SOME ASPECTS OF FLOOD HAZARD ASSESSMENT AND RESPONSE WITH PARTICULAR REFERENCE TO CUMBRIA.

by

GRAHAM A TOBIN.

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Abstract

There were two principal aims to this research : (i) to gain a better understanding of the authoritarian response to the flood hazard; (ii) to produce a predictive model of the residential response to the problem. Following an initial review of flood plain management techniques, three scales of spatial analysis were identified. 1. The National Level : A broad investigation was undertaken into flood plain management programmes in Britain. This survey illustrated the narrow authoritarian response in the past, and the recent move towards non-structural measures, particularly forecasting and warning schemes, and highlighted the need for a greater consideration of social factors in flood plain planning. 2. The Regional Level : Regional level studies examined various flood types, the severity of the hazard, and the response to the flood problem by the responsible organisations in the county of Cumbria. 3. The Local Level : Detailed local level surveys were carried out at Carlisle and Appleby to assess the significance of residential and commercial behaviour in affecting the extent of flood losses. An extensive questionnaire survey of residents and business-men was undertaken in the two research centres, to examine the behavioural aspects of the flood plain population in terms of perception and awareness of the flood hazard, the degree of fear associated with flooding, the awareness of authoritarian alleviation measures, and the perceived effectiveness of individual adjustments to the problem. The evidence indicated that the perceived hazard is more important than the actual hazard in determining the individual response to the flood problem. The final research model suggested certain significant social

characteristics which could be used to predict flood plain behaviour and thus reduce potential flood losses. This is critical to flood loss reduction programmes, especially with the trend towards non-structural alleviation schemes, since inefficient flood plain behaviour could significantly reduce the effectiveness of such programmes.

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Introduction

This work was developed to examine the problem of flooding with a view to reducing the losses accruing from such hazards. The study incorporated a full review of the physical characteristics of the flood hazard, as well as a detailed analysis of the human adjustments to the flood problem. Through these surveys, the research aimed to explain the precise causes of the failure of previous flood alleviation schemes, and to make practical proposals for improvements in future flood plain management policies.

These studies were considered necessary because of the scale of the flood problem throughout the world. The problem, it should be noted, has been created almost entirely by man's response to the natural environment, which has culminated in the high density of urbanisation on many flood plains. This research, therefore, focuses on the zone of interaction, between the physical parameters of the natural environment, and the social characteristics of the human use system. Kates (1970,3) summed up this aspect of natural hazards:

> "Natural hazard is an aspect of the interaction of man and nature, arising from the common process in which men seek in nature that which is useful and attempt to buffer that which is harmful to man. This process whether employing elaborate technical and social mechanisms or simple ones, makes possible human occupance of areas of even frequent and recurrent natural hazard."

The severity of the flood hazard was also critical to this study as far as flood losses were concerned, but again this aspect of flooding did not depend purely on the characteristics of the natural environmental system, but also incorporated facets of the human response system. For example, a flood with a return period of (say) ten years would cause considerably less economic disruption in a predominantly rural area, than a flood of similar magnitude in an urban area. A further factor of relevance to the severity of flooding is the relative adequacy of the human response system to the hazard. The same flood, for instance, could cause varying degrees of damage within the same urban area, depending on the effectiveness of any response to the flood hazard. It is suggested, therefore, that any assessment of flood severity should incorporate three principal studies : (i) a review of the physical parameters of flooding, (ii) an examination of the social characteristics of the flood plain, and (iii) an analysis of the human response to the flood hazard.

The necessity for further flood studies can be seen from figures of the extensive damages, and huge loss of life caused by the hazard in recent years. Dworkin (1974) has estimated the total loss of life from flooding in comparison with other natural hazards between 1947 and 1973 (see table 1). These data show the significance of flooding throughout the world, and particularly in Europe, where flooding represented the greatest single cause of death from any natural hazard during the study period. Burton and Kates (1964) also estimated the loss of life from flooding and other natural hazards, and related these to the extent of economic damage caused by the various events in the U.S.A. These figures

TABLE 1 (after Dworkin, 1974)

Loss of Life by Disaster Type 1947 - 1973

	Asia	Australasia	Europe	Africa	S. America	Caribbean & Central Amer.	North America
Floods	160617	60	11120	3377	3471	2355	1270
Typhoons, Hurricanes, Cyclone	453428	240	250	850		10792	1948
Earthquakes	47048		1839	14232	38350	7532	75
Tornadoes	3657		39	535		26	2224
Thunderstorms and Gales	20210		120		60	310	240
Snowstorms	6360	17	1340			200	1810
Heatwave	4155	100	340		135		925
Coldwave	1330		1440				600
Volcanoes	2630	4000			440	150	
Landslides	2816		300		912	260	
Rainstorm	1090		20		130		15
Avalanches	105		340		3840		
Tidal waves	3120						60
Fog			3550				
Sand & Dust Storms							10
Total	706566	4417	20698	18994	47338	21625	9177

were expressed in terms of mean annual losses (see table 2).

Losses accruing from flooding have been increasing over the years despite greater investments in flood alleviation schemes. Hanke (1972) and Porter (1970) have both examined this aspect of flooding and quote various figures to confirm these findings (see chapter one). Two factors would appear to have been the cause of these rising flood losses; first, the increasing development of flood plains has put more property at risk, and second, the generally poor flood plain management policies have led to poor project selection. There does not appear to have been a significant increase in the actual frequency of flooding, which could have caused the rise in flood losses. Thus, this research set out to examine the policies of flood plain management, with particular emphasis on the form of response to the hazard.

The aim of this study, therefore, was to improve the understanding of flood plain management techniques, through an examination of various aspects of the flood hazard, and thus reduce potential flood losses. The early data confirmed that a serious flood problem existed, and hence further research was essential to establish precisely why certain flood plain policies in the past had failed significantly to reduce losses. These findings could then be applied to future flood plain programmes so that similar mistakes would not be repeated. The first part of the research, therefore, was devoted to a review of the full range of alleviation schemes available to the flood plain planner. This survey discussed the general trends and policies of flood plain management over the years. The actual design and selection of flood alleviation schemes was also examined, to establish why

TABLE 2 (after Burton and Kates, 1964).

Estimates of average annual loss of life and property from selected hazards in the U.S.A.

Hazard	Mean annual loss of life	Mean annual property damage (millions of dollars)
Tuberculosis	11,456	-
Venereal disease	3,069	-
Lightning	600	100
Tornadoes	204.3	45
Hurricanes	84.8	100
Floods	83.4	350-1000
Weeds	-	4,000

the flood problem continued to be a major hazard despite the tremendous investment in alleviation schemes. This took the form of a series of feasibility tests, which were designed to assess the efficiency of flood alleviation schemes from various viewpoints.

Part two of the research incorporated the findings of the previous part, in a detailed examination of the flood problem in Britain. Examples of the adjustments to flooding were quoted from various parts of the country, while particular attention was devoted to the relatively new measure of flood forecasting and warning systems. This review of the flood problem in the British context was included to assess the trends in flood plain management, and to see where improvements could be made to the human response system.

It was on the basis of these initial studies that the more detailed analysis of the research was established. These early studies illustrated the lack of attention devoted to the social implications of flood plain management, which suggested that this could be one of the causes of the failures of past flood alleviation programmes. The evidence indicated that schemes were generally implemented without any consideration of the behavioural response of the local population, on the assumption that <u>all</u> alleviation schemes would promote favourable behaviour by those affected by flooding. This was the case apparently even for non-structural measures, which rely on a positive response by the flood plain population to have any effect at all on flood losses.

A review of the literature, relevant to the social aspects of flood plain management, confirmed firstly that very little research of this nature had been undertaken in this country, and secondly that further research was deemed necessary. Both the early research and these complementary studies indicated that the response and behaviour of the flood plain population was an important aspect of flood plain management. Hence, the research was set up to study the behavioural aspects of flood plain residents and business-men in relation to both the physical characteristics of the flood problem, and to the authoritarian adjustments to the hazard.

The examination of the behavioural aspects of flood plain management was carried out through a general assessment of the flood hazard in Cumbria, followed by more detailed analyses of the problems at Carlisle and Appleby. These studies included a review of the flood problem in the research area, with particular attention to the two case studies of Carlisle and Appleby, as well as an evaluation of the authoritarian response to the hazard. These two studies were combined with a discussion of the morphological development of the research centres, Carlisle and Appleby, to establish any relationships between these three variables.

The final aspect considered in Carlisle and Appleby was the individual behavioural response to the flood hazard, which involved an examination of both the residential and commercial sectors of the two communities and their attitudes towards the flood problem. These behavioural studies were carried out to see how such factors could significantly effect the scale of losses accruing from flooding. Various facets of behaviour were examined including the perception and awareness of residents and business-men towards the flood hazard. Other characteristics of the flood plain population were studied in an attempt to model the important factors which influence individual decision-making on the flood plain. It was hoped that from these studies, certain findings would emerge that would be applicable to other flood plain areas, and that this knowledge would contribute to improved flood plain management, and hence a reduction in future flood losses.

Therefore, this research is divided into three principal parts. Part I examines the flood problem and the range of adjustments available to control or reduce the effect of the hazard. This review was also employed to establish where the major failings lay in previous flood plain management programmes. Part II considers the flood problem in the British context, and particularly the trend towards flood forecasting and warning schemes in the country. Finally, part III examines the complete relationship of the natural hazard system and the human response system, especially in relation to the behavioural aspects and social implications of flood plain management. These more detailed analyses were carried out in the research area of Cumbria, and the two research centres of Carlisle and Appleby.

PART I

THE FLOOD PROBLEM

CHAPTER ONE

RESPONSE TO THE FLOOD HAZARD

Introduction:

The response to the flood hazard in the past has produced a variety of flood alleviation projects designed to reduce or eliminate flood losses. Unfortunately, recent statistics suggest that these schemes have failed in their objective. The mean annual losses accruing from flooding have continued to rise, despite the massive investments in schemes designed to control the flood problem and hence reduce losses. While accurate data are difficult to obtain, estimates by several workers tend to confirm this trend. For example, Burton and Kates (1964) estimated the annual flood losses in the U.S.A. to be between 350 and 1000 million dollars, while Goddard (1971) using data from the past 35 years, put mean losses at 1000 million dollars per year. During the same period Goddard calculated that 8000 million dollars had been spent on flood alleviation projects. Hanke (1972) suggested that expenditure on flood alleviation by the Army Corps of Engineers and the Soil Conservation Service in the last 30 years had amounted to 7000 million dollars. He added that annual expenditure now amounted to 500 million dollars and was still rising, whereas the losses accruing from flooding had also risen to 1000 million dollars, which was twice as much as reported losses in 1936, when the Flood Control Act was passed. Similar figures were produced by Porter (1970) who estimated mean flood losses of 700 million dollars in 1938 rising to a projected 760 million dollars in 1980, during which time 11,500 million dollars will have been spent on flood alleviation schemes. All researchers, therefore, tend to agree that flood losses have continued to mount during a period of high investment in flood alleviation in the U.S.A.

In Great Britain the situation would appear to be similar. Porter (1970) estimated the mean annual flood losses for England and Wales to be about £10 million, with up to £6 million spent on alleviation in any one year. Based on the census data for 1961, this indicates a per capita loss of 0.83 dollars in England and Wales compared to 0.218 dollars in the U.S.A. (Porter 1970). In some ways, therefore, the British situation is worse than the American, although both countries appear to have serious problems regarding flood plain management programmes.

According to Holmes (1961), the somewhat paradoxical situation, where flood losses have increased in spite of great investment in alleviation schemes, has occurred because.

(i) changes in price levels

(ii) improvement in the accuracy and coverage of data losses.

(iii) increases in the occupancy of flood plains

(iv) changes in the flood frequency and magnitude of flooding.

All four factors would appear to have some relevance to particular flood plain situations. For instance, changes in price levels could give the appearance of greater flood losses, where in real terms none existed, although this does not appear to be a major contributory factor in the present situation. On the other hand, there have been improvements in accuracy and coverage of data on flood losses, which Hanke (1972) suggested could account for ten to fifteen percent of the real increase in losses. However flood loss data is still far from satisfactory. An increase in the occupancy of flood plains is probably one of the most significant causes of the general rise in flood losses. This movement has gradually aggravated the flood problem by placing more and more property in flood prone areas. Burton et al (1968) estimated that there were over 2000 towns and cities in the U.S.A. situated on flood plains, 200 of which had populations of over 1000. In Canada there were over 1000 towns located in flood prone areas, which gives an impression of the scale of the problem in North America alone.

The fourth factor advocated by Holmes has been less well studied, although evidence would suggest that flood magnitude if not flood frequency, could have increased during the last 30 years. For example, the large scale construction of houses and other buildings on the flood plains would undoubtedly raise flood levels, in what Hanke (1972) termed the 'bath tub' effect. Similarly, urbanisation has been shown to increase flood levels and the frequency of smaller floods, due primarily to the large impermeable areas and efficient secondary drainage systems of urban settlements. (Hollis 1974, Espey et al 1969, Kadoya 1973, Maniak 1973). Nevertheless, there is little evidence to suggest that flood frequency has increased because of changes in climatic characteristics.

The evidence suggests that there are two major factors contributing to the general increase in flood losses. Firstly, that increasing pressure on land has brought about further urban expansion into flood risk areas, and thus exposed more people and property to flooding. Secondly, the response to the flood hazard has been less effective than initially anticipated, and this has been revealed by improvements in data collection. These two aspects of flood plain management would appear to be the prime causes of the present situation, and hence are examined in greater detail to discover the underlying reasons for the failures in the past.

Encroachment onto the flood plain has been recognised as a problem in flood alleviation for many years. For example the U.S. Congress Senate in 1966 stated

> "Next to the irregularities of flood damages, the most obvious fact is the upward trend. The latter can be calculated as about 5½% annually; this contrasts with the upward trend in total population of somewhat less than 2% annually. Thus the upward trend in flood damages is somewhat greater than is due to increased population and increased economic activity. It reflects the tendency to move onto the flood plains."
>
> (from Porter 1970, 175).

Clearly, the U.S. Senate, even in 1966, was aware that flood losses were rising faster than could be accounted for by population increases, and attributed this phenomenon to movement onto the flood plains. While in the past flat land, such as flood plains, were essential for communication and building, this is no longer a strict requirement. However, as Burton (1970) pointed out, urbanisation of flood plains has actually increased and the incidence of flooding has had little deterent effect on further settlement. The flood problem, therefore, exists because man has encroached into flood prone areas.

The only way to eliminate the flood problem completely is to evacuate the flood plains, and allow the land to revert to its previous state. Naturally, this is neither desirable nor economically viable, particularly in densely populated areas, and thus man must adjust to the problem of a flood plain location, by minimizing the risk of flooding. This then incorporates the second factor, that of an effective response to the flood problem. Despite so-called detailed investigations into the relative advantages of various flood alleviation schemes, primarily on the basis of weighing the benefits of a scheme against the costs, the selected projects have seldom reduced losses to the extent proposed during the planning stages. Thus, it would appear that a review of the decision making criteria is long overdue, to see why such policies have failed to attain anticipated levels of safety.

In the past, the basic approach to project selection has been benefit-cost analysis, which, quite clearly has failed to reflect the real benefit and costs accruing from proposed alleviation schemes with any degree of accuracy. It would appear that certain relevant and apparently most significant data have been omitted from these calculations, and this has led to grossly inadequate flood plain policies.

Recent work on flood plain management (for example White

1964, 1965, 1970; Kates 1970; Penning-Rowsell and Parker 1973, 1974) has suggested that the most noticeable omission from previous decision making policies was the social dimension of the proposed projects. While the physical properties of flooding, and the economic aspects of implementing flood alleviation schemes have invariably undergone quite rigorous analyses by experts, generally it has been assumed that the social implications of any project would be insignificant as far as the efficiency of that scheme was concerned. The basis of this assumption lay in the thesis that flood plain inhabitants would all respond rationally to minimise flood losses. Unfortunately, this is probably not the case, since preliminary work by White and Kates has shown that individuals perceive the flood hazard in different ways, and subsequently will behave in different ways. In this way flood plain behaviour patterns may be an extremely important consideration in decision-making criteria, since a socially unacceptable scheme could adversely affect the benefit cost ratio of a particular alleviation project.

In conclusion, the situation exists now where further research is essential if flood losses are to be successfully reduced in the future. Consideration must be given not only to the generally accepted criteria of decision-making, but also to the social implications of different schemes, if economic and social disruption are to be avoided. This chapter, therefore, reviews the range of adjustments open to the flood plain managers to alleviate flood problems, and assesses the relative advantages and disadvantages of each project. The past and current trends in flood alleviation projects are also discussed while the second part of the chapter examines the role of the decision makers and the various feasibility studies necessary prior to project selection. Chapter two completes part one of the thesis with a brief discussion of recent research into flood plain management.

Response to the flood hazard

The implementation of a flood alleviation scheme is the result of various pressures on the flood plain managers to respond to the flood hazard and to achieve one or more preconceived goals. It is these goals or aims that should help determine which alleviation programme is finally selected since these should be the raison d'etre of the project. Kates and White (1961) in this respect, saw four basic aims:

(i) to reduce flooding,

(ii) to reduce damages,

(iii) to save lives,

(iv) to save property.

A particular scheme may well include all four of these aims, for an alleviation scheme that reduces flood peaks will also reduce damage, save property, and possibly save lives. On the other hand, a small scale scheme, such as one protecting an individual building, will only have a limited effect, and for the rest of the flood plain achieve none of the goals.

A similar proposal on the aims of flood response was suggested by Horner (1955), although he stressed the dynamic nature of flood plain planning and the importance of actually improving flood plain lands and not just offering protection.

> "The term flood control is a misnomer.
> Man does not really control floods.
> He attempts rather to prevent the over
> flow of certain portions of the flood
> plains with two objectives in mind
> (i) Alleviating damage to existing
> property, that is, preventing the
> reduction of existing values (ii)
> Enhancing the usefulness of flood
> plain lands, that is, increasing
> their value."
>
> (from Kazmann 1972, 258).

The aims of response to the flood hazard will vary between areas, but in general they will follow those outlined by Horner, Kates and White.

<u>Range of flood alleviation schemes</u>

In order to achieve the desired aim(s) as outlined above, the flood plain planner must select and implement a flood alleviation policy, which will include one or more of a variety of flood alleviation schemes. The range of schemes available has not changed for many years (White 1965) with the same types of schemes available now as in 1930. However, the relative importance of each scheme has altered, and the more limited selection policies of the past are gradually giving way to wider considerations of overall flood plain management.

Several authors have classified the various flood alleviation schemes according to different criteria, although basically they all retain the same general range. For example, compare the lists suggested by White (1965) and Sewell (1969).

