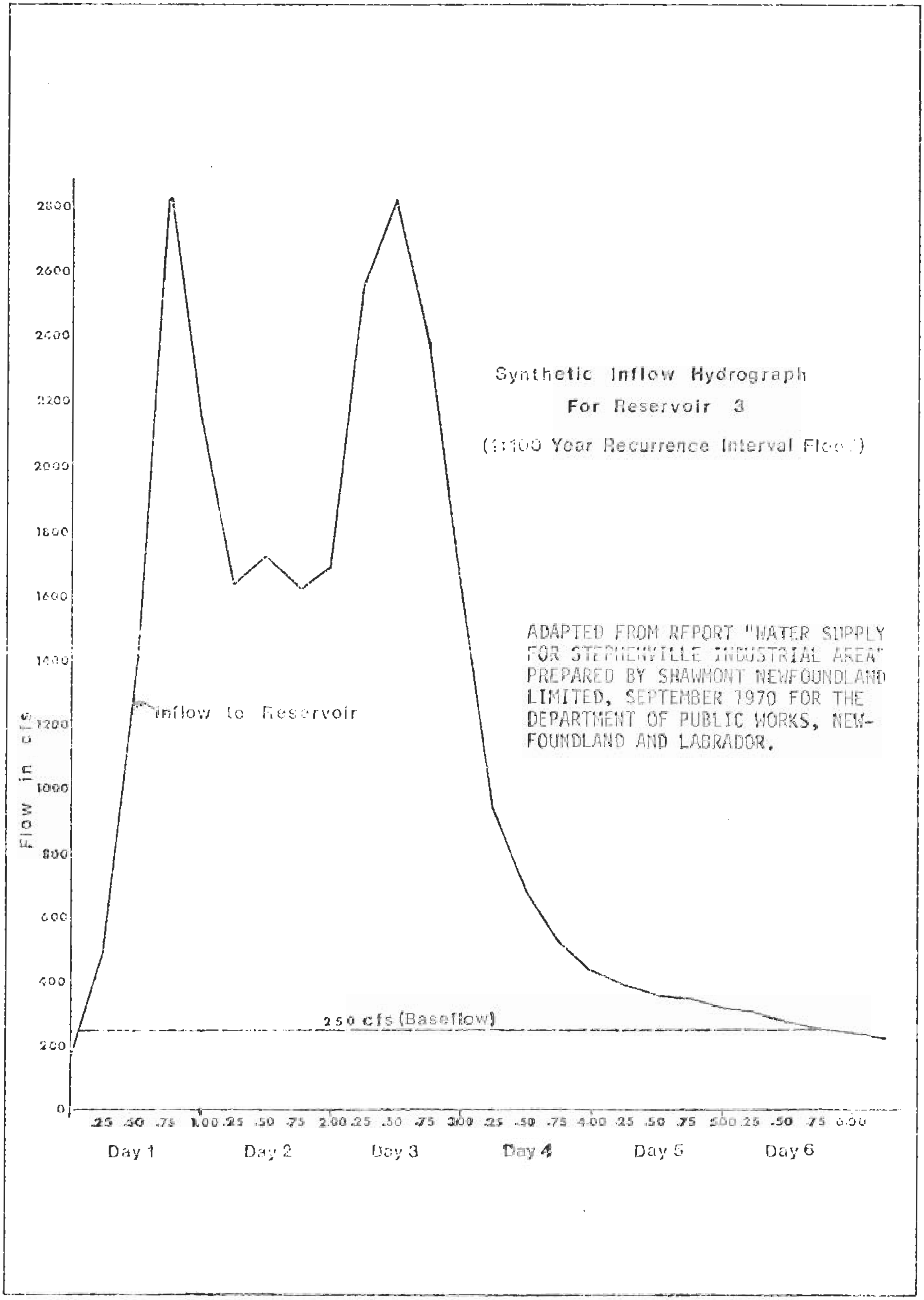

NOTE: Prepared From Map
Produced by Lockwood,
Kessler and Bartlett,
New York, April, 1951.
N
Blanche
Brook
Reservoir
Dam Site 3
Spillway
Dyke
400
350
330
280
300
310
320
340
360
370
380
390
APPROXIMATE SCALE 1"=1,250'
ENVIRONMENT CANADA
ATLANTIC REGION—INLAND WATERS DIRECTORATE
STEPHENVILLE FLOOD STUDY
Location Map
Dam Site # 3
LEGEND
Reservoir
DEC., 1975

FIGURE 19



Distance From Centerline of Blanche Brook (feet)
1000
500
0
500
1000
1500
2000
2500
3000
Profile Along Axis of Dam Site 3
400
390
380
370
350
340
* Elevation above Mean Sea Level (feet)
Crest of Dam Elevation 350 (feet)
Small Dyke Required
Blanche Brook
* Note: Profile Prepared From Map Produced by Lockwood, Kessler, and Bartlett, New York, April, 1951

FIGURE 26



Synthetic Inflow Hydrograph
For Reservoir 3
(1:100 Year Recurrence Interval Flood)
ADAPTED FROM REPORT "WATER SUPPLY FOR STEPHENVILLE INDUSTRIAL AREA" PREPARED BY SHAWMONT NEWFOUNDLAND LIMITED, SEPTEMBER 1970 FOR THE DEPARTMENT OF PUBLIC WORKS, NEWFOUNDLAND AND LABRADOR.
Inflow to Reservoir
250 cfs (Baseflow)
Flow in cfs
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
.25 .50 .75 1.00 .25 .50 .75 2.00 .25 .50 .75 3.00 .25 .50 .75 4.00 .25 .50 .75 5.00 .25 .50 .75 6.00
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6

FIGURE 21

from a prior study by Shawmont Newfoundland Limited[4] and modified to correspond to data presented in Appendix B. An analysis of the hydrograph indicates that 12,000 acre-feet of flood control storage would be required to completely control the design flood at this site. The storage available at Reservoir 3, however, is only 8,700 acre-feet or about 3,300 acre-feet short of the required amount.

The flows were routed through the reservoir on a 6-hour basis using standard hydrologic routing techniques. The flow in Blanche Brook was determined by adding the estimated lateral inflows between the dam and the town to the routed inflow from the reservoir.

The outlet works were designed to pass a flow up to 1,000 cfs, at a stage of 15 feet, which is considered to be the flow at which little or no damage occurs in the Blanche Brook reach upstream of the confluence. Under the foregoing design criteria, it is estimated that the reservoir could be emptied in 4 days.

The spillway was designed to pass the 1:10,000 year recurrence interval flood, the magnitude of which was determined to be 5,900 cfs based on an analysis carried out by Shawmont Newfoundland Limited[4] and which was verified by several techniques.

Design Concept: As indicated earlier, an earthfill dam was considered to be the only type technically and economically

4. Water Supply System for Stephenville Industrial Area, Shawmont Newfoundland, Limited, September 1970.

feasible in view of foundation conditions and the availability of materials. The design concept that follows is based on a review of various successful designs derived from various sources; notably the United States Bureau of Reclamation. A zoned embankment type of dam with a relatively small impervious core was selected in view of the remoteness (20 miles) of clay/silt deposits. In view of the assumed pervious nature of the foundation, a clay/silt key and upstream blanket were incorporated into the core to provide protection against seepage. The core would be flanked by local material sloped at 3:1 on the upstream face and at 2:1 gradually increasing to 4:1 on the downstream face for stability. The crest width was taken as 20 feet. The upstream face would be protected against wind and wave action by a 3 foot layer of rip-rap evenly graded from 1 foot to 3 feet in diameter resting on a 1 foot mat of gravel filter to prevent erosion of the embankment. The downstream face would be protected against wind and rainfall by a 1 foot layer of cobbles. A cross sectional view of the embankment is shown on Figure 22.

Spillway and Outlet Works: The outlet structure would consist of a tunnel located near the lowest part of the dam. It was determined that a reinforced concrete lining one foot thick, 6 feet by 6 feet (inside dimensions) and 500 feet long would be adequate to pass a flow of 1,000 cfs at a head of 15 feet. Appropriate structural features such as a sluice gate, a mechanism to adjust the gate and an access shaft were considered in the cost estimates.

NOTE: Elevation Refers To Datam Used In Maps Produced by Lockwood, Kessler and Bartlett, New York, April, 1951.

