A REVIEW OF TECHNIQUES BEING USED FOR DELINEATING FLOOD-PRONE AREAS

(AS OF DECEMBER 1978)

INTERNAL REPORT
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PREFACE

The need for a report of this nature was recognized early in the implementation of the National Flood Damage Reduction Program in this region. Questions arose regarding the high degree of accuracy required and associated high costs of mapping flood risk areas under the Canada-New Brunswick Flood Risk Mapping Agreement. It was speculated that a reduction in the potential of flood damages could be achieved with a more cost effective approach to mapping the flood risk areas.

From discussions with other regions participating in the Flood Damage Reduction Program it became apparent that the technical guidelines were being interpreted and applied differently. Also, it became known that other agencies involved in flood programs have developed various approaches that are reportedly working well. As a result, an investigation was made into techniques being used elsewhere for flood risk mapping so that many of the questions that arose regarding flexability and alternatives for mapping could be answered.

One of the findings of this report is that the procedures set for mapping and hydraulic and hydrologic studies under the Flood Damage Reduction Program should be considered as minimum desireable standards. There are, however, special circumstances where using these standards

is not practical and in such cases, the best state of the art and cost effective methods available should be used.

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1.0 SUMMARY

The present "Guidelines" (6, 7) for Flood Risk Mapping under the flood Damage Reduction Program call for "state of the art" technical work in developing flood risk maps. This is a very desirable objective but, depending upon available data, the complexity of the variables, and development of the watershed, it is sometimes impractical to produce the required maps at a reasonable cost and within a practical time period. Consequently, the question arises as to whether or not the "Guidelines" should be strictly followed regardless of the cost. According to initial inquiries by Inland Waters Directorate, Atlantic, the answer to this question was "yes". Further investigation revealed that the work being carried out under the Canada-New Brunswick Flood Risk Mapping Agreement appears to conform to the "Guidelines" more rigidly than work being done elsewhere. A summary of the different methods being used is presented in Table 1.

From the review of areas and mapping techniques being addressed for defining flood prone areas, maps take two forms, floodline maps and flood hazard maps. The most common is a map showing floodlines. These floodlines may result from: a storm of given frequency, i.e. 1:20, 1:100, 1:200 plus a freeboard; a recorded historical event; a design storm; or

Table 1

Summary of Methods Being Used

Area or Agency	Maps	Map Scale	Map Contour	Flood Mapped	Method Used to Obtain Floodlines	Comments	Flood Forecasting	Regulation
[1]CMHC	None						No	Study required if a big project, otherwise site inspection
[2]N. S.	Hazard	1:4800	5 ft.	Historical	Photos, interviews, etc.		No	Zoning
	Hazard	1:4800	5 ft.	Design	High flow plus 3 feet		No	
	Flood Risk	1:1200-1:2400	1/2 m.	1:100;1:20	FDR Guidelines	To be produced	No	
[3]N. B.	Flood Risk	1:1000	1/2 m.	1:100;1:20	Regional Flood-Frequency Analysis, DWOPPER, HEC-2, FDR Guidelines	Work in progress	Yes	None
	Flood Risk	1:1000	1/2 m.	Historical	Photos, interviews, etc.			None
	P. R.	1:10,000		Historical	As above			None
[4]Quebec	Flood Risk	1:10,000	1/2 m.	1:100;1:20	Frequency analysis... FDR Guidelines		Yes	Designation under FDR
[5]Ontario	Flood Risk				FDR Guidelines	To be produced	No	
5a Conservation Authorities	Flood Risk& Hazard	1:2000, 1:5000 or 1:10,000	1/2 to 2 m.	Regional Storm or 1:100	Gumbel extreme value, Log Pearson III, HYMO, HEC-2, USSCS	See authorities listed below for further detail.	Yes	Community Planning Advisory Function
Metropolitan Toronto	Flood Risk			Hazel	Gumbel			Zoning, court cases where they've had to prove area susceptable to flooding
Sault Ste. Marie	Flood Risk			Timmins				None
Saugeen Valley	Hazard					Based on degree of slope, slope stability, soils, flooding, etc.		Zoning
Otonabee	Flood Risk	1:2000		Regional	HYMO, HEC-2	Also do hazard mapping		Zoning
Kettle Creek	Flood Risk			Hazel				Zoning

Table 1 cont'd

Area or Agency	Maps	Map Scale	Map Contour	Flood Mapped	Method to Obtain Floodlines	Comments	Flood Fore-casting	Regulation
Cataraqui	Flood Risk			1:100				Zoning; Problems where discrepancies in hydro-technical analysis found by consultants
Central Lake Ontario	Flood Risk	1:2400	2 1/2 ft.	Hazel	HYMO, HEC-2			
Nottawasaga Valley	Flood Risk	1:2000, 1:5000 or 1:10,000	1/2 to 2 m.	Timmins				
Maitland Valley	Flood Risk			Hazel				None
Credit Valley	Flood Risk	1:2400	1/2 m.	Hazel		No problem in regulating development		Regulations exist
Ganaraska	Flood Risk	1:2400		Regional				No court cases
Halton	Flood Risk	1:2000		Regional		Also have hazard mapping		Regulations exist; Problems in court where line based on aerial photography
Grand River	Flood Risk	1:2400	2.5 ft.	Regional		Save harmless clause in agreements; Puolic information program stressed	Yes	Regulations exist
Niagara	Flood Risk			Regional		No court cases; Comment on fill & construction in floodplain		Pending
South Nation River	Flood Risk	1:2400	2.5 ft.	1:100	Gumbel, SCS			None
Hamilton	Flood Risk	1:2400	5 ft.	Hazel or 1:100	HEC-2, HYMO			Regulations exist
Mississippi	Flood Risk	1:2400		1:100		Also hazard mapping		None as yet

Table 1 cont'd

Area or Agency	Maps	Map Scale	Map Contour	Flood Mapped	Method Used to Obtain Floodlines	Comments	Flood Forecasting	Regulation
North Grey	None					Floodplain mapping by developer		None
Rideau Valley	Flood Risk	1:5000	None	1:100	Snowmelt and/or run-off models			Regulations exist; Engineering techniques used have stood up in court and are of importance in cases where the effect of proposed development on storage capacity, life, investment, etc. are significant
Raisin	Flood Risk			1:100				Regulations exist
Crowe Valley	Flood Risk			1:100		Work in progress		None
Essex	Flood Risk			Hazel & 1:100				None
Napanee	Flood Risk			Regional or 1:100	HEC-2			None
[6]Manitoba	Flood Risk				FDR Guidelines	Work in progress		Some previous zoning in existance
[7]Saskatchewan	Flood Risk				FDR Guidelines	Work in progress		
[8]Alberta	Flood Risk	1:4800		1:100;1:50	Pearson III, HEC-2		Yes	Influence on zoning
[8a]Hay River	Flood Risk	1:2000	1 m.	1:100;1:20 plus ice jam	Frequency analysis, correlation analysis, HEC-2...FDR Guidelines		No	None
[9]B. C.	Flood Risk	1:2500& 1:5000		1:200 plus freeboard	HEC-2		Yes	Flood control requirements in zoning by-laws
[10]Britain								Local government control

Table 1 cont'd

Area or Agency	Maps	Map Scale	Map Contour	Flood Mapped	Method Used to Obtain Floodlines	Comments	Flood Forecasting	Regulation
11 U. S. A.	Flood Risk	1:24,000		1:100	Log-Pearson III, frequency analysis, HEC-2	For regulation purposes		
	Flood Risk	1:24,000		1:100	Best information available; quality variable	For initial quick maps		
	Flood Risk	1:4800 to 1:12000		1:10,1:50, 1:100,1:500	Accuracy depends on development in area	For Flood Insurance Studies		
11a Maine	Flood Risk			1:100	Log Pearson III			Zoning
11b Nebraska	Flood Risk			1:100	HEC-2, Log Pearson III, surface water profile to 1 foot accuracy			Zoning

of one with a given frequency plus an ice jam. The types of activities allowed below a given floodline vary considerably and depends on the risks and damages an agency is willing to accept versus the economic gain of allow development.

On hazard maps, areas are designated for controlled or no development based on a combination of factors such as flooding, soils, slope stability, degree of slope, etc. Usually simple methods are used to obtain the hazard line. For instance , the interpretation of soil, contour, and vegetation maps may be the methods used.

The range of scales used for both types of mapping is from 1:1000, to 1:24,000 with a range in contour intervals from 1/2 meter to 2 meters. The scale and contour interval used appear to have no bearing on the successful enforcement of regulations in different areas. There is a large variation of maps being used but all are being locally accepted. For instance, within the province of Ontario the mapping scales vary from 1:2000 to 1:10,000 and the contour intervals vary from 1/2 meter to 2 meters. These maps are accepted regardless of contour interval and at least for the scales of 1:2000 to 1:5000. In the U. S. maps at scales of 1:4000 to 1:24,000 are widely used.

Of the 22 Ontario Conservation Authorities indicating the type of flood mapped, 13 use a regional storm, 6 use a 1:100 year flood, and 3 use both. Of those areas using a regional storm, the application of the models HYMO and HEC-2

is popular. Throughout the rest of Canada and in the U. S., the 1:100 or larger year event is widely used along with HEC-2 as the hydraulic model. Although the 1:100 year flood and the regional storm are the most often used, other floods are mapped and accepted. In addition, there is variation in the accuracy with which the models are applied. This degree of accuracy used does not appear to directly relate to the ability to enforce regulations as long as reasonable effort and judgement is used.

Generally, there are accepted variations among the different areas and within provinces in the methodology being used to produce flood risk maps. It becomes apparent that the work being done under the Canada-New Brunswick Flood Risk Mapping Agreement adheres to the "Guidelines", set out under the Flood Damage Reduction Program, quite strictly while other areas consider the "Guidelines" as desirable objectives to be achieved in their studies. This fact was confirmed at the August 22-23, 1978, Regional-Headquarters Flood Damage Reduction Meeting. At that meeting, it was decided that the "Guidelines" should be followed with the Technical Committees, which are formed under the federal-provincial agreements, determining the stringency of application to suit the circumstances.

2.0 CONCLUSIONS

Recent judicial trends indicate that if a community proceeds in good faith and to the best of its ability to try to protect the lives and investments of its citizens, the courts will stand behind the zoning regulations. Therefore, the accuracy of floodline data required for floodplain mapping will likely depend on its use. Imprecise flood data may be acceptable for interim designation and where the limitations imposed on the landowner in the designated area are minimal. Imprecise data would be unreasonable for prohibitation of all urban floodplain development where property and other taxes are high and open space uses are uneconomical.

Within the process of flood risk mapping, it appears as if it is becoming acceptable practice to carry out the mapping work and hydrologic and hydraulic studies to the best ability and within the fiscal restraints, given the specific data, physiographical conditions and damage potential in a given area. This is not to say studies should be bordering on research projects, but that the best and reasonable job be done with the information available. The "Guidelines" for the Flood Damage Reduction Program should be considered as desirable minimum acceptable standards. Each area should be considered separately as to how stringent the "Guidelines" should be applied.

To elaborate on the above, for an area such as Perth-Andover where the main cause of flooding is ice jams and where

the 1:100 year open water floodline is expected to be within the main channel, it makes little sense to spend a lot of time and effort to map the 1:100 year open water floodline. The mapping of a historical ice jam event rather than using a detailed technical and/or statistical analysis was recommended here as there is little known on how to deal with the problem of ice jams and partly because there is little available data with which to work. Physical modelling would be one way of analyzing the problem but it would be very expensive and time consuming. For other areas, lack of data, and complexity of floodplain hydraulics due to the influence of several watersheds, tides, winds, and ice jams are some of the problems encountered. These factors should be considered for each floodplain in assessing the practicality of using a specific method for floodline determination.

It should be pointed out here that under the terms of the agreements signed with both New Brunswick and Nova Scotia there is the freedom to use a design flood that has a return period greater than 100 years. For floodplains with complex hydraulics this would result in a considerable saving of time and money and in some cases a more accurate floodplain delineation. In retrospect, it may have been wise to delineate the 1973 flood at Fredericton instead of using detailed analysis to determine the 1:100 year flood.

In the future our mapping standards could be relaxed and use made of existing mapping where this is reasonable.

Each area should be considered separately as to what scales and contours should be used depending on the topography, existing mapping, and present and anticipated future development in the area.

It is well recognized that there is no such thing as a perfectly determined floodline. It is therefore thought that the idea of allowing redefinition of the floodline, should a land survey show that a specific area in question was above the flood elevation as determined from the river profile, is a good one. Floodlines are placed on maps by extending the water level profile to where it would intersect the land surface by using contour interpolation. A land survey is a more accurate but much more costly method of doing this. Given this flexibility, a relaxation of our mapping standards would be quite practical.

3.0 INTRODUCTION

The first agreement signed under the Flood Damage Reduction Program was in March 1976, with New Brunswick. Given the experience gained since that time, the question has been raised of why such precise flood risk maps, requiring costly hydrologic and mapping studies, are required. Could we achieve the same purpose and spend less money? It is the objective of this report to review the methods being used in Canada and to investigate what the situation is in other areas that are not subject to the National Flood Damage Reduction Program.

3.1 Background Information

The first step taken towards the development of a Flood Damage Reduction Program was in June 1973 when a seminar was held to discuss the possibility of implementing a flood risk mapping program for high risk areas in Canada and to suggest regional priorities, methodologies, cost-sharing arrangements, etc. Representatives of all the provinces were invited to attend the seminar as well as representatives of Canada Emergency Measures Organization, Central Mortgage and Housing Corporation and the U. S. Army Corps of Engineers. It was decided at this meeting that (1) a joint federal-provincial program should be established and that a joint federal-provincial steering committee on flood risk mapping pursue the detailed aspects of flood risk mapping and (2) the Steering Committee should select pilot project areas and explore possible cost-sharing and work-

sharing arrangements. Subsequent to this, six pilot project areas were established to get some knowledge of costs and problems of flood risk mapping in various parts of Canada. In a memorandum to Cabinet from Mr. J. S. Tener to Mr. Jean Luc Pepin, September 13, 1974, on the "Use of Federal Programs and Federal-Provincial Accords for Flood Damage Reduction" the following comments are made: "The National Emergency Planning Establishment and the Department of Finance have both been consulted and are in full agreement that flood risk maps would be a firm prerequisite to implementing a policy of withholding disaster relief and further agree that such a policy would reduce potential future damages for federal disaster assistance." It was stated that "Consideration was given to the possibility of pursuing a superficial mapping program based on currently available information, rather than the more comprehensive program suggested. This alternative was rejected due to the immensely important investment decisions which may hinge upon the flood risk maps. Complete and comprehensive in-depth information must be gathered before we can expect both the public and private sector to abide by the recommendations contained in any floodplain management program."