White	Sewell
Land elevation.	Accept losses.
Flood abatement.	Public relief.
Flood control.	Flood proofing.
Emergency action.	Structural changes.
Structural changes to buildings.	Emergency action.
Land use changes.	Regulation of land use.
Public relief.	Insurance.
Insurance.	Control - land phase channel phase.

A more comprehensive classification was proposed by the Tennessee Valley Authority and later advocated by Relph (1968). This classification divides the alternatives into four categories based on the perceived action or effect of each. For instance:

(i) Compensatory Measures

(a) Flood relief.

(b) Flood insurance.

(ii) Corrective Measures (A)

(a) Flood forecasting.

(b) Emergency action.

(c) Structural alterations.

(iii) Corrective Measures (B)

(a) Flood control.

(b) Flood abatement.

(iv) Preventive Measures

(a) Flood plain development and regulation.

In this classification, compensatory measures include those schemes which rely on the recoupment of losses after the flood event. Corrective measures aim to control the flooding and are subdivided into 'A' temporary, and 'B' permanent measures. Preventive measures involve the reduction of flood losses by altering human activity rather than the physical forces of flooding.

Other classifications have been advocated in the past, based on various criteria. For example, Leopold and Maddock (1954) divided schemes into administrative, engineering and land control, while other classifications could be based on the scale of the adjustment or even on the permanency or temporary nature of the project. However, for the purposes of this study the range of adjustments is classified according to the structural/non-structural nature of the schemes. The latter may also be termed behavioural, since they require some form of response from the individual flood plain inhabitant. This classification has been adopted because it is symptomatic of the changes which have taken place in flood alleviation programmes during recent years. There has been a gradual trend away from the large scale structural measures of the 1930's, when the answer to flooding in the U.S.A. was essentially a large storage reservoir, to smaller more complex alleviation strategies. These later schemes have frequently involved more than one flood alleviation scheme, and are increasingly incorporating non-structural measures, such as flood warning schemes and insurance policies. While these non-structural adjustments are still not fully accepted as viable alternatives to structural measures, they do reflect the more dynamic outlook to flood alleviation which is currently developing according to White (1965).

The reasons for this change in emphasis away from structural and towards non-structural measures is threefold. First, the failure of old structural adjustments to effectively reduce flood losses has brought about a reappraisal of flood plain policies and a search for 'new' adjustments. Second, the expense of these large scale structural projects is frequently a prohibitive factor, whereas non-structural measures are relatively cheap to set up and run. Finally, the vast improvements in technology in recent years has greatly improved the efficiency and reliability of certain non-structural measures, in particular flood forecasting and warning schemes, which has made non-structural measures viable alternatives to the structural adjustments.

Structural and non-structural measures range from extremes of large scale structural schemes to the non-structural response of loss bearing. Structural schemes primarily concern engineering works which vary in scale from localised river training schemes to large scale construction of dams and reservoirs. Other structural measures include flood abatement policies and permanent flood proofing techniques. Non-structural measures range from loss bearing and public relief funds to policies of weather modification, flood insurance and flood plain zoning. All these schemes are described and analysed below in terms of their relative advantages and disadvantages, beginning first with the structural schemes and followed by non-structural measures.

Structural flood alleviation schemes

In the past, flood problems were invariably alleviated by the implementation of large scale structural measures designed to control the physical characteristics of the hazard. This policy was followed to such an extent, particularly in the U.S.A. during the 1930's, that structural measures became a synonym for flood alleviation. The range of adjustments open to the flood plain planner, therefore, tended to be restricted to those schemes, such as dams and levee systems, which restrict or confine flood waters to certain areas.

Complete control of a flood is impractical since without tremendous over investment, it is virtually impossible to provide one hundred percent protection from flooding. Instead, structural measures may alter the frequency and magnitude of flood events, but they will not eliminate the hazard completely. The protection offered by structural measures is normally incorporated into the design and planning stages of the project. For example, a levee system may protect an urban area from the one in fifty year flood, while a large dam and reservoir may well provide protection up to the one in two hundred year flood. (Details of flood frequencies and protection levels are described in Appendix I). Naturally, if a flood of greater magnitude than the design standards of the project is encountered, then either the system will be overtopped or will fail completely, and hence flooding will result. This predicament of limited control was aptly summed up by Horner in Kazmann (1972, 259).

> "Flood control is an unfortunate, designation from still another stand point. Floods are not controlled in the sense they are rendered harmless. Nor are they controlled in the sense that they are eliminated except in some instances immediately below very large and costly storage reservoirs. Generally flood control works are designed to confine the flood waters to a certain part of the valley bottom by such means as levees, and to store enough of the flood water to reduce rates of flow, and thus provide a reasonable degree of protection to certain parts of the flood plain."

Structural measures include three types of scheme; (i) engineering schemes which range from very large to quite small localised projects, and which aim to control the flooding (ii) abatement policies which attempt to control floods during the upland catchment phase; (iii) flood proofing which offers protection to individual buildings.

(i) Engineering schemes

Engineering schemes to alleviate flood problems can be divided into two basic types depending on the scale of the project. Small scale adjustments are essentially concerned with very localised flood problems, while the very large scale features may offer flood protection to extremely large areas.

Small scale engineering works are basically river training measures rather than flood alleviation schemes, although they may often be incorporated as part of a larger, more complex project. The aim of these small adjustments is to control the river on a very local level, since the effects of such measures downstream may be minimal. These adjustments include such works as 'willow piling', 'Fascines', 'stone training works','gabions steel mesh boxes' and groynes, all of which aim to prevent local bank erosion (Nixon 1966).

Large scale structural measures are more widely known as flood alleviation schemes, of which there are basically six different types. Each of these is reviewed in turn below, and illustrated in several figures after Nixon (1966).

a) Embankments and levees:

Flood embankments and levee systems are designed as a flood control measure, to restrict water to well defined limits on the flood plain, and hence, by the construction of artificial banks reduce the spatial extent of inundation (figure 1-1 and 1-2). This adjustment allows controlled flooding of certain areas and provides relative safety for those areas outside the flood bank system. However, as with all structural measures, levees do not eliminate completely the probability of flooding, since protection is limited to the design standards of the project.

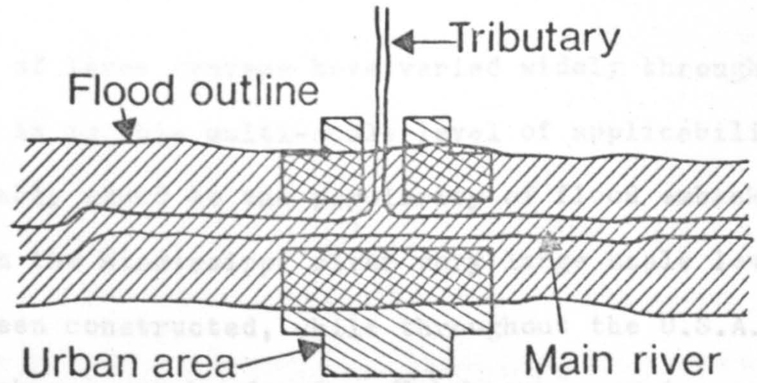


Fig. 1-1

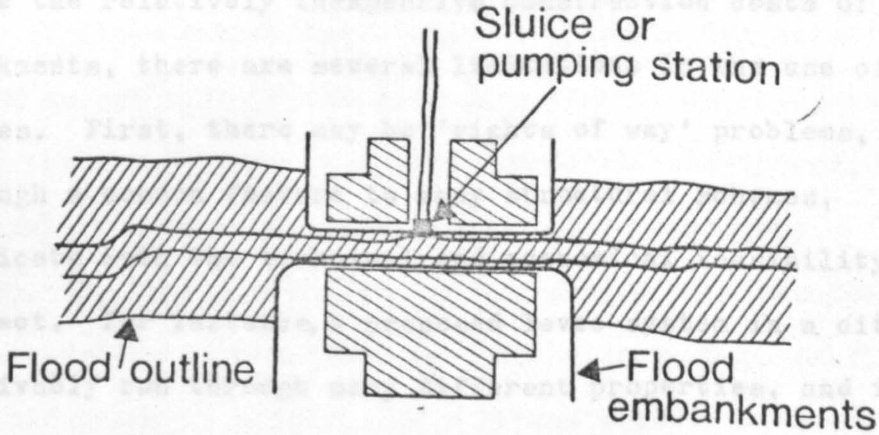


Fig. 1-2

Fig. 1-1. The flood problem (after Nixon, 1966).

Fig. 1-2. Solution: embankments and levees (after Nixon, 1966).

Nevertheless, the relative cheapness of these schemes and the lack of design problems have made this measure very popular as a means of controlling flooding. Given that the structure can cope with the smaller floods, then genuine protection may be offered up to the design standards of the project.

The scale of levee systems have varied widely throughout the world, and it is this multi-scale level of applicability which has probably added to the popularity of flood embankments. For example, on the Mississippi river very large scale levee systems have been constructed, while throughout the U.S.A. similar such schemes may be found. Ericksen (1971) estimated that in 20 years, 1600 miles of embankments had been erected in New Zealand, while in Britain flood embankments can be found on all scales throughout the country. These may range from the larger schemes designed to protect the lower lying parts of cities, such as Nottingham, to the smaller features protecting fields and agricultural land.

Despite the relatively inexpensive construction costs of flood embankments, there are several limitations in the use of such measures. First, there may be 'rights of way' problems, which although a common feature to many structural schemes, could complicate both the technical and economical feasibility of the project. For instance, a proposed levee system in a city would conceivably run through many different properties, and it would probably require considerable legal discussion of the rights of way of various owners before the scheme could be implemented. A second problem involves the technical aspects of project design and the degree of protection offered. To a certain extent this may be determined by the feasibility studies (see below) but still there remains the additional problem of exactly where to construct the structure. The careful surveying of the flood plain would undoubtedly help, but the general lack of hydological data may make calculations of the design standards somewhat suspect. Following the construction of the embankment system, the problem emerges of what to do with the land still prone to flooding. Ideally, this land should be devoted to uses not seriously affected by flooding, such as car parks and recreational facilities, although in many urban centres this is not always possible. Finally, flood banks, particularly if made of a soft material such as earth, should be regularly maintained to preserve the design standard of protection.

The problems associated with flood embankments and levees, discussed briefly above, all relate to the economic and physical restrictions of implementing such measures. However, the effect of these structures on the attitudes of the flood plain inhabitants is probably of even greater significance. The construction of flood embankments tends to generate the belief that the land on one side of the structure represents absolute safety, where the flood hazard has been completely eliminated, while the other side represents an area of flood certainty. In this sense, the design standards of the project are overlooked and the flood problem is perceived as a clear issue between flood prone areas and areas of safety. This 'levee effect' frequently causes a reduction in land values inside the embankments, and a corresponding rise in values in the supposedly safe areas outside, which promotes a general decline in the former areas, and encourages development in the latter areas. If this occurs then more property may be put at risk to major flooding than prior to the construction of the embankments. In this way, the emphasis of flood losses in the community may well change from small flood events causing small scale damage, to less frequent but large scale losses from catastrophic flooding, which because of the development in 'safe' areas could produce larger mean annual flood losses than previously occurred without the embankments. Thus the implementation of a flood embankment system, with no further restrictions on flood plain development, may aggravate the problem, since the subsequent movement of people may nullify any anticipated advantages of the alleviation scheme. Yevjevich (1973) aptly described this levee effect and suggested that similar developments would occur with other structural measures.

> "The result is an accreration in investments in flood plains for many advanced activities of industrialised societies. The substantial decrease of flood risk in protected areas is counteracted by a huge economic risk and loss of human life in the case of floods exceeding even the new high level of protection. This type of flood control represents a significant decrease in both the number and frequency of (damaging) floods. Floods become rare, but catastrophic events with extensive damage in the case of a flood. Practically a frequent random process with smaller economic risk is transformed de facto into a random process of rare occurrence, but with tremendous economic risk."
>
> (Yevjevich 1973, 372)

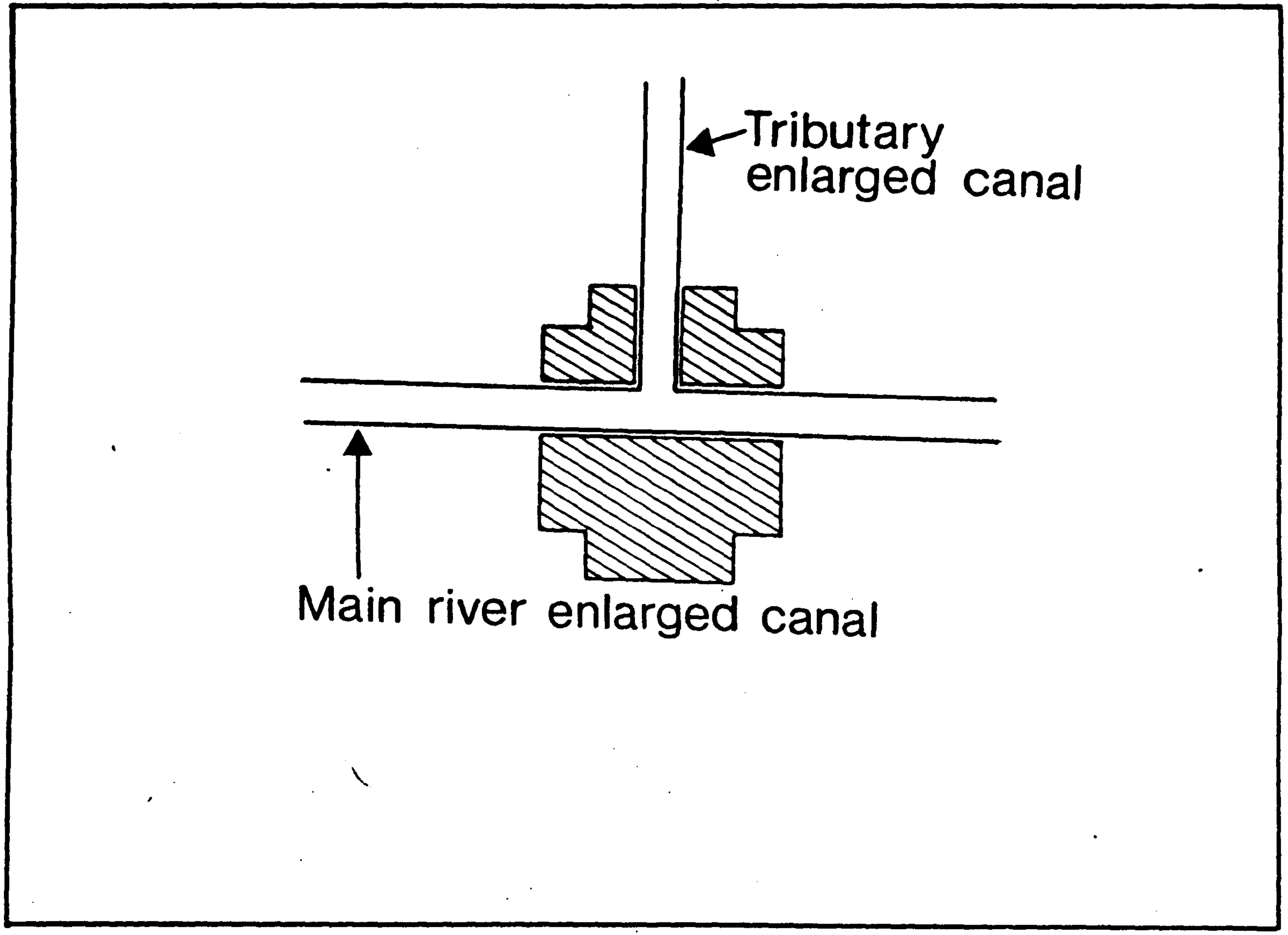
Embankment and levee systems, therefore, while they are both relatively cheap and easy to construct, do have certain drawbacks, not least that the planned effects of the scheme may be completely nullified.

b) Channel enlargements:

The second structural alleviation scheme, channel enlargements, is designed to control flooding, by confining the excess water to the channel system. The principle of this response is to increase the carrying capacity of the stream by enlarging the channel cross-sectional area through the area to be protected, so that flood flows remain within the channel system. (Figure 1-3). This adjustment, like the flood embankments, is comparatively cheap compared to the majority of large structural measures, and is particularly valuable in areas of fairly intensive urban development where there may be a premium on land.

However, as with the other structural schemes, there are also some drawbacks to this measure. Like the levee system, the channel enlargements may actively encourage development on the flood plain, by creating the same false sense of security from flooding, well above the design capabilities of the structure. This could also lead to an increase in flood losses rather than the reduction anticipated at the outset of the scheme. A second problem is one of maintaining the full effectiveness of the project since such channels are frequently prone to silting. When a channel is enlarged, the undersized stream will tend to deposit sediment on the channel floor, and thus progressively minimise the effectiveness of the scheme by reducing the original

Fig. 1-3. Solution: channel enlargements (after Nixon, 1966).



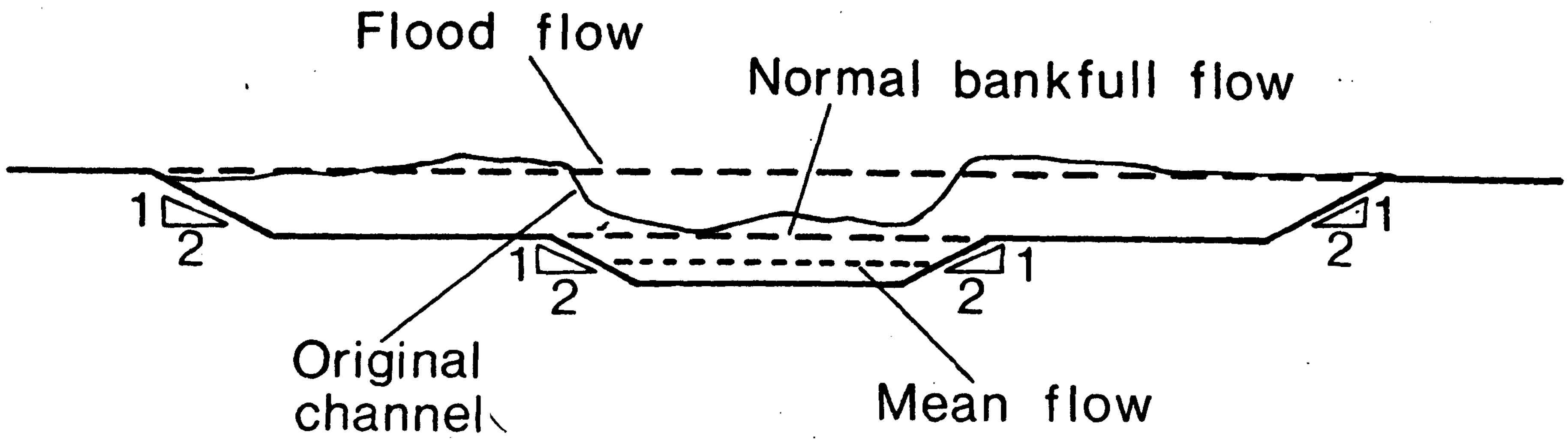
design standards of the project. Unless there is regular dredging of these structures to counteract this process, the scheme will eventually have little effect on any high river floods. To solve this problem, the engineers derived a system of compound channels to cope with differing extremes of flows (figure 1-4 as described by Butler, 1972). In these compound channels, flows up to the normal or original bank-full stage are confined to a small cross-sectional area, and hence the system is essentially self maintaining in that little sediment will be deposited, because the area corresponds to the natural channel dimensions. To accommodate flows in excess of this, but only up to the design standard limits, a further much larger area is maintained. Examples of these structures are now fairly commonplace, for instance in Britain the River Cole at Chelmsey Wood on the Tame at Birmingham.