Dam Site # 3 – Representative Cross-Section

(at Deepest Location)

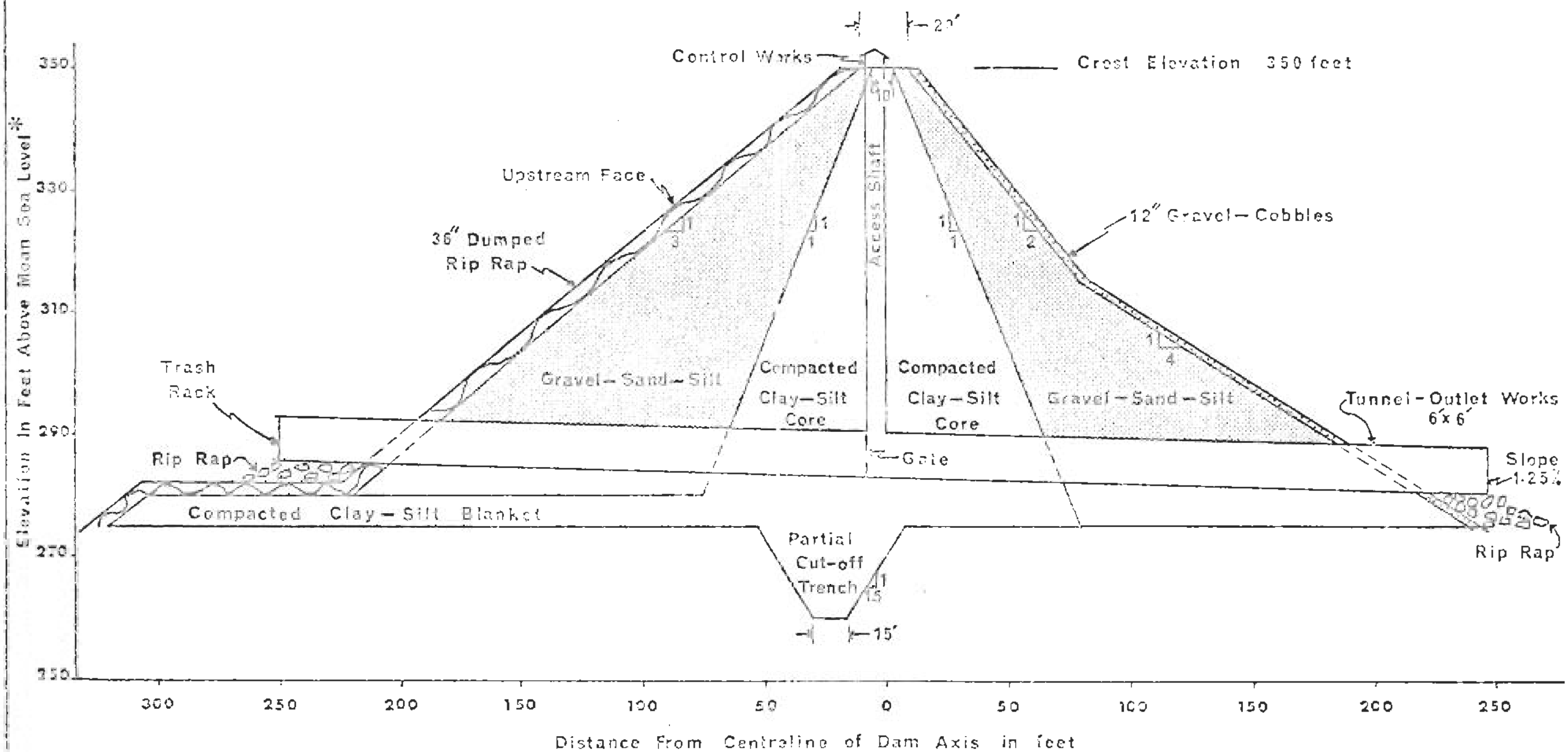


FIGURE 22

A reinforced concrete spillway was designed to pass the 1:10,000 year flood flow. The spillway would be 300 feet wide and 4 feet high at the crest (including an 1 foot allowance for freeboard).

At the base of the reinforced concrete downshute, a stilling basin would be necessary as well as some excavation to channel the flow away from the toe of the dam.

Hydrologic/Hydraulic Effectiveness: As was previously indicated, an upstream storage volume of 12,000 acre-feet would be required to eliminate, to the degree possible, the existing flood damage potential along Blanche Brook under the 1:100 year flood event. This would mean that flood flows along Blanche Brook, upstream of its confluence with Warm Creek, would be about 1,100 cfs under the 1:100 year event. However, even if this optimum level of storage is provided, flood flows in Blanche Brook below the confluence would still be as high as 3,600 cfs. Under this condition, the water surface elevation at the brewery would be about 21.5 feet which is about 2.5 feet below the 1:100 year recurrence interval flood elevation or about 0.5 foot higher than the mean annual flood elevation. The velocity of flood waters in the brewery area would be reduced considerably, thus reducing the damage potential and the level of bank protection that would be required.

The foregoing relates what could be technically achieved with respect to upstream storage development. The following is an analysis of effectiveness of the dam/reservoir alternative, as described in the foregoing sections, under the 1:100 year flood event. The minimum regulated flow downstream of the dam would be approximately 700 cfs which, when combined with local inflow, would represent a flow of approximately 1,800 cfs or about the mean annual flood upstream of the Minnesota Drive bridge. The flow downstream of the confluence would be about 4,300 cfs or about the 10 year recurrence interval flood. The water level at the brewery would be about elevation 22.0 feet or about 2 feet lower than the 1:100 year recurrence interval flood level or about 1 foot higher than the mean annual flood.

Quantities and Cost Estimates: The total quantity, unit cost and capital cost of each major component of the dam and reservoir is shown on Table 6. An allowance of 20% for contingencies and 10% for final design, construction supervision and administration have bee provided in the estimate. As can be seen, the total first cost of the dam has been estimated to be $8.1 million. Based on an amortization period of 50 years and an interest rate of 10%, the average annual cost is estimated to be about $816,000. This does not include any allowance for operation and maintenance.

As shown on Table 6, the largest cost item is the compacted clay/silt material which would form the core, key and upstream blanket of the dam. The design concept as presented herein is viewed to be on the conservative side. It is estimated that should a less conservative design be adopted in the final analysis, the total first cost of the

TABLE 6

SUMMARY OF FIRST COST

DAM SITE 3 - BLANCHE BROOK

Item	Quantity*	Unit	Unit Cost* ($)	Amount ($)
Earth Fill Dam				
Clearing and Stripping	173,500	yd^3	3.00	520,000
Excavation	38,400	yd^3	3.00	115,200
Compacted Clay/Silt	361,000	yd^3	8.50	3,068,500
Gravel/Sand/Silt fill (compacted)	307,000	yd^3	4.50	1,381,500
Rip-rap	58,500	yd^3	5.00	292,500
Gravel, Cobbles	12,200	yd^3	4.75	58,000
Reservoir clearing	420	acres	600.00	252,000
Reinforced Concrete				
(a) spillway	1,750	yd^3	185.00	323,800
(b) outlet works	550	yd^3	185.00	101,800
Gate and appurtenances	1	unit	12,000.00	12,000
Sub Total				6,125,800
Contingencies at 20%	--	job	--	1,225,200
Sub Total	--	job	--	7,351,000
Engineering Design, Supervision and Administration at 10%	--	job	--	735,100
Total First Cost				$8,086,100

* All quantities and unit costs are for materials in place.

dam could be reduced by up to $2 million. This would involve decreasing the size of the core and eliminating the upstream blanket. Should local material be suitable for the core, a further cost saving of up to $600,000 could be realized. It is therefore suggested that when considering this alternative further, the average annual cost could lie somewhere between $550,000 and $820,000.

Summary: In order to provide slightly over 70% of the required upstream storage to eliminate the flood damage potential, under the 1:100 year event, along Blanche Brook upstream of the confluence, it is estimated that the cost lies between $5.5 and $8.1 million. As far as the brewery is concerned, it is estimated that, even if upstream storage is developed to its fullest degree, the 1:100 year flood event would be reduced to conditions slightly above those resulting from mean annual flood. It was therefore decided not to pursue further investigation of additional sites.

No consideration was given to a multi-purpose storage development such as the incorporation of additional live storage for water supply. A cursory examination of prior water supply investigations carried out for the Stephenville area suggests that there are probably more economical ways of meeting water demand. Nevertheless, officials of the Town of Stephenville and the Harmon Corporation may wish to consider this further as conditions change.

7.2 Local Alternatives

Regional structural measures such as those just described are rarely economically viable for communities of the size and damage potential of Stephenville. Rather, structural alternatives such as dykes, channel improvement, floodproofing, channel realignment, etc. which are designed to protect the most vulnerable areas usually prove to be economically viable in most instances provided that an effective balance between non-structural and structural solutions is obtained. For the purpose of this report, the Stephenville area has been divided into three sub-areas which are considered to have similar problems or which can be subjected to similar flood control measures. These areas are (see Figure 23); Sub-area 1, which includes that portion of the floodplain southeast of the confluence of Blanche Brook and Warm Creek including Labatt's Brewery and Humber Motors; Sub-area 2 which includes that portion of the floodplain northwest of the confluence area and south of Main Street-Caroline Avenue including the Federal Building and the Shopping Mall (partial); and, Sub-area 3 which includes all the floodplain on Blanche Brook north of the Main Street Bridge.

7.2.1 Dykes

The protection of flood prone land by a system of dykes is a well recognized and often practised flood control method. Quite often, however, dykes are not constructed to the design standards which are necessary to ensure success.