A seminar was held December 15, 1975, to review proposed formats of the agreements to be signed between Ottawa and the Provinces. Points made at this session include: 1) Schedule A's should include developed areas and areas where development is likely (this will not

necessarily exclude agricultural or "open" areas that could be developed) and areas already mapped and 2) a multi colour map with a scale of 1:10,000 will be provided for public information and a 1:2,000 scale monochromatic map will be provided for planners.

The possibility of flood insurance was investigated but rejected. Since a flood insurance program would have to be heavily subsidized, there would be an income transfer to a small segment of society, similar to disaster assistance payments. As well, such insurance could tend to encourage rather than discourage development in flood risk areas.

By May, 1976, guidelines had been established for the hydrologic and hydraulic studies and survey and mapping procedures for floodplain delineation. These were developed to standardize procedures across the country.

In summary, the Flood Damage Reduction Program and Agreements were developed after a process of seminars, Regional Headquarters meetings, departmental and inter-departmental review, Cabinet consideration and federal-provincial negotiations.

3.2 Notes on the Present Flood Damage Reduction Program

A coordinated federal-provincial approach to reduction of flood damages under the Canada Water Act is based on the following principles[3]:

(a) Programs of federal agencies concerned with flooding must be coordinated, both at the federal level and

with related programs at the provincial level. This co-ordination can take place through federal-provincial general agreements, and through federal inter-departmental co-ordination mechanisms.

(b) The cornerstone of a coordinated program will be flood risk maps, as a basis for joint agreement on the definition of flood prone lands.

(c) Information on floods, on federal policies and programs and on the susceptibility of specific areas to flooding, through flood risk maps, must be provided to the public, the municipalities and all others concerned.

(d) Federal agencies such as CMHC, DREE and Department of Public Works will not develop or support development in areas identified by the mapping program as high risk areas.

(e) Federal disaster assistance will be refused, with respect to new or further developments within defined high flood risk areas once the public has been made fully aware of the hazard.

(f) The provinces would be asked to restrict their investments in agreed high flood risk areas and would be asked to encourage appropriate zoning regulations in such areas.

"The federal Cabinet has directed that should it not be possible to work out a mutually acceptable Agreement with any individual province, the federal government will

nonetheless act in accord with the above principles within its own areas of responsibility. That is, federal disaster assistance will be withheld on new or further development in areas where a high flood risk has been identified. In addition, federal investments and federally-financed investments will be required to locate outside known flood risk areas."(3)

High priority is being given to the flood risk mapping program for two reasons. First, the precise identification of flood risk areas is recognized as a prerequisite for most of the other proposed programs. Second, the provisions of flood risk maps is seen as an important step in the prevention of further development in flood risk areas. Where developments already exist in flood risk areas, studies will be carried out to determine the best measures to reduce or prevent damage from flooding.

"Great care must be taken in delineating the flood risk area because the line depicted on flood risk maps could be used for legislative action or zoning as well as for information purposes. It may therefore come under very close scrutiny from professionals engaged by local interest groups or developers who have a monetary interest in the definition of the flood risk area. Experience where municipal governments are introducing hazard land zoning has shown that one of the residents' first line of attack is to question the engineering consultant's report in its determination of the flood risk area."(4)

3.3 Degree of Technical Accuracy Required for Mapping

Recently New Brunswick Department of the Environment has cut back on the monies to be allotted to the Flood Risk Mapping Program in that province. Consequently, people involved in the program are starting to question whether the same results could be achieved by spending less money.

In a letter, February 7, 1978, to Mr. Brian Burrell of New Brunswick Department of the Environment, Mr. J. Bathurst offered the following personal comments:

> "(a) Even if hydrologic engineers were able to precisely define the 100 year (or any other frequency) flood line - whatever that word "precisely" might mean - it would not permanently retain its precision and validity. Over a period of time, the characteristics of a basin and its river do not remain static; physical developments will occur, land management practices will have an influence, natural channel configurations will fluctuate, vegetative cover will advance, recede or change, and so on. Indeed, the imposition of zoning regulations, and any structural flood damage reduction measures, pursuant to the mapping program, can themselves be expected to change the floodplain. The environment is dynamic. Therefore, with or without flood damage reduction efforts by Man, the flood line will be dynamic, not fixed. To my mind, I think this argument alone casts serious doubts on the wisdom of, or necessity for, making expensive sophisticated engineering computations.
>
> (b) On the reverse side of the coin, the nub of the problem is captured in the following sentence from Wolman's paper (61): 'The author says that the resistance to the use of simplified methods appears to rest on the concern that imprecise delineations will not hold up in court'. I believe this is a very genuine and well-founded concern, again to judge by U. S. experience. This leads me to wonder whether, in order to achieve our overall goals relatively quickly (and not repeat the kind of depressing statistics on progress cited by Dingman (15), our national program should aim to first delineate, by simplified methods, something

> less than the 100 year flood and leave the determination of the latter to be followed up gradually as resources permit. For example: supposing we have aerial photography of a recent major flood which is known to have a return frequency of about 75 or 80 years. This could be mapped and "provisionally" designated. Any zoning regulations subsequently enacted could be based on the 100 year flood, as contemplated in our federal-provincial agreements, so that this provisional line would likely be well within the intended ultimate line, thus precluding any dispute about, or legal challenge to, the precision of the boundary. In this way, a major part of a substantial percentage of flood prone communities could be brought under the umbrella of our national program in the shortest possible time and as inexpensively as possible. Admittedly, I have not thought through all the implications of such a two stage approach. It may be quite impractical."

Rather than see the program die due to lack of finances, we must ask ourselves the same questions. The following is a summary of information obtained when the question was asked of why such precise flood risk maps, requiring costly hydraulic studies and surveys, were needed.

(1) At a Regional Headquarters meeting on the Flood Damage Reduction Program, February 3, 1978, it was pointed out that the best available tool should be used when applying federal Flood Damage Reduction policies and that there should be some consistency (in this tool) across the country. As maps may eventually be used as a basis for zoning or for changes in federal regulations, they could become a basis for legal proceedings and should be of sufficient technical quality to support judicial decisions.

(2) Mr. H. Rosenberg, Acting Director, Water

Planning and Management Branch, made the following comments, March 23, 1978:

> "If the flood risk maps are to be used for zoning purposes, which it is hoped they will be, the best technical knowledge must be used to derive the maps so that the zoning will stand up in court. These accurate maps are also necessary to influence departments and agencies, not to offer financial assistance for any further undertakings, in the designated area, which are vulnerable to flood damage."

(3) Comments made by Mrs. G. Page, Water Planning and Management Branch, Ottawa, March 28, 1978 include:

> "Federal policy is to use the best methods available to derive flood risk maps so that Canada will have a uniform national policy, that is, the use of the best obtainable 100 year flood line for the flood risk maps. This is necessary to apply the federal policy of limiting financial assistance to further undertakings in the designated flood risk area.
>
> It is the intention that flood zoning under the Flood Damage Reduction Program be applied to urban areas rather than rural areas.
>
> There is little if any documentation or reports on development or evolvement of the Flood Damage Reduction Program and the accuracy requirements of the technical studies to produce a flood risk map.
>
> In the proposed Flood Damage Reduction Program agreements between Alberta and Canada, Alberta will have discretionary powers to interpret DOE reports "Survey and Mapping Procedures for Floodplain Delineation" and "Hydrologic and Hydraulic Procedure for Floodplain Delineation"."

(4) Dr. E. Watt, Queens University, made the following comments, March 28, 1978:

> "The Technical Committee can control the costs of flood risk mapping by choosing a historical

> flood (Ref. Sentence 2, paragraph 1, page 2, "Hydrologic and Hydraulic Procedures for Floodplain Delineation" - Specification of the flood event that defines the Designated Flood Risk Area will vary from province to province; it could be based on probability, a specified input or a large recorded flood) and/or by the choice of contour interval."

He did not, however, point out the next sentence of that paragraph states that"in all cases, however, the elevation of the water surface must be no less than that of the 100 year flood".

> "Detailed technical work is required for zoning. With zoning, money is being taken from the people in terms of land values, and as a result people fight the zoning regulations by legal action. Therefore, the present standards were developed to eliminate court battles. There have been a number of cases in Ontario that have been successfully tried in court due to incorrect maps, inappropriate models and incorrect usage of Hurricane Hazel or the Timmins Flood to derive maps. Where proper methodology has been used, the zoning stood up in court. There was a case in Kingston where a "quick" flood zoning map was turned down by an Ontario municipal agent until a proper, technically accurate map was prepared.
>
> The agreements were meant to cover urban and future urban areas."

(5) Mr. G. Nix, Water Planning and Management, Ottawa, made the following comments, April 3, 1978:

> "High accuracy flood risk maps are required to stand up in court. The main areas of interest for flood risk mapping include Montreal, Calgary, Winnipeg, i.e. the major flood damage areas. If possible, other areas should be mapped.
>
> The guidelines were interpreted rather loosely in developing maps for the Montreal area. The flow frequency at Lac de Deux Montagnes and St. Lawrence flows as obtained from the Leendertse

model were used to arrive at a design flow value and HEC-2 was used to determine the flood profile. Mapping was done to a scale of 1:10,000 with 1/2 meter contours. On the Ottawa River, regulated flow frequencies as checked with Lac de Deux Montagnes were used to determine design flow."

(6) Comments made by Dr. B. MacLock, Inland Waters Directorate, Western Regional Office, April 5, 1978, include:

"In June, 1973, a seminar was held to discuss a flood damage reduction program. Present were people from the U. S. and Ontario, who were involved in flood risk mapping, and some people from the present Steering Committees. The Americans claimed from their experience that you can't do a partial job because of the ultimate social and economic impact of flood risk zoning; otherwise too much time is wasted in courts. Mr. John Murray of Ontario claimed they had problems with court cases due to using less than technically accurate maps. Mr. A. Prince and Mr. N. James decided to set up projects on a pilot basis. The purpose of this was two-fold - (1) to encourage the provinces to sign agreements and (2) to examine the merits of using different methods to obtain a flood risk map. Later, the results of these studies were used as background information in setting guidelines for the hydrologic and hydraulic and surveying and mapping procedures to be used for flood risk mapping. EMR assisted in setting up the surveying and mapping procedures. One important aspect considered was that each component of a study should be of a compatible order of accuracy with each of the other components. In view of these facts, it was decided that a minimum of a 100 year design flood line obtained using high technical accuracy should be used for flood risk maps. It would be necessary to adhere to these standards so that the credibility of the program could be maintained across the country, that is, if one province is permitted to use less than the minimum standards, then the credibility of the work of the other provinces who adhere to the standards is questioned.

One item that is subject to debate is the use of more expensive line mapping as compared to the orthophotographic map for the public relations map. It was felt that the line mapping was a better product and the extra cost of this over orthophotographic mapping was small compared to the total cost of a study for an area.

It was intended that small towns and areas where there is potential for development should be mapped but not agricultural areas.

For Hay River, 20 and 100 year open water flood profiles have been determined as well as 20 and 100 year flood profiles under ice jam conditions. In the later case, the approach adopted was simplistic in nature. The 20 and 100 year flood flows were superimposed on historic ice jams."

(7) The following remarks were made in an April 27, 1978 letter from Mr. Rosenberg, Acting Director, Water Planning and Management Branch:

"The goals and objectives of the Flood Damage Reduction Program are presented in the outline in the Preamble and in the Basic Approach Section of the General Agreement.

In adopting the cartographic specifications for the maps they have been guided by a number of considerations - the views of federal and provincial officials, the "pilot" mapping projects, good cartographic practice, the national nature of the program and public acceptability, to name several. These same considerations apply with respect to the hydrologic specifications. There are at least two important additional considerations (1) the likely increased acceptance of the maps by the courts and (2) easier up-dating of maps in the future. There is in addition the need for a reasonable degree of consistency in mapping standards since the Flood Damage Reduction Program is national in scope.

Zoning is likely to be a municipal (but in some cases a provincial or federal) matter. Since no flood risk maps have received federal-provincial designation*, there has been no zoning based on

* Montreal has since been designated.

federal-provincial specifications. Lawyers are not likely to unequivocally state that maps prepared to such and such specifications will stand up in court. However, it seems logical to expect those prepared with a high degree of accuracy and equal to the state of the art technically would have a greater chance of being considered reasonable in the eyes of the courts. As indicated above court challenges are only one aspect relating to specifications.

Basically Schedule A consists of a mutually agreed upon list of places which are flood prone, and which have been developed, are presently being developed, or which have prospects for development in the near future. Thus rural fringe of urban areas could be included where these are likely to be developed. Areas not on Schedule A (e.g. towns with little or no development prospects and rural areas) would not be subject to the policies of the federal-provincial agreements in a formal way. (Some of these policies, however, may be applied by individual federal or provincial agencies, acting separately from the agreements.) The agreements provide for priority setting within Schedule A and Schedule A can be amended with the agreement of the Parties. It is hoped that the places listed in Schedule A can be mapped within the dollar limits set out in the Agreement, although it is recognized that there may be over-riding considerations which preclude this. Note that the Committees have tasks relating to setting annual budgets and progress and hence are expected to closely monitor the situation.

The problem of ice jams is a vexing one since these are characteristic of many Canadian water bodies. The Engineering Division, Water Planning and Management Branch, Headquarters, had earlier proposed a meeting on the topic but other duties have precluded the organization of such a meeting. Mr. Bathurst's group is being asked to give consideration to the early convening of such a meeting."

Hutchinson and Watt[28] made the following points at the Symposium of Risk and Reliability at Waterloo in June, 1978:

"Maps are a means of informing the general public of areas where these is a risk of flooding. If available, to regional planners, they would encourage an integrated approach to the development of river valleys as far as floods are concerned. They would help identify potential flood disaster areas before a flood occurred and hence expedite planning comprehensive solutions to flooding problems. In addition, the maps could form the basis for implementing land use restrictions on the part of either federal, provincial, regional or municipal governments.

Whether "shortcut" techniques are sufficient to lead to economic and earlier adoption of land use restrictions is an area for further research and consideration with regard to the situation in Canada. A "shortcut" which is successfully challenged in a court case may not be much of a "shortcut" in the long term. On the other hand, it may be sufficient for self-regulation.