One further disadvantage of channel enlargements is the effects on the timing of the river, and hence the subsequent effect on communities downstream of the scheme. Channel enlargements, for instance, in increasing the carrying capacity of the river will at the same time reduce the roughness of the stream (for definitions see Appendix I). As a result, flood flows are no longer retained in the system, but will be transmitted rapidly downstream where other communities may suffer more frequent or more devastating flooding than before.

C) <u>Flood relief channels:</u>

This scheme works on the principle of controlling flood flows by the use of a series of channels, in addition to the

Fig. 1-4. The design of a compound channel (after Butler, 1972).



natural channel, to prevent the inundation of surrounding areas. (figure 1-5). The objective of the scheme is to reduce flood levels by confining and storing the flood water to prepared channels. The main advantage of this policy is that the natural channel is not altered in any way that could be detrimental to the community, while the construction of the relief channels is relatively cheap, particularly if there are no serious problems over land-ownership. This particular adjustment is most valuable in flat lowland areas, where there would be widespread inundation and difficult drainage problems without a channelised system of alleviation. However, it may not always be possible to protect very large settlements in this way. Nevertheless, there are many examples of settlements being protected by flood relief channels, such as Houston in Texas, Spalding on the River Welland or Walthamstow on the River Lea. Goddard (1971) commented on the use of flood relief channels in the U.S.A. and estimated that 17,600 acres of land in the Tennessee Valley Authority area alone were protected by such a policy.

The disadvantages of flood relief channels are much the same as for levee systems and channel enlargements, although in this case there is no problem of silting in the main channel, because daily flows are preserved. However, relief channels can also generate a belief in complete safety from flooding and hence also encourage further flood plain development, while at the same time, by changing the timing of the river, settlements downstream may suffer accordingly. One further problem encountered with relief channels, but not with the previous structural measures, was one of water management. For instance, a comprehensive knowledge of the hydrological characteristics of the river is required to know exactly when to open sluice gates and bring the relief channels into operation. This may be further complicated by land-use in these flood channels. For instance, relief channels are frequently leased out at low rents to farmers who use them for grazing pastures, and hence any planned flooding will require some warning so that livestock may be evacuated.

d) Intercepting or Cut-off channels:

Intercepting or cut-off channels are very similar in both construction and objectives to flood relief channels, except that all, or most of the permanent river flow is diverted into the artificial channels, while the natural channel is used only during more extreme flood events (figure 1-6). The advantages and disadvantages of this scheme are very similar to those of relief channels, although a further criticism made concerns the interference with the natural channel. An example of this technique can be found at Ely on the Great Ouse.

e) Flood storage reservoirs

The construction of dams and reservoirs as a means of managing water resources has been employed for a very long time. Some of the earliest examples date from the third century B.C., the 'tank' reservoirs of Sri Lanka, while larger structures have been found in North Africa following the Roman occupation, and Byzantine structures from the sixth century. Smith N. (1971) quoted further examples in South America, the Aztecs in the

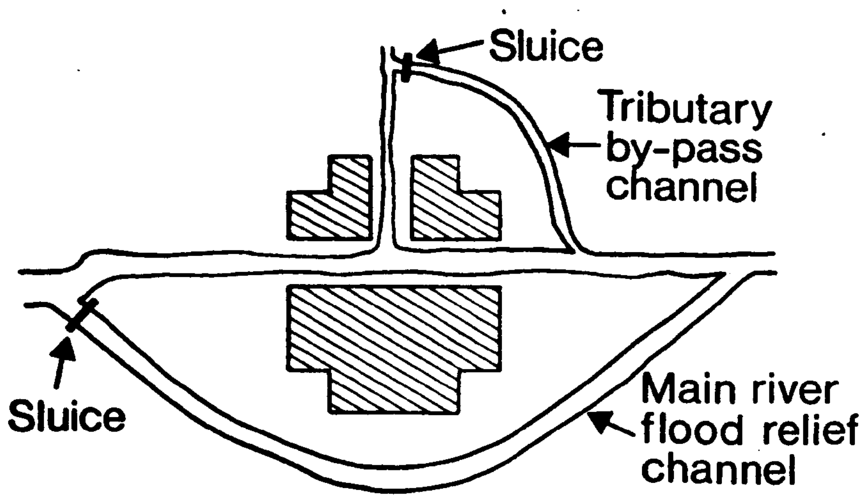


Fig. 1-5

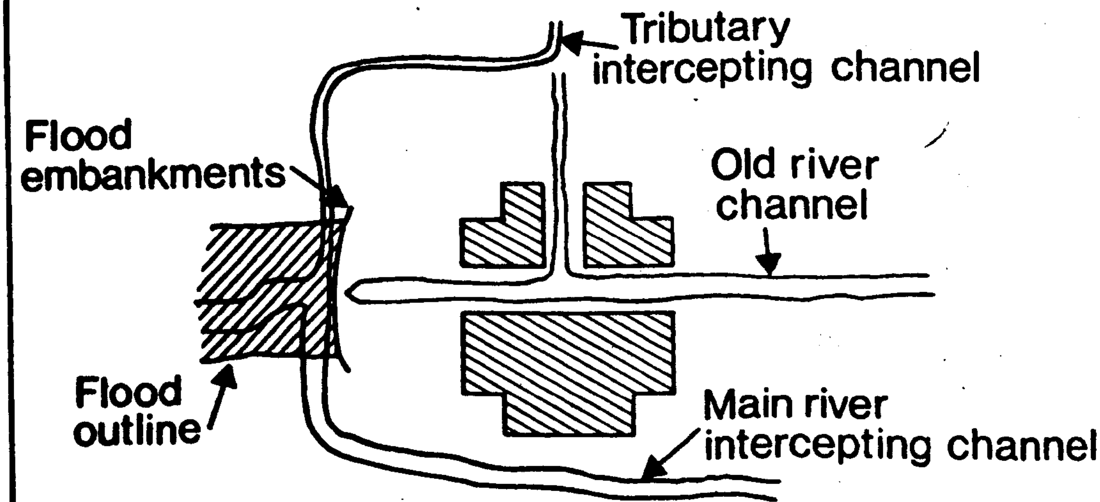


Fig. 1-6

Fig. 1-5. Solution: flood relief channels (after Nixon, 1966).

Fig. 1-6. Solution: intercepting channels and cut off channels (after Nixon, 1966).

fifteenth century and a scheme for Mexico City in the seventeenth. At the same time in Europe, Leonardo da Vinci is said to have suggested similar structures for the protection of Florence. However, the first recorded dam and reservoir system purely for flood control in Europe was probably that at Pinay on the Loire in France, constructed during the early part of the eighteenth century (Hoyt and Langbein 1955). A later example was the Ternay reservoir (1868) which provided a degree of flood protection for Arnoway also in France (Smith N. 1971). Hoyt and Langbein suggested that the first flood storage reservoir in the U.S.A. was initiated by the Miami Conservancy District following the disastrous flood in 1913. There are now numerous examples of flood storage reservoirs throughout the world, particularly in the U.S.A. where the 1930's saw tremendous investment in large scale dams and reservoirs. The Miami Conservancy constructed several dams for this purpose. In Britain, no dams have been constructed purely for flood control, which Nixon (1966) attributed to two factors; the expensive nature of such projects, and the lack of suitable reservoir sites in the right places.

Flood storage reservoirs work on the principle of flood control. Excess water is stored in the upper reaches of the catchment, and then by careful regulation of the hydrological system, the water is gradually released after the threat of flooding has passed (figure 1-7). The advantages of this adjustment are quite considerable in comparison with other flood alleviation schemes. For example, the flood plain inhabitant has complete security from riverine floods up to the design standards of the structure, while the downstream environment will remain virtually unchanged. The structure will also have a relatively long life span and provide many years of security. However, there are also several major disadvantages of such a flood policy. To begin with there is the problem of finance, since the implementation of a dam is quite expensive, and the benefits to be gained from flood protection may not warrant such a major undertaking. (Details of benefit - cost analysis are given in the second part of this chapter). A second financial problem concerns who should pay for such a structure, the Central Government, Local Authorities or the direct beneficiaries of the project? Since these schemes are usually so expensive, the financial backing is usually provided by a combination of various responsible bodies.

Once a reservoir has been constructed there may well be further problems encountered. The reservoir, for instance, like the levee system, is designed to control flooding only up to certain design limits, and yet frequently the popular belief perceives a complete elimination of the flood risk. If this relief generates additional investment in flood plain then more property may be at risk after the implementation of the scheme than before. A flood, above the design capabilities of the dam could cause even greater damage.

Another problem with dam structures is one of silt accumulation. The very nature of dams and reservoirs in interrupting the flow of the natural stream means that they are particularly prone to silting, which can significantly reduce the effectiveness of the dam in alleviating floods. Kazmann (1972) pointed out that up to an eighth of the storage assigned to flood control in some American reservoirs had been lost in the last fifty years. As an example he quoted the Elephant-Butte Dam which had lost ten percent of its reservoir area and sixteen percent of its storage capacity in the twenty years up to 1957 Kazmann further stressed the ever decreasing protection offered by such structures. (1972, 261.)

> "It is, thus entirely possible that even if floods are completely controlled on a given date by existing construction only a few years later damaging floods will become increasingly probable. Ultimately, instead of protection from the 200 year flood, the protection afforded will be against the 50 year flood, and the protection shortly thereafter will be reduced still more."

A further problem of flood storage reservoirs concerns the operation of the scheme in relation to water management. In order to operate the scheme successfully, there must be careful administration of the reservoir to ensure that water levels are drawn down sufficiently to cope with the next major storm event. Failure to do this could result in too much water passing through the control system and hence inundating an unsuspecting population on the flood plain downstream. Water resource management, therefore, is an essential part of storage reservoir programmes.

The technical problems of water resource management are even greater if the reservoir has been designed for more than one purpose. For instance, a flood control reservoir may incorporate

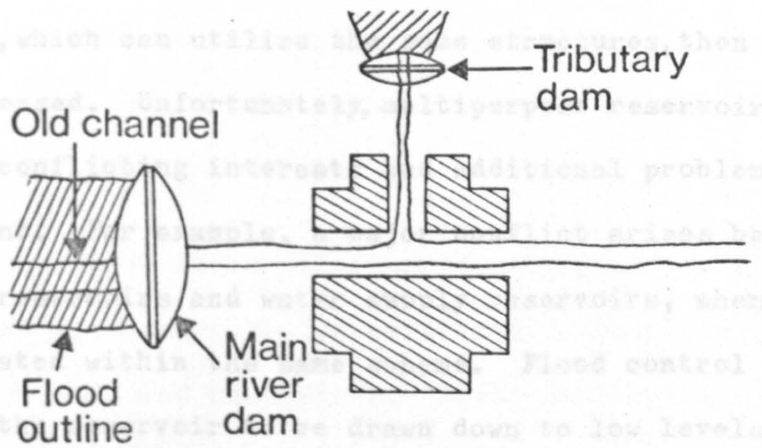


Fig. 1-7

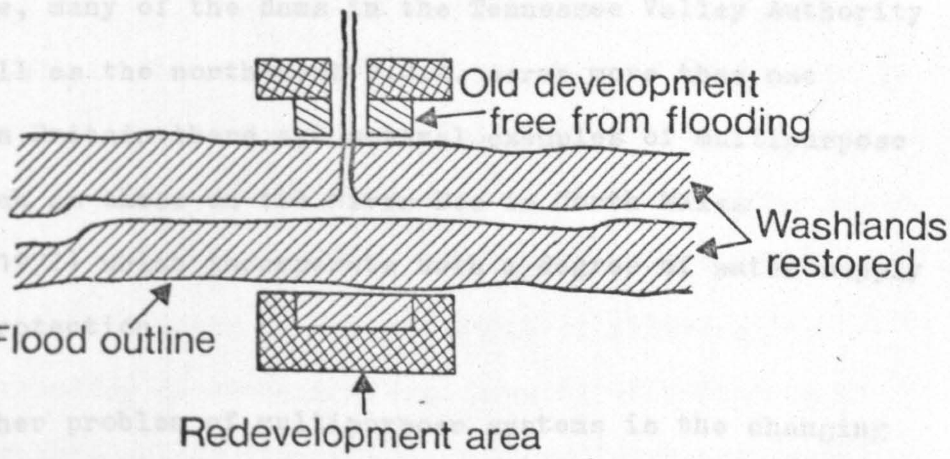


Fig. 1-8

Fig. 1-7. Solution: reservoirs for flood storage (after Nixon, 1966).
Fig. 1-8. Solution: washlands and zoning (after Nixon, 1966).

some degree of water supply or a component of power generation. These multipurpose systems have developed primarily for economic reasons, because the benefits accruing from the construction of a dam for one aspect were frequently insufficient to warrant investment in the scheme. In combination with other management policies, which can utilise the same structures, then the benefits are increased. Unfortunately, multipurpose reservoirs tend to promote conflicting interests and additional problems of water management. For example, a major conflict arises between flood control reservoirs and water supply reservoirs, when both are incorporated within the same scheme. Flood control policies require the reservoir to be drawn down to low levels at all times, while water supply requires the direct opposite, maintaining the water level at full or near full capacity. Nevertheless, despite such conflicting interests many multipurpose dams and reservoirs have been constructed, incorporating such widely different projects as flood control, water supply, power generation, irrigation facilities and recreational schemes. For instance, many of the dams in the Tennessee Valley Authority area, as well as the north-west U.S.A. serve more than one purpose. In Britain there are several examples of multipurpose projects such as those on the River Dee in North Wales (Jamieson, 1972) which incorporate both a degree of water supply and flood protection.

A further problem of multipurpose systems is the changing emphasis given to different aspects of the project. For example, following a series of dry years the water supply component of a structure may be increased at the expense of flood control. A change in policy such as this would automatically reduce the level of protection to downstream settlements. Cossins (1969) described just such an event as this on the Somerset Dam in Queensland, where the original forty percent storage capacity was increased to well over fifty percent, at the expense of flood control, because of a series of dry years. While this policy does allow a more dynamic approach to water management, these changes should only occur following detailed studies of any long term climatic trends.

An unplanned flood alleviation programme may also come about inadvertently through the construction of water supply or power generation dams and reservoirs. These structures will bring some control to the river flows by altering the timing of the river, and the smaller variations between different flows will be reduced. Laurenson (1973) in this respect stated that the smaller more frequent floods will be reduced particularly in the vicinity immediately below the dam structure.

f) <u>Washland schemes</u>:

The washland scheme is essentially a form of water storage that reduces the spatial extent of flooding by retaining water in controlled areas, while the flood is at its peak. The scheme incorporates a combination of the levee system and storage reservoir, since it works on the principle of allowing the controlled flooding of certain areas, usually delimited by levee structures, and holding water in those 'washland' until the flood peak subsides (figure 1-8). This system is quite successful, particularly for smaller floods, if water management is carried out efficiently. For example the washland scheme above Doncaster (Map 3-2) has been successfully utilized on a number of occasions (private communication with Yorkshire River Authority 1974).

There are some associated problems with washland areas as a means of flood alleviation. For instance, the scheme requires large areas of flat land for storage areas, and although these may be rented out to local farmers, there can be very little guaranteed economic return from them. Secondly, washland schemes require careful river management if the maximum security is to be obtained from the scheme, and river flows kept below bank-full stage.

(ii) Flood Abatement schemes:

The second group of structural adjustments to the flood hazard may be classified as flood abatement schemes, and do not require large scale engineering projects as described above. Flood abatement is an alleviation measure designed to control floods during the land phase of the hydrological system. The principle of the abatement policies is to reduce flood peaks downstream, by a series of land use changes upstream, so that the volume of run off and the timing of the flood hydrograph is altered. This is usually achieved by implementing land use changes which retard the flow of water from the land to channel phase. Suggested changes normally include afforestation, which will not only retard water movement, but through evapotranspiration 'lose' more water to the atmosphere.

Not all workers are in complete agreement on flood abatement policies, particularly regarding the relative effectiveness of the scheme. Crawford (1969) for example, suggested that any changes in land use would have to be very large scale to have any significant effect on the hydrological system, whereas Matson et al (1955) believed that forestry could effectively reduce run-off. Molchanov (1960/63) agreed that forestry would alter stream hydrographs and reduce run-off, although he questioned the effectiveness of such measures in different geological and climatological conditions. Other workers have made studies of the effects of forestry on run-off, and although most agreed that forestry would change the flood hydrograph, they questioned the relative effectiveness of abatement as a flood alleviation policy (Fleming, 1973, Law, 1957, Worley and Patric, 1971). In fact, as a flood alleviation policy, there are very few examples of flood abatement, which may explain why so much controversy surrounds the scheme. Hoyt and Langbein (1955) described the case of White Hollow in the Tennessee Valley Authority area, where during a twelve year period of active afforestation (1935-47) the flood hydrograph was altered to the extent that flood peaks were reduced by eighty-five percent and lag time increased from one and a half hours to eight hours. However, they found no significant difference in the volume of total run-off. In conclusion, it would appear that flood abatement could be an effective method of alleviating flood losses, but to do so would require large tracts of land and hence would not be a feasible proposition in all catchments. Similarly, if Molchanov is correct the measure may prove more effective in some environments than others.

(iii) Flood Proofing Measures:

Flood proofing measures are neither entirely structural nor non-structural schemes, and have only recently been accepted as a viable alternative to the more conventional flood alleviation schemes. Flood proofing consists of those adjustments to structures and the contents of buildings, which are designed or adapted to reduce flood damage. These measures can be either permanent or temporary, but both must prevent flood waters entering property and allow the easy evacuation of goods.