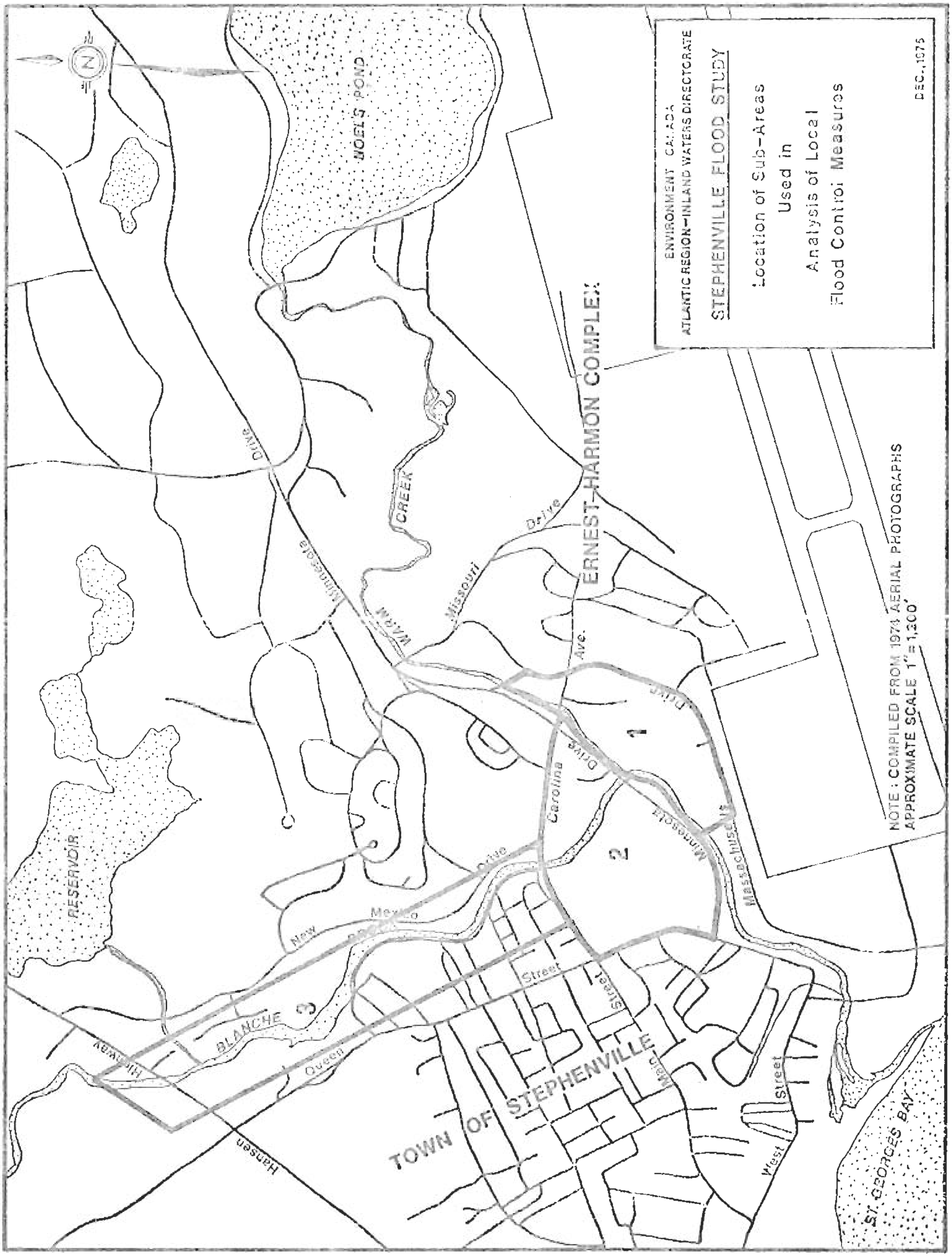

ENVIRONMENT CANADA
ATLANTIC REGION—INLAND WATERS DIRECTORATE
STEPHENVILLE FLOOD STUDY
Location of Sub-Areas
Used in
Analysis of Local
Flood Control Measures
DEC., 1975
NOTE: COMPILED FROM 1974 AERIAL PHOTOGRAPHS
APPROXIMATE SCALE 1"=1,200'
NOEL'S POND
ERNEST-HARMON COMPLEX
RESERVOIR
TOWN OF STEPHENVILLE
ST. GEORGES BAY
WARM CREEK
BLANCHE
Minnesota Drive
Missouri Drive
Carolina Drive
Ave.
Massachusetts
New Mexico Drive
Hansen Highway
Queen
Main Street
West Street
Street
1
2
3

FIGURE 23

The following is a listing of the design standards, adopted from various practical applications notably those of the United States Bureau of Reclamation, used in this study.

(1) The crest elevation of the dyke must be of sufficient height to prevent overtopping during the 1:100 year recurrence interval flood with adequate allowance for wind and wave action.

(2) The dyke must provide protection against seepage, both through and under the dyke section, which could lead both to the development of small underground channels (piping) and saturation of the dyke section. Under either condition, the probability of dyke failure is high.

(3) The side slopes must be constructed such that adequate bank stability and overall structural stability is provided.

(4) The dyke, along the water side, must be protected against the erosional forces of water combined with the forces created by ice and debris. Velocities of up to 10-12 feet per second can be expected along that portion of the dyke near the brewery while velocities of 5-6 feet per second can be expected at most other locations.

(5) The land behind the dyke must be drained of all water, resulting from uncontrolled seepage and local runoff, to prevent flooding and to enhance the structural stability of the dyke.

Sub-Area 1: A dyke, reconstructed after the August, 1973 flood presently exists along Blanche Brook and Warm Creek. The dyke has served to protect the brewery from minor flooding. However, signs of sloughing are already evident and it is doubtful that it could withstand a flood of the magnitude of the mean annual flood.

Design Concept: Two design concepts for the basic dyke were explored. The first consists of a homogeneous embankment constructed from local materials, the second a zoned embankment consisting of a clay core and cutoff trench flanked by local materials. In each case, the existing fill would be excavated. The rationale for this is based on the requirement that the materials used in the construction of a permanent dyke must be compacted in layers (preferably 6 inches) by appropriate equipment (preferably sheepsfoot roller). The zoned embankment type was selected as the basic design concept based on the assumption that the existing material would not provide adequate protection against seepage, an assumption which should be verified by soil testing before further design work is carried out. An estimate of the cost of a homogeneous dyke is also provided for comparative purposes.

Layout and Cross Section: The layout for the dyke is shown on Figure 24. As can be seen the dyke consists of two basic sections. The first section, protecting Labatt's Brewery, the Curling Rink and the Gymnasium, is about 2,400 feet in length, while the remaining section, protecting Humber Motors, is about 1,000 feet in length. There are some complications around the Carolina Avenue bridge, where the dykes would have to be extended along the easterly approach road on both sides, and along Warm Creek where space limitations may be a problem near Humber Motors. These should be thoroughly investigated during final design activities. An obvious alternative to the former would be to increase the grade of the approach road to an elevation comparable to the elevation of the bridge.

The crest elevation of the proposed dyke is shown in Figure 25 together with the 1:100 year flood profile and the ground elevation of the land on which the dyke would be founded. An allowance of 2 feet has been provided for freeboard. As can be seen, the top elevation of the existing dyke protecting the brewery is similar to that proposed.

The dyke, as shown on Figure 24, consists of a clay key extending 5 feet below the existing ground elevation, a clay core extending above the clay key to the crest of the dyke all of which would be flanked by till material (gravel/sand/silt) which is assumed to be the composition of the existing dyke. The side of the dyke exposed to the stream would be sloped at 3:1 and protected with truck-dumped rip-rap 3 feet in thickness and ranging in size from ½ ton to 1 ton evenly graded. The opposite side of the dyke would be sloped at 2:1 and protected with vegetation (seeded).