By using a frequency analysis or best estimate it is implied that the precise value of the 100 year flood will never be known. Therefore, it seems unlikely that, if frequency analysis techniques are employed, the magnitude of the 100 year flood would not be successfully challenged. What is more likely to be challenged is the hydraulic and mapping techniques if a specified flood actually occurs and results in a significantly different level of inundation than is indicated on the map. It should not be argued that because of the high level of uncertainty in determinig the 100 year flood, precise hydraulic and mapping techniques are not required."

4.0 METHODS USED IN VARIOUS AREAS FOR FLOODPLAIN MAPPING AND THEIR EFFECTIVENESS

Information on what is being done for floodplain mapping in various areas is presented herein. Sources of information include reports, articles and answers received in response to questions. Information is included on CMHC, most Canadian Provinces, and the U. S. A.

CMHC:

CMHC has no formal policy regarding the restriction of NHA funding on lands prone to flooding. For single family dwellings, an initial site inspection is used to indicate whether a particular site is in a risk area. Local knowledge in the area would then allow the local branch to accept or reject the site. For larger projects, it is not uncommon to require engineering reports or other documentation (the degree of accuracy varying with the situation), confirming the acceptability of a potential problem site.

They try to ensure that basements are sufficiently elevated so that hydrostatic pressure is kept to low values. Where such is not the case, floors on ground and exterior surfaces of walls below ground level shall be waterproofed with acceptable materials.

Nova Scotia:

Nova Scotia signed agreements (general, mapping and studies) under the Flood Damage Reduction Program with Canada in June 1978. The first area expected to be mapped is Truro. Previous to this, the only form of mapping was

development plans by the Nova Scotia Department of Municipal Affairs. Hazard lands, which take into consideration the flooding problem, are designated generally for recreation, agriculture or open uses. For example, the method used in the Annapolis Valley to determine the hazard line was based on the high water profile as determined from dyke height plus 3 feet. In Antigonish, the area inundated by Hurricane Beth was zoned for open space use.

New Brunswick:

New Brunswick signed a "General Agreement", a "Flood Risk Mapping Agreement" and a "Studies Agreement" with Canada in March 1976. The Agreements with other provinces are similar. New Brunswick has subsequently signed a flood forecasting agreement under the provisions of the General Agreement as well as the Marsh Creek Agreement for control works.

The"General Agreement" sets out the "Basic Approach for Reducing Flood Damage" and the policies agreed upon by the two governments. The "Flood Risk Mapping Agreement" provides for a cost-sharing mapping program for specific flood prone areas and the "Studies Agreement" provides for cost-shared studies of three local flood situations - Marsh Creek in the City of Saint John, downtown Fredericton and Walker Brook in Campbellton.

The "Basic Approach" is that where damage reduction measures are proposed, all practicable structural

and non-structural alternatives are to be considered, including the alternative of letting some flooding occur, and that effectiveness, costs, corollary benefits and environmental impact are to be taken into account in selecting amongst alternatives. It is also intended that preference is to be given to measures which prevent any undertakings vulnerable to flood damage in flood risk areas. This intention is given greater substance by the other specific provisions of the General Agreement. Both Parties agree, for example, that where a flood risk area has been designated, their departments and agencies will not undertake projects, or assist others to undertake projects, which are vulnerable to flood damage. The programs of both Central Mortgage and Housing Corporation and the Department of Regional Economic Expansion, are specifically referred to in this provision. In addition, the Parties will encourage zoning on the basis of flood risk, where it is under their legislative jurisdiction and agree to comply with such zoning restrictions. Disaster assistance would also be denied for all new undertakings commenced after the flood risk area is designated and the information made available to the public.

The General Agreement makes provisions for other subsidiary agreements on such flood related matters as flood forecasting and warning, flood proofing techniques, land use planning, structural works, acquisition or easements to reduce flood damage, and studies, research or surveys

relating to flood problems.

The Flood Risk Mapping Agreement, in which flood prone areas are to be mapped using the hydrologic and cartographic specifications established for the national program, has a life of five years whereas the General Agreement has a life of ten years. The Flood Risk Mapping Agreement can be extended by mutual agreement. Thus, there are at least five full years after the completion of the last flood risk map to observe the effectiveness of the policies contained in the General Agreement.

Under the General Agreement a Steering Committee, composed of two federal and two provincial representatives, has been established. The Steering Committee is to maintain co-ordination between the Parties in the implementation of the General Agreement and reports directly to Federal and New Brunswick Ministers of the Environment. Under the Flood Risk Mapping Agreement, the main functions are to arrange for the production of maps, and recommend designation of flood risk areas. The Steering Committee is specifically charged with carrying out a public information program and a strong emphasis is likely to be placed on this aspect.

The Flood Risk Mapping Agreement also provides for the establishment of a Technical Committee which reports to the Steering Committee. Its duties include: recommending to the Steering Committee the sequence in which areas shall be mapped, review of contract proposals, review of maps

already published for possible use, and ensuring that the specifications set out in the Agreement are complied with in each study or survey undertaken and each map prepared.

Quebec:

Quebec signed an agreement under the FDR program in October, 1976. Maps, showing the 1:100 and 1:20 year floods, at a scale of 1:10,000 with half meter contours are now available for information purposes for Montreal. Areas have now been designated using these maps. Others at scales of 1:1000, 1:2000 and 1:2500, will be available at municipal offices for the use of local authorities and residents of the floodplain.

Since 1974, the Committee on Flow Regulation, Montreal Region, has studied the hydraulic network with a view to selecting the most appropriate engineering (dykes, dams, channel dredging) and administrative measures (zoning, building codes) for reducing flood damages. This led to the construction of dykes in the municipalities of Roxboro and Pierrefonds in 1976 and Pointe-Calumet in 1977.

Ontario:

In Ontario, floodplain regulations are administered directly or indirectly by three Acts. Authorities are established under the Provincial Conservation Authority Act to carry out a comprehensive and coordinated program for the conservation of the renewable natural resources within its watershed(s). This program includes: 1) alleviation of potential loss of life and damages to existing development in flood prone areas, 2) prevention of encroachment of

new developments in floodplain lands, 3) improvement of land use practice in flood prone areas thereby eliminating uneconomic, hazardous and unnecessary activities and 4) creation of a safer and better environment. Each Authority has the power to regulate floodplain lands in its jurisdiction. As a corporate body, the Conservation Authority can operate with relative independence in carrying out its programs. However, financial and technical assistance is available through the Ministry of Natural Resources. Since establishment of a Conservation Authority depends on local interest and initiative within the watershed, Authorities have not been established throughout the entire province. Information on various Authorities is given in Appendix A.

The Planning Act, designated to complement the Conservation Authorities Act, is the primary tool by which the municipalities are able to control the nature and location of development within their area of jurisdiction. The Ministry of Housing is in a position to approve all municipal official plans and plans of subdivisions as well as review of zoning by-laws and local decisions on current applications. It exerts further influence through its community planning advisory function and financial assistance program for municipal planning studies. Floodplain management practices are built into planning policies and regulations by virtue of the powers under the Planning Act.

In addition, the Lakes and Rivers Improvement Act regulates dam construction and other works on lakes and rivers.

During recent years the province has undertaken a review of its floodplain criteria and management policy. There was a lack of understanding of the criteria used in defining floodplains and a difference of opinion on the level of risk to assume. Criticism existed on the leniency in the enforcement of floodplain regulations. Another important factor was the insufficient funding to acquire and protect all the lands within the floodplain. Following are some of the issues presented in a report on"Floodplain Criteria and Management Evaluation Study" prepared for the Ontario Ministry of Natural Resources and the Ontario Ministry of Housing:

1. Floodplain regulations have been successful in controlling new development but have been less than successful when applied retroactively to non-conforming uses. In general, properly authorized regulations will be valid if they are adopted in compliance with statutory requirements, treat similarly situated individuals equally and are based on sound data. An appeal procedure provides some flexibility in the application of the regulations.
2. Generally, where relief compensation is given, hazard perception remains low and floodplain development persists. Past flood events such as the 1974 flood on the Grand River has not appeared to appreciably

increase hazard perception of floodplain users. Citizens assume by meeting requirements of floodplain regulations, they are completely protected.

3. Reliance soley upon flood control works indicates that the vulnerability to catastrophic losses will increase.
4. The use of flood frequency in the definition of design criteria would permit the introduction of a risk factor. The selection of one flood frequency for purposes of floodplain management throughout the Province (Ontario) would permit a more equitable basis for regulatory policies. A review of the uncertainties involved with the present state of the art of hydrologic investigations and the accuracy of topographic mapping, indicates that the use of the 1 in 100 year flood should be considered as a minimum criterion. Past floodplain management experience reveals that whenever urban areas are involved, the tendency has been to increase the protection level to 100 years and much higher for design purposes.

   The use of a two zone concept would also allow the introduction of a risk factor.
5. Calculation of design floods could be based on any of: a) synthetic flood, b) highest observed flood and c) selected frequency flood. The design flood chosen depends upon what is considered a desired allocation of costs (money, life and health) when flood damages occur.

Table 2

Alternatives for Reducing Flood Losses*

Goal	Corrective		Preventive	Other
	Structural	Non-Structural		
Modify the flood	Dams and reservoirs levees or walls, channel improvements, stream diversion, storm drainage systems	Watershed treatment, meteorological modification, snow management, prevention or removal of ice jams.	-	-
Modify the susceptibility to damage	Flood proofing, fill and/or elevate new structures, relocation	Evacuation and emergency flood fighting measures. Flood forecasting and warning systems. Urban re-development.	Regulations -To disclose flood hazard in real estate transactions. -For subdivision development -For sanitary and health -For encroachment and fill Zoning by-laws Building codes Development policies Warning signs and education programs. Public and private purchase of open space for easements. Tax adjustments for open space.	-
Modify the loss burden	-	-	-	Flood insurance, tax write-offs, relief and rehabilitation, protection from looting.

* Note: Reference No. 14 -
Dillon, M. M., Ltd., and MacLaren, James F., Ltd., "Flood Plain Criteria and Management Evaluation Study". Prepared for Ontario Ministry of Natural Resources and Ontario Ministry of Housing. December, 1976.

Advantages and Disadvantages of Alternatives

Alternatives	Advantages	Disadvantages
Dykes levees, floodwalls	Low initial cost provides effective barrier to development	High maintenance cost. Decreased floodplain. Higher floods create excessive damage. Space requirement in urban areas.
Dams, Reservoirs	Could be multi-purpose project	Floods in excess of design could create problems downstream. Environmental constraints-fish, wildlife, sediment, water temperatures. Requires careful operational procedures.
Channel Improvements. Stream diversions	Minimum land requirement, reduces levels for floods greater than design floods, localized effects.	Possible increase in downstream flows. Expensive utility relocations. Safety of children. Higher velocities. Increased erosion.
Watershed Treatment	-	Not very effective. Only long term effects. Difficult to estimate and plan.
Floodplain Regulations	Can be used with other structural alternatives. Single district or two district approach can provide flexibility if required.	Not effective for existing development in the floodplain. Requires accurate mapping and flood data. Necessitates redefinition of the floodplain after encroachment.
Flood proofing	Can be used with other alternatives.	Not applicable over 2-3 foot depth. Does not eliminate floods. Lacking adequate technology. Requires detailed regulations.
Urban Redevelopment	-	Frequently not feasible. Expensive.
Forecasting	Inexpensive.	Not effective on its own. Only on large rivers is effective. Requires extensive data base and instrumentation.
Insurance	Residents are made aware of risks. Good for transition periods between change in land use. Provides immediate assistance.	Requires the government to underwrite. Will not eliminate flooding. Requires complimentary control.

6. Experience has shown that no single management alternative (See Table 2) is free of disadvantages. The merits of each must be considered on a case by case basis. Advantages and disadvantages of alternatives are given in Table 3.
7. Officials plans should include floodplain designation and land use policies for the floodplain.
8. In order to curb future flood damages in established urban municipalities, it will be necessary to adopt comprehensive floodplain management programs involving both regulatory and corrective measures.
9. The engineering criteria should be non-complex, understandable and reproducible.
10. Urban redevelopment can provide an excellent opportunity to remove undesirable structures from the floodplain and to use the land for more appropriate purposes such as recreation or to provide flood protection, perhaps in the form of a road which acts as a dyke.

The Ministry of Natural Resources felt that the most significant of the recommendations was the adoption of a two zone concept and that the criteria used to define the floodplain would not change.

Methodology Used for Floodplain Mapping

At present, mapping is based on one of the following: the 1 in 100 year flood, the Timmins storm or Hurricane Hazel depending on the area. Methods used for flood flow prediction include statistical analysis of streamflow records,

flow synthesis including the Rational Method for small drainage areas and the unit hydrograph method such as developed by the USSCS*. For ungauged areas, regression and correlation analysis is used for determining peak flow. Where records are short, simplified models are used and where records are long a frequency analysis (Gumbel extreme value and Log Pearson III) with records adjusted to reflect urban changes is used. The degree of development and economic value of the lands usually reflects the order of prediction and complexity of analysis justified. Flood lines and flows are generated using HEC-2 and HYMO.

Mapping is usually on scales of 1:2000, 1:5000 or 1:10,000. In aerial photography, mapping may be done as orthophoto scale-ratio rectified photo enlargements. On scales of 1:2000 and 1:5000; 1 m. contour intervals with 0.5 m. interpolations is recommended, and for very steep areas 2 m. and 1 m. interpolations. For 1:10,000 photo maps, 2 m. and 1 m. interpolation is recommended. Under the newly signed Federal-Provincial Agreement, working maps are to be produced at a scale of 1:2000 and public relations maps at a scale of 1:10,000.

Work Done by the Authorities

A further breakdown of what is being done in the Authorities is given in Appendix A. This was compiled from responses to questions posed to each of the Authorities. Not all Authorities responded.

*USSCS - United States Soil Conservation Service

Manitoba:

The Province of Manitoba during the period 1961 to 1969, carried out a 96 million dollar flood control program on the Red and Assiniboine Rivers. In the Red River Valley, above Winnipeg, seven communities with populations ranging from 150 to 1500 were protected by ring dykes. In the rural flood prone areas of the province, approximately 1500 farm building sites have been protected with provincial assistance to individual landowners. During the past four years, a number of flood protection investigations were carried out to determine the feasibility of constructing flood control works for communities with populations ranging from 500 to 2000. These investigations have indicated that due to the natural topography and the location of the centres on the immediate banks of the waterways the cost-benefit ratio has been unfavourable. These studies have further demonstrated the need for alternative measures to reduce the damages from floods.