Temporary measures include the blocking-up of seldom used entrances to buildings; the stocking of heavy shields for doors and windows, to be placed in position prior to a flood, heavy sliding doors to protect other entrances, and low water proofed walls to protect other areas. Further adjustments may include such schemes as the greasing and covering of mechanical equipment prior to a flood, or the use of flood prone areas for storage of non-damageable goods. Although this list is virtually endless, the effectiveness of these measures relies entirely on the individual house owner or factory manager being aware of the flood hazard, and in his receiving a flood warning so that such schemes can be implemented.

Permanent flood proofing measures include more structural alterations, such as the raising of buildings above the flood level, the permanent use of lower storeys for car parks, or the inclusion of pumping facilities in basements. Sheaffer (1967) even suggested in some circumstances the intentional flooding of basements by clean water. In this way, structural damage to the building is prevented by the equalisation of pressures inside and out, and the basement does not suffer deposits of sediment. Permanent flood proofing measures can be quite effective in reducing flood losses and are relatively cheap to implement. They also permit the building to continue functioning throughout the flood, which may be particularly important to residential properties. Flood proofing also provides protection from all types of flooding which,unlike some structural measures,may confine protection to the main river channel. Relph (1968) calculated the potential efficiency of flood proofing measures to be as high as eighty percent in ideal conditions and even thirty percent of losses in less ideal conditions. Jones (1971a, 1971b) also stressed the importance of flood proofing measures even where the probability of flooding was quite remote.

However, there are several disadvantages of flood proofing measures as a means of reducing flood losses. To begin with, different conditions can significantly alter the effectiveness of certain measures. For example, flood proofing tends to be less effective in high, fast flowing floods of long duration than in small, slower moving floods of short duration (Sheaffer 1967). From this, Burton (1970) listed six criteria leading to ideal flood proofing conditions. These were where:

(a) flood stage is fairly low and velocities not very high,

(b) dams and dykes are not really feasible,

(c) group action is not really possible and strong individual action can be encouraged,

(d) groups shun government action and advice,

(e) activities requiring sites need protection,

and

(f) resource managers feel greater protection is required,

Apart from these conditions there are additional drawbacks to such adjustments. For instance, such policies require the individual flood plain managers to be aware of the flood risk and to take the initiative of implementing flood alleviation measures. While this could be actively encouraged by the local authorities, the policy could result in very few protected properties on the flood plain. These problems of flood awareness and personal initiative are major considerations and are discussed in great detail in subsequent chapters of this study.

Examples of flood proofing are fairly widespread particularly in the U.S.A., although there has been no general policy towards this alleviation adjustment. Sheaffer (1967) cited many cases, such as, the Pittsburgh Press Building, the Manker Tennis Centre in Chattanooga and the Dixie Square Shopping Centre in Harvey, Illinois. Ericksen (1967, 1971) in New Zealand quoted the case of houses located in a former river channel at Opotiki being raised by over one metre. In Britain, however, evidence of flood proofing is limited although Relph (1968) and Butler (1972) quoted several examples. However the picture is still confused in Britain with flood proofing still regarded as a levee type system. For example Butler (1972, 318) stated,

> "Where channel improvements are not possible, or are uneconomic, flood proofing may be a practical alternative. This usually consists of earth flood-banks or hard defences such as concrete and sheet steel piled walls."

Shell House in London is probably the only major property protected in this way in Britain. Porter (1970) estimated that each emergency operation to prepare for floods cost £750.

In conclusion, structural schemes, apart from flood proofing, all endeavour to change the magnitude and frequency of flood events, by the control of excess water, and hence in this way reduce flood losses. They are, for the most part, all fairly expensive measures, although they are quite reliable up to the design standards of the project. There are of course many disadvantages with these schemes, the most significant being the so-called 'Levee effect', which tends to result in increased investment in flood prone areas.

Non-structural flood alleviation schemes:

The non-structural range of adjustments to the flood hazard is less well known than the structural measures, although in recent years some of these measures have become more acceptable. This situation has arisen for a variety of reasons, such as technological improvements which have made certain schemes more efficient, for example, flood warning systems. Probably one of the prime reasons for this general trend towards non-structural measures, is the inhibiting cost of implementing large scale structural alleviation schemes. Kollmorgen (1953) was an early proponent of such policies, suggesting that larger structural projects were too expensive and tended to utilise more land for the actual scheme, than area protected downstream. Added to this, the failure of structural measures to effectively reduce flood losses encouraged flood plain planners to consider alternative techniques.

Non-structural measures are essentially behavioural adjustments, which rely on some form of preplanned action by flood plain residents and business men prior to a flood. While some of these measures amount to little more than a negative attitude to the flood hazard, others require sophisticated responses in order to reduce flood losses. Six types of behavioural adjustments are described below.

i) Loss bearing

Loss bearing or accepting the losses accruing from flooding as an occupational hazard is probably the most negative of all responses to flooding. No attempt is made by the person(s) at risk to adjust to the hazard, except to replace lost or damaged goods following a flood event. This response could well be economically acceptable in benefit-cost terms, in comparison with other expensive measures of alleviating flood losses. However, this attitude is generally socially unacceptable, because the majority of people or business men have little choice on site location and hence may have no opportunity to move away from the hazard. Thus, this adjustment is found most frequently in rural areas where other flood alleviation schemes would be difficult to justify.

(ii) Public relief funds

Public relief, if relied on as a means of alleviating flood losses, is merely an extension of the loss-bearing attitudes described above. In this case those people in flood prone areas may come to expect, as a right, both financial aid, and other types of support, following a flood, and, as a result, may do very little to prevent future flood losses. Nevertheless, following most floods, relief funds are set up by the local authorities in the affected area. Two major funds in Britain were the Lynmouth Flood Disaster Fund 1952, and the East Coast Fund of 1953.

Relief funds can play a valuable role in flood plain planning and, naturally, are particularly beneficial to those members of the community who could not afford to replace damaged property. Also, an advantage of this adjustment is that money collected is normally proportional to the scale of the disaster. For example, small local flood events will attract aid from the immediate vicinity, whereas a major catastrophe will generate financial support on a national or even international level. Unfortunately, relief funds, rarely succeed in collecting enough money to compensate all flood losses, unless the Central Government adds a further contribution to the fund. Relph (1968) stated that the average recoupment from a public fund can be as low as four percent of actual losses, and only twenty-six percent at a maximum. However, these figures could be improved significantly by a permanent National Flood Relief Fund (or even a general Natural Hazard Fund) which would collect contributions at any time, and invest the money until required. To date this has not been considered a very popular measure by successive Governments.

Flood relief funds are generally highly inefficient and extremely unreliable methods of alleviating flood losses. The collection of money from the same area as the flooding usually means that the region is no better off than before, although the redistribution of wealth does help the actual flood victims. White (1966) saw relief as a source of increased flood losses rather than a reasonable alleviation policy.

> "Even if full information were available to all owners of flood plain property. There would still be conscious decisions to build in areas where protection has not been feasible, for the private owner may not perceive the hazard in the same way as the hydrologist and he does not expect to bear

> all the costs of his use of the hazardous property. Moreover, the chief encouragement he now receives under Federal programme is the prospect of relief or future Federal protection."

Flood relief funds may generate a poor response to the flood hazard, but on humanitarian grounds they would appear to be necessary, given that no national system exists for compensation.

(iii) Flood insurance:

This response to the flood hazard does not reduce flood losses, nor does it have any effect on the flood characteristics; instead flood insurance allows the payment of flood losses to be made over a period of years, rather than all at one time. Because of these apparent limitations, the Tennesse Valley Authority in classifying alleviation schemes placed flood insurance in the compensatory division. However, flood insurance policies allow the flood plain inhabitant to pay an annual premium against the possibility of flooding in that year.

In the past flooding was considered a high risk event, and hence uninsurable by most insurance companies, because of the apparent random nature of the event. However, recent improvements in flood prediction techniques have made flood insurance a feasible form of flood alleviation. As a result, flood insurance premiums can accurately reflect the potential damage, if assessed according to the degree of risk for that particular area. In reality, premium rates may have to be a little higher to cover administrative costs, but even this minor problem could be overcome by Government support to the insurance companies.

In Great Britain flood insurance has been available since the 1920's (Doublet, 1966) although it is only since 1960 that policies have become readily available. Unfortunately, most premiums are still not assessed according to the degree of risk and most companies are content to employ two basic rates dependent on whether or not an area has been flooded in the past. However, flood insurance is now quite widely used in this country (see chapter three for further details). Porter (1970) estimated that over fifty percent of flood losses in 1968, which amounted to between five and six million pounds were recouped through insurance.

In the U.S.A. flood insurance schemes did not really develop until the 1950's, and were not really effective until the National Flood Insurance Programme started in 1968. This plan provided relatively cheap premiums for flood plain residents for property values up to 35,000 dollars and possessions up to 10,000 dollars (Loughlin, 1971). By 1971 it was estimated by Goddard (1971) that over 100,000 policies had been purchased under the scheme. However, Baumann (1976) in a study of Texas flood plain communities, and Emmer (1976) in Oregon, gave the general impression that the national programme had not been very successful. Baumann also pointed out two important features of the insurance programme. First, the scheme aims to help flood victims to repair immediate flood damage, and second, to minimise future flood risk; the objective being to provide flood insurance cover where the companies are unwilling to quote rates. A similar such policy to the U.S.A. national programme exists in New Zealand, where insurance is obtainable through the Commission if no companies will offer cover (Ericksen, 1971).

Flood insurance may eventually prove to be an effective method of alleviating flood losses, provided some form of association between insurance premiums and flood risk can be established. Kunreuther and Sheaffer (1970) put forward several different methods for accurately determining basic insurance rates. A composite system was suggested, which included estimates of depth-damage relationships for property, computed flood frequencies from gauging station data, construction of area flood conditions, and the relationship of structures to flood conditions. However, in general, insurance companies do not relate the flood risk with the cost of premium (with any degree of accuracy).

In conclusion, flood insurance is still not developed to full potential, despite the relative success of the scheme in some areas. More improvements are required in rating the risk so that premiums accurately reflect the mean annual losses from flooding. Krutilla (1966) suggested compulsory flood insurance, since he believed this would produce a more realistic and efficient use of the flood plain. If premiums were proportional to the risk involved only economically viable concerns would theoretically remain in flood prone areas.

(iv) Flood plain zoning

Flood plain zoning works on the principle of reducing flood losses by controlling flood plain development, rather than altering the hydrological characteristics in any way. Theoretically, the ideal form of zoning is to evacuate the flood plain completely and return the land to its natural state. For most areas this would be a highly impractical solution, because of the tremendous costs involved and the social implications of moving large numbers of people. The American Corps of Engineers have shown that costs would generally outweigh benefits with such an evacuation policy, with the most expensive item being the provision of services at the new centre. (Hertzler, 1961). Liebman (1973) also mentioned the legal problems associated with such policies.

Instead of complete evacuation of flood prone areas, it has been suggested that flood plains should be divided into distinct zones, each restricted to well defined uses. Kates and White (1961) put forward a three zone, flood plain policy (figure 1-9).

(1) A prohibitive zone - where there should be no further development, although the present situation should be preserved.

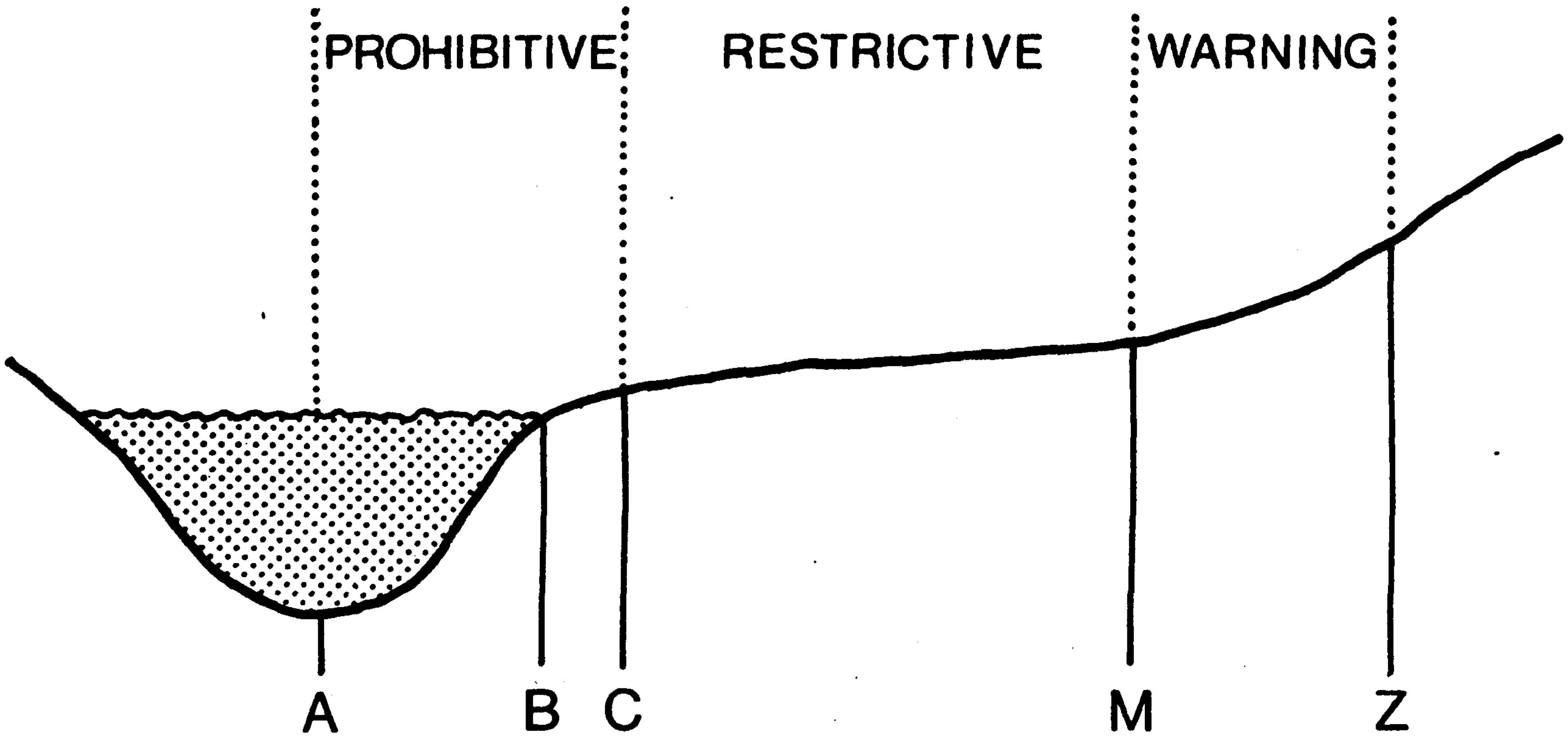
(2) A restrictive zone - where only certain essential development should be permitted.

(3) A warning zone - where the inhabitants should receive warning of impending floods and be regularly reminded of the flood hazard.

These zones were to be based on different areas of flood risk.

Fig. 1-9. Flood plain zoning policies (after Kates and White, 1961).

Suggested flood zones:
A - C Encroachment would be against the public interest.
C - M Restricted land use only.
M - Z Zone where property managers should receive flood warnings.



Other workers have suggested similar such divisions for a flood plain zoning policy. Wilkes (1973) for example, described eight lines, which could be used to control flood plain development, in his study of the Connecticut river basin. Whipple (1969) examined the role of zoning policies and general benefits derived from such a scheme. Because of this attention to zoning, several such schemes now operate in the U.S.A. notably Iowa City and Plymouth in Indiana. Sheaffer <u>et al</u> (1970) suggested a zoning policy based on mapping of flood data, but for the most part zoning has not been widely used in the U.S.A.

In Great Britain flood plain zoning has developed differently, because of the different legal and political systems operating in the country. With the more stringent planning regulations in this country, the basic structure for a flood plain zoning policy already exists. However, until fairly recently the planning laws had not been enforced for zoning policies, due to a lack of consideration of the flood hazard. Development of property onto flood plain lands, therefore, has continued virtually unchecked until quite recently, and there are examples of such development in nearly all British cities which are prone to flooding. Penning-Rowsell and Parker (1974) suggested that Planning Departments and River Authorities should work more closely together in future to prevent further expansion in flood hazard areas.

There are several disadvantages of a flood plain zoning policy, which could create greater problems than the flood hazard. First, there is a problem of accurately defining the different zones on the flood plain, since this could be critical to the efficiency of the system. Wolman (1971) suggested several techniques for flood plain mapping based on a variety of criteria, while Burgess (1970) and Popov and Gavrin (1970) proposed the usage of air-photographs. A second problem may result from the classification system. For example, a zone classified as 'high risk' could result in the zone becoming a depressed area in both economic and social terms. The stigma attached to such a classification may result in general deterioration of property, since buildings may not even be satisfactorily maintained. Stillwater, Oaklahoma, experienced this problem following the implementation of zoning ordinances after the flooding in 1963, and despite alterations of the ordinances, loans on property in certain areas were still very difficult to obtain (Trautman 1970). It was for this reason that Kates and White (1961) recommended the preservation of property in prohibitive zones.

Another problem with flood plain zoning is the effect on the behaviour of flood plain inhabitants. Like the levee system, zoning ordinances can create the impression of safety in areas outside the line demarking the prohibitive zone and hence encourage investment in these areas. Kates and White (1961, 139) took particular reference of this problem.

> "A line marking a flood plain on a map is a levee in reverse, barring channelwards expansion of human occupance. This line can encourage expansion into the defined area, by encouraging the inference among land users that it limits the area of

> safety. When such a line fails as surely it will, if it is anything short of the maximum possible flood, it, like the levee may be guilty of setting the scene for catastrophe."

Renshaw (1961) also suggested that the zones created by such a policy would be sensitive to any changes in the flood hazard. Lind (1967) could see no value in zoning policies at all, unless no other schemes were possible.

Flood plain zoning, therefore, would appear to have many advantages and disadvantages as a means of alleviating the flood hazard. However, in attempting to control man and the development of the flood plain, rather than restricting the forces of flood water, the policy is approaching the flood problem in a more realistic manner. In the long term, such policies may lead to the most efficient use of the flood plain with zones similar to those outlined by Kates and White. Until then it is hoped that further expansion in flood prone areas will be severly curtailed. Situations, such as that quoted by Porter (1970) should not arise under any circumstances. Letter from the Tennessee State Planning Commission to the house owner:

> "They have checked your building and advised us that in order to be reasonably safe, the floor should have been one foot higher and the building should not have been so close to the river. Of course your building is well underway, but we did want you to be aware of the problem."
>
> (Porter 1970, 72)

(v) Flood forecasting and warning schemes

Flood forecasting and warning schemes work on the principle of reducing flood losses by encouraging remedial action by flood plain residents and business men prior to a flood. The scheme consists of three separate subsystems, each one an integral part of the overall system, all of which must operate smoothly and efficiently to have a significant effect on flood losses. Mileti and Krane (1973) in a general consideration of all hazard warning systems called these (a) evaluation, (b) dissemination and (c) response.