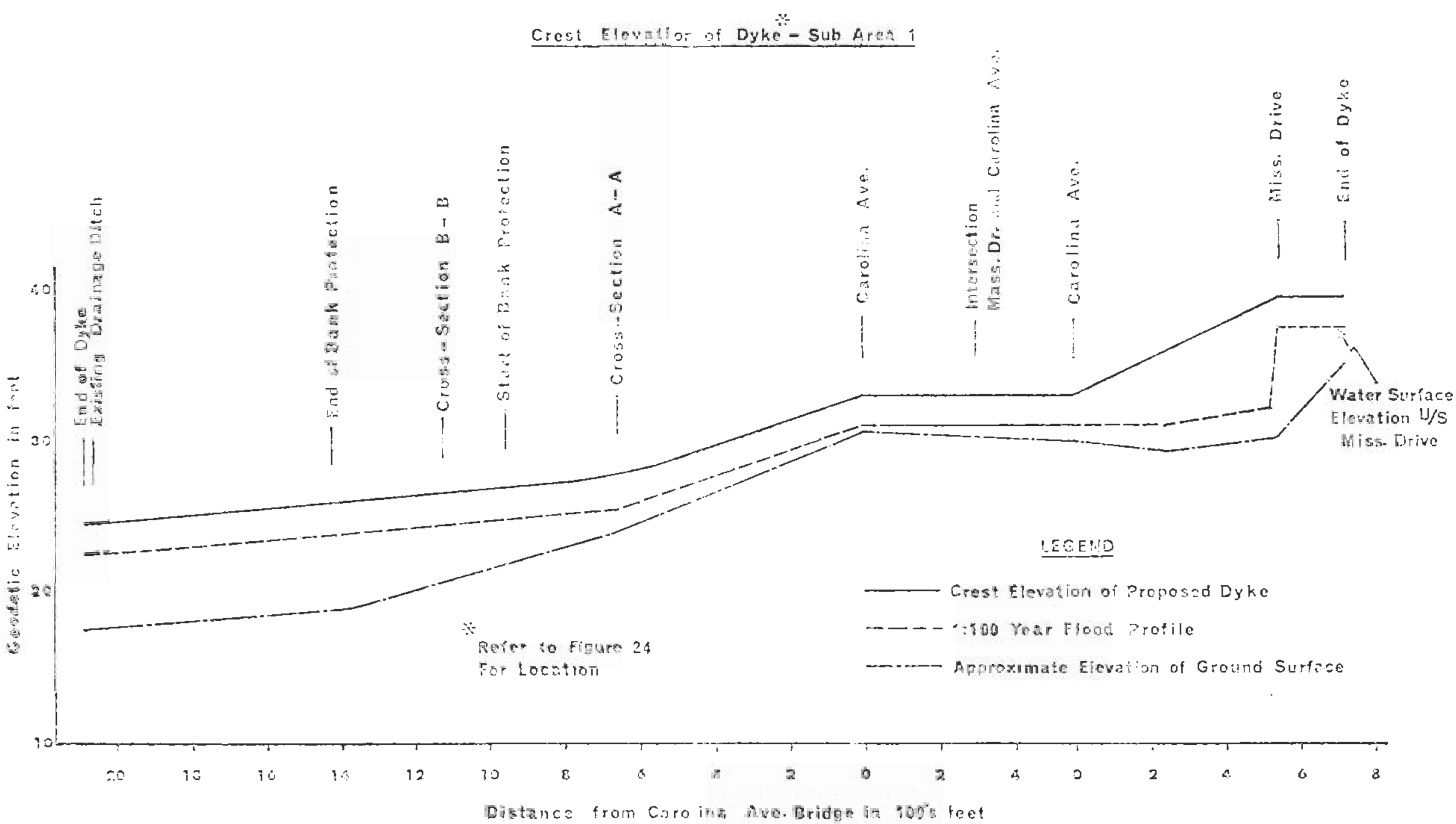

Crest Elevation of Dyke* - Sub Area 1
End of Dyke
Existing Drainage Ditch
End of Bank Protection
Cross-Section B - B
Start of Bank Protection
Cross-Section A - A
Carolina Ave.
Intersection
Mass. Dr. and Carolina Ave.
Carolina Ave.
Miss. Drive
End of Dyke
Water Surface
Elevation U/S
Miss. Drive
40
30
20
10
Geodetic Elevation in feet
* Refer to Figure 24
For Location
LEGEND
Crest Elevation of Proposed Dyke
1:100 Year Flood Profile
Approximate Elevation of Ground Surface
20
18
16
14
12
10
8
6
4
2
0
2
4
0
2
4
6
8
Distance from Carolina Ave. Bridge in 100's feet

FIGURE 25

All materials excepting rip-rap are to be compacted in 6 inch layers by a mechanical means (sheepsfoot roller).

As described previously, Blanche Brook will follow the path of least resistance and eventually cut through the existing dyke, or for that matter the proposed dyke, unless proper protection is provided. The Brewery lies directly in the "firing line" of Blanche Brook so to speak. Several methods of bank protection were investigated. It became apparent that armour stone (4-5 tons), which can be obtained from a local quarry and which should be of good quality, is the least costly and, judging from the literature, the most effective bank protection measure. Because of its size, the armour stone would have to be placed by a heavy crane. The area requiring protection, as outlined in Figure 24, is about 350 feet in length.

Drainage Network: A drainage ditch is required behind the proposed dyke to drain water which seeps through/under the dyke and/or which results from local runoff. This is required to maintain the structural stability of the dyke which may weaken under saturated conditions.

The outlet of the existing drainage ditch would have to be blocked to prevent backup of the stream into the floodplain at that location. It is proposed that a new drainage ditch be provided which would transmit water from the floodplain to a point just upstream of the Recreation Centre Bridge. It is also proposed that a culvert be placed under the easterly approach road to the Carolina Avenue Bridge to provide drainage of the Humber Motors Property. The layout for the drainage network is shown on Figure 24.

Quantities and Cost Estimates: The quantities, unit cost and cost estimate of each major component of the dyke proposal is shown on Table 7. The estimate includes an allowance of 20% for contingencies and 10% for final design, construction supervision and administration. The total first cost has been estimated to be approximately $252,000. By way of comparison, the total first cost of the homogeneous dyke was estimated to be approximately $200,000.

A dyke of this nature, designed and constructed to rigid standards, should provide an economic life of at least 50 years provided preventative maintenance is carried out on a routine basis. Based on an interest rate of 10% and an amortization period of 50 years, and assuming a nominal annual maintenance cost of $3,000, the average annual cost of the dyke is estimated at $28,000.

It should be remembered that irregardless of the alternative adopted, with the possible exception of upstream storage, that bank protective works should be strongly considered. The above estimate includes this cost ($75,000).

Sub-Area 2: Because the flood damage potential of this portion of the floodplain is negligible at the present time, no consideration was given to dyking. However, future development such as the proposed motel could be protected by

TABLE 7

SUMMARY OF FIRST COST

PROPOSED DYKE - SUB-AREA 1

Item	Quantity[1]	Unit	Unit[1] Cost ($)	Amount ($)
Excavation	4,400	yd^3	3.00	13,200
Clay Core-Key	9,000	yd^3	6.50	58,500
Sand/Gravel/Silt	6,850	yd^3	3.00	20,550
Rip-rap	10,650	yd^3	5.00	53,250
Armour Stone	3,400	ton	11.00	37,400
Grass Seeding	42,300	ft^2	0.10	4,200
Miscellaneous	-	-	-	4,000
Sub Total				191,100
Contingencies at 20%	-	job	-	38,200
Sub Total	-	-	-	229,300
Engineering Design Supervision and Administration at 10%	-	job	-	22,900
Total First Cost				$252,200

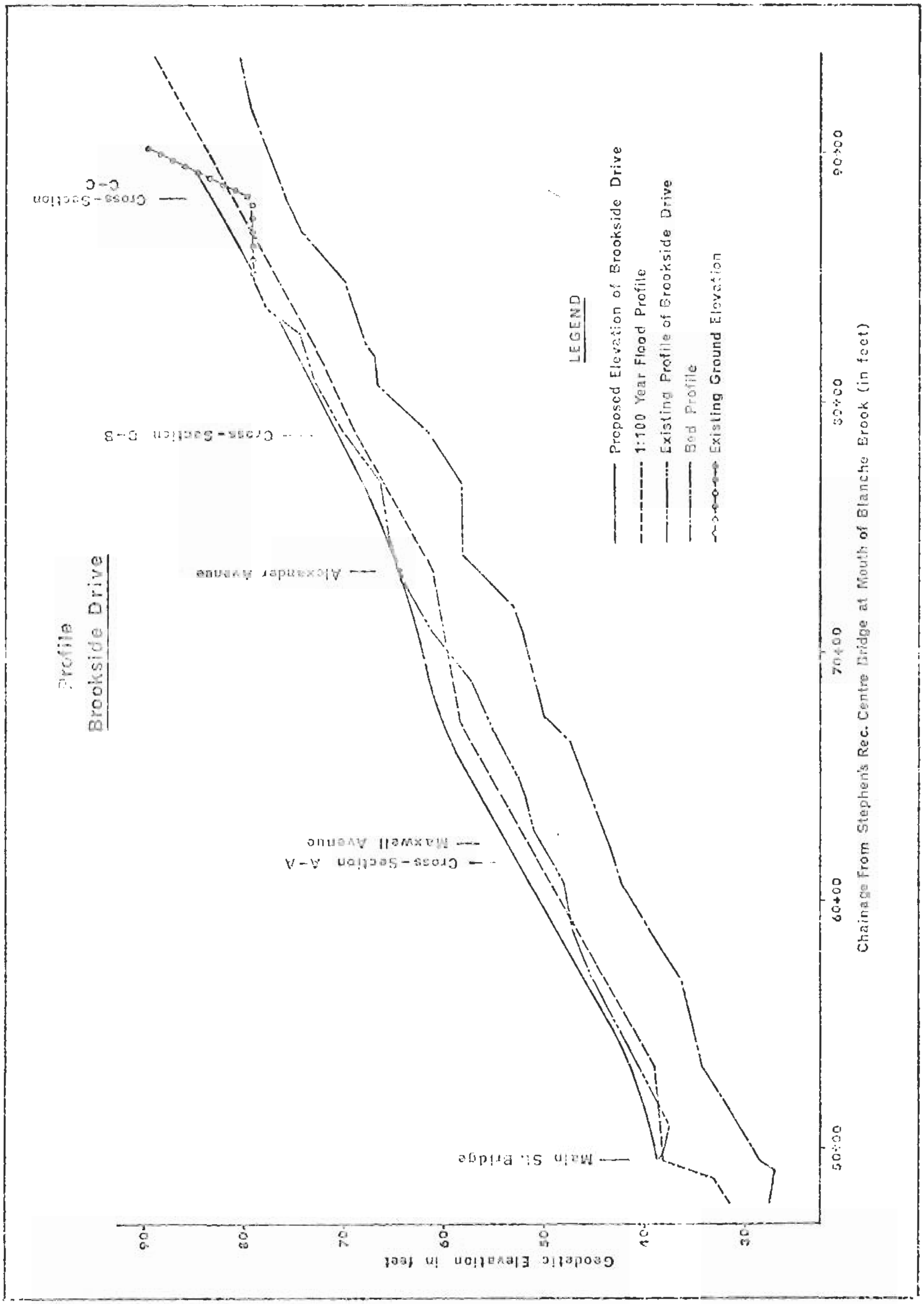
1. All quantities and unit cost are for materials in place.

dykes similar to those described above. However, it is felt that floodproofing would be a more viable method. This will be discussed in section 7.2.4.

Sub-Area 3: In view of the relatively low damage potential in this reach of the brook, extensive flood control measures were not considered to be warranted. The only practical measure that emerges here is the upgrading and extention of the existing Brookside Drive coupled with bank protective works.

Brookside Drive can be considered to be a dyke which, if upgraded and extended, would provide protection against major flooding with the exception of a small area just upstream of the Main Street bridge. Here a "relief valve" for flood waters is considered necessary in the event of serious ice jamming which occurs from time to time. Otherwise the Main Street Bridge could be jeopardized.