In December 1976, Manitoba entered into an agreement with Canada under the Canada Flood Damage Reduction Program. It provided a range of practical and effective alternatives for the reduction of flood damages in areas of the Province where the traditional type of physical flood control works could not be justified on an economic basis.

Under the Manitoba Flood Fighting Plan, a co-ordinated organization of various affected departments can be quickly activated to deal with forecasted flood conditions in the Province. This plan provides for the provision of the early

forecasts of possible flooding during the spring runoff. Depending on the severity of the flooding, action by the Province may range from the provision of technical assistance to the assumption of full responsibility for the flood fighting activities in any area. Financial assistance has been made available to the local municipalities amounting to 100% of the cost of dyking and 87½% of the cost of other flood fighting activities. During the period of high flows in the years 1974 to 1976, flood fighting and flood damage expenditures in the Province have amounted to $6.8 million.

The Department of Municipal Affairs discourages universal development in flood hazard areas. New development is generally not permitted in flood prone areas unless the flood hazard can be prevented by permanent works without affecting other riparian owners. Zoning regulations imposed by individual municipalities represent the only other institutional control over floodplain use.

Saskatchewan:

In April 1977, Saskatchewan entered into an Agreement with Canada under the Flood Damage Reduction Program. Mapping is presently being carried out under the guidelines as set out for the Program. This is explained more fully under the New Brunswick discussion.

Saskatchewan is planning to introduce amendments to The Water Resources Management Act to authorize a flood hazard area management program. The program for flood prone areas would be almost identical to the program for the management of reservoir development areas which is also

provided for under this Act. Since 1964, reservoir development areas have been established to ensure orderly development at eight reservoirs in the province. The Province has worked harmoniously with municipal governments to achieve high quality development of the reservoirs.

The Provincial Government takes the view that where development has already occurred in flood prone areas, the most reasonable course of action will probably involve protective measures. In some cases, relocation may be possible. However, there should be strict control over new developments in hazard areas. "Open space" use such as recreational, agricultural or certain services, e.g. parking areas, may be the best use in many flood prone areas.

The co-operation of municipal governments is regarded as paramount. Municipalities are best able to manage land development and use in their areas. Without the understanding and co-operation of municipal governments, the program cannot succeed. The program provides an opportunity for municipal government to assert its authority and responsibility in bringing about improvements in dealing with the flood problem in Saskatchewan. For its part, the Province of Saskatchewan would issue Guidelines covering both existing developments and underdeveloped areas, including flood proofing requirements which would form the basis for building and zoning by-laws to be issued by the municipality following approval by the Minister of Municipal Affairs.

Alberta:

In 1960, provision was introduced into the Alberta Water Resources Act giving the Minister authority to establish flood control zones and to set forth terms and conditions regulating the use of lands within these zones. A further measure of control became available in 1966 when the Alberta Department of Agriculture established a Land Assembly Program for acquiring lands for special purposes, or lands where existing use was not suited to the land characteristics.

To date, structural measures have been relied upon to deal with flooding problems, particularly in rural areas. Desirable protection for agricultural land is generally for a 1:10 or 1:20 year flood. In urban areas, development is discouraged within the 1:100 year flood line. Presently the trend is toward non-structural alternatives, including purchase-base arrangements and relocation for both rural and urban application.

Under present legislation, the Regional Planning Commissions or the Department of Municipal Affairs continue to regulate floodplain lands through the approval of subdivision applications or changes in zoning with the Department of Environment providing a technical review. Alberta DOE has been significantly influential in the decisions of the Commission and in a great many instances, such proposals were rejected on the basis of their recommendations. Major industrial development requires Alberta DOE approval. Opportunity for an applicant to appeal is provided. One

loophole in this procedure is that owners of existing property in flood prone areas may also undertake development or improvements not requiring approval from a government agency.

A program of floodplain mapping has been initiated to define lands prone to flooding. Information is made available to the public, principally on major streams and rivers.

Generally, the procedure used for floodplain mapping in Alberta is to derive at least the 1:50 and 1:100 year flood using the Pearson III distribution and sometimes the log-normal distribution of maximum annual mean daily discharges. In the past they have used other statistical distributions, but recently have identified the above methods as being most appropriate. Mean daily discharges are converted to maximum instantaneous by use of a correlation equation. If sufficient data is not available, records are derived from a regional analysis of all relevant data. The HEC-2 model is used to obtain the water level profile. The floodline is then put on 1:4800 scale orthophoto maps with contours imposed on a mosaic of the area. The result is considered more acceptable for public presentation and more useful in the future. Cost is the main restriction as they are considerably more expensive than normal mosaics or contour maps. They are beginning to produce maps (brochures) for public information. Ice jams are handled separately and a statistical analysis of elevations helps to advise the towns involved so they can make preparations.

Hay River

In July 1978, Underwood McLellan Ltd. completed a Flood Risk Mapping Study of Hay River, Northwest Territories, for the Department of Fisheries and Environment. Although the study is concerned with mapping the lower 30 kilometer reach of the Hay River, it is particularly concerned with the sensitivity of the "new townsite" of Hay River to flooding, as a result of severe open water floods and ice jams. The intent was to define Hay River flood levels for five specific flood conditions, as follows:

1. Open water with a flood flow having an estimated return period of 100 years (1% probability of exceedence).
2. Spring break-up with a flood flow having an estimated return period of 100 years (1% probability of exceedence) combined with an ice jam having a return period of 100 years.
3. Spring break-up with a flood flow having an estimated return period of 20 years (5% probability of exceedence) combined with an ice jam having a return period of 20 years.
4. Spring break-up with an ice jam having a return period of 20 years (5% probability of exceedence) and an open water flood having an estimated return period of 100 years (1% probability of exceedence).

5. The historic flood of 1963, resulting in high water levels throughout the study area.

The hydrometric station, within the study area, Hay River near Hay River, has been in operation since 1963 and as such did not have sufficient record to estimate 1:20 and 1:100 year flood flows. The regional analysis concept did not apply because of dissimilarities in physiographic and climatic characteristics of the region and the need to estimate flows during flooding events prior to 1963. Typically floods in Hay River occur during the spring (May) as a result of snowmelt runoff combined with ice jams and during the summer (July) as a result of rainfall. Since the first peak typically exceeds the second and since the Consultant was focusing on ice jam flooding, only the snowmelt peak was considered. Using a graphical technique, the snowmelt portion of the spring runoff hydrograph was determined for each of the 14 years of record along with a corresponding volume. This snowmelt runoff volume was then correlated with total snowfall over the winter months. Using this relationship, the total snowmelt runoff volume was synthesized over the period 1936-1963. The annual peak flows for the period 1936-1963 were then synthesized by using a unit hydrograph approach because it was the simplest means of accounting for the integrated effects of all the physical features within the basin as a whole.

Flood frequency calculations were then carried out using the Flood Damage Reduction Flood Frequency Analysis

computer program available from Environment Canada. The three-parameter log normal distribution was used.

The data collection program for the hydraulic analysis included some 31 surveyed river cross-sections, a number of intermediate sections derived from 1:2000 scale mapping with a 1 meter contour interval and streamflow measurements on the East and West channels of the river around Vale Island on which most of Hay River is located. These discharges were required to obtain the split in flow around the Island for modelling purposes.

Water surface profiles were determined using HEC-2 for open water conditions. The consultants report leads one to believe that the model was calibrated for a July flow event, a non-snowmelt event, and that there was no validation of the model.

A review of prior reports and investigations plus an observation program during 1977 failed to provide any substantial information for the ice jam analysis. It was concluded that little could be done to ascribe a frequency to ice jam flooding. The approach used was a very simplified one. By assuming a constant Froude number under a variety of ice jamming conditions, the depth of flooding is directly proportioned to velocity squared, the upper limit of which is defined by the physical characteristics of the floodplain, i.e. where relief channels are formed.

Flood levels were indicated on 1:2000 scale, 1 meter contour, flood risk mapping.

British Columbia:

In British Columbia, floodplains are occupied because they are the most fertile and easily developed land in the mountainous province. A combination of approaches has been found to be the most workable solution to problems of flooding. Floodproofing, inclusion of flood control requirements in zoning by-laws and subdivision regulation and delineation of a design flood (1 in 200 year) on floodplain maps are the techniques used. Since it is assumed floodplains will continue to be occupied, structural controls will still be used where justified, but the trend is toward planning and regulation of new developments on floodplains in conjunction with a public information program.

Based on the floodproofing standards, flood control requirements were developed and at the request of the Water Resources Service, the Deputy Minister of Municipal Affairs recommended to all municipalities and regional districts, that flood control requirements be incorporated into their zoning by-laws. Some measure of success has been achieved, particularly in the case of village municipalities and those parts of regional districts outside municipal boundaries as zoning amendment by-laws in respect to these areas are subject to the approval of the Inspector of Municipalities. A referral system allows comment by the Water Resources Service prior to such approval being given, and hence incorporation of appropriate flood control requirements. Allowance is made, however,

in the recommended requirements to allow relaxation of the provisions subject to the approval of the Deputy Minister of Environment. All proposed subdivisions within the floodplain are subject to concent which is either denied or agreed contingent on floodproofing and the waiving of any damage claims in the event of future flooding.

Because of the mountainous terrain of British Columbia, the river hydraulic characteristics, and the fact that most of the communities are developing in the valley bottom lands adjacent to rivers and streams, in order to provide adequate safe guards, it was decided to use a design flood with a 200-year frequency, which approximates the largest flood of record.

The magnitude of the design flood for a river under study is supplied by the Hydrology Division who do the various frequency studies and regional runoff analysis required.

The field survey data of the rivers is supplied by the Survey Section. The general request for the survey requirements is as follows:

(1) Cross-sections should be taken where distinct changes occur in slope, cross-sectional area, channel roughness, and at the beginning and end of dykes or natural levees. The confluence of two rivers require cross-sections immediately upstream and downstream of the tributary.

(2) Bridges should have a cross-section immediately upstream and downstream and one through the centre line to show abutments, piers, bottomchords and roadway.

(3) Cross-sections are also required upstream and downstream of a bridge at a sufficient distance to show the cross-sections free from backwater or turbulences caused by the bridge.

(4) Photographs should be taken to show reaches of representative channel roughness and overbank vegetation, bridges, and culverts.

(5) The time and date should be recorded with all water surface elevations so that the water elevations may be related to recorded flow, and for certain rivers the effects of tides.

(6) The distance or location of the thalweg between cross-sections should also be recorded.

(7) A key map should be provided showing the position of cross-sections and other survey data obtained.

(8) If possible, a table showing river bottom materials at and between cross-sections should be included in the river survey data.

Once this data, plus any other data peculiar to the individual river has been obtained and processed, the calculation of the flood profile can be made. Based on Bernoulli's equation and Manning's formula, they use a computer program based on the U. S. Corps of Engineers' HEC-2 program to calculate the design flood profile.

After the profile of a 200 year frequency flood has been determined, an allowance for freeboard is added. This is a safety factor intended to allow for inexactness

of measurements and of the profile calculation, and for usual wave action. Generally the freeboard is taken to be 2 feet; however, on large lakes or turbulent rivers it will be increased if it is felt necessary to protect against additional dangers such as: above normal wave action, bank erosion and an excessive difference between daily mean flows and instantaneous peak flows.

While the field crews obtain the hydraulic data of the river, control for floodplain mapping is generally also obtained. The mapping uses an orthophoto base map with various overlays to show contours and spot heights, cadastral information, floodplain boundaries developed from the flood profile plus any other information required. This mapping is in metric and produced at scales of 1:5000 and 1:2500.

For the future, the Water Resources Service is continuing on with flood control measures utilizing both structural controls and planning controls. Guidelines for floodplain development were to be issued during 1976. The delineation and mapping of floodplain areas will continue, with priority emphasis on the most urgent problem areas.

The supply of flooding information and advice to the public and local authorities will be increased together with an increased educational program to foster greater acceptance of proposed flood control measures at both the provincial and local levels. And, of course,

research is ongoing to refine the methods of flood forecasting, to improve the data base for the hydraulic modelling of river flood profiles, and to continue the basic objective of reducing injury, eliminating loss of life, and minimizing property damages by floodwaters within British Columbia.

Britain:

Flood problems in Britain are regarded primarily as a local or regional concern, not the business of the central government. Flood control schemes are financed by regionally supported River Boards, and decisions to undertake engineering works made by the local authorities entail responsibilities for a substantial proportion of the cost. The central government participates in the financing of schemes in roughly inverse proportion to the ability of a given River Board to meet the full cost. In consequence central government assistance for flood control work is frequently smaller in urbanized river basins such as the River Trent area, than in rural and agricultural basins such as the River Great Ouse area.

Town and country planning is more highly developed and effective in Britain than in the United States, and local planning regulations frequently, though not always, prohibit or restrict further floodplain development. The avoidance of flood hazard areas has also been facilitated by a rural settlement pattern in which nucleated villages are often located on terraces above the level of the present floodplain. Modern expansion of these villages

has been guided away from floodplains by careful planning. In consequence heavy expenditures on flood control have been avoided in Britain, although the country is densely populated and heavily urbanized. Flood losses occur, but there is insufficient evidence to indicate whether they are increasing or decreasing.

There are no figures of flood losses recorded on a consistent basis. It is difficult to isolate from the expenditures of all the levels of government involved, the amount of money spent on flood control works.

The success of the British policy, however, has been dependent, in part, on central government initiative. The River Boards are organized on a river basin basis, their activities being controlled largely by constituent local governments that provide money in the form of a tax for most of the normal expenditures of the Boards. It was found necessary to make the establishment of such Boards obligatory.

U. S. A.:

The trend in the U. S. is to implement regulation policies similar to an established Ontario practice - the reduction of future damage susceptibility by preventing new development in the floodplain. Widespread implementation of floodplain regulations in the U. S. has been very slow because local levels of government are quite independent and have resisted the implementation of regulatory techniques.

As part of this effort, maps depicting the areas

subject to flooding are prepared by the U. S. Corps of Engineers. Floodplain delineation usually comes with one of three bases. The most obvious is a map showing the extent of an actual flood based on high water and run-out marks. A second is an approximate area map of the type which the National Flood Insurance Program identifies as a Flood Hazard Boundary Map (FHBM). This is based on the best information available and is of variable quality. The third type, and the one which best serves for flood-plain regulations, requires the development of floodwater-surface profiles using hydrologic and hydraulic techniques; and the transfer of elevation information from profiles to a map or photo with contours. Floodplain maps of this type have been prepared as part of the Floodplain Management Services program effort by the U. S. Corps of Engineers since the early 1960's. In the more recent National Flood Insurance Program, they are identified as Flood Insurance Rate Maps (FIRM's).