(a) Evaluation:

The first stage in flood warning systems, evaluation, involves the comprehension of hydrological and meteorological processes so that a warning message may be formulated. Naturally, this requires a full understanding of the behaviour of catchment characteristics to a given input, so that accurate forecasts can be made of the time of arrival of the flood, the depth of the flood at its peak, as well as other characteristics such as duration of flooding or velocity of flows. Flood forecasts, with this basic knowledge, are based either on the effect of given input of precipitation on the river regime, or on the relationship of river levels throughout the hydrological system. The latter method, flood routing generally, provides the more accurate warnings, because relationships are more easily established between river flows, rather than between precipitation and flows. However, precipitation based schemes can provide much earlier warnings, which in areas of highly responsive streams, may be the only way of giving several hours flood warning. Flood routing techniques in large catchment areas can provide accurate forecasts several weeks in advance. Rodda (1970) quoted the case of Operation Foresight in 1969 on the Mississippi River, when an estimated 350 million dollars worth of potential damage was reduced to 100 million dollars, due to remedial action during three weeks of flood warnings.

(b) Dissemination:

Dissemination of the warning message, the second stage in flood forecasting and warning systems, has received less attention in the past than the preceeding stage, and as a result, many schemes have been less effective than anticipated. Obviously, an efficient method of spreading a flood warning amongst all flood plain residents and business men is essential if time for effective remedial action is to be allowed. However, warning dissemination is usually confined to police touring the flood prone areas with loud hailers, and more recently broadcasting warnings on local radio stations.

(c) Response:

The final subsystem, response to the warning message has been totally ignored in the past on the assumption that flood plain inhabitants would react in a rational manner to reduce flood losses. Evidence from various studies (Kates, 1962, White, 1964, James, 1974) suggest this assumption is unjustified, and that people will respond to various preconceived ideas. Details of this aspect of flood warning systems are given in the second part of this chapter, and later followed by more general research into the aspects of perception and behaviour.

Flood forecasting schemes have developed over the years to become fairly reliable and sophisticated mechanisms, whereby the response of a river to a given input can be quite accurately predicted. However, to begin with, flood forecasting was very much a hit or miss affair, with warnings dependent either on local knowledge of the hydrological conditions, or on the personal decisions of a man living in the upper reaches of the catchment riding down the valley to warn others of the impending disaster. With the development of the telegraph, flood forecasting was immediately transformed into a more efficient system, since warning messages could be transmitted further in advance of the approaching flood, thus lengthening warning times. As a result, several official warning schemes were developed in the second half of the nineteenth century. In 1854, for example, such a scheme provided three days warning of flooding in the Seine, while by 1866 similar projects were operating in Italy and Bohemia, and by 1871 in the U.S.A. (Hoyt and Langbein, 1955).

Flood forecasting and warning systems continued to develop from that time, helped by improvements in communication systems such as the telephone and radio, and by advances in data collection equipment. Rain and river level gauges became more sophisticated instruments, which could record data for long periods, and thus by providing information from relatively inaccessible places, improved the understanding of the hydrological system. In Britain, it was not until the mid 1960's following serious flooding during this period, that the most significant advances were made in flood forecasting techniques.

The innovation of the telemetry gauge (rainfall and river level) transformed flood forecasting into a highly sophisticated flood alleviation measure, which was relatively cheap to install and quite reliable. These gauges could be installed at the upper ends of catchmentsand regularly supply details of the hydrological or meteorological conditions to headquarters.

A more recent advance in flood forecasting occurred with the implementation of self-operating flood warning gauges. These were an extension of telemetry gauges that could actively instigate a flood warning if any of the preset conditions are reached. This project has tremendous advantages over other systems, since it can operate 24 hours a day for 7 days a week, and will issue a flood alert immediately there is any danger. Computers have now been adapted for this scheme, so that large volumes of data can be analysed quickly and efficiently, and thus adding to the effectiveness of the scheme.

Many workers have considered different aspects of flood forecasting schemes and tried to improve the efficiency of such measures. Kohler (1969) and Appolov et al (1964) examined the general problems of flood forecasting, while Body and Rainbird (1964) and Davidson and Hargreaves (1966) discussed the merits of unit hydrograph techniques in the flood routing approach to forecasting. Aitken (1973) looked at several rainfall runoff models used in forecasting and found all to have certain systematic errors. Johnson (1975) and Johnson and Archer (1972) stressed the particular problems of snow, and in assessing the water content of snow fields, in relation to flood flows. Away from the standard river level or rainfall relationships of estimating flooding, several other authors have suggested different techniques. For example, several workers have tried to establish a relationship between synoptic conditions, heavy rainfall and flooding. Beran and Sutcliffe (1972) have tried to develop a flood producing rainfall index based on rainfall and soil moisture deficits. Cordery (1970), Lowndes (1968, 1969) have also looked at this problem of heavy rainfall and flood levels, while Holgate (1973) has already been involved in issuing warnings of heavy rainfall to the River Authorities. Others have looked at synoptic weather types as a means of predicting heavy rainfall, including Goodhew (1970), Matthews (1972) and Nicholass and Harrold (1975). Most authors agreed, however, that such techniques are acceptable for large areas, but there are many inaccuracies for smaller basins, which at present prevent their use in flood forecasting schemes. Benwell (1967) and Ratcliffe(1974) considered the use of the 500 mb jet stream as a predictor of heavy rain, but again the accuracy of this for forecasting flooding was doubtful.

The use of satellites to improve flood forecasting techniques has also been considered. Rainbird (1969), Body (1969) and Painter (1973) E.S.S.A. (1968, 1970) all suggested that satellites could be a valuable asset to flood forecasting, both as a means of collecting and assessing data, and as a means of transmitting such information to the flood prone areas. However, the general concensus suggested that this would only be feasible for larger sized basins, which presented major problems of data collection and transmission.

Probably the most significant advance in the future for flood forecasting and warning schemes will be in the field of radar. Extensive experiments are now being carried out in Britain by the Water Resources Board, the Meteorological Office and Plessey Radar Ltd. into the use of a radar network for the measurement and quantitative forecasting of precipitation. (Water Resources Board 1973, 1974). If this scheme is successful then accurate areal rainfall measurements may prove a great step forward for forecasting schemes. Kelway and Warner (1973) have made a comparison study of rain gauge and radar systems of measuring precipitation but have yet to reach any firm conclusions. Austin and Austin (1974) in a study of Ottawa came out in favour of the use of radar in urban hydrology. Fuller details of the value of radar in Britain can be found in chapter three.

In conclusion, a significant factor in the development of flood forecasting and warning systems has been the close association with technological advances over the years. The telegraph, telephone, radio, computers, satellites and now radar have all been incorporated into forecasting systems at one time or another, and this does not include the improvements which have occurred in the gauges themselves. All these measures have made flood forecasting an accurate and highly efficient technique, at least as far as the first stage of the system is concerned. It would now seem that the major problems with flood forecasting and warning schemes lies with the second two stages, dissemination of the warning message and response to the warning.

Despite certain disadvantages as well as the technical difficulties of implementing flood forecasting schemes, this adjustment to the flood hazard may be found throughout the world. Examples range from the quite sophisticated schemes operating in the British Isles to large scale projects offering many days warning in the U.S.A. In India, for example, Ahuja (1960) described the value of flood warnings to the country, and Datar and Mohammed (1969) gave details of the radio telemetry links at Poona. Strangeways and Lisoni (1973) examined the flood forecasting system for the Upper Paraguay Basin in South America, which also employs radio links as the cheapest method of data transmission over long distances. Kawabata (1960) compared the flood problems and particular warning systems of Britain with Japan, while Dougherty (1969) discussed the flood warning system in New South Wales, Australia.

The importance, therefore, of flood forecasting and warning systems has increased over the last century and especially during the last fifteen years. This has corresponded to an awareness that previous flood alleviation measures have not been as successful as was anticipated, and to the rapid technological advances in this field in the 1960's. These two factors have made flood forecasting and warning systems a major alternative to the more accepted forms of flood alleviation, throughout the world.

(vi) Weather modification

Weather modification has yet to be tried as a means of alleviating flooding, although such measures have been employed to aid water supply, and to suppress hail damage. The principle of weather modification at present relies on the seeding of clouds to encourage rainfall in certain areas, although in the future even greater control of the weather will undoubtedly be possible. As a result this represents the only new alleviation scheme available to the flood plain planner. However, Haas (1970) stressed the dangers of weather modification without full consideration of the consequences. Farhar (1974) carried out a study into the social implications of weather modification and found opinions generally favourable. This was after a major flood in Rapid City which had been preceded by cloud seeding to prevent hail damage to crops. Nevertheless, while public opinion in South Dakota remained relatively favourable, opponents in the Pacific North-West have cited the Rapid City flood as a reason to oppose cloud seeding projects.

In conclusion, the choices of flood alleviation schemes are much the same today as they were fifty years ago. Changes, however, have taken place in the relative importance of these different measures. At one time, flood alleviation was synonymous with flood control and the implementation of large scale structural schemes, such as dams and reservoirs, whereas since the early 1960's more attention has been focused on non-structural alleviation schemes, in particular flood forecasting and warning systems. Ideas on flood alleviation have also changed, and it now agreed that instead of trying to control the forces of flooding, man should adapt to his natural environment. It is also believed by some that flood alleviation policies should be a dynamic process, constantly open to review and change.

Looking ahead to the future, non-structural schemes, other than flood warning systems, will probably become increasingly important as projects incorporating more than one scheme are developed. Even further ahead, weather modification may become a feasible alternative to control flooding, although at present the technology is still in relative infancy.

However, the present situation exists because of the past response to the flood hazard, and despite the wide choice of flood alleviation schemes, many policies have been quite unsuccessful and flood losses have continued to rise. The selection of alleviation projects has been severely limited in the past to a few structural adjustments with little or no consideration for non-structural measures. It is important, therefore, to look at reasons behind project selection and the decision criteria of the flood plain planners.

SECTION B

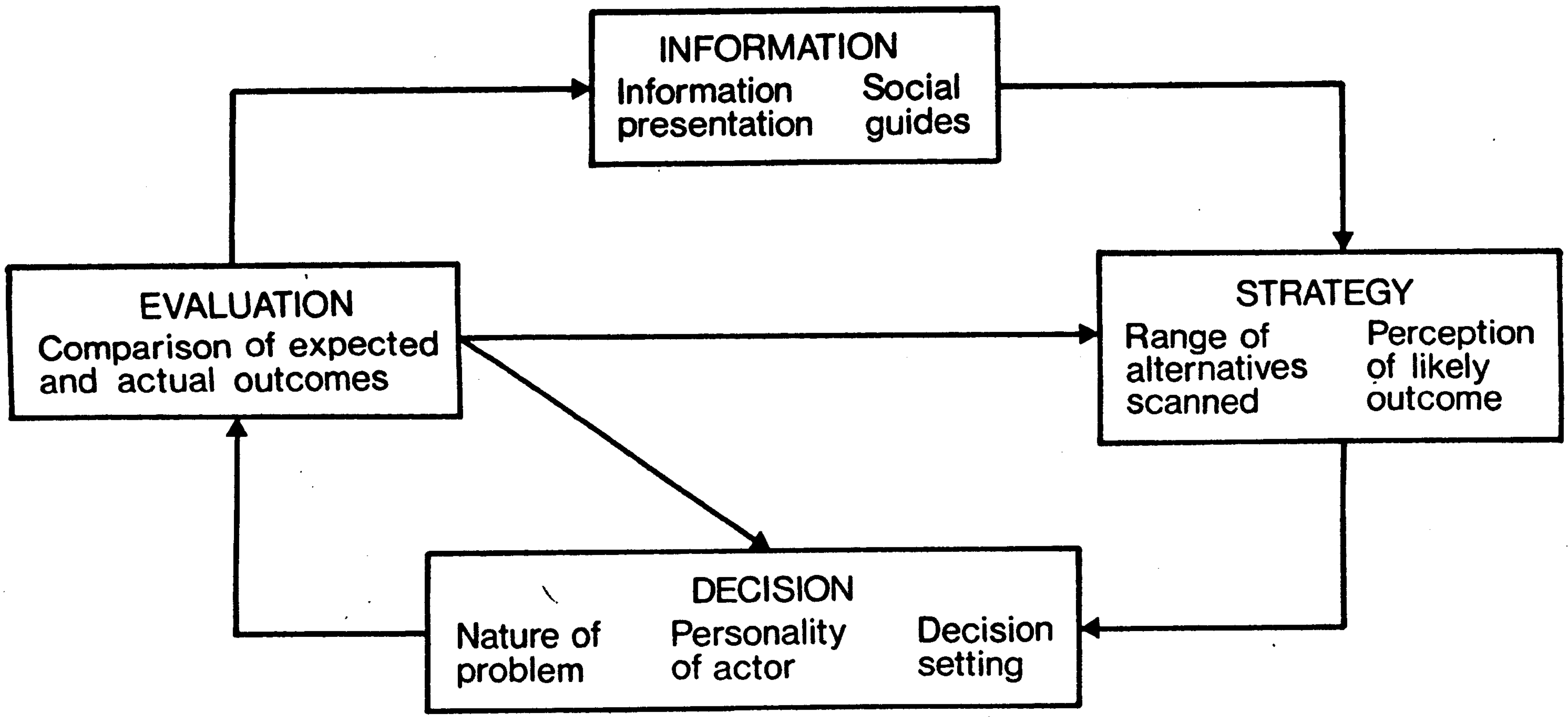
Flood plain management - Decision making

In the past, flood plain management policies have been highly ineffective as far as the reduction of flood losses is concerned. Flood losses have continued to mount, despite considerable expenditure on various flood alleviation schemes. The situation, therefore, calls for a review of the range of flood alleviation schemes discussed in part (A), and analysis of the flood plain planners, and a review of the criteria involved in project selection. The second part of this chapter looks at these latter two aspects, the decision-makers and the strategies of flood plain planning, followed by a consideration of the feasibility studies of project selection.

1) Decision making

A degree of decision making is necessary because, although most flood alleviation schemes will reduce flood losses, in certain circumstances, some schemes will be very effective, while others will be grossly inadequate for their designed purpose. Hence, it is of paramount importance to select the ideal scheme or combination of schemes, for a given flood problem, and to avoid the implementation of costly and ineffective projects. Such a poorly selected project could actually increase flood losses by stimulating an unwarranted response from flood plain users. O'Riordan (1971) proposed a flood plain management model to make the process of project selection more clear, (figure 1 - 10). This model, based on work by the University of Chicago flood hazard

Fig. 1-10. Model of decision-making (after O'Riordan, 1971).



research team, described four principal stages : Information, Strategy, Decision and Evaluation. Information, the first stage in project selection, represents the initial process when a particular flood problem may receive official recognition, and from which the objectives of flood plain management may be established. Moore (1968) suggested that there are essentially only two main objectives in flood plain management;

(1) To bring about the most effective use of the flood plain consistent with overall community development.

(2) To promote the health and safety of the present occupants of land subject to flooding.

At this stage the decision-maker may propose a series of goals ranked in order of their perceived necessity. These goals will be more detailed than the longer term objectives, outlining not only the precise areas to be protected, but also the nature of the flood prône area.

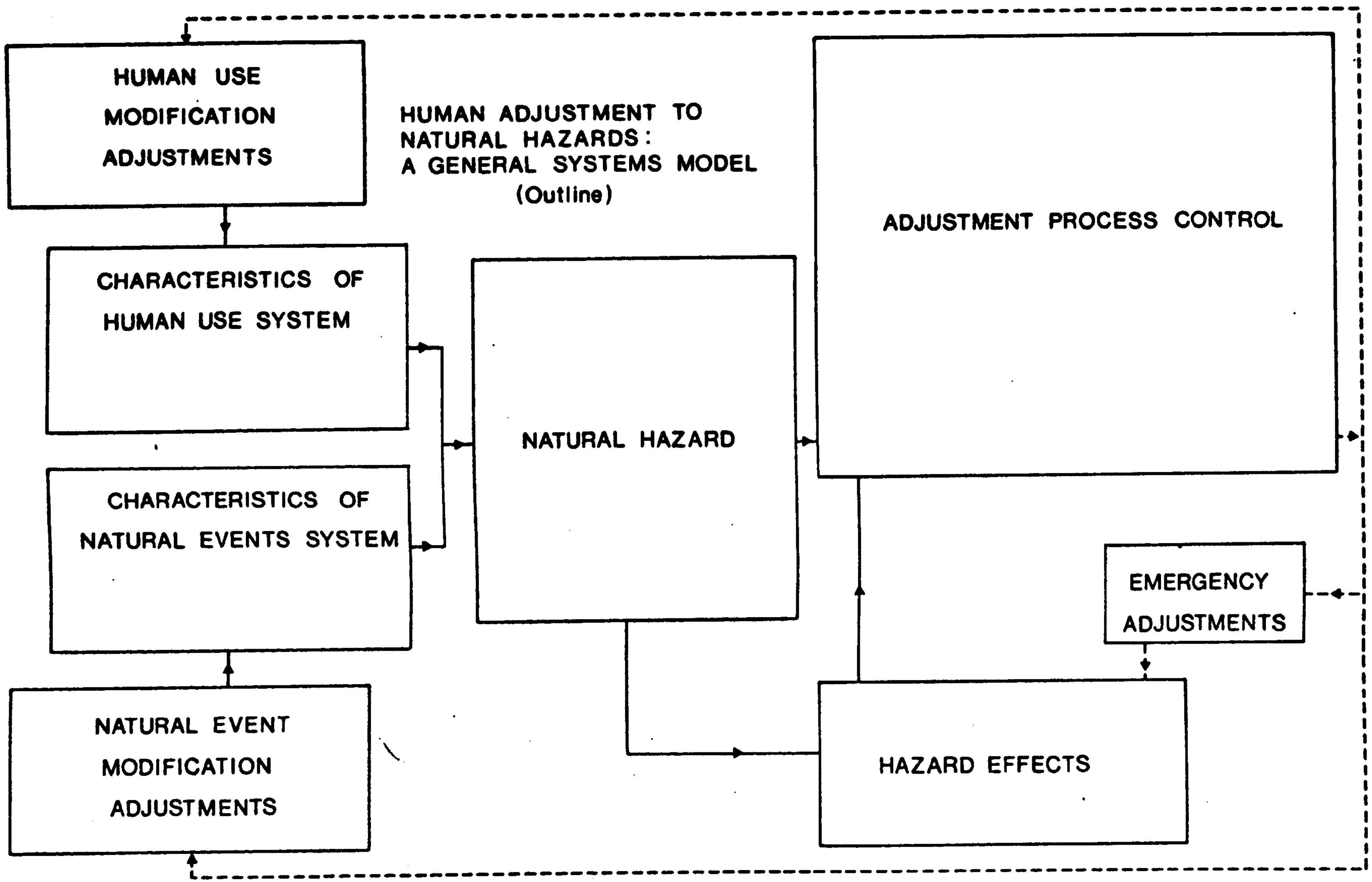
Once the goals have been established and the flood problem officially recognised, the planner can move onto the second phase of the model, that of flood plain strategies. This phase requires the decision-makers to propose various alternative strategies to combat the flood problem and to achieve the more specific goals. According to White (1973) these proposals are the result of various social characteristics of the flood plain planners. For instance, White suggested that proposed schemes would be seriously influenced by personal knowledge of the flood hazard, by perception of the future hazard, by the role of the decision-maker in the community as well as by various other personality traits, (figure 1-11).