A profile of existing Brookside Drive is shown on Figure 26. The 1:100 year flood profile as developed in this study is also shown. It is suggested that Brookside Drive be upgraded to the elevation indicated, which incorporates a freeboard allowance of 2 feet. It is also suggested that Brookside Drive be extended northerly about 500 feet to prevent flood waters from getting in behind the dyke. The areal extent of the improvements required together with representative cross sections is shown on Figure 27. It is also suggested that all storm drains, culverts or openings of any kind that drain into Blanche Brook, if any, be stopped



Profile
Brookside Drive
Cross-Section C-C
Cross-Section B-B
Alexander Avenue
Maxwell Avenue
Cross-Section A-A
Main St. Bridge
LEGEND
Proposed Elevation of Brookside Drive
1:100 Year Flood Profile
Existing Profile of Brookside Drive
Bed Profile
Existing Ground Elevation
Geodetic Elevation in feet
90
80
70
60
50
40
30
50+00
60+00
70+00
80+00
90+00
Chainage From Stephen's Rec. Centre Bridge at Mouth of Blanche Brook (in feet)

FIGURE 26

up to prevent backup. It is suggested that rip-rap be placed along Brookside Drive to prevent erosion of the dyke.

Approximately 9,300 cu. yards of fill (in place) would be required to upgrade and extend Brookside Drive. Based on a unit cost of $4.50 per cu. yard and allowing 20% for contingencies and 10% for final design, contract supervision and administration, the total first cost of improving the height of the roadbed is estimated at $55,000. This does not include resurfacing. Based on a unit cost of $5.00 per cu. yard with similar allowances for contingencies, etc., the total first cost of rip-rap is estimated at $58,000.

It is possible that the cobbles which presently exist in and along the banks could be used to protect the dyke and as such a signficiant cost saving could be achieved. It is suggested that where the river changes direction (i.e. the flow is directed towards the dyke), rip-rap be provided. Those areas which should be rip-rapped are shown in Figure 27.

7.2.2 Channel Improvements

As with a dyking system, the improvement of the hydraulic capacity of a watercourse is a well recognized structural alternative employed in the prevention of flood damages. Conceptually, this involves the deepening and/or widening of the channel such that it can carry river flows at lower water levels and as such reduce flood levels. As was indicated in the previous section, bank protective works would still be required below the confluence of Blanche Brook and Warm Creek. The side slopes of the channel excavation must be designed to ensure bank stability consistent with the physical/mechanical properties of the soil.

The methodology used to evaluate the hydraulic effectiveness of the various dredging schemes investigated is similar to that used to develop the flood profiles in section 5.2 and may be found in Appendix C.

Sub-Area 1: Blanche Brook, from its mouth to its confluence with Warm Creek, is an artificial channel constructed prior to 1952 in conjunction with the expansion of the air base. It is not known whether or not the hydraulic capacity of this reach has been reduced over the years by sediment build-up. However, the drop in water surface elevation over this reach is approximately 13.5 feet under 1:100 year flood conditions. It was therefore decided to investigate the feasibility of dredging this reach of the river.

Design Concept: Two dredging schemes were explored in detail to assess the cost/effectiveness of the range of possible schemes. Both schemes involved the lowering of the existing riverbed by three feet from a point about 500 feet upstream of the Recreation Center bridge up to the Carolina Avenue bridge. Channel improvement upstream of the Carolina Avenue bridge was not considered because of the fact that the Carolina Avenue ridge would have to undergo a major structural modification before any such dredging would be effective.

Layout and Cross Section: Scheme 1 involved lowering the riverbed elevation by 3 feet on the average and widening the channel 80 feet, where necessary, at the base along

Blanche Brook and to 60 feet, where necessary, at the base along Warm Creek. The side slopes were taken at 2:1 which is considered to be adequate from the point of view of bank stability considering the nature of the materials involved. The areal extent of Scheme 1 is shown, together with representative cross sections, on Figure 28.

Scheme 2 was similar to scheme 1 with the exception of the Blanche Brook reach where the base width was expanded to 160 feet

Hydraulic Effectiveness: The water surface elevation near the brewery was determined to be 20.5 feet and 17.7 feet for schemes 1 and 2 respectively. This may be compared to an estimated elevation of 23.9 feet which occurs under existing channel conditions for the 1:100 year flood. The relationship between volume of channel excavation and water surface elevation near the brewery is plotted on Figure 29 to permit extrapolation. As indicated in Section 6 of this report, there would be virtually no flooding damage at the brewery when the elevation of Blanche Brook, near the brewery, is below 19 feet. Therefore, referring to Figure 29, approximately 170,000 yd^3 of material would have to be excavated from Blanche Brook to eliminate the flooding problem at this location.

Cost Estimates: The unit cost of dredging can be extremely variable depending on the type of materials excavated, the method of disposal, site conditions, the availability and

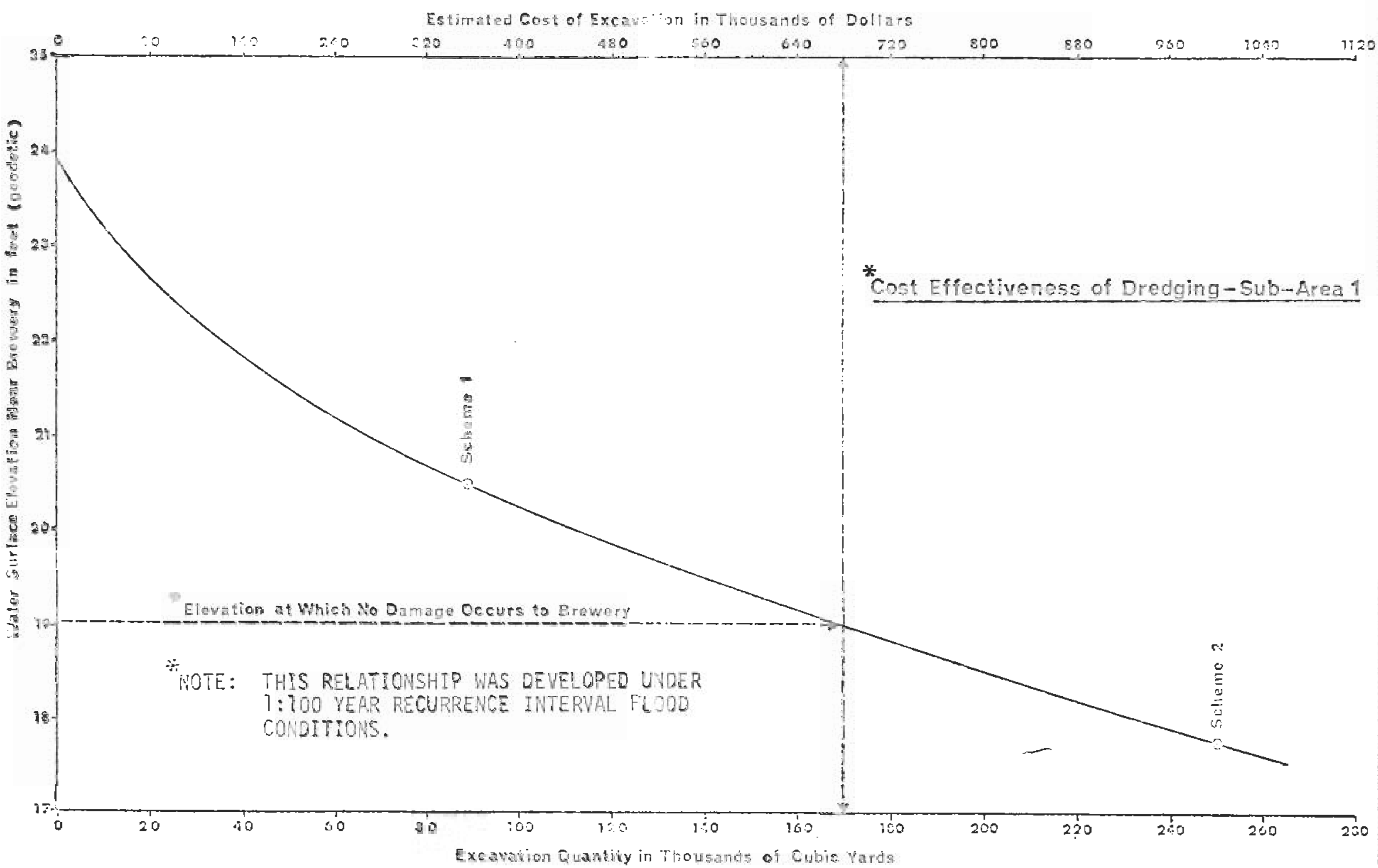

*Cost Effectiveness of Dredging–Sub–Area 1
Estimated Cost of Excavation in Thousands of Dollars
0
400
480
560
640
720
800
880
960
1040
1120
Water Surface Elevation Near Brewery in feet (geodetic)
24
23
22
21
20
19
18
17
Scheme 1
Scheme 2
Elevation at Which No Damage Occurs to Brewery
*NOTE: THIS RELATIONSHIP WAS DEVELOPED UNDER 1:100 YEAR RECURRENCE INTERVAL FLOOD CONDITIONS.
Excavation Quantity in Thousands of Cubic Yards
0
20
40
60
80
100
140
160
180
200
220
240
260

FIGURE 29

capability of local contractors, etc. It has been assumed that the material can be excavated by conventional drag-line and hydraulic bucket equipment and that the material would be deposited within a 2 mile radius of the side. Based on a limited analysis of recent dredging and excavation costs a unit cost of $4.00 per cubic yard was developed.

The cost of dredging was therefore determined to be $680,000 to provide complete protection against flooding. The cost of lesser protection, say scheme 1, would be $360,000. It was concluded that dredging in this area was not economically feasible in comparison to the dyking alternative based on the following rationale:

(1) The high initial capital cost

(2) Relatively short economic life, say 10 years. Maintenance dredging would have to be carried out on a regular basis.

(3) Bank protection would still have to be provided at the brewery at an estimated capital cost of $75,000.

(4) Flood problems would be almost as extensive at Humber Motors.