Although they have done both the experienced-flood mapping and approximate area mapping, detailed flood-plain delineation has been the main effort. In detailed delineation studies, a Log Pearson III frequency analysis as discussed in Bulletin 17 of U. S. Water Resources Council, is used. This guideline presents currently accepted methods for flood frequency analysis. Natural trends, randomness of events, watershed changes, mixed populations, and reliability of flow estimates are discussed as a reminder to be aware of basic potential data errors. The

Log Pearson III distribution is recommended as the basic distribution for defining the annual flood series. The method of moments is used to determine the statistical parameters of the distribution from station data. Generalized relationships are used to define the skew coefficient for short record stations. Methods are proposed for treatment of most flood record problems encountered. Procedures are described for refining the basic curve determined from statistical analysis of the systematic record to incorporate historic flood data, information gained from comparisons with similar watersheds, and flood estimates from precipitation. Procedures for computing confidence limits of the frequency curve are provided along with those for calculating risk and for making expected probability adjustments.

Profiles are developed using "backwater routines" such as those produced by the Hydrologic Engineering Center and identified as the HEC-2 Program. Valley cross-sections are run to a plus or minus 1 ft. accuracy. By varying the hydrology to simulate floods of differing probabilities, sets of profiles are created and hence the ability to map them. Maps are at scales of 1:24,000 or larger.

Although there are arguments for both more or less detail than those adopted, they believe that theirs will stand the test of time. Furthermore, without such systematized hydrologic studies, there is no consistent basis for updating data, nor for analyzing the "floodway" as is often required in a two-zone ordinance.

House Document 465 gives the U. S. G. S.* the responsibility for outlining the floodplain on maps or aerial photographs. For this work they have prepared a guideline for the preparation, transmittal and distribution of flood-prone area maps and pamphlets. The instructions and advice given are to be considered as guidelines. Delineation of boundaries may require liberal interpolation in unusual situations. Highly accurate flood mapping methods that make use of refined techniques, accurate field surveys, backwater computations, and detailed frequency analysis, are considered too costly and time consuming. In contrast, flood prone area maps will often be defined from less data, by techniques that produce boundaries in which there is a lower degree of confidence.

These guidelines state that a 7 1/2' or 15' topographic base map be used. Significant flood prone areas wider than 400 feet are to be shown on 1:24,000 scale maps. If flood information is available for regulated conditions, the flood boundaries are to be based on this information. If not, natural conditions are used for mapping and this is stated on the map.

In the case of ice jams, personal judgement is used.

Methods to estimate the required 100 year flood boundary are:

1. Regional stage-frequency relations

Average relationships between flood depth, flood discharge and frequency of occurrence can be developed. The regional stage-frequency curve can then be defined by

*United States Geological Survey

plotting these 100 year flood heights against an estimating variable, preferably drainage area or perhaps mean annual flood discharge. Assuming that the contours on a topographic map are exact and intersect streams at about median flow stage, a normal flow profile can then be determined and drawn from measurements on the map. For selected sites along this profile, the 100 year flood stage is determined from the regional stage-frequency curve and a flood profile drawn. Elevations along the 100 year flood profile can then be utilized to define the flood boundaries by interpolation on the topographic maps.

2. Profiles of theoretical floods of specified frequency

Profiles of floods of specified frequency are sometimes available from other governmental agencies. These profiles commonly show the 25 year, 50 year, and "Standard Project" floods (SPF). The SPF is often close to a 100 year recurrence interval but this should be checked. An increment of elevation, based on the shape of the stage-discharge relation, can be added to the 50 year profile to elevate the 100 year flood profile satisfactorily. A constant increment can be used over a long reach.

3. Profiles of observed floods

Profiles of past floods can sometimes be constructed from high-water marks. To use these profiles it is necessary to establish the recurrence interval of the flood and then adjust the profile to approximate the 100 year profile by using an increment of elevation based on the shape of the stage-discharge relation. It is usually satisfactory to

assume that the recurrence interval of the observed flood is a constant for a considerable length of river reach.

Elevations and locations of high-water marks of past floods provide information for defining a flood profile. Where topographic maps are available, the profile can be transformed into flood boundaries by interpolation between contours.

Several thousand miles of flood profiles can be developed from information published in Geological Survey flood reports. A great deal of additional floodmark information exists in engineering offices of Federal, State, and local governments.

4. Aerial photographs of flooding

To use aerial photographs of floods it is necessary to first construct a profile from information picked from the photographs, and determine the recurrence interval of the flood. The profile may then be adjusted to approximate the 100 year profile.

Floodplains usually can be defined by viewing pairs of photographs through a stereoscope. The edges can be marked directly on the photograph and then transferred to a map or photomosaic base with proportional dividers. Field checks may be necessary with this method. Complete photographic coverage of the United States is available.

So far there is mention of two different agencies doing floodplain mapping. It is my understanding that the U. S. G. S. prepares "quick" maps such that all areas subject to flooding are mapped quickly. Later, the U. S. Corps of

Engineers prepares maps based on more detailed or more technically accurate information. These would be more suitable for floodplain management purposes.

The U. S. Department of Housing and Urban Development has also established guidelines and specifications (October, 1977) for study contractors. The scope of a study covers all the area within the boundary of the community, except areas where development is not likely to occur. Flood risk areas are determined for all flooding sources.

Flood Insurance Studies generally involve both detailed and approximate study methods. For purposes of the National Flood Insurance Program, detailed study methods are those that, as a minimum, include engineering studies that result in the determination of the 100 year flood profiles. Approximate study methods are those that do not include detailed engineering (field) studies and result only in a determination of the 100 year flood boundaries. Flood risk determinations for flood sources that affect developed or developing areas should be based on detailed studies; determinations for other flooding sources should be carried out by studies using approximate methods. Detailed and approximate study shall normally be terminated where the width of the 100 year floodplain is less than 200 feet. Detailed study shall also normally be terminated where the drainage area of the flooding source is less than one square mile.

The contractor shall make use of any existing flood maps for areas of approximate study. Peak flood discharge shall be obtained for the 10, 50, 100 and 500 year events and when possible, use available flood flow frequency information. Flood flow frequency analysis shall be made in accordance with the latest recommended method by the Water Resources Council. For ungauged streams, the regional flood frequency report by U. S. G. S. is to be used. For unique situations, models or empirical equations are not to be used.

Available work is to be used for the hydraulic analysis if possible. Survey work shall be done to determine channel and floodplain cross-sections but where possible, available vertical control and detailed topographic maps shall replace field surveys. Flood elevations for riverene areas are normally determined by step backwater computer models. Scales ranging from 1:4800 to 1:24,000 are to be used for a work map base with developing areas using a 1:4800 to 1:12,000 scale. Contours are generally not closer than 1 inch. Community officials are to be kept advised of the progress of the study and are to have ample opportunity to provide information for the study.

For coastal studies, statistical analysis is used when the gauge data provide sufficient records and are representative of the area to be studied. Otherwise, a numerical simulation using the FIA storm surge model is recommended.

Information on work being done in Maine and Nebraska is discussed herein.

Maine

Approximate studies are employed in areas where the danger from flooding is minimal. This can be attributed to the size of the drainage area or the extent of development in the basin. In these areas the following information is utilized. In 1972, a regional analyses was made between the stages of the 100-year flood and the fifty percent duration discharge (previously published for areas in the U. S.) at sites where streamflow data was available. This method shows that generally the 100 year flood elevations are ten feet higher than the mapped stream elevations. This elevation is then mapped. Along the coast of Maine where detailed studies are as yet not complete, the U. S. Geological Survey, in consultation with other government agencies, selected the 20 foot contour as the best approximation of the 100 year flood.

For the more detailed studies, computer modelling is done to an accuracy ± 0.5 feet elevation for 10, 50, 100 and 500 year floods. Flood flows are calculated using U. S. G. S. Gauging Station data and a Log Pearson Type III analysis of annual peak flows. If data is unavailable, regional relationships are developed, and if these do not apply, the basics of hydrology are used.

They have had no problems with zoning regulations.

Nebraska

Unless conditions at a particular site justify unusual input effort, short comings on map detail, discharge records, and hydrologic investigations will limit the quality of the delineation of floodways. It is generally felt that water surface profile computation to an accuracy of about 1 foot is about as precise as can be expected on the average using the technology available at this time. The Nebraska Water Resources Council Bulletin 15, provides a uniform technique for the 1:100 year frequency discharge computation, and the Army Corps of Engineers' HEC-2 Water Surface Profile Computer Program are utilized to standardize procedure and provide the basic output data required by the delineation program (the floodway necessary to convey the flood of 1:100 year frequency with a 1 foot rise in stage). Additional studies are necessary from time to time to update the delineations to reflect the effects of changing physical conditions such as extensive urbanization of the drainage area and the installation of flood control measures or channel rectification programs, or both.

The Nebraska Natural Resources Commission legally establishes these floodways and their respective encroachment lines by order following a public hearing. The orders, together with such maps, rules, standards, and other pertinent data are then turned over to the political subdivision of government having zoning jurisdiction over the area and are recorded with the Register of Deeds in the county or counties where the delineated floodplain is

located. The Act specifies that the local governing body shall have 1 year following receipt of floodplain data in which to adopt a program of floodplain regulation that meets or exceeds the minimum standards of the State. It is felt that providing the local political subdivision with the statutory opportunity of local control with backup authority on the State level is one of the outstanding aspects of the program.

Floodplain zoning legislation and ordinances must meet and pass several severe constitutional tests. The regulations imposed must not be arbitrary or capricious, they must bear a reasonable relationship to the objectives to be accomplished, and they must not result in a taking of property without just compensation. To not be arbitrary or capricious, the regulations must treat all property owners similarly situated in a like manner.

If the techniques utilized for determining the magnitude of the 100 year frequency flood, or for delineating such floodways are not scientifically acceptable, judicial inacceptance can also be anticipated. In Nebraska, the Log Pearson three method of computing flood discharges is considered the most appropriate method available under the science of present day hydrology. It is not an exact science, and a judicial determination on the acceptability of this method has never been made.

U. S. Flood Insurance Program

One of the main objectives of the flood insurance program is to force communities to initiate a more comprehensive approach to floodplain management, including

floodplain regulations. Local governments adopt floodplain regulations that meet or exceed minimum federal criteria in order to be eligible for flood insurance. Flood insurance is required to receive federal financial assistance for acquisition or construction purposes in identified flood hazard areas. While approximately 13,000 communities are participating in the National Flood Insurance Program, the effectiveness of the implementation of the program is under review at the present time. Numerous positive and negative considerations of this approach to floodplain management have been identified. On the positive note, the following advantages can be listed:

1. Requires communities to address their flood related problems.

2. Sets out standards for land use and building codes in flood prone areas.

3. Discourages unnecessary use of floodplains by charging actuarial rates after the regular program is operative.

4. Differentiates between existing uses and new uses through risk rates.

5. Reimburses flood victims more quickly and fully than they would be through other federal programs.

On the negative side, the flood insurance program has the following disadvantages:

1. Increasing the possible future losses while encouraging the use of the 100 year flood as a limit to

regulation rather than any higher regional flood.

2. It is unable to check abuses because the Federal Insurance Agency does not have a field officer to supervise implementation of land use regulations.

3. Providing insurance in some hazard areas may encourage lending institutions to support construction they formerly considered too risky.

5.0 SOME METHODS FOR FLOODPLAIN MAPPING

There are many methods of implementing floodplain mapping. The following list was obtained from a literature review.

Soils:

Where soil maps exist, they may be used to extend more restricted information on areas subject to flooding. There is reason to believe that soils, like topography, will correlate well with specific flood heights, but such relations must be established locally before they can be extended to provide an evaluative tool for floodplain mapping.

Vegetation:

Physiological evidence and the distinctive age differences in the floodplain trees produced by destructive floods suggest the possibility of designating maximum flood heights or minimum land elevations subject to flood from associations between flooding and vegetation.

Occasional Flood:

Mapping the occasional flood is dependent on the existence of photographs, historical records, and some gauging station records. The accuracy of the mapping is limited not only by the availability of such information but by the accuracy of the maps on which the data are presented. Satelite imagery can be useful in helping to determine boundaries for larger river systems.

Regional Flood:

Flood heights of chosen frequencies may be mapped on a regional basis from records at selected localities. By relating flood heights of different return periods to parameters such as drainage area and mean annual flood, discharge curves can be drawn that permit flood heights to be determined at ungauged sites of known drainage area within the region. The regional or flood heights techniques require verification from available information on floods. Their effectiveness depends on the purpose to which the information of flood prone lands is to be put and on the extensions of existing knowledge that the regional approaches may permit.

Flood Lines and Backwater Curves:

Refined techniques for delineating flood lines including computation of backwater curves are a matter of standard engineering practice. Detailed surveys are precise and often replicable to a high degree of precision for a selected flood discharge when we assume no significant changes to the channel.

Geomorphic Method:

This involves the more extensive investigation of morphology, sedimentology, distinctive erosional features, time sequence of channel abandonment, and the compilation of existing pedologic, botanic and hydrologic information. The geomorphic approach to flood hazard delineation should include inventories of historical

flood marks on the ground surface, aerial photographs of actual flood events, and local interpretations of existing stream gauging data. It should also be a subjective appraisal of all existing physiographic, botanic, pedologic, occasional flood, and regional hydrologic studies to be done by skilled scientists as part of a regional environmental inventory.

Hydrogeomorphic methods offer a powerful potential to aid certain aspects of solving the "map gap" that plagues floodplain management. Specifically, it can aid in the following ways: (1) depicting features that indicate flood susceptibility over very large areas, (2) allowing the extension of detailed but expensive hydraulic-hydrologic floodplain information from local areas into larger unmapped regions, (3) providing the basic flood hazard information in hydrologically data sparse regions, and (4) establishing "upstream" flood response models.

The true promise of hydrogeomorphic analysis will probably be realized when the output of all craft and satellite scanning equipment will feed directly into a computer system capable of automatic drainage network recognition and automatic computation of morphometric parameters. This will eliminate the need for operator scanning of imagery, even when assisted by pencil following and digitizing equipment. Before this is

feasible, however, considerable manual testing will be required to establish the ground truth for apparent drainage network patterns on the imagery and to evaluate the effects of scale on the hydrologic utility of hydrogeomorphic parameters.