The third stage of the decision-making model involves the actual selection of one of the proposed strategies. This final decision is made on the basis of several feasibility studies which seek to evaluate the perceived outcomes of the various strategies in terms of recognised social goals. (Details of these feasibility studies are described below). The last phase, that of evaluation, incorporates the learning process inherent in flood plain management policies. For instance, the actual outcome of a plan can be compared with the perceived outcome from the decision-making phase, and future flood plain planners could bear sucesses or failures in mind when confronted with similar problems. O'Riordan (1971) stressed this learning process in the model of decision-making.

> "It should be noted that decision making is an on going process, where decisions of the past are usually reflected in decisions of the present and where the outcomes of any present decisions affect the basis for any future choice".
>
> (O'Riordan 1971, 114).

However, there are two particular points which are not incorporated in the model, but which should be emphasised, since it is generally believed that they can have a profound effect on the efficiency of any flood plain management policy. Firstly, there is now the suggestion that projects to alleviate flooding will be more successful if the strategy incorporates a combination of measures suitable to the particular area, rather than single purpose schemes. The implementation of more than one scheme,

Fig. 1-11. Model of flood plain decision-making (after Burton, Kates and White, 1968).



especially involving non-structural measures, will achieve more individual goals and add to the efficiency of the overall project. For example, the efficiency of a flood forecasting and warning system would be considerably enhanced by the active encouragement of a flood proofing policy. Similarly, a flood insurance programme could be adopted alongside a proofing policy by offering reduced premiums to those undertaking such protection work. A flood plain zoning policy could incorporate both flood proofing and insurance schemes in certain defined areas, which would significantly reduce losses for those in high risk zones. Not all the possible combinations of schemes have been stated here, but it is clear that a flood plain management scheme may be more effective in achieving its goals if a multiple strategy is adopted, particularly where differing combinations of structural and non-structural schemes are employed in both the private and public sectors of the community. It should also be noted that the <u>active</u> encouragement of one or more non-structural measures may even maintain a general awareness of the flood risk by the flood plain community, as well as providing additional protection following the construction of a large structural scheme. In this way, the poor community response, which frequently follows such schemes, may be prevented.

The second point not emphasised in the model, but still of great importance, is the necessity to exercise caution in the final project selection, to allow for changing circumstances in the future. White (1973) stressed the importance of flexibility in the final choice as a hedge against the uncertainty of flooding, so that whenever possible, opportunities would be left open for the adoption of new solutions, O'Riordan (1971 , 112) commented, "Thus the aim would be to minimise the possible foreclosure of future courses of action, by forestalling whenever possible, the on set of irreversible processes by avoiding the adoption of single purpose schemes."

Thus, both White and O'Riordan agreed that the opportunities for change should be left open for as long as possible, and that both the nature of the flood problem and the feasibility of different alleviation schemes should be periodically reviewed. Obviously, this would be less easy if there was massive investment in a large single-purpose structure measure, than if a series of small scale, less expensive adjustments had been made. Therefore, flood alleviation should be a dynamic process that changes with technological developments, and responds to any alterations in the characteristics of the flooding.

The rapidity with which changes in the hydrological characteristics of a catchment can be brought about would support the need for the periodic reassessment of the flood hazard. For example, just as afforestation policies can increase the lag time of a river (see flood abatement policies above) so developments such as urbanisation can have the reverse effect. Urbanisation, by increasing the area of impervious surfaces, and installing an efficient secondary drainage system can significantly reduce lag times and increase flood peaks, by making the hydrological system highly responsive to input. Hollis (1974) studied the effects of urbanisation on Canon's Brook at Old Harlow, Essex, and found that over an 18 year period, summer flood peaks increased by 11.5 times. Espey et al

(1969) also discovered this effect with peak storm run off increased by 2 to 4 times with the response time reduced by one third. In such catchments, therefore, there should be a continuous reappraisal of flood alleviation techniques, because of the dramatic changes in hydrological parameters. Smith H.F. et al (1969), Kadoya (1973) and Maniak (1973) also considered the problems of developing urban watersheds, and suggested models to predict future behaviour of the flood characteristics. However, these predictive studies should not discourage constant surveillance in rapidly developing catchments.

In conclusion, it would appear that flood plain management requires considerable skills, throughout the four stages of the decision-making model described by O'Riordan. However, probably the major problems are encountered at the decision-making stage, where the flood plain planner must evaluate the benefits of different strategies under certain feasibility tests. Nevertheless, the model clearly indicates the four stages of project selection, while other authors have stressed the importance of flexibility in decision-making and the dynamic nature of flood alleviation.

2) Feasibility studies

The above section described the strategies involved in flood plain planning, and the problems of attaining certain social and economic goals. During this process, the decision-maker is normally required to select from several different schemes, the most beneficial measure to suit each particular environment. The tests applied on the proposed schemes represent a series of feasibility studies, designed to assess the acceptability of different strategies on a variety of grounds. James and Lee (1971) suggested five such feasibility tests, financial, political, technical, economic and social, while O'Riordan and More (1969) included the further constraints of legality, administrative and ownership.

(a) Political feasibility

Political feasibility is established if a scheme is acceptable on the grounds of the administration of the country. For example, a flood plain zoning policy could be easily introduced in Great Britain, because the essential planning laws already exist to control development. However, this sort of restrictive control may be politically unacceptable in other countries, such as the U.S.A., or require major political decisions to alter political policies. Almost every alleviation project causes harm to someone, and if enough people are harmed or if those harmed are sufficiently vocal, they may be able to use the political processes to prevent the project being implemented. Penning-Rowsell and Chatterton (1976) commented on the political constraints of planning flood alleviation works in Britain, and they saw the recent administrative reorganisation (Water Act 1973) as adding to the problems of efficient flood plain management. They suggested that the increasing centralisation only adds to general distrust of planners by those affected by the planning policies.

(b) Financial feasibility

Financial feasibility is satisfied if money can be found to pay for the project, although this does not necessarily mean the proposed scheme is economically acceptable. While financial feasibility should be contingent on technical feasibility, some projects have been constructed which simply do not work. Similarly, many schemes have not been developed because financial backers have not been found, despite the scheme satisfying other feasibility tests.

(c) Legal, Administrative and Ownership constraints

These problems may arise with any scale project, from the large structural measures to small individual adjustments to the hazard. For instance, a large scale structural scheme may transcend national boundaries, which would probably involve legal, administrative and ownership problems. Similarly, on a smaller scale within a country, agreement between several local authorities may be required before a measure can be implemented. Even on the very local level, individual adjustments may require complete agreement between several householders to be entirely successful. Clearly, where ever a scheme encroaches on more than one political area, then legal, administrative and ownership disputes could arise. Land ownership could also prevent particular problems, although to what extent would depend on the political values of the country involved. Other legal problems may also have political connotations, for example the rights of water users downstream. In the U.S.A. the riparian user maintains a right to water, which may affect the decision of the flood plain planner.

(d) Physical/Technological feasibility

Physical or technological feasibility is satisfied if a scheme can be constructed or operated in the particular environment under review. While all alleviation schemes are technically feasible, the physical environment may in practice reduce the range of schemes possible. For example, it is technically feasible to install a flood forecasting and warning scheme on most rivers, but the hydrological conditions may make this form of adjustment unacceptable. A highly responsive stream can be gauged for a warning system, but if this provides only a few minutes warning time, the scheme would be impractical.

The most important aspects of technical feasibility probably concern the large scale structural features, where not only is a great deal of money invested, but considerable property and people put at risk should the project fail. However, there are quite a few structures which have failed, causing considerable loss of life and property, due to a variety of factors. The St. Francis Dam in California failed in 1926 because inadequate consideration had been given to the geological structure, and as a result 426 people were killed. Other structural failures due to insufficient attention to the underlying geology include the Bouzey Dam in 1895 and the Malpasset Dam in 1959, both in France, where 86 and 300 people respectively were killed (all quoted by Walters, 1971). In Britain, the failure of the Woodhead Dam in 1850, Holmfirth in 1852 and Skelmorlie in 1925 were probably due to geological weaknesses (Smith N. 1971). The further failure of Dale Dyke Dam in 1864 when 250 were killed (Amey 1974) and Dolgarrog Dams in 1926 when 16 were killed

(Smith N. 1971) were probably due to general incompetence, either in the design or construction stages. Other structures have suffered from their location; for instance the Van Norman Dam in the U.S.A., which has rotated due to earthquakes, or the Pitlochry tunnels at Comrie which have fractured due to earth movements (Walters 1971). More recently, the failure of the dam on the Snake River in the U.S.A. in 1976 has brought renewed fears of major dam failures. While most of these structures were for water supply reservoirs, their failure demonstrates the importance of technical feasibility considerations.

(e) Economic feasibility

Economic feasibility is attained if the benefits accruing from a particular scheme are seen to be greater than the costs of implementation. Probably the oldest and certainly the most commonly used technique for assessing the economic viability of any project is the benefit-cost analysis approach. This technique was developed into its present form by the Navigation Boards in the U.S.A., who used the approach to evaluate harbour policies in the 1920's. By 1936, with the ever rising costs of flood alleviation structures, the benefit-cost technique was incorporated into the American Floods Control Act, so that there should be some attempt to assess the economic feasibility of flood alleviation schemes. Until then there had been little evaluation of schemes, and as a result many highly inefficient schemes were constructed. The 1936 Act aimed to change this with a policy that "the benefits to whomsoever they accrue must justify the costs".

Benefit-cost analysis is a methodological approach for assessing the economic feasibility of alternative flood alleviation projects. The technique has three broad uses according to Sewell et al (1962):

(1) to assess the economic characteristics of a particular project;

(2) to determine which of a number of projects designed to serve a given purpose results in the largest ratio of benefits to costs, and

(3) to determine which of a number of projects designed to serve different purposes confers the largest net benefit on the economy as a whole.

In the first case, benefit-cost analysis will assess the economic feasibility of a project by comparing the benefits with costs. If this produces a ratio greater than unity, then the project is usually acceptable on economic criteria, since the benefits will outweigh costs. In the second case, the benefit-cost ratios of a series of flood alleviation projects can be estimated and compared to find the most efficient scheme for a given area. The third case is necessary to distinguish between projects of different design purposes, so that alleviation schemes may be compared with other schemes such as water supply or navigation improvements. This alternative can be particularly valuable to a community with many problems, but with only very limited resources, since the benefit-cost approach will theoretically indicate which scheme will give the best return for the investment.

In order to be able to undertake any of these comparisons, considerable data must be collected first, on both the potential costs and benefits of the proposed schemes. In general, costs are fairly readily estimated and present few problems, since engineering firms usually produce quotes for different undertakings. Benefits, on the other hand, are extremely difficult to assess to any significant degree of accuracy. In the case of flood alleviation, benefits amount to those damages which would be prevented if a certain scheme were implemented. Some consideration, therefore, should be given to future flood plain changes, because flood damages will be reduced throughout the lifespan of the project. However, calculations should not be based on the anticipated changes, such as flood plain encroachment, which often occurs as a direct result of implementing an alleviation scheme, because these changes would not take place without the project. Haveman (1965) explained this approach as the 'with and without' principle, which compares with the 'before and after' principle used with most benefit-cost analyses.

Basically, there are three types of benefits which must be evaluated before any economic assessment of the projects can be made. These are direct, indirect, also known as primary and secondary, and intangible losses. (Different authors use varying classifications, see for example Eckstein, 1958 or Kuiper, 1971). Direct benefits are calculated on the basis of the expected cost of physical damage resulting from a flood, on the principle of mean annual losses. Indirect benefits are losses of a secondary nature, such as lost production and the costs of clearing up after a flood. Both are classified as benefits, since they represent losses that would occur without the alleviation project.

Intangible benefits are extremely difficult to assess in monetary terms. For instance, flood alleviation schemes will reduce the threat of flooding, but how can this reduced psychological fear be reflected in monetary terms? Even more difficult to assess is the value of human life, which may be a significant factor in some countries, where flooding causes major catastrophies. For example, in India between 1950 and 1959, according to Ahuja (1960) 3251 people were killed by floods. In Japan, Nakano (1973) estimated that a total of 21,901 people were killed between 1946 and 1970 from flooding caused by typhoons, heavy rain and strong winds. Over 3000 people, for instance, were killed by 3 floods, two occurring in 1953 and one in 1957. In the U.S.A. several estimates have been made of the loss of life from flooding. Burton et al (1968) stated that 70 people were killed between 1955 and 1964, although an earlier estimate by Burton and Kates (1964) put the mean annual loss of life from flooding at 83. The problem of loss of life, therefore, can be a significant factor in the feasibility of flood alleviation projects. Necessarily, the question arises, can human life be evaluated in monetary terms. Several workers have put forward methods for dealing with this problem, but none as yet have produced a satisfactory answer. Prest and Turvey (1965) for example, suggested that in economical terms it would be better to save a productive man than an unproductive man but then agreed that this would be socially and ethically unacceptable. Of a practical nature, Mushkin (1962) anticipated using median wage values to assess the value of life, and Klarman (1965) the use of average wage earnings. Layard (1962) commented on the problems of life assessment in project selection;

"Perhaps the most difficult item of all to value is a human life. Yet it is quite clear that countless policy decisions affect the incident of death and none of them aim to minimise its incidence regardless of cost. So each decision implies some valuation of human life."

(Layard 1962, 26).

Intangible benefits tend to be very subjective, and to date, no accurate method has been found for calculating them. Chambers (1975) proposed, purely for want of a better method, that other benefits should be multiplied by a factor of two, to account for the intangibles. This is a very arbitrary method, but it does give some weighting to those benefits which are known to exist, but which cannot be satisfactorily evaluated in monetary terms.

In order to assess all the benefits from flood alleviation schemes, it must be possible to say firstly <u>how much</u> damage is to be expected from a flood of given magnitude in a particular location, and secondly to estimate <u>how often</u> floods of different magnitude are expected to recur. However, on the whole, the damages resulting from flooding have not been studied in any great detail (which makes the evaluation of benefits, i.e. losses not sustained, very difficult) which is a little surprising considering the interest shown in other aspects of flooding. White (1964) has looked at synthetic flood losses to relate flood stage with increasing flood losses, and he established several stage-damage curves from these studies, for different building types. He later compared these with actual damages reported in the town of La Follette and adjusted the graphs accordingly to allow for remedial action by residents prior to a flood (figure 1-12).

In Britain a few studies into damage estimates have been carried out, but nothing to the extent of White's work. Unfortunately, these stage-damage curves are not applicable to Britain, because of differences in building material and flooding characteristics, although they do provide an indication of the general damage trends. Parker and Penning-Rowsell (1972) have tried to develop this technique, but so far the results have been inconclusive. Also Chambers and Rogers (1973) and Chambers (1975) have made a small study of flood stage and damage relationships to private homes, using the Towcester area as a case study (figure 1-13). Other studies of flood losses have included the work by McDonald (1972) on agriculture in the Nith Valley and Struyk (1971) on rural land values near the Missouri River. Because of the general lack of understanding, flood losses are frequently calculated by extremely crude methods. Chambers (1975) cited three very common examples:

(i) Damage per flood event is taken to be a fixed, proportion of the market value of each property. In the absence of better information this proportion is frequently taken as ten percent, although it is recognised that this is likely to exceed physical losses and include and allowance for inconvenience.

(ii) Damage per flood event is taken to be a fixed multiple of the rateable value of each property.

(iii) A constant value per flood event for each property

Fig. 1-12. Flood stage-damage curves (after White, 1964).