Sub-Area 2: Because of the relatively low damage potential of this portion of the floodplain, channel improvements, per se, were not considered. Because of the design of the Minnesota Drive bridge, dredging in this reach of Blanche Brook is not likely to be effective unless of course the bridge is relocated/reconstructed. The cost of realigning the channel was considered, however, in view of the erosion potential near the brewery. This will be considered in a latter part of this report (section 7.2.3).

Sub-Area 3: As with sub-area 2, the relatively low damage potential in this reach of Blanche Brook would not justify dredging, some of which would involve rock. It is felt that, to be effective, the Main Street bridge would have to undergo a major structural change and that, because of the physical properties of the existing channel, significant volumes of material would have to be removed. However, this is not to say that the channel clearing and maintenance program initiated by the Town in 1970 should not be continued. In fact, this type of program is viewed as a very necessary measure. The environmental impact, especially on the fishery resource, should however be considered.

7.2.3 Channel Realignment

Another structural measure to relieve the confluence area from high velocities and water levels is to realign Blanche Brook to meet Warm Creek downstream of the present confluence. The realignment plan studied directed the Blanche Brook flow in a gradual arc from just below the Main Street bridge, through the existing sports field, to rejoin the Warm Creek flow just south of the school (1,700 feet downstream of the confluence).

This realignment scheme would require the excavation of about 60,000 cubic yards and the closure of the existing channel. The excavation alone could cost $240,000 (at $4.00 per yd^3). The sports field would have to be moved and one or two new bridges constructed. The only benefit would be the reduction of high velocities at the confluence and therefore, the removal of the necessity of bank protection at that location ($75,000). Of course, the flood hazard in sub-area 2 would be virtually removed under the 1:100 year flood. It would possibly, however, alter existing development plans. In view of the high cost, it was decided not to pursue this alternative further.

7.2.4 Floodproofing

Besides erecting major structures to protect assets on the floodplain, it may also be possible to protect them by floodproofing. In contrast to other structural measures which normally imply protection from a distance, floodproofing usually implies protection by altering the building to be protected (or activity within it) in such a manner as to make it less vulnerable to the flood hazard.

One type of floodproofing is the use of materials, which are less susceptible to water damage, in the construction of new buildings. This would have applicability to future development on the Stephenville floodplain, not to existing vulnerability.

A second type of floodproofing is the placing of new structures high enough such that a design flood (1:100 year event or greater) will not significantly affect them. This type of floodproofing has already been used in Stephenville in the construction of the Federal Building. The costs associated with this measure are very much dependent on site conditions and as such are extremely difficult to generalize. In most cases, however, the additional cost that must be borne by a prospective developer is substantially less than the additional flood damage potential that he will experience if he fails to floodproof his new building in this manner.

A third possibility is to allow the water to enter the building, but to insulate key installations against damages by means of shut-off valves, concrete casings, etc.

The final type of floodproofing is to seal off the building entirely. This makes the exterior of the building the only line of defense. It is also possible and sometimes desireable to combine the latter two approaches, depending on the particular building involved.

The current damage potential on the floodplain is described in section 6 of this report. This damage potential exists at both residential and non-residential structures. The latter include Labatt's Brewery, Humber Motors, Wesmount Realty, Stephenville Building Supplies, and the Curling Rink. The possibility of floodproofing each of these locations is addressed below.

At the outset, it must be stated that without a detailed evaluation of each building in terms of its capability to be floodproofed, it is extremely difficult to develop a reliable cost estimate. Cost estimates, therefore, are indicative only.

Sub-Area 1: The vulnerable locations in this sub-area are Labatt's Brewery, Humber Motors, and the Curling Rink.

For the Curling Rink, it appears that the best type of floodproofing would be to permit the flood waters to enter the structure and to provide floodproofing for only electrical and mechanical installations. The 1:100 year flood level would inundate the curling surface to a depth of about 2 feet. Although the curling rink itself was not specifically studied during the project, it is anticipated that the only damage potential of any consequence from such a flood would be to the electrical and mechanical installations.

In the absence of first hand knowledge of the design of the building, it is assumed that a concrete wall, 100 feet in length (total), three feet high and one foot thick would be adequate to protect these installations. It has been assumed that the assets to be protected are presently located on a concrete slab and that some sealing would be required. A rough estimate of the cost of carrying out these measures in the assumed conditions would be approximately $4,000.

At Humber Motors it appears that the 1:100 year event would inundate the building to a depth of about 2 feet. It has been assumed that the rolling stock located on the property could be moved to higher ground in advance of the flood. All tools and equipment should be stored above the flood level. The building itself is not easy to floodproof. Should it be desired to do so, the easiest way would probably be to ring the structure with an impervious material (concrete wall-earth dyke-etc.). No cost of doing this has been estimated because it does not appear that floodproofing

Humber Motors to this extent would be economically efficient.

At the brewery, a critical situation would exist under 1:100 year conditions. Water would inundate the floor to a depth of about 5 feet. Due to the scale of damage which would occur during even a small flood, it would be desirable to prevent water from entering the building entirely. It has been assumed that the building is structurally sound and can withstand the hydrostatic forces involved. In this regard, as has been referred to in earlier sections of this report, it has been assumed that bank protective works will be installed and as such the dynamic forces of water, ice and debris will be minimal.

There are approximately 62 windows (estimated dimensions: 3' X 5') which would be partially covered by the flood waters. If floodproofing is to be done at the brewery these windows should be removed, the bottom three feet or so be filled in with concrete or solid blocks, and a new window installed in the remaining 2-3 feet. Alternatively, metal plates with rubber seals could be mounted in advance of a flood and removed after the flood threat has passed. The latter method would be more approoriate if inside lighting becomes a factor. However, an early warning system would have to be established.

There are six small door and eight large loading door openings. Water tight doors of solid construction with good seals and interior fasteners would be required. For the loading doorways these could be attached either inside or outside (preferable) the existing doors and would have to be 6 feet high.

There are two locations on the building exterior where large tanks or machinery are located. These installations should be surrounded by reinforced concrete walls six feet high. The concrete wall should be founded on a concrete base which should extend under the equipment to the brewery wall.

Other floodproofing measures would include provision of an early warning system which might consist of a river stage recorder, assigning personnel to keep tabs on the weather and hydrologic conditions, etc. (see Chapter 8); sump pumps to remove any seepage and relieve uplift pressures and valves to prevent backup of water in conduits into/from the plant.

The best current estimate of the costs of carrying out the activities mentioned above is between $90,000 and $120,000.

As an alternative to the above concept, a dyke, similar in design features to that discussed under section 7.2.1, could be constructed around the brewery to an elevation of 25 feet. Appurtenant works such as sump pumps, valves, etc. would be required as well. In addition, an entrance capable of being temporarily sealed would have to be provided. The costs associated with this concept are very similar to those described above. If, for example, it was determined that the building is not structurally sound enough to support the floodproofing measures formerly described, the latter concept could be adopted. On the other hand, the dyke would occupy a significant area (about 30 feet at base).

Assuming an amortization period of 50 years for the floodproofing measures in sub-area 1 and a discount rate of 10%, the average annual cost of floodproofing the brewery and the curling rink is estimated at between $9,500 and $12,500.

It must be recognized that the above estimate is no more than an indication of the order of magnitude of the total cost. Substantially more study should be made of both the building and the possibilities for changing it, prior to actually carrying out any floodproofing measures.

Floodproofing appears to be a viable alternative for sub-area 1, based on the costs of doing so compared with the expected benefits. However, three factors must be considered when comparing this alternative to others such as the dyke. Firstly, it only protects the brewery and the curling rink. No other assets in sub-area 1 would be made less vulnerable by floodproofing the brewery. Secondly, the adjustment depends on a fairly adequate warning system. Because of this, and because of the timelag in human reaction to a warning, there is a considerable risk factor attached to this alternative at a location as highly susceptible to flood damages as the brewery. Thirdly, bank protective works, as described in section 7.2.1, costing about $75,000 would be required to protect the brewery from being undermined and structurally damaged by Blanche Brook.

Sub-Area 2: There are no vulnerable structures in this area. However, the potential exists for investment and it is suggested that all future developments be floodproofed, e.g. by the use of minimum foundation heights.

Sub-Area 3: At both the Stephenville Lumber Supplies and Wesmount Realty buildings, floodproofing is not judged to be feasible. Damage potential originates not from the water itself, but from the ice, and flood protection against the relatively small amount of ice damage does not seem to be warranted.

In the residential areas upstream of Main Street, it might be possible to undertake floodproofing of the estimated twenty-five structures located in the vulnerable zone. The type and cost of floodproofing would have to be determined on a case by case basis. However, attempts have been made in the past to generalize the cost of floodproofing. One such attempt was by Sheaffer[5] in the Bristol, Tennessee case. In this study, the average costs of floodproofing twenty-one types of establishments were calculated per foot of depth of flood water. As a result of his study, the following function for estimating the costs of keeping water out of the buildings was formulated:

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5. Sheaffer, John R., Floodproofing: An Element in a Flood Damage Reduction Program, University of Chicago, Geography Research Paper No. 65, Chicago, 1960.

$$Cfp = 0.035\ Msh$$

where Cfp = cost of floodproofing in dollars

Ms = Market value of structure flooded in dollars

h = water depth for which floodproofing measures are designed (in feet)

This function could be applied to residential structures in the floodplain as follows: There are eleven homes within the high hazard area, denoted on Map 1 (1:100 year flood) for which tax assessment information was available. An average market value (Ms) of $8,600 was determined based on the premise that the assessed value is 75% of the market value. As noted in section 6, estimated water depths in these residential structures could be two feet. Thus the cost of floodproofing the 25 vulnerable homes may be estimated at:

Cfp = (0.035) (8600) (2) (25) = $15,050 or $600 per home. It is entirely likely that the floodproofing of homes on the outer fringe of the vulnerable area could be done for less than $600 and it is equally likely that higher vulnerable homes would require more than this.