Remote Sensing:

Multi-spectral digital classifications of land cover features indicative of floodplain areas permits satellite results to be displayed at 1:24,000 scale and aircraft results at even larger scales. Experiment has shown that remote sensing techniques can delineate flood prone areas more easily in agricultural and limited development areas than in areas covered by a heavy forest canopy. At this time it appears that remote sensing data would be best used as a form of preliminary planning information or as an internal check on previous or ongoing floodplain studies.

The continued acquisition of remote sensing data will serve to record actual flooding events on an increasing number of streams. Such data will increase the availability of actually observed flooded area maps and update flood hazard boundary maps where they already exist. Continued remote sensing research in floodplain management should concentrate on attaining the optimum resolution with multispectral sensors, whether from high altitude aircraft or space platform.

Spatial Data Management Techniques:

Spatial data management techniques can be used within a traditional analysis framework to permit and encourage comprehensive, systematic, practical assessments of present and alternative future basin wide development patterns as reflected by alternative land use patterns and physical works in terms of flood hazard, economic damage potential and selected environmental consequences. The analysis methodologies are centered about integrated use of computerized spatial, gridded geographic and resource data files. A family of special purpose utility computer programs access the data file and extract appropriate variables and interpret and format the data into specific analytical parameters that are subsequently formatted for input to traditional modelling computer programs.

5.1 Problems

Problems associated with simple mapping procedures include:

1. A small difference in stage may encompass quite large areas on the ground.

2. There is a measure of uncertainty in the designation of any floodline.

3. Because the differences in costs are significant, simplified techniques might well be used to supplement existing detailed information permitting planners to extend their coverage of areas subject to flooding so that

comprehensive or large area planning would have the benefit of at least preliminary information prior to the strongest pressures for local land development.

4. The resistance to use simplified techniques for floodplain mapping appears to rest primarily on the concern that imprecise delineations will not hold up in court. Often the testimony of a live of photographic witness is more convincing than engineering surveys and computations of flood heights of expected or probable floods.

Commonly used methodologies for the determination of flood profiles are based on estimation of flood magnitude by hydrologic computations and the estimation of the flood elevation by hydraulic computations. Statistical analyses of flood frequency gives some assessment of the risk and uncertainty in estimates of magnitude of the flood of interest. Elevations attained by that flood contain uncertainties in flood magnitude (hydrology) and flood routing (hydraulics). Problems encountered with a more detailed method include:

1. Uncertainties in the computation of flood profiles due to the uncertainties inherent in the hydrologic analysis and its combination with that in the estimation of parameters such as Manning's "n", can be significant.

2. Depending on the step-backwater computation model used, the computed profiles may vary significantly due to the use of different computational schemes and parameter values.

3. Use of surveyed cross-section information of the stream and overbank to develop the flood profile does not necessarily give more accurate answers than do the results obtained by using data from good topographic maps or from other much less detailed information.

4. The consideration of alternative methodologies for floodplain delineation should consider the uncertainties inherent in present methods, and compare the relative uncertainties, if a cost-effective decision concerning development of methods is to be accomplished.

6.0 REFERENCES

1. Alberta Environment, "Flood Information Index". May, 1977.

2. Baker, Victor R., "Hydrogeomorphic Methods for the Regional Evaluation of Flood Hazards". Environmental Geology Vol. 1, pp 261-281. 1976.

3. Bruce, J. P., "The National Flood Damage Reduction Program". Canadian Water Resources Journal, Vol. 1 No. 1. 1976.

4. Bruce, J. P., Rosenberg, H. B., and Page, G. A., "The National Flood Damage Reduction Program". Paper presented at Canadian Hydrology Symposium: 77 Floods, Edmonton, Alberta. August, 1977.

5. Burton, Ian, "A Preliminary Report on Flood Damage Reduction". Geographical Bulletin, Vol. 7, No. 3. 1965.

6. Canada Department of Environment, Inland Waters Directorate, "Survey and Mapping Procedures for Flood Plain Delineation". Ottawa, 1976.

7. Canada Department of Environment, Inland Waters Directorate, "Hydrologic and Hydraulic Procedures for Flood Plain Delineation".Ottawa. 1976.

8. Coutts, G. M., "Water Management Functions of the Grand River Conservation Authority". Canada Water Resources Journal, Vol. 1, No. 1. November, 1976.

9. Crysler & Lathem Ltd., "Bear Brook Floodplain Mapping Study - Hydrology Study". Prepared for South Nation River Conservation Authority. September, 1977.

10. Davis, Darryl W., "Comprehensive Flood Plain Studies Using Spatial Data Management Techniques". Water Resources Bulletin, Vol. 14, No. 3. June, 1978.

11. Dawdy, David R., and Motayed, Asok K., "Uncertainties in Determination of Flood Profiles". Proceedings: International Symposium On Risk and Reliability In Water Resources, University of Waterloo, Waterloo, Ontario. June 26-28, 1978.

12. Department of the Army, "A Perspective On Flood Plain Regulations For Flood Plain Management". Washington, D. C. June, 1976.

13. Dillon, M. M., Ltd., "Proposal For Services - Flood Plain Mapping". Prepared for South Nation Conservation Authority. February, 1976.

14. Dillon, M. M., Ltd., and MacLaren, James F., Ltd., "Flood Plain Criteria and Management Evaluation Study". Prepared for Ontario Ministry of Natural Resources and Ontario Ministry of Housing. December, 1976.

15. Dingman, S. Lawrence, Platt, Rutherford H. "Floodplain Zoning: Implications of Hydrologic and Legal Uncertainty". Water Resources Research, Vol. 13, No. 3, pp 519-523. June, 1977.

16. Doughty-Davis, J. H., "Floodplain Management in British Columbia". Canadian Water Resources Journal, Vol. 1, No. 1. 1976.

17. Dupose, R. K. and Yaremko, E. K., "Flood Studies for Flood Protection - Peace River at Peace River". Alberta Environment. September, 1972.

18. Edelin, George W. Jr., "National Program for Managing Flood Losses - Guidelines For Preparation, Transmittal and Distribution of Flood-Prone Area Maps and Pamphlets". U. S. Geological Survey. 1976.

19. Environment Canada, "Flood Damage Reduction Seminar". November 5, 1975

20. Environment Canada, "Flood Damage Reduction Status Reports".

21. Environment Canada, "Proceedings of Flood Hazard Mapping Seminar". June 25, 1973.

22. Fisheries and Environment Canada, "Canada Water Yearbook 1976". Ottawa, Ontario. 1976.

23. Fisheries and Environment Canada, "Canada Water Yearbook 1975". Ottawa, Ontario. 1975.

24. Fisheries and Environment Canada and Ministire des Richesses Naturelles, "Flood Damage Reduction Program, Montreal Region". Quebec. 1978.

25. Giles, Walter, "Floodplain Policies In Ontario". Canada Water Resources Journal, Vol. 1, No. 1. 1976.

26. Grand River Conservation Authority, "1977 Annual Report".

27. Grand River Conservation Authority, "Fill Construction and Alteration to Waterways Regulations Made Under the Conservation Authorities Act".

28. Hutchinsin, Ian P. G., and Watt, W. Edgar, "A Systematic Approach To Flood Risk Mapping". Proceedings of International Symposium On Risk and Reliability In Water Resources, University of Waterloo, Waterloo, Ontario. June 26-28, 1978.

29. Liebman, Ernst, "Legal Problems In Regulating Flood Hazard Areas".

30. Lindner, D. H., "Flood Risk Mapping - Map Requirements for Hydraulic Evaluation". Environment Canada, Ottawa, Ontario. May 10, 1973.

31. Lorant, F. I., "Flood Plain Studies in Ontario". First Canadian Hydraulics Conference: Proceedings. 1973.

32. Lowe, S., and Samide, G. W., "Flood Plain Study of the North Saskatchewan River Through Edmonton". Alberta Environment. 1974.

33. Lowe, S., and Samide, G. W., "Flood Plain Study of the Red Deer River Through Drumheller". Alberta Environment.

34. MacLaren, James F. Ltd., "Rural Fill Line Mapping". Prepared for Kettle Creek Conservation Authority. Draft. December, 1976.

35. Mathews, Albert E., "Nebraska Flood Plain Management Program - Part I and Part II". Journal of the Hydraulics Division, ASCE. July, 1975.

36. Metropolitan Toronto and Region Conservation Authority, "Plan for Flood Control and Water Conservation". Woodbridge, Ontario. 1959.

37. Ministry of Natural Resources, "Discussion Paper - Flood Plain Criteria and Management Study". June, 1977.

38. Page, Gillian, "Flood Maps". Contact, Fisheries and Environment Canada. No. 5, Vol. 2. July/August, 1978.

39. Rideau Valley Conservation Authority, "Fill and Construction Regulations". November, 1976.

40. Samide, G. W. and Szabon, William, "Floodplain Study - Sturgeon River Through St. Albert". Alberta Environment. August, 1975.

41. Sollers, Scott C., Rango, Albert and Hennigar, Donald L., "Selecting Reconnaissance Strategies In Floodplain Surveys". Water Resources Bulletin, Vol. 14, No. 2. April, 1978.

42. South Nation River Conservation Authority, "Terms of Reference for the Flood Plain Mapping of Bear Brook". September 23, 1975.

43. Spargo, R. A., and Watt, Dr. W. E., "The Canadian Flood Damage Reduction Program". United Nations Water Conference, Mar Del Plata, Argentina. March 14-25, 1977.

44. Tener, J. S., "Memorandum to Cabinet: Use of Federal Programs and Federal Provincial Accords for Flood Damage Reduction". September 13, 1974.

45. Underwood McLellan Ltd., "Flood Risk Mapping for Hay River, Northwest Territories". Prepared for Inland Waters Directorate, Department of Fisheries and the Environment. July, 1978.

46. U. S. Department of Housing & Urban Development and Federal Insurance Administration, "Guidelines And Specifications For Study Contractors". October, 1977.

47. U. S. Department of Housing & Urban Development, "Flood Insurance Study, Pacific County, Washington", Federal Insurance Administration. July, 1977.

48. U. S. Department of Housing & Urban Development, "Flood Insurance Study, Town of Barnstable, Massachusetts". Federal Insurance Administration. August, 1977.

49. U. S. Department of Housing & Urban Development, "Flood Insurance Study, City of Hazen, North Dakota". Federal Insurance Administration. March, 1977.

50. U. S. Department of Housing & Urban Development, "Flood Insurance Study, City of Encorse, Michigan". Federal Insurance Administration. November, 1977.

51. U. S. Department of Housing & Urban Development, "Flood Insurance Study, City of LaVernia, Texas". Federal Insurance Administration. November, 1977.

52. U. S. Department of Housing & Urban Development, "Flood Insurance Study, City of Aberdeen, Mississippi". Federal Insurance Administration. July, 1977.

53. U. S. Department of Housing & Urban Development, "Flood Insurance Study, City of Merriam, Kansas". Federal Insurance Administration. November, 1977.

54. U. S. Department of Housing & Urban Development, "Flood Insurance Study, Town of Hanover, New Hampshire". Federal Insurance Administration. January, 1978.

55. U. S. Geological Survey, "A Technique in Determining Depths for T-Year Discharges in Rigid-Boundary Channels". Water Resources Investigations 77-83. December, 1977.

56. U. S. Water Resources Council, "Guidelines for Determining Flood Flow Frequency". Washington, D. C. June, 1977.

57. U. S. Water Resources Council "Regulation of Flood Hazard Areas to Reduce Flood Losses". Washington, D. C. Volumes 1 and 2.

58. Vanderbrug, B. W., "Floodplain Management in Southern Ontario". Hamilton Region Conservation Authority. July, 1976.

59. Vanderbrug, B. W., "Review of Floodplain Regulations for Town of Dundas". Hamilton Region Conservation Authority. May, 1978.

60. Wisner, Paul E., "Engineering in Flood Control". Canadian Water Resources Journal, Vol. 1, No. 1. 1976.

61. Wolman, M. Gordon, "Evaluating Alternative Techniques of Floodplain Mapping". Water Resources Research, Vol. 7, pp 1383-1392. December, 1971.

LETTERS

1. Barnes, Harry H. Jr., U. S. Geological Survey, Reston, Virginia. March 29, 1978 and April 27, 1978.

2. Bathurst, J. B., Environment Canada, Ottawa, Ontario. February 7, 1978.

3. Card, J. R., Alberta Environment, Edmonton, Alberta. July 10, 1978.

4. Chalk, A. W., Raisin Region Conservation Authority, Martintown, Ontario. May 2, 1978.

5. Deslouriers, Ian, Maitland Valley Conservation Authority, Wroxeter, Ontario. May 9, 1978.

6. Fontaine, Richard, U. S. Geological Survey, Augusta, Maine. April 17, 1978, May 9, 1978.

7. Jackson, G. L., Napanee Region Conservation Authority, Napanee, Ontario. May 16, 1978.

8. Johnston, James, Niagara Peninsula Conservation Authority, Fonthill, Ontario. May 5, 1978.

9. Lemp, W. Eric, Grand River Conservation Authority, Cambridge, Ontario. April 18, 1978.

10. Lowe, S., Alberta Environment, Edmonton, Alberta. June 14, 1978.

11. McKeen, R., Kettle Creek Conservation Authority, St. Thomas, Ontario. June 2, 1978.

12. Martin, Roger D., North Grey Region Conservation Authority, Owen Sound, Ontario. May 5, 1978.

13. Mather, J. C., Metropolitan Toronto and Region Conservation Authority, Downsview, Ontario. July 20, 1978.

14. Merrian, J. W., Otonabee Region Conservation Authority, Peterborough, Ontario. June 12, 1978.

15. Merritt, Lorne, Prince Edward Conservation Authority, Picton, Ontario. May 31, 1978.

16. Messervey, Robert W., Central Lake Ontario Conservation Authority, Whitby, Ontario. May 18, 1978.

17. Musclow, K. G., South Nation River Conservation Authority, Berwick, Ontario. July 20, 1978.

18. Noels, Basil, Credit Valley Conservation Authority, Meadowvale, Ontario. May 9, 1978.

19. Parker, John A., Cataraqui Region Conservation Authority, Glenburnie, Ontario. May 31, 1978.

20. Powell, J. R., Upper Thames River Conservation Authority, London, Ontario. May 3, 1978.

21. Prince, A. T., Environment Canada, Ottawa, Ontario. May 11, 1973.

22. Quazi, M. E., Alberta Environment, Edmonton, Alberta. May 5, 1978.

23. Rogers, Robin, Mississippi Valley Conservation Authority, Carleton Place, Ontario. May 4, 1978.

24. Rowat, James A., Ganaraska Region Conservation Authority, Port Hope, Ontario. May 2, 1978.

25. Schmidt, Ken J., Essex Region Conservation Authority, Essex, Ontario. May 5, 1978.

26. Shwaiko, Alex., U. S. Corps of Engineers, Washington, D. C.

27. Simpson, W. L., Environment Canada, Ottawa, Ontario. May 11, 1973.

28. Stirajs, Q., Rideau Valley Conservation Authority, Manotick, Ontario. May 5, 1978.

29. Vanderbrug, B. W., Hamilton Region Conservation Authority, Ancaster, Ontario. May 8, 1978.

30. Vilneff, R. S., Crowe Valley Conservation Authority, Havelock, Ontario. May 3, 1978.

31. Waters, R. C., Central Mortgage and Housing Corporation, Halifax, N. S. April 10 and 25, 1978.

32. Westman, Ken R., Saugeen Valley Conservation Authority, Hanover, Ontario. June 21, 1978.

33. Yanni, Ralph P., Sault Ste. Marie Region Conservation Authority, Saut Ste. Marie, Ontario. May 2, 1978.

APPENDIX A

FLOOD RISK MAPPING

by

THE ONTARIO CONSERVATION AUTHORITIES

APPENDIX A

Information on what is being done by various Authorities for flood risk mapping is contained in the following pages. This was compiled from the 24 responses to questions asked each of the 38 authorities. Generally, each Authority is discussed under headings of "Flood Risk Mapping", "Method", "Maps", "Court Cases". "Regulation", and "Ice Jamming".