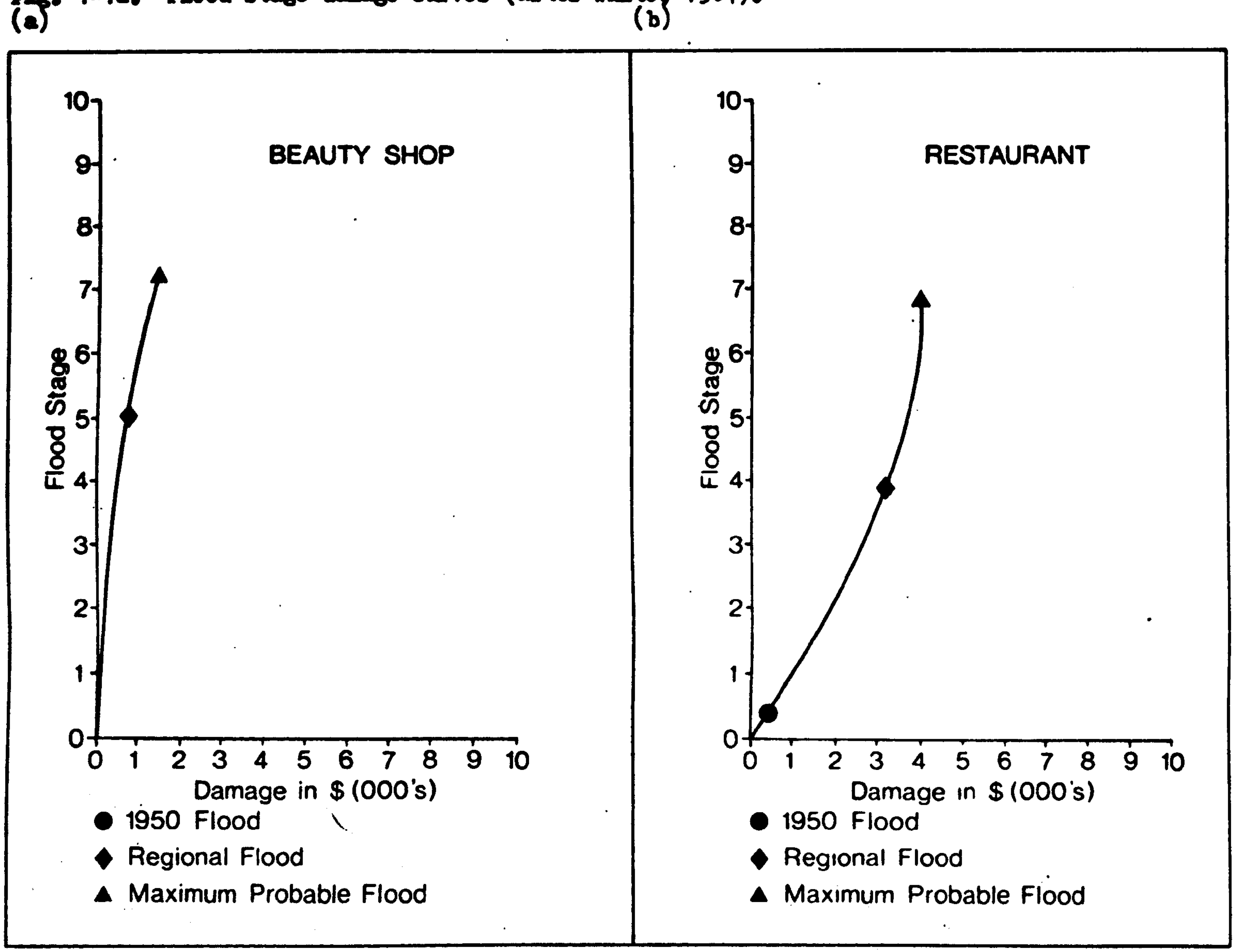
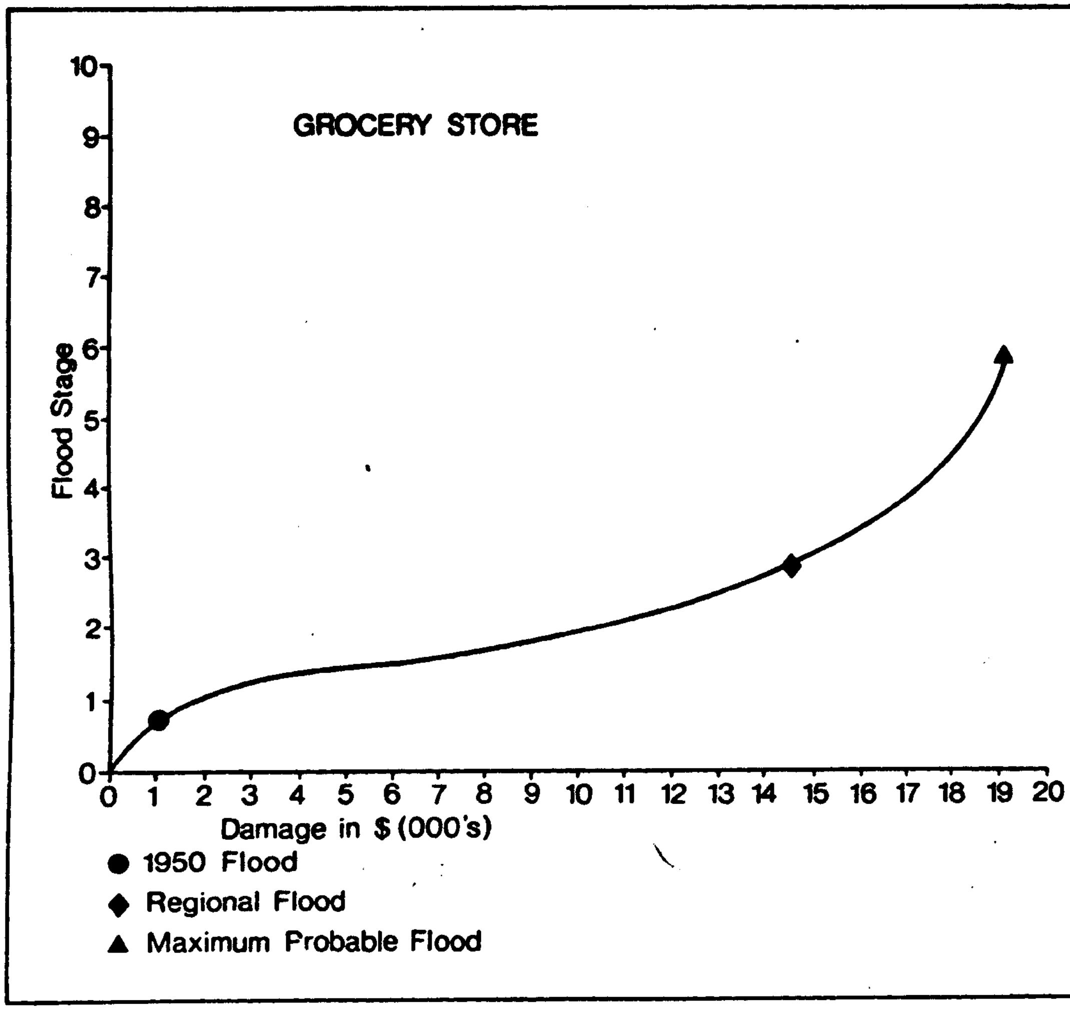


Fig. 1-12. Flood stage-damage curves (after White, 1964).

(c)



(d)

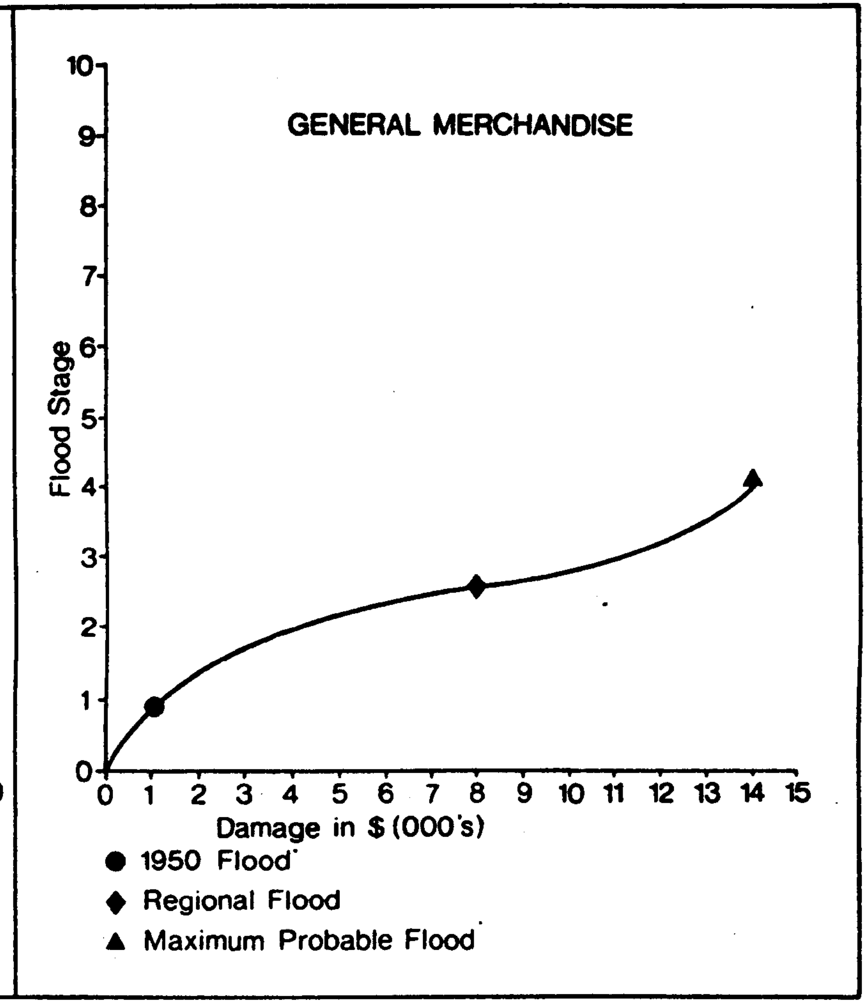
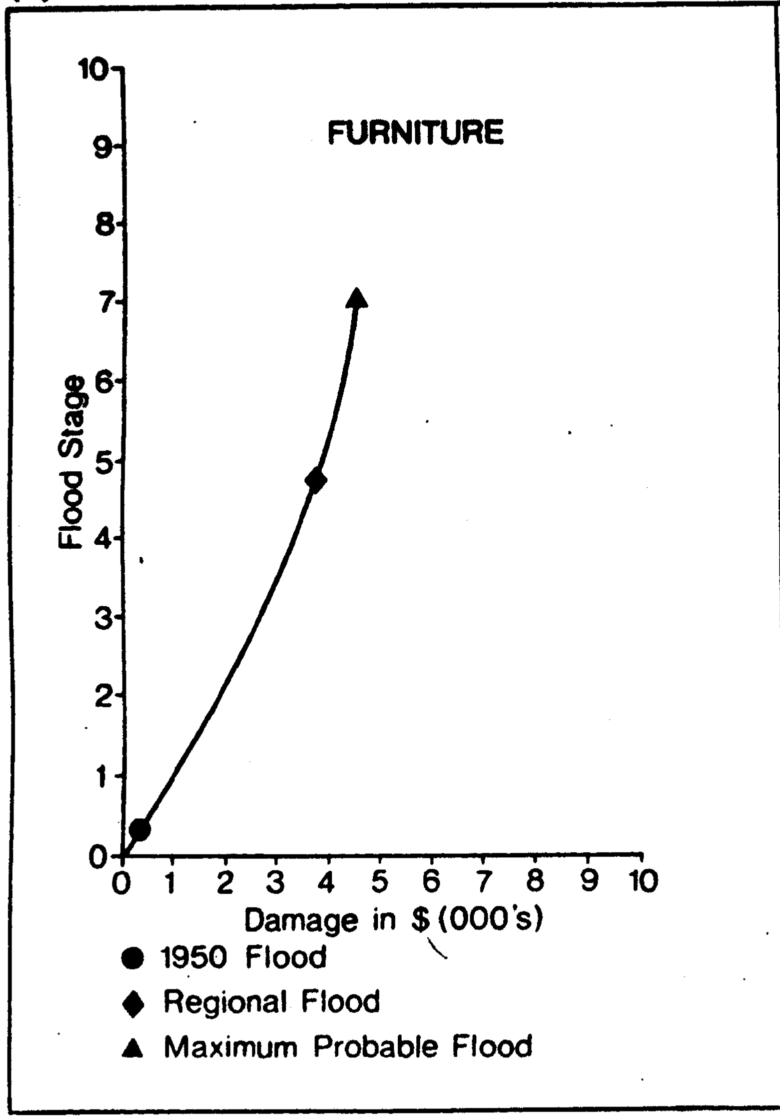


Fig. 1-12. Flood stage-damage curves (after White, 1964).

(e)



(f)

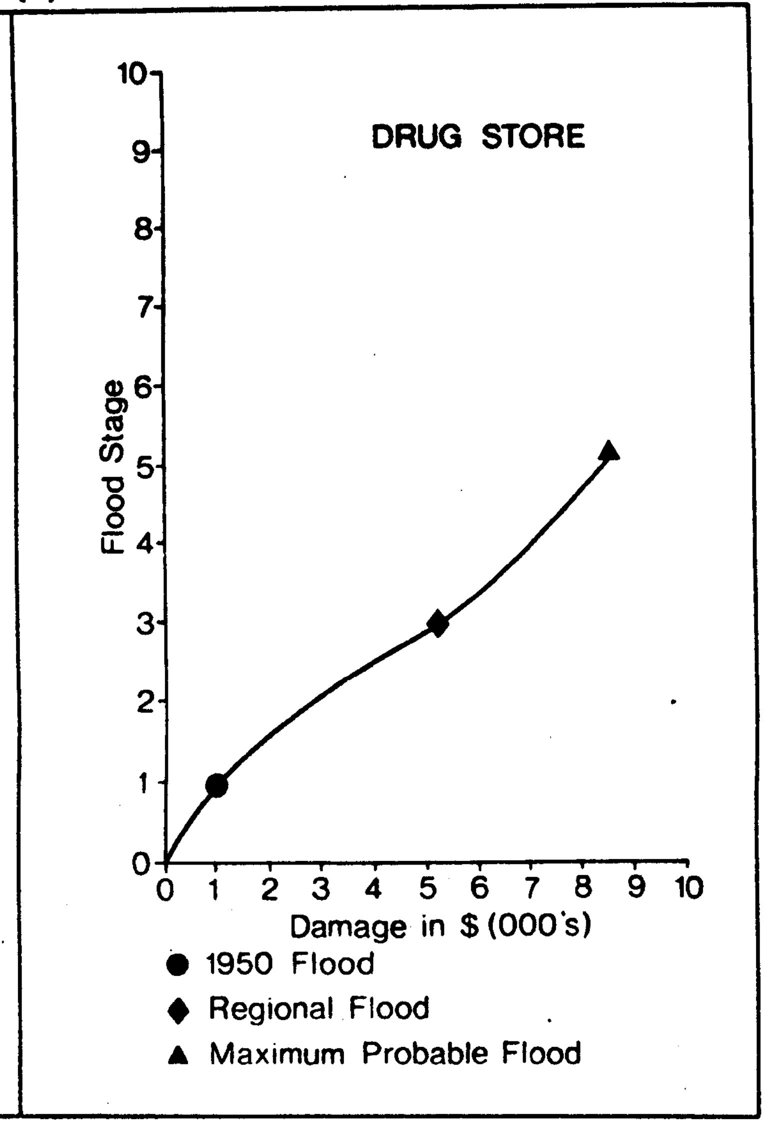
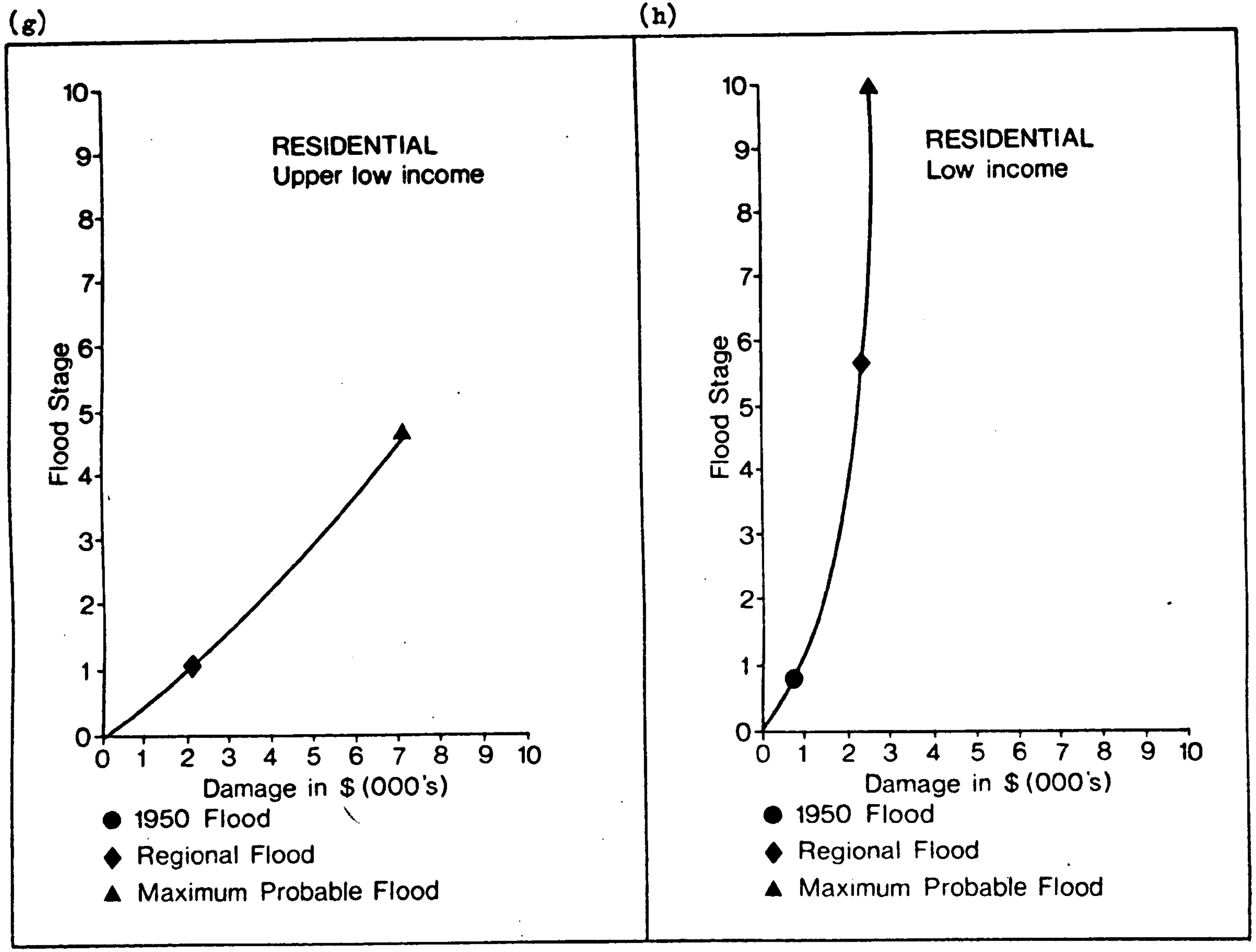


Fig. 1-12. Flood stage-damage curves (after White, 1964).