Assuming an effective life of 15 years for the floodproofing measures and a discount rate of 10%, the average annual cost of floodproofing sub-area 3 becomes roughly $2,000.

8. NON-STRUCTURAL MEASURES FOR FLOOD DAMAGE REDUCTION

In addition to the various structural adjustments possible there are a few non-structural alternatives that appear to be at least partially feasible on the Stephenville floodplain. A brief description of each is provided under the following headings: watershed management, flood forecasting and flood warning, zoning regulations, and other considerations.

8.1 Watershed Management

In this report, watershed management has been defined to include the management of those activities which can contribute to increasing the magnitude of flooding. These activities include a wide range of land use practices ranging from agriculture and forestry to urban expansion. In the Blanche Brook watershed, two activities, forest cutting plans and practices and tree/debris control, are viewed to be significant enough to warrant management action or at least future consideration.

8.1.1 Forest Cutting Plans and Practices

In a small watershed such as Blanche Brook, land use changes can influence (increase) the magnitude and timing of flooding. The removal of the forest cover, for example, reduces the interception of precipitation and increases direct insolation causing snow to melt earlier and more rapidly. Flood peaks can be further increased because of soil freezing which is aided by the removal of forest litter and humus. Exposed soils, puddled by rain in the fall, can become completely impermeable when frozen. In contrast, forest soils are generally not frozen solid and usually retain some degree of permeability, thus storing a component of the spring freshet. The extent to which forest cutting can increase the flood peak is not well documented. Studies in the United States have indicated that the flood peak could be increased by up to 50%. However, it has also been concluded that changes in land use can influence the runoff volumes of small or medium sized floods, but have little effect on major floods such as the 1:100 year flood described in this report.

Much of the Blanche Brook watershed is forested. Forest cutting has been extensive in some areas in the headwaters, but this is relatively minor in relation to the basin as a whole. Future cutting plans are unknown at this time. It is suggested that forest cutting plans and practices be reviewed and monitored and that appropriate steps be taken to ensure that both environmental and flood hazard concerns associated with them are allayed.

8.1.2 Tree/Slash Removal Program

The flooding problem in Stephenville has historically been complicated by trees and other debris being transported downstream and getting hung up at constrictions (i.e. bridges) in the Town. Steep slopes in the upper watershed coupled with the high degree of erodability of soils along the banks of Blanche Brook appear to have contributed to this problem in the past and may be expected to continue to do so in the future.

In order to offset the impact on the flood problem, it might be feasible to carry out a tree clearing program in the downstream reaches of the brook. Such a scheme would involve the periodic removal of debris from reaches below the Hanson Highway in order to increase the channel capacity in times of flooding. The cost of such a program has not been estimated in this study, but it is readily apparent that it would not be excessive and it could be organized by the municipal government.

There also exists the possibility of tree clearing and/or bank stabilization upstream of the Hanson Highway. Tree clearing could be performed in conjunction with the downstream program, but the effects of this procedure should first be evaluated in terms of its effect on bank stability. Although no evaluation was carried out, it is anticipated that the costs of this type of program would be prohibitive.

8.2 <u>Flood Forecasting and Flood Warning</u>

If a flood can be predicted in advance and flood bulletins issued, the inhabitants of floodplains can take individual or collective action to minimize their damages. Public agencies are also given the advantage of preparing for such emergency action as may be necessary during time of flood.

Flood forecasting systems ideally provide accurate information on the areal extent of flooding, when it will occur and the depth of water for critical locations. The development of a detailed flood forecasting system requires a considerable amount of effort. Months, if not years, may pass before a reliable forecast can be issued.

The first step in the development of a forecasting system is to identify the nature and extent of the flooding problem. This problem has been partially addressed in the current study. However, substantially more data would be required to adequately predict flood flows. This data should include precipitation records, snowpack surveys, temperature of the ambient air, wind speed, solar radiation, detailed cross-sections and bed profiles, ice surveys and streamflow records.

The above variables would have to be fully investigated in preparing a detailed flood forecasting model for the Stephenville floodplain. However, in small watersheds like Blanche Brook, this ideal system would have to be scaled down to keep the cost in line with the anticipated benefits. A few stage recording stations, at key locations, connected to alarms may provide an adequate warning of rising water levels. These stations, coupled with a few response functions (i.e. relationships between runoff-precipitation and snowmelt), meteorological data, and an accurate weather forecast could represent the most practical solution to the forecasting requirements in Stephenville. However, as in the case of the more sophisticated approach, it would probably take several years of data and experience to develop a reliable flood forecasting system.

The use of a forecasting system does have some potential for reducing damages in certain circumstances. Accurate forecasting could be extremely fruitful should floodproofing be adopted at the brewery. The forecast could also be used to warn residents to move property out of the vulnerable zones.

However, at least three factors operate against the formulation and installation of such a system for the Stephenville area. First, there is not sufficient reliable hydrologic and climatic data in the drainage area. The cost of obtaining this data, in a watershed as physically variable as that of Blanche Brook, would probably be prohibitive. Second, the greatest damage potential exists at the brewery. Unless the brewery is to be floodproofed, flood warning is not likely to be effective since most of the damage potential is to virtually immoveable assets. Third, the flashy nature of the brook has been referred to elsewhere. The short period of time between the origination of the flood and the flood peak would make early warning in the Stephenville case extremely difficult.

In short, the use of a rudimentary forecasting system appears to have some potential for reducing flood damages. However, in this particular case, this usefulness is limited and the level of investment made in forecasting and emergency measures should be tempered accordingly.

8.3 Restrictive Zoning

Restrictive zoning has already been applied to parts of the Stephenville floodplain (Figure 17). However, the

Harmon Complex has not yet been subjected to zoning to date.

In the current development plan for the Town, development area 7 is critical. It is here that most future development is expected to take place. A school, shopping mall and federal building have already been built and more growth is planned. To zone this area of the floodplain for no development does not seem warranted, especially in view of the successful floodproofing of the federal building. The opportunity costs that would be incurred here as a result of prohibiting investment would likely outweigh the potential increase in total vulnerability.

A large proportion of development areas 8 and 9 are currently zoned for restricted development. If nothing is done about the hazard in the area, this zoning seems appropriate for all lots inside the 1:100 year flood line. The remainder of the lots (i.e. outside of the 1:100 year flood line) could be developed in view of their low degree of exposure to the hazard. Should dykes or other structural measures be adopted for the area, restricted development zoning could be removed. However, this is potentially quite dangerous. If a flood larger than that for which the measures are designed should occur, the increased damage potential would outweigh the reduction in opportunity costs that would result from the rezoning. These opportunity costs are not likely to be very great in the first place, since there does not appear to be a severe shortage of land suitable for housing development in the Stephenville area. As a result, it would probably be a prudent decision to maintain zoning restrictions on the most vulnerable areas even after any adjustments are made in these development areas.

Development areas 26B and 27 are not currently zoned since they fall within the boundaries of the Harmon Complex. However, it does not appear that extensive growth will occur in these units as long as a flood problem persists at the brewery. There seems to be no reason why future development should be prohibited in this area on account of the flood problem, provided that foundations are built to minimum heights as suggested for development area 7 and that these structures do not interfere with the hydraulic properties of the stream as referred to in section 5.3.3. To illustrate this latter point, take the hypothetical situation where a structure is placed in development area 7 such that it constricts the flow of water under flooding situations. There is a possibility that it might jeopardize the new shopping mall.

In short, restrictive zoning has been fairly effective in the past in ensuring that economic growth is compatable with the flood hazard, and its usefulness should be considered in future floodplain management. However, there appears to be no sound reason for excluding conforming land uses from the floodplain. To do so would be to ignore the economic utility of the land in question.

8.4 Other Considerations

In addition to the three types of non-structural measures discussed above, there are a host of other tools that can be utilized. Of these, the development of public awareness about the flooding problem should come first. All activity in the floodplain and much of the activity in the drainage area should be interpreted in terms of its potential impact on the flood problem. The only way to do this is to ensure that the public is aware of the basic nature of the problem. It became quite apparent during the resident survey (Appendix A) that public understanding of the flood hazard is limited.

Flood insurance is sometimes suggested as a useful tool in floodplain management. It would not be appropriate in Stephenville because of the obvious inability to spread the risk of flood damages over either time or space.

Other potential adjustments which have only limited applicability to the problem are residential redevelopment, tax policies to discourage development on the floodplain, and warning signs showing past flood heights.

9. EVALUATION OF FLOOD ADJUSTMENT ALTERNATIVES

There are several possible ways to deal with the flooding problem in Stephenville. These range from complete inaction to complex structural solutions involving millions of dollars. Neither of these extremes is particularly appealing. The various possibilities must be narrowed down to enable practical choices to be made.

In this section, the alternatives explored in sections 7 and 8 are compared on the basis of their varying impacts on the flood problem. At the outset, it is important to make a few statements explaining the scope of the section.

The various options are discussed entirely in terms of the flood problem itself. For example, if floodproofing a certain building is suggested, no opinions are expressed regarding who should pay for this work; institutional considerations are therefore virtually ignored. Not all conceivable adjustments have been assessed in previous sections. Some have been rejected because their further investigation would not be productive.