METROPOLITAN TORONTO AND REGION CONSERVATION AUTHORITY

Floodplain Mapping: Yes

Method: Floodline mapping is based on Hurricane Hazel. The basic method used to derive flood frequency is the Gumbel distribution.

Court Cases: They have not had a great many instances where a refusal to allow development in the floodplain has been taken to court. Usually developers have agreed to the requirements. Where court action has resulted, they must be able to prove that the development is susceptible to flooding and/or its effect on flood levels upstream or down, or the loss of natural flood storage.

Ice Jamming: Flooding due to ice jams etc. is a problem in certain areas however, they feel that the floodplain as now defined should provide more than enough protection to new developments. In existing areas where development is within the floodplain, structures have been constructed such as channels to protect the development. Knowledge of the rivers and potential ice or log jam sites enables,through a good flood warning system,action to be carried out if necessary before private residences etc. are flooded.

PRINCE EDWARD REGION CONSERVATION AUTHORITY

Flood Risk Mapping: No

SAULT STE. MARIE REGION CONSERVATION AUTHORITY

Flood Risk Mapping: Yes

Method: Mapping is being based on the Timmins storm.

Court Cases: None

Regulations: None

SAUGEEN VALLEY CONSERVATION AUTHORITY

Flood Risk Mapping: No, but fill-line mapping is carried out.

Explanation: After completion of the floodplain determination by certified engineers, fill-lines are also plotted above the floodlines. Fill-lines are an administrative set-back from the floodline based on hazard land conditions (degree of slope, slope stability, soils, etc.). Once the fill-line has been approved by the Conservation Authority, the benefiting municipalities and the local member of Parliament, the mapping is then registered as an Ontario Statute under the Conservation Authorities Act. Fill-line mapping is often conducted without floodplain mapping. Such is the case at the Saugeen Valley Conservation Authority which is presently involved in establishing fill-lines for its entire watershed.

On registration of a fill-line, development is controlled below that line. It holds the same power as a zoning by-law. Problems encountered with fill-line regulations are associated in halting the addition of fill and establishing the violation associated with such action. The statute of limitations in such cases is six months.

Ice Jamming: It is difficult to determine flood elevations on ice or log jams because of the variety of factors involved in each case. The location and probability of jams may be determined, given river conditions, but the extent of flooding would be difficult to assess.

OTONABEE REGION CONSERVATION AUTHORITY

Flood Risk Mapping: Yes

Method: Maps are developed based on engineered "Regional" storms centered over each watershed. The magnitude of the storm is derived from the largest storm that has occurred within the region.

Floodlines and flows are generated by using the computer models generated by HYMO and HEC-2. This method is dictated to the Authority by the Ontario Ministry of Natural Resources but has been subject to years of study and modification.

Maps: A 1:2000 scale is used.

Alternative Damage Reduction Measures: In areas not covered by flood risk maps, the Authority enforces its regulations. This is justifiable as the regulation is a permissive one and, as can be expected, is applied (i.e. no building or filling allowed) in the most obviously dangerous situations. In the case of large scale development, the Authority will often require the developer to flood risk map the developed area.

Court Cases: Problems involved in court cases include:

1. The municipality involved won't support the Authority;
2. Maximum fine is not a good deterrent (only $1,000 per offence);
3. As in most environmental legislation, judges will require iron clad proof of guilt before passing sentence; and
4. A court order to remove the problem structure/fill is difficult to obtain as costs will run easily into thousands of dollars.

Regulation: The Authority has never prosecuted an individual for violation of the Regulation. However, injunctions have been granted.

Because of the nature of the Regulation, the fact that the individual did not obtain a permit before proceeding, is sufficient for conviction.

In prosecuting, as much information as possible is obtained, i.e. condition of land, flood elevation, elevation of house and/or fill and projected effects of placement of house and/or fill.

Ice Jamming: Flood risk mapping already has a large number of assumptions. Unless jams of one sort or another occur quite frequently, it is not possible or economically feasible to produce maps showing the predicted flooding from such an event.

KETTLE CREEK CONSERVATION AUTHORITY

Floodplain Mapping: Yes. With regard to localized flood problems, the Authorities are embarking on a program to undertake such mapping, however, at the present time they have no such mapping.

Method: Floodlines are prepared on the premise of a Hazel Force Storm since the use of the 100 year storm forecast has proven to be inappropriate within the watersheds. Mapping is field checked and adjusted in areas when known flooding took place frequently, due to topography, hydrology or soils.

Court Cases: Primarily, the Authorities have had few problems in court as the majority of incidents have been solved prior to the initiation of legal action. However, several cases have been lost in rural areas, due to the lack of registration of policies. They anticipate that these problems will be solved upon registration.

Regulation: The Authorities develop and employ a floodplain mapping system with corresponding policies and provincial legislation. In addition, two watersheds have been mapped with Fill, Construction and Alteration to Waterways Regulations. Within the urban municipalities, these flood and fill line policies have achieved legal status by registration with the Province of Ontario. Within the rural areas, registration should take place this year.

The Fill, Construction and Alterations to Waterways

Regulations were established by registered professional engineers, based on the following criteria - slope stability, erosion, flooding, potential pollution, groundwater recharge, marsh and organic soils, natural habitat value and historical data. It should be noted that in all areas, the fill lines encompass all the floodplain areas, plus additional setbacks and safety margins.

Zoning: In terms of zoning regulations, the authorities, with close consultation with area planning boards, have designated many of these flood susceptible areas as hazard land within the area Official Plans, and subsequently, comprehensive zoning by-laws. Therefore, the majority of the lands are regulated either by approved official plans or registered authority policies which provide legal control to the Authority and the area municipalities.

In addition, they are now using a two zone concept to permit the use of various hazard land areas, but maintain a strict regulatory control on use and development.

CATARAQUI REGION CONSERVATION AUTHORITY

Flood Risk Mapping: The Authority commissions independent consultant engineers to undertake floodplain and high water-line mapping studies.

Method: Mapping is done on the basis of the 100 year design storm.

Alternative Damage Reduction Measures: In the event mapping is lacking, the Authority still has the authority to control placing or dumping of fill.

Court Cases: Mapping tolerance is an important factor. In one case a ground survey by an applicant revealed that the flood line location was not precise and his rezoning application was approved on this basis.

The most severe problem encountered was due to a misinterpretation of the intent of the Authority. A Commissioner's Order granting the formerly denied permit was authorized filling in a much more extensive area than was even applied for. It was only after significant legal dealings that the Order was squashed.

Ice Jamming: Flooding is occasionally aggravated by ice jams but they are not frequent enough or sever enough to warrant special mapping techniques.

CENTRAL LAKE ONTARIO CONSERVATION AUTHORITY

Flood Risk Mapping: Floodplain mapping has now been completed for all of the major watersheds, which generally includes a watershed or tributary to a watershed with a drainage area in excess of one half square mile.

Method: This Authority's floodplain mapping has been carried out by a number of consultants, who have employed various computer models and programs in computing floodlines. Generally, however, the HYMO and HEC-2 programs have been utilized to conduct flood routing and backwater analyses necessary to develop the floodplain mapping. Obviously, extensive field survey is required in preparation of the card decks fed into the various programs. Information derived is then applied to 1:2400 base contour mapping with 5-foot contour intervals based on 2½ foot contour interpolations. The criteria presently utilized by the C.L.O.C.A. for floodplain mapping is the regional storm, which is based on Hurricane Hazel that was centered over the Humber watershed in western Toronto. The type of mapping and mapping program undertaken by this Authority were based upon the criteria set down by the province of Ontario, and based upon the most advanced techniques in floodplain mapping available at the time.

Court Cases: In actual court cases when the Authority is enforcing its Fill, Construction, and Alteration to Waterways Regulation, which is supported by the detailed hydrologic and hydraulic information contained on the floodplain mapping, most

problems encountered have related to precedent. Obviously, where substantial development has occurred in areas subsequently identified as floodplain, there is difficulty in explaining to a development proponent with lands in such a floodplain area that existing criteria and policy dictate that he may not further encroach into an already developed floodplain. Obviously, the proponent would prefer the hazard flooding risk, which in many cases they don't perceive, rather than forego the potential economic gain. In a number of other cases where development proposals or violations have occurred on the extreme flood fringe areas i.e. where flood risk is lowest and where flood hazard is least perceived, explaining or enforcing the Authority's policies and criteria of floodplain management have been difficult.

Zoning: This Authority does not defend zoning, which is entirely a municipal responsibility. However, this Authority has circulated zoning by-law regulations or amendments to zoning by-laws for comment. Generally, the criteria utilized by the Authority is that no new development should be permitted within an area that is susceptible to flooding under regional storm conditions, and in the areas of new subdivision development, no portion of any lot which ultimately would fall into private ownership should extend into the regional storm floodplain. Because this Authority's floodplain mapping is accurate to 2 1/2 feet, a minimum of 90% of any test sample cases, the Authority generally has no difficulty in stipulating development or zoning limitations nor defending same. Any difficulties encountered previously in subdivision or zoning delineations of flood zones or floodlines have been a

result of discrepancies pointed out by other consultants in terms of the base contour mapping of their floodplain mapping.

Ice Jamming: There are situations where flooding was caused not only by normal rainfall-runoff situations, but also by culvert obstructions due to ice jams or debris collection and/or snowmelt. Because the mapping is based on a regional storm the magnitude of Hurricane Hazel, and no other factors such as snow accumulation, floodplain mapping based on factors other than the rainfall event have not been developed. Mapping is based on the assumption that culverts are not obstructed. Under flood advisory or flood warning situations, they dispatch Authority staff and municipal Public Works Department staff to areas which could become potentially dangerous should such accumulations of debris occur or where culvert construction for any reason could cause severe flooding hazard.

NOTTAWASAGA VALLEY CONSERVATION AUTHORITY

Flood Risk Mapping: The floodplain is based on the Timmins storm.

Maps: The Province of Ontario now insists that mapping be carried out on the basis of Geographical Referencing Standards, i.e., northerly oriented maps on the 6° UTM grid or multiples thereof, usually on scales of 1:2000, 5000 or 10,0000. The aerial photography mapping may be done as orthophoto (mostly for floodline mapping) scale-ratio rectified photo enlargements. Fairdrawn is also acceptable, although not recommended, due to lack of detail. In scales 1:2000 and 1:5000 1 meter contour intervals with 0.5 meters interpolations is recommended, and for very steep areas 2 meters and 1 meter interpolations. For scale 1:10,000 photo maps, 2 meters and 1 meter interpolation is recommended.

Regulations: A reference exists in the zoning by-law to the Conservation Authority's floodline mapping and the statement that e.g. "Hazard Land" zoning or "Open Space" zoning concurs with the floodline.

MAITLAND VALLEY CONSERVATION AUTHORITY

Flood Risk Mapping: Yes

Method: Presently Hurricane Hazel is used in determining floodplain areas of the watershed. Consideration is being given to use the 1 in 100 year storm event to allow development of a floodway and flood fringe zones within urban municipalities that have historically built adjacent to river floodplain areas.

Regulations: Because of the severity of Hurricane Hazel to floodplain zones, all municipalities have refused to agree to the registration of these maps. Without registration of these maps with the Province of Ontario, the Authority is reluctant to enforce floodplain mapping through the courts. The mapping is used for technical comments on things such as zoning changes, severances, and subdivisions.

In the Towns of Harriston and Listowel, they are presently persuing the two zone concept and developing special policy regulations which will apply to infilling of lots and redevelopment on already existing serviced land within the floodplain. The municipality has agreed to incorporate such concerns in their secondary plan and to require that any permits in this area must have Conservation Authority approval. Only through compromise has this approach worked and the process is not yet complete at present since many of the technical details must be hammered out with the Ministry of Natural Resources engineers.

Ice Jamming: In such areas, the municipality has requested the Authority to identify a special hazard line, indicating where ice jams have occurred in the past.

CREDIT VALLEY CONSERVATION AUTHORITY

Flood Risk Mapping: Yes

Method: Mapping is based on Hurricane Hazel. The Authority obtains the approval of the technical details, i.e., formulas, criteria, and data from the Ontario Ministry of Natural Resources who also undertakes the final approval of the consultant's computer results and mapping.

Maps: Orthophoto maps to a scale of 1:2400, with contour intervals of 0.5 feet and 2.5 feet.

Regulations: The Authority has a broad scope of powers in areas susceptible to flooding during a regional storm and, if any discrepancy occurs, then the applicant has the option of obtaining floodplain mapping which must be approved by the Ministry.

The regulations are irrespective of zoning, although they request the various municipalities to designate the areas below the floodline as "Open Space Conservation". It is not necessary that this be done in order to uphold the regulations.