The objective of floodplain management should be to reduce flood damages to the point where the costs of achieving these reductions just equals their value. That is, there exists a floor below which it is inefficient to further reduce flood damage potential. In this report, the costs of performing adjustments and the benefits to be derived from them have been quantitatively estimated. However, it has been emphasized throughout the text that these quantitative values are merely indicative since they provide only "order of magnitude" impressions of the quantities involved.

Provided that this fundamental limitation to the data is recognized, it is possible to carry out a rudimentary cost-benefit comparison of the various solutions possible in Stephenville. Each of the adjustments discussed in sections 7 and 8 are evaluated in this light in paragraph 9.1 below. Those adjustments which are judged to be superior are summarized in paragraph 9.2. All benefit and cost impressions were determined in sections 6, 7, or 8 above. The average annual costs are based on an amortization period and economic life of 50 years. All structural measures were evaluated on the basis of the 1:100 year event. There is a risk involved in assuming that protection only needs to be provided for up to the 1:100 year level. Due consideration should be given to the possibility of higher magnitude floods before any structural alternative is adopted.

In addition to these risk factors, most structural measures involve land enhancement benefits that have not been quantitatively expressed in the analysis, but which should also be considered in the asssessment of alternatives.

9.1 Determination of the Economic Viability of Various Adjustments

1. Floodway: This would eliminate the flooding problem, but two floodways would have to be constructed (one for each stream). Major ex-

penses for excavation and bridge and highway construction/relocation would be necessary. Even though it is possible that the benefits derivable from a floodway could exceed the costs of constructing it, these costs are so high as to make the alternative unattractive when other measures are considered.

2. Diversion: This would eliminate the flooding problem on Blanche Brook and Warm Creek, but would cost about $200,000 annually for diversion channels alone. Because of this very high cost, no estimates of other costs (e.g. channel improvements on Gadons Brook) were made. As with the floodway alternative, a diversion scheme might be possible in which the costs would exceed the benefits, but when compared with other alternatives, the relative efficiency of the diversion alternative is much lower.

3. Upstream Storage: This would reduce the 1:100 year event at the brewery to about 1:10 year event, thereby saving an estimated $125,000 annually. (The hydraulics involved with the dam/reservoir are such that the upstream storage scheme evaluated in this report will provide greater protection to the brewery in lower magnitude

floods). The average annual cost of the dam/reservoir complex was estimated at between $550,000 and $820,000. The costs are therefore sufficiently higher than the benefits that no further consideration was accorded this alternative.

4. Dyking Sub-Area 1: This would protect the brewery, Humber Motors and the Curling Rink as well as all land within sub-area 1 not yet developed. This will involve savings of an estimated $485,000 annually in flood damages. The costs of the scheme are estimated at about $28,000 annually. As such, the alternative is clearly viable. However, it should be pointed out that there is some risk associated with this alternative should a catastrophic flood occur.

5. Dyking Sub-Area 2: This would only be efficient if more vulnerable development were to be located in the floodplain. At the present time, the potential benefits do not justify the expense. Furthermore, it is clear that other measures, notably floodproofing, would be a more efficient method to prevent damage to future development in sub-area 2.

6. Dyking Sub-Area 3: This would save an estimated $10,000-$12,000 annually. The approximate annual cost of upgrading the road is $5,900. In addition,

it is estimated that rip-rapping would be necessary along about 50% of the length of Brookside Drive. This could cost an extra $3,000 annually. Based on available data, the upgrading of Brookside Drive appears to be economically feasible.

7. Dredging Sub-Area 1: Under the optimal dredging scheme all of the existing damage potential in sub-area 1 (excluding Humber Motors) would be eliminated. This would mean savings of some $485,000 annually. The cost of this scheme would be in the order of $68,500 annually, but this does not include the large maintenance costs that would be associated with the dredging alternative on virtually an annual basis. Nor does it include the costs of bank protection (estimated at $7,500 annually) which would have to be constructed near the brewery even if dredging were to be done. One benefit of the dredging alternative is that protection against catastrophic flooding is substantially greater than for either floodproofing or dyking.

From available data, it appears that dredging is more feasible than floodways, diversions or upstream storage, but not as efficient as either dyking or floodproofing.

8. Dredging Sub-Areas: 2 and 3

There is insufficient damage potential in sub-area 2 to justify a dredging scheme. In sub-area 3 there is a significant amount of rock in the channel bed which would substantially increase the costs of the project. In addition, considerable structural alterations would have to be carried out on the Main Street bridge to improve its hydraulic efficiency and to reduce the possibility of ice/debris jams. The very low level of potential benefits (about $15,000 annually) would not justify such large expenditures.

9. Channel Realignment Sub-Areas 1 and 2

Flood stages at the brewery would not be materially affected by this adjustment, but velocities would be substantially reduced. In addition, a new bridge would be required across Blanche Brook on Minnesota Drive and a substantial amount of valuable real estate in development area 7 would be affected. Bank protection at the brewery would not be required under the realignment alternative. Excavation of the channel alone would cost an estimated $24,000 and benefits realized would not be commensurate with anticipated costs. Because of these factors and the poor benefit cost position, no further consideration was given to this alternative.

10. Floodproofing in sub-area 1: Floodproofing Humber Motors against the 1:100 year event does not appear to be technically feasible within the limits of the level of vulnerability at that location. The annual cost of floodproofing the brewery and Curling Rink is estimated at $10-13,000. Additional costs associated with the required bank protection near the brewery would escalate the annual cost to about $20,000. In addition, the costs of a flood warning/forecasting system would have to be included. The benefits are the complete reduction of damage potential at the brewery and curling rink (a saving of about $485,000 annually). Floodproofing is therefore viable for the area and should be given further consideration. However, it should be noted that floodproofing will protect only the buildings it is designed for. No protection is offered to future development on the floodplain by the floodproofing alternative.

11. Floodproofing sub-areas 2 & 3: Floodproofing is not necessary in sub-area 2, based on existing levels of development. In sub-area 3 the annual cost of floodproofing has been estimated at $2,000. When compared with a benefit level in the order of $5,000-$10,000 it is evident that floodproofing would be viable.

12. Monitoring Forest Cutting Practices in the Basin:

No costs were estimated, but this would appear to be a prudent practice for the basin. If it becomes apparent that major cutting activity is likely to occur in the headwaters it would probably be worthwhile for the potential impact of that activity on the flood hazard to be studied in more detail.

13. Maintaining a Tree/Slash Removal Program:

This appears to be worthwhile within the Town limits. By keeping constrictions free of debris, backwater problems will be reduced and the danger of washouts diminished. It appears that the costs of a tree clearing and/or bank stabilization program upstream of Hanson Highway would probably outweigh the benefits, although this has not been studied in detail.

14. Maintaining a Flood Forecasting System:

This would only yield a favourable cost-benefit position if used in conjunction with the floodproofing alternative at the brewery. Otherwise, no major effort should be expended on this alternative.

15. Institution or Maintenance of a Restricted Zoning Policy:

This would be highly desirable in areas where the hazard is extreme even if structural measures are built, since risk factors are associated with construction behind dykes (the dykes could fail or be overtopped). In less vulnerable locations, there appears to be no reason why development should be prohibited provided that it conforms to appropriate floodproofing regulations.

9.2 Evaluation of Superior Alternatives

Based on the preceding analysis, no regional structural alternatives appear to be justified in the Stephenville case. It is evident that neither an upstream storage scheme nor floodways nor diversions would be as efficient as more localized solutions.

In the case of local measures, the flood problem in sub-area 1 can be mostly offset by the structural alternatives of dyking, dredging or floodproofing. All three are economically viable, but dredging is not as efficient as either of the other two. On the basis of preliminary calculations, floodproofing appears to be a superior adjustment. However, a number of qualifications to this should be pointed out. First, the level of detail and accuracy embodied in both the cost and benefit estimates is not sufficient to discriminate between alternatives except on an "order of magnitude" basis. The floodproofing and dyking alternatives are close enough in terms of impacts that one cannot be selected over the other on the basis of costs and benefits without more detailed study. Second, dyking will protect all vulnerable land in sub-area 1 whereas floodproofing protects only isolated locations. Third, the floodproofing alternative would involve the creation of an early warning system, the accuracy of which is uncertain. The effectiveness of the floodproofing technique would largely depend therefore, on an unknown element. For all these reasons, it is suggested that further investigation of the two alternatives should be undertaken prior to the adoption of either one. However, it is likely that the optimal long term solution to the problem in sub-area 1 will be dyking.

In sub-area 2, the current level of vulnerability is low. Even if new development should occur in the area, it is likely that the best way to offset the flood problem would be to use non-structural measures, such as the regulation of minimum foundation elevations.

Apart from floodproofing structures in sub-area 3 or upgrading Brookside Drive, no other structural alternatives seem to be justifiable. There, a similar choice exists here as would be required in sub-area 1. The cost-benefit considerations are as similar here as in sub-area 1, so the same arguments apply. However, the land enhancement benefits that would result from dyking rather than floodproofing are probably more imminent in sub-area 3 than in sub-area 1, because it is likely that residential construction would almost immediately follow construction of a dyke.

Of the various non-structural measures considered, all appear to have some applicability to the problem. A flood forecasting system would be more relevant if floodproofing were to be adopted and the monitoring of forest cutting activity would be more applicable if major activity were planned for the watershed. The restriction of new building construction by zoning for no development does not seem to be warranted, but appropriate floodproofing techniques, such as minimum foundation elevations, should be regulated. A program to remove trees and debris from the two channels should be considered.

Specific conclusions have been drawn from the above analysis. These conclusions as well as other general insights obtained during the course of the study are presented in point form in section 1.2.