Court Cases: Because of the way the "Conservation Authorities Act" and the Authority's "Ontario Regulation 211/73" are drawn up, the Authority has had no problem in regulating the development of the floodplain.

Ice Jamming: Present mapping does not attempt to incorporate ice jamming. The Authority is attempting to alleviate such problems through capital work projects.

GANARASKA REGION CONSERVATION AUTHORITY

Floodplain Mapping: Yes.

Method: Floodplain mapping is derived from criteria set out by the Provincial Government, that is flooding which would result under regional storm conditions. The "regional storm" means a storm producing in a forty-eight hour period, in a drainage area of, (i) ten square miles or less, a rainfall that has the distribution set out in Table 1, or (ii) more than ten square miles, a rainfall such that the number of inches of rain referred to in each case in Table 1 shall be modified by the percentage amount shown in Column 2 of Table 2 opposite the size of the drainage area set out opposite thereto in Column 1 of Table 2.

Table 1

2.90 inches of rain in the first 36 hours
0.25 inches of rain in the 37th hour
0.17 inches of rain in the 38th hour
0.25 inches of rain in the 39th hour
0.50 inches of rain in the 40th hour
0.66 inches of rain in the 41st hour
0.50 inches of rain in the 42nd hour
0.91 inches of rain in the 43rd hour
0.50 inches of rain in the 44th hour
0.50 inches of rain in the 45th hour
2.08 inches of rain in the 46th hour
1.49 inches of rain in the 47th hour
0.50 inches of rain in the 48th hour

Column 1 Drainage Area (square miles)	Column 2 Percentage
11 to 17 both inclusive	99.2
18 to 25 both inclusive	98.2
26 to 35 both inclusive	97.1
36 to 45 both inclusive	96.3
46 to 55 both inclusive	95.4
56 to 65 both inclusive	94.8
66 to 75 both inclusive	94.2
76 to 85 both inclusive	93.5
86 to 95 both inclusive	92.7
96 to 105 both inclusive	92.0
106 to 175 both inclusive	89.4
176 to 225 both inclusive	86.7
226 to 275 both inclusive	84.0
276 to 325 both inclusive	82.4
326 to 375 both inclusive	80.8
376 to 450 both inclusive	79.3
451 to 550 both inclusive	76.6
551 to 650 both inclusive	74.4
651 to 750 both inclusive	73.3
751 to 850 both inclusive	71.7
851 to 950 both inclusive	70.2
951 to 1050 both inclusive	69.0
1051 to 1750 both inclusive	64.4
1751 to 2250 both inclusive	61.4
2251 to 2750 both inclusive	58.9
2751 to 3000 both inclusive	57.4

Maps: Scale of 1:2400.

Court Cases: None.

Ice Jamming: The regional storm is so extensive that these areas are already covered in the mapping and therefore, regulated. However, in areas where development has already taken place on the flood susceptible lands, structural approaches are taken to mitigate the jam problems on an individual basis jointly by the Conservation Authority and the municipality.

HALTON REGION CONSERVATION AUTHORITY

Flood Risk Mapping: Yes

Method: Flood plain mapping is done for flood susceptible areas in the watershed where development is occurring, using a regional design criteria as for the Ganaraska Region. Various engineering methods for calculating the maps have been used over the years.

Maps: 1:2000 scale.

Alternative Damage Reduction Measures: While the Conservation Authority maps an engineered floodline wherever development pressures justify the expense, the rural areas are regulated with a fill regulation line. The fill line is mapped through aerial photo interpretation to a scale of 1:5000 and field checked for accuracy. These regulated lines protect headwater swamps, natural ravines and well defined watercourses.

Court Cases: They have not encountered any difficulties in court regarding engineered floodline maps. The mapping is undertaken by using professional consulting engineering firms and the individuals involved are often available to defend the maps in court. Some problems do arise however, if their position in court is based on a fill line which stems from aerial photo interpretation only. In these events, a detailed explanation as to the rational behind the line is necessary.

Ice Jamming: A backwater calculation is undertaken for each restriction in the floodplain, usually due to a bridge or culvert. These restrictions are invariably areas where ice jams or log jams are likely to occur. The backwater calculation which extends the floodplain mapping above the restriction is based on the type of restriction and not the additional backwater effect due to a log jam being created. They do not attempt to develop hypothetical lines based on the possibility of log jams in the river.

GRAND RIVER CONSERVATION AUTHORITY

Flood Risk Mapping: Yes

Method: The design storm used is as described for the Ganaraska Region Conservation Authority.

Maps: A 1:2400 scale is used with a contour interval of 5 feet and an auxiliary contour interval of 2.5 feet. Regional and maximum on record floodlines are shown.

Court Cases: They have found it helpful, but not essential, to have their Consulting Engineer responsible for calculating the floodlines present at court hearings. It depends upon the appellant's solicitor and what amount of engineering evidence he will accept, and what he wants proven.

The types of court cases encountered, are usually violations to the regulations dealing with buildings placed within the floodplain. They have been very successful in these cases, either getting a favourable decision, or at least, a favourable compromise. Compromises may take the form of physically elevating the first floor of the building above the Regional Storm Elevation, or blocking up basement windows, etc. The greatest problem they have run into is dealing with alterations of watercourses. A loophole exists in the Conservation Authorities Act, in which it gives the Authority the power to levy a fine only, not the power to have the offending works removed. They are attempting to have that section of the act amended.

Regulations: Yes. The policy of the Grand River Conservation Authority to achieve control is:

1. To co-operate fully with member municipalities and provide technical assistance, if required, so that the local Official Plans and Zoning By-laws will complement the fill regulations.

2. To establish restrictive and prohibitive zones in accordance with the Fill Regulations, floodplain mapping and other technical information available or to be acquired.

3. To process an application for permit within 30 days following the receipt of complete information.

4. To recognize that the greater public interest shall govern in conflicts between public and private interests.

Ice Jamming: Ice jam situations do occur, but since the resulting levels would be below the Regional Storm Floodline, no attempt is made at mapping.

Comments: The majority of permits granted, required a save-harmless agreement, whereby the applicant acknowledged the potential flood hazard and accepted responsibility for flood damages in the event of flooding.

Public information, education, and involvement, are considered important elements of the basin plan, and fundamental in its development and implementation.

NIAGARA PENINSULA CONSERVATION AUTHORITY

Floodplain Mapping: Yes

Method: The technical criteria used is the Regional Storm as described for the Ganaraska Region Conservation Authority.

Alternative Damage Reduction Measures: Recommendations and comments are provided on filling and construction near water-courses.

Court Cases: None

Regulations: Pending

Ice Jamming: Ice jams and debris blockages do occur, and partially account for high water levels every spring. The actual mapping does not take these items into account. The mapping created delineates a floodplain which has never been observed in this area in recorded history, thus the criteria are felt to be sufficiently stringent as they exist presently.

SOUTH NATION RIVER CONSERVATION AUTHORITY

Floodplain Mapping: Yes

Method: When streamflow records are of sufficient length, a frequency analysis utilizing the Gumbel distribution is used to obtain the 100-year floodline. If rainfall and/or snowfall are of longer period of record than are streamflow records, they can be related to runoff frequency by some synthetic hydrograph approach. Where a regional analysis is necessary, the SCS project formulation hydrologic computer program is used. Design flows are derived by calculating the instantaneous peak or maximum flow of the hydrographs as they are routed through the watershed.

Snowmelt is being calculated using

$$M = (0.029 + 0.0084KV + 0.007\ Pr)(Ta - 32) + 0.09$$

for partially forested areas and

$$M = (0.074 + 0.007\ Pr)(Ta - 32) + 0.05$$

for heavily forested areas where M is daily snowmelt (in./day), Pr is the total daily rainfall (in.) and Ta is the average daily temperature (^{o}F), K is a basin constant and V is wind speed (m.p.h.). By adjusting some of the parameters, the above equation may be made to estimate snowmelt for varying time increments.

HEC-2 is also used for obtaining surface profiles.

Maps: Maps to a scale of 1:2400 with a contour interval of 5 feet and machine interpolations to 2.5 feet are used. All work is tied into the 3^{o} Modified Transverse Mercator Grid System. Four vertical control points are used for each photogram-

metric model, and accuracy is double-checked by bridging. Spot elevations are used for bridge decks, dams, or road crossings of the river, on water surface in all pools and in the river at intervals not greater than 1000 feet.

Regulations: None

Special Situations: Water levels in the South Nation River below Plantagenet are controlled by the Carrillon Dam on the Ottawa River. They would floodplain map this area based on maximum regulated water levels. Having no control over the dam, they do not promulgate any regulations.

HAMILTON REGION CONSERVATION AUTHORITY

Floodplain Mapping: Yes

Method: Hurricane Hazel or the 1:100 year flood is used. Runoff quantities resulting from this rainfall are calculated with the model HYMO by the U.S. Agricultural Research Service of the U.S. Department of Agriculture. The backwater profile is developed using HEC-2.

Maps: Topographic maps with 1:2400 scale and 5 foot contour intervals.

Regulations: Yes.

MISSISSIPPI VALLEY CONSERVATION AUTHORITY

Flood Risk Mapping: Yes

Method: The 1:100 year flood is used for floodplain mapping. The criteria is set by the Ontario Ministry of Natural Resources.

Maps: Scaled such that individual lots and buildings can be shown, i.e. 1:2400. Floodlines based on regional storm and fill and construction limits are shown.

Regulations: Not yet in effect.

Ice Jamming: Ice jams do cause local flooding problems, but they do not prepare maps of these areas.

NORTH GRAY REGION CONSERVATION AUTHORITY AND SAUBLE VALLEY CONSERVATION AUTHORITY

Flood Risk Mapping: None

Alternative Damage Reduction Measures: Efforts in floodplain development control to date have been concentrated in liason with local and Provincial planning agencies in an attempt to ensure that adequate protection is provided in local official plans and zoning bylaws. The hazard areas defined in these documents usually reflect subjectively identified valley lands and historical flood prone areas.

The Authorities are given the opportunity by local and Provincial planning bodies to comment on a variety of development proposals. When a significant development proposal (i.e. subdivision) appears to be in an area subject to flooding, they will request that the Provincial Ministry of Housing require floodplain mapping by the developer to determine the flood risk. The Ministry usually acts upon these requests.

Court Cases: None. However, they have been involved in Ontario Municipal Board Hearings involving appeals against decisions of land division committees and planning boards denying development in flood prone areas. Success in these hearings usually depends on the evidence of historical trend in flooding. The flood risk or potential is impossible to justify without floodplain mapping. It is their experience, that until the floodplain mapping criteria are changed to something other than a regional storm (i.e. 1:100 year storm or two zone floodplain) flood risk mapping

and accompanying regulations will be difficult to implement.

Regulations: None.

RIDEAU VALLEY CONSERVATION AUTHORITY

Floodplain Mapping: Yes

Method: The 1:100 year storm was used for developing floodplain maps. The models used estimate floods on the basis of snowmelt and/or rainfall.

Maps: Orthophoto at 1:5000 scale with Floodplain Limit and Fill and Construction Limit shown. No contours given.

Court Cases: Although the development control regulations established on the basis of the floodplain mapping have not been tested in court, the Authority has had several administrative hearings based on the regulations and in all cases, the engineering report and techniques used to establish the mapping have been upheld in the tribunal. It has, however, been found necessary to establish the significance of the effect of a proposed development on the storage capacity of the floodplain; the cumulative or precedential effect on development; hazard to life and investment as well as the necessity of preserving the natural hydraulic character of the channel.

RAISIN REGION CONSERVATION AUTHORITY

Floodplain Mapping: Yes

Method: The floodplain mapping is based on the 1:100 year storm, to which may be added the possible effects of wave action from wind or navigation or both. These studies conform to the terms of reference which are approved by the Ontario Ministry of Natural Resources.

Alternative: Damage Reduction Methods without floodplain mapping, judgement and current knowledge of the area are used to justify the regulations.

Court Cases: None.

Zoning: None of the floodplain mapping has been incorporated into Municipal Zoning By-Laws.

Ice Jamming: Not considered in developing of maps. The approach has been to try to take measures that will prevent ice jamming, such as channelization and break up of jams.

CROWE VALLEY CONSERVATION AUTHORITY

Floodplain Mapping: In process

Method: A unique stiuation exists in that some of the area to be mapped was flown in the spring of 1976 when the Crowe experienced its 1:100 year flood. Photographing the area at this time not only made it easier in plotting but also introduced a high degree of accuracy in the floodlines themselves.

Regulations: There is no flood and fill regulations due to the minimal amount of mapping which has been performed so far.

Ice Jamming: None.

ESSEX REGION CONSERVATION AUTHORITY

Floodplain Mapping: Yes

Method: The floodway is calculated using the 1:100 year flood. Hurricane Hazel is used as a basis for the limits of the floodway fringe area where development may be permitted, subject to acceptable flood proofing. The mapping techniques of the Conservation Authorities Branch, Ministry of Natural Resources, are used.

Court Cases: None.

Regulations: Once final mapping is available, fill and construction regulations will be implemented.

Ice Jamming: This is an infrequent problem which has not been given specific consideration in developing floodplain maps. It is felt that present floodplain mapping, and associated restrictions would provide adequate protection in most cases.

Comment: Because of the very flat topography which is found in Essex County, the existing methodologies used to calculate floodlines are found to be grossly deficient in some regards, e.g. the computer calculations associated with hydrology aspects assumes limits to the study area. In fact, spills run from one watercouse to the next, and methodologies used to date have not allowed for same. This problem is now being resolved by the Conservation Authorities Branch.

NAPANEE REGION CONSERVATION AUTHORITY

Floodplain Mapping: Yes. Prepared by Crysler and Lathem Consulting.

Method: The Ontario Regional Storm or the 1 in 100 year design storm is used to derive the floodline on the flood risk maps. The terms of reference as defined by the Province are used. Computation of the floodline profiles was carried out using the HEC-2 surface profile program. The calculations are based on purely technical findings - channel and valley characteristics, slope, water surface assessment of bridge and culvert losses and the effects of dams and valley encroachments.

Regulations: Draft fill and construction regulations have been submitted for the Minister's approval. Presently, they provide a technical evaluation of the site based on an educational opinion. This opinion of course can be challenged.

Ice Jamming: Flooding at times is caused by ice jams and log jams. Present maps are conservative estimates and do not make provision for such cases. The Authority refers specific problems to the Chief Engineer of the Conservation Authority Branch, Ministry of Natural Resources, in Toronto.

Date Due