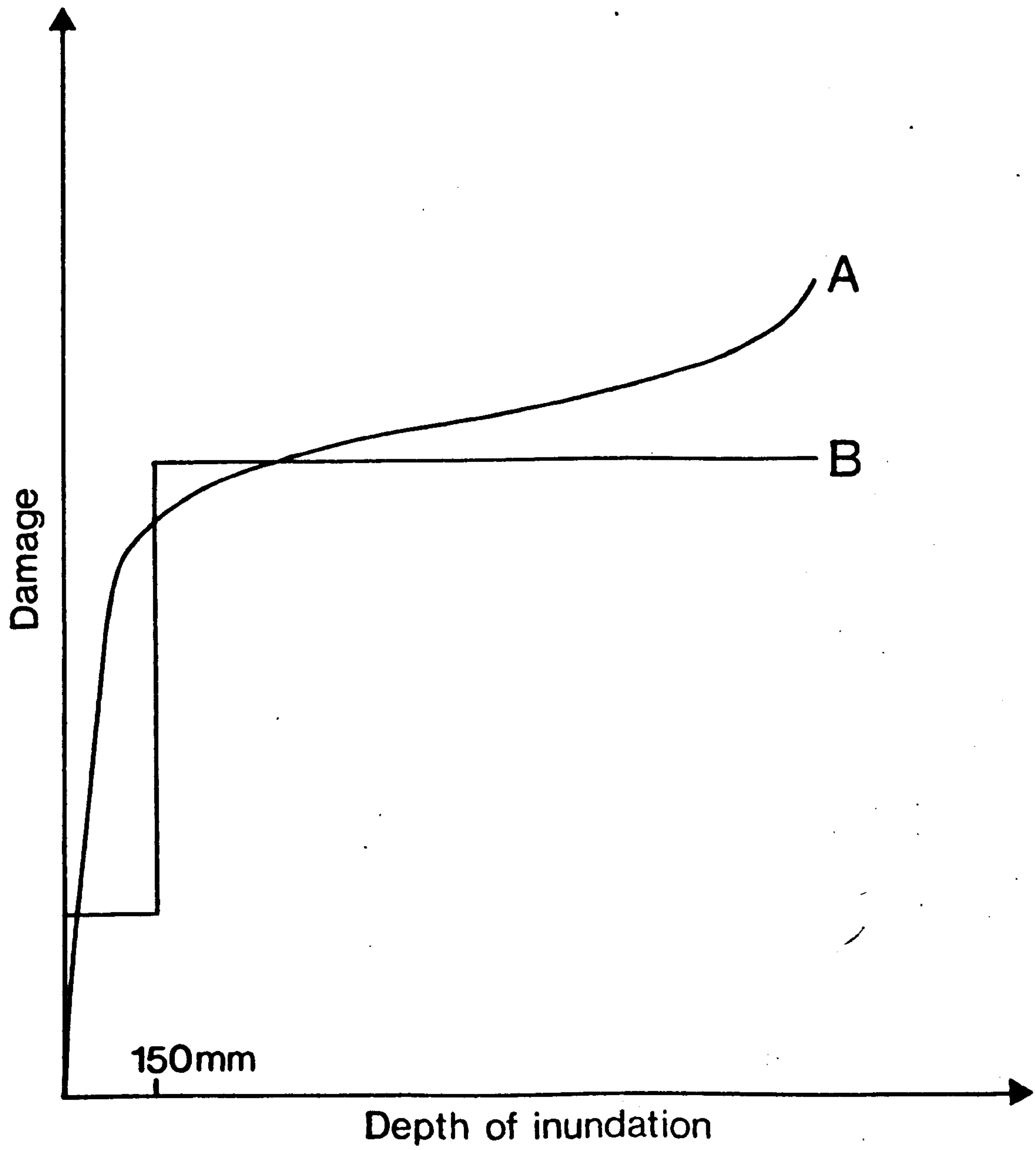


Fig. 1-13. Relationships between damage and depth of inundation for private houses (after Chambers and Rogers, 1973).

is assumed. A commonly used figure has been £500, a sum that is supported by insurance information on a specific flood in 1970, which represented the mean insurance contribution, according to Chambers.

There are many drawbacks to these three methods, especially since little or no allowance is made for indirect and intangible losses. Also, the structural damage that is not immediately apparent will not be included, nor will the unpaid assistance of friends and neighbours in clearing up. The three methods, therefore, are basically unsatisfactory for assessing potential flood losses, and would be of little value to any benefit-cost analysis.

Another drawback of such synthetic methods of estimating potential flood scheme benefits is the lack of consideration for different flood characteristics (Appendix I). The only variable considered in detail above was flood depth and the relationship between the flood depth and flood damage. However, other variables may also alter the damage resulting from flooding, even from floods of the same depth. For instance, if the flood has a high sediment load, or even greater significance sewerage load, then damages may be considerably higher than from relatively clean flooding. The duration of a flood may also be significant in this respect, for it is conceivable that losses will be proportional to flood duration. Velocity of the flood flows may have a profound effect on flood losses, since high velocity floods may be responsible for structural damage to property. Numerous other characteristics of floods, such as the rate of rise of flood water, turbulence, seasonality and timing may all affect actual and potential flood damages.

There are many advantages and disadvantages to the benefit-cost analysis approach to evaluating flood plain strategies. Advantages include:

(i) The principle of benefit-cost analysis is fairly easy to understand.

(ii) It includes a long term assessment of both benefits and costs, and allows some scope for expected changes in the flood plain.

(iii) By sifting out the uneconomic proposals, it does provide a yardstick for measuring relative feasibility of different programmes, whereby public money will achieve the most satisfying return.

(iv) It gives an indication of who will gain and who will lose from the project.

Disadvantages include:

(i) In the real world, the calculation of benefits is extremely difficult and schemes have been accepted in the past on very poor estimates of damage.

(ii) The policy of reducing everything to monetary terms is not only very difficult but in many cases undesirable..

(iii) There is no account of the redistribution of benefits to the losers of the scheme.

(iv) The discount rate at which money investments depreciate will vary during the lifetime of the project, and may affect its economical viability.

In conclusion, benefit-cost analysis can be a useful tool if used purely as a guide or indicator of the most economically efficient scheme, although all the other feasibility tests should also be undergone before the final project selection is made. Benefit-cost, however, should still not prevent the implementation of a scheme, which is considered socially desirable. All flood alleviation schemes may be assessed by benefit-cost ratio, not only those large scale structural schemes for which the approach was initially adapted. For instance, Day et al (1969) and Serra (1969) examined the benefits from non-structural schemes such as forecasting techniques. Finally, future studies will undoubtedly become more sophisticated as data collection techniques improve. James (1967) has already attempted the theoretical evaluation of alternative combinations of structural and non-structural measures by computer. It is to be hoped that such approaches as benefit-cost will improve, so that economic feasibility will become a realistic assessment of the relative merits between different schemes.

(f) Social feasibility

The test of social feasibility is passed if the potential users respond favourably to the introduction of the flood alleviation scheme. In the past, the social implications of flood alleviation schemes have seldom been considered, except as a possible indirect factor in political feasibility. The principal tests of project feasibility have always been economic and physical or technological constraints, while it is always assumed that there would be no social limitations to the project. It was thought that any scheme implemented to reduce flood losses would automatically be accepted by flood plain communities, and produce a favourable response from individuals. However, this attitude is now being seriously questioned and many workers (such as James, 1973, 1974, James et al 1971, Kates 1970) have advocated greater attention to the social aspects of flood plain planning. This apparent reversal in opinions has arisen because of the general failure in past flood alleviation schemes to reduce effectively flood losses. Despite the supposedly objective evaluations of benefit-cost analysis and other feasibility studies in the selection of so called efficient schemes, the decision-making programme appears to have failed. It would appear, therefore, that social factors may play a significant role in flood plain management, and could influence the overall effectiveness of different flood alleviation schemes. The encroachment on to a flood plain, for instance, is a typical response to large structural adjustments, and has been one of the prime causes for the increase in the value of property exposed to the flood hazard. This form of social response has not always been fully appreciated by the planners, and hence flood losses have continued to rise. Social considerations of each measure, given such a response, may have been a factor in the rejection of the scheme, or at least encouraged the introduction of a zoning policy into the flood plain strategy.

A second reason for the greater attention to the social aspects of flood alleviation projects has been the current trend towards non-structural adjustments which require certain behavioural responses. With the original development of these measures, there was little or no regard for social acceptability because it was assumed that residents would behave rationally to minimise flood losses. Unfortunately, this is not always the case, for some people will be unaware of the most effective action, or be unwilling to undertake such adjustments for a variety of reasons. As a result of this response, flood losses would be higher than anticipated, and the scheme could be considered a relative failure. For example, the only persons to benefit from a flood insurance and flood proofing policy are those who take part in the scheme, while others who do not respond will continue to suffer severe flood losses. Social feasibility therefore is an essential requirement of decision-making in flood plain planning.

Even more significant at the moment, because of the widespread implementation of such projects, is the response to flood forecasting and warning schemes. Response to a flood warning, which represents the third subsystem (see above) of the flood forecasting and warning system, requires effective remedial action prior to a flood, if the scheme is to have any effect whatsoever. Again, the policy of early schemes was to assume that flood plain communities would react to a warning in a logical and systematic manner to reduce flood losses. However, there are many variables which may affect the response of the flood plain inhabitant, and produce a poor response to the warning. Some people, for example, may well react in the anticipated manner, but others will either respond in a highly inefficient manner, or disbelieve the warning and hence take no precautions. Mileti and Krane (1973) suggested a series of variables which could possibly influence the response of an individual to a warning message, such as, past experience of flooding, the present perceived risk, geographical proximity to the source of the hazard, socio-economic status, age, sex, warning source and content, number of warnings received, perceived time to impact, and the perceived response of others. The true effectiveness of a flood forecasting and warning scheme, therefore, cannot really be assessed without adequate consideration of the social feasibility of the system.

Another aspect of social acceptability is the question of perception, which is becoming increasingly more important to flood studies. In an examination of community behaviour, certain authors, such as Kates (1962), White (1964) and James (1973, 1974) have suggested that the role of perception may be considerably more important than conditions in the real world. For instance, White (1964) proposed that a flood plain inhabitant would respond not to the statistically calculated flood risk, but instead to the way he perceives both the risk and effect of the flooding. If these hypotheses are correct, and they would appear to be from the evidence of James (1974) then analysis of project efficiency will require detailed perception studies in the future.

A few researchers have examined various aspects of perception of the flood hazard in Britain. Gately (1973) in a brief account of perception classified flood plain residents according to their perception of the hazard. Penning-Rowsell (1972) found that perception of the flood hazard by flood plain residents tended to underestimate the real risk involved in such a residential location. Other flood perception studies in Britain have included the work by Harding and Parker (1972), Harding and Lillicrap (1973) on Shrewsbury, and Parker (1976) with various studies in Wales. A full review of many of these perception studies follows in chapter two, to provide more detailed background for the present study.

The final aspect of social feasibility regards the problems of generating an acceptable response from the flood plain community, because most people appear reluctant to change past behaviour patterns. James and Lee (1971) believed that the more drastic the changes required by the project, in the lives of the beneficiaries, the greater would be the inertia from those slow to change their way of living. The infusion of productive capital will not automatically transform a tradition-bound society. This aspect of social acceptability was clearly demonstrated by Theiler (1969) in Coon Creek, Wisconsin, where prior to the implementation of a structural alleviation scheme there was no consideration of social factors. In fact, the evaluation technique assumed that such a scheme would lead to an intensification in land-use with a change from cattle to crops. This change in agricultural patterns did not materialise because; (1) the changing agriculture economy lessened the demand for crops; (2) there was an increase in the number of retired and semi-retired farmers, who did not want to use crops; (3) there was a feeling by some that they did not need additional cropland. Had the social aspects been considered earlier at least the latter two points would have emerged, which may have been sufficient to forestall the construction of the alleviation scheme.

As a final analysis, the social implications of flood plain planning should be considered in much more detail than has been the case in the past, if flood alleviation schemes are to be more efficient and flood losses reduced. Also studies of perception of the flood hazard and the response of residents to certain schemes requires urgent attention to prevent further mistakes in flood plain management. Thus, while the range of adjustments to the flood hazard has remained roughly the same, there has been a general trend away from the large scale structural measures, to smaller, less expensive non-structural projects. This change in policy has originated from the failures of previous alleviation schemes to reduce flood losses, and a greater awareness by the flood plain managers of the overall problem.

CHAPTER TWO

BEHAVIOURAL STUDIES IN FLOOD PLAIN MANAGEMENT

Introduction

Outlined above is the full range of adjustments to flooding available to both the flood plain planner and the individual. This is followed by a series of feasibility studies which should automatically be included in any flood plain management policy, if the choice of flood alleviation project is to be anything like a rational decision. There is now considerable literature on most aspects of flooding, from the physical characteristics of the hydrology, to the wide range of adjustments available to reduce the effects of the hazard. Unfortunately, however, the processes of project selection, the real factors governing the decision-making, have received little attention, with the exceptions of physical and technological feasibilities. As a result, very inefficient and often costly schemes have been implemented, which have failed to reduce overall flood-losses. More research is required into the real factors governing decision-making, which is believed by many American authors to be the crux of efficient flood plain management in the future.

A second factor which has stimulated interest in social feasibility has been the recent trend towards the non-structural measures as a means of reducing flood losses, where instead of attempting to control completely the physical forces of nature, emphasis is placed on the manipulation of human behaviour, in conjunction with other technological adjustments. This trend in flood alleviation policies has brought out the second major social consideration, that of the behaviour of residents and industrialists in the flood hazard areas. The behaviour of these persons will have a significant bearing on the efficiency of the alleviation projects, especially those incorporating some form of non-structural response.

Thus, current research into flood plain management is paying increasing attention to these two facets of social feasibility and decision making. The failures of the old schemes, the introduction of new projects incorporating the planned response of flood plain inhabitants, and the realisation that previous flood plain management has been far from rational in its decision making have all promoted these further studies into human behaviour. As a result, several recent studies have been undertaken into the importance of behaviour with respect to flood alleviation projects. These have included in particular an examination of the residents' perceptions of and attitudes towards the flood hazard, as well as analysis of the processes of public planning, to discover the real factors behind flood plain management.

To put this particular piece of work into context, it is necessary to look briefly at similar studies carried out recently in Britain and the rest of the world. Current research into the physical aspects of flooding and technological adjustments to the hazard have already been discussed in chapter one, and hence will not be considered here. Instead, emphasis will be placed on research into the social aspects and implications of flood plain management and the various case studies undertaken.

Recent case studies in flood plain behaviour

Research into this latest field of flood plain management is not very extensive, with the majority of case studies coming from the United States of America and Canada. In the United Kingdom, Harding with others from the University of Swansea, and the Middlesex Polytechnic Research Team have been looking at two particular areas but the scope of their work is small compared to that undertaken in the U.S.A., especially under the leadership of G.F. White in the University of Chicago. This team has set the trend for later researchers, and they have continued to stress the importance of both spheres of adjustments to flooding, structural and non-structural, and at the same time, encouraged the implementation of combinations of measures to alleviate the flood problem more effectively.

However, one of the first workers to consider the behaviour of residents and officials during a flood event was Clifford (1956) and although this was primarily a sociological study, it had implications on later geographical works. Clifford looked at the effects of the Rio Grande flood of 1954 on two communities, one in Mexico, Piedras Negras, and the other in the U.S.A. Eagle Pass. Both these towns suffered extensive flood damage which amounted to nearly four million dollars in Eagle Pass, and an officially estimated sixty-five million dollars in Piedras Negras. Clifford, in studying the reaction of officials, noted the problems created by the international boundary, and the differences of opinions generated by the aid donated by the U.S.A. He also recognised that behaviour patterns of the two groups of flood plain residents was quite different, although for both towns there appeared to be a hierarchical order of unofficial support, first the family group and other family ties, secondly religious connections, and finally other social links. This then was one of the first studies to imply that the characteristics of individuals and their behaviour before, during and after a flood could be significant in determining to some extent the degree of flood damage.

Roder (1961) extended this type of survey of behaviour patterns during a flood, by looking at residential attitudes and knowledge of the flood hazard in Topeka (Kansas). Originally, the study set out to see whether or not flood protection was associated with optimism about the possibility of recurrence of floods in the minds of people located on the flood plain. Topeka had a long history of flooding, and had implemented a series of structural measures, including a levee system in 1939 (repaired in 1951 after a major flood) and more recently two control dams upstream on the Kansas river. The study was undertaken by a questionnaire survey of a small number of residents and a few business people in the private sector, in three areas on the Topeka flood plain, where the frequency of flooding varied. The results of the survey were inconclusive, since Roder found no significant differences between the responses for the three different areas, despite the wide range of flood experience. Also, there did not appear to be any direct relationship between the individuals knowledge of the protective structures, and their expectations of future flooding. Roder inferred from this that in an established community like Topeka, the public promise of flood protection was not directly linked with further invasion of the flood plain, although a policy of education about the flood hazard schemes could well accelerate the processes of invasion. As far as the business men were concerned, they were aware of the hazard but were generally contented with the current situation.

At the same time as Roder was investigating Topeka, Burton (1961) was carrying out a similar survey of the Little Calumet area in North Indiana. This flood plain area approximately one mile in length, had experienced frequent flooding, but unlike Topeka had recently seen new development on the flood plain. Burton also carried out a questionnaire study of a small percentage of flood plain residents, in areas exposed to varying degrees of risk from flooding. Like Roder, he found very little difference in the responses from the different areas, or even between different socio-economic groups. However, Burton did emphasise the significance of personal flood experience (over 50% had experienced flooding in the Little Calumet area) and in particular the severity of flooding experienced, and stated that this could be a major factor in efficient flood plain management. Both Roder and Burton, therefore, attempted to examine various aspects of the behaviour of flood plain residents. Roder looked particularly at the attitudes and knowledge of flood plain inhabitants to structural flood alleviation measures implemented at Topeka, while Burton carried out a similar study in the Little Calumet area. Although neither case study produced any distinguished findings, both studies did indicate the importance of behaviour of flood plain residents in any appraisal of the flood hazard.

From this time, the human element in flood plain management began to be taken more seriously, especially in terms of the effects upon the efficiency of flood alleviation measures.

Perhaps the most significant work into the factors governing decision-making on the flood plain, both in the public and private sectors of the community, was undertaken by White and Kates in the early sixties. This work was more sophisticated and more detailed than the previous studies, and therefore represented a major advance.

The research by White and Kates involved a detailed analysis of the town of La Follette (Tennessee) followed by comparative studies of five other towns, where the frequency of flooding was either greater or less than in La Follette. These included Darlington (Wisconsin) and Aurora (Indiana) where the flood risk was greater; El Cerrito (California) which was about the same as the original study in flood frequency; and Desert Hot Springs (California) and Watkins Glen (New York State) where the flood risk was less and the frequency of flooding somewhat unpredictable.

Kates (1962) devoted his attentions to the private sector of the community and the response of individuals to the flood hazard in the six towns. He believed that it would be through a greater understanding of the working of individual behaviour patterns, and the factors which govern individual decisions to locate in hazardous areas, that improvements could be made in flood plain management, so that flood losses could be reduced. Kates outlined four principle factors, which he saw as playing a major role in controlling individual decision-making. First, he stated that man is not rational in his decision making, and even with further education could only move towards greater rationality. Here Kates suggested the use of the concept of 'bounded rationality' a theory which accepts that the simplified model of a given situation in most peoples' minds may well be biased when making a decision. Secondly, Kates saw three types of choice processes involved in decision making : conscious, habitual and unconscious; where each individual decision would be the product of one or more of these processes. For example, he saw resource allocation as a conscious decision to consider all the relevant variables in order to produce an overall optimum plan. However, this could in itself unconsciously include a third factor - degree of knowledge. For instance, through ignorance of the full implications, a 'rational' decision could be made based on only partial knowledge of the full facts, which would probably result in unsound decision making. Furthermore, in areas of great uncertainty, Kates claimed there was a tendency to resort to habitual processes and to rely on tried and proven techniques, rather than fully investigate the new situation and then formulate original plans.

Finally, Kates considered evaluation of the hazard and the effects this could have on the decision making. For example, if evaluation of the hazard was to be assessed in economic terms then a flood could well be classed as catastrophic. However, if the individual only perceived slight losses or merely inconvenience from this potential flood, then he could well make an uneconomical response to the hazard.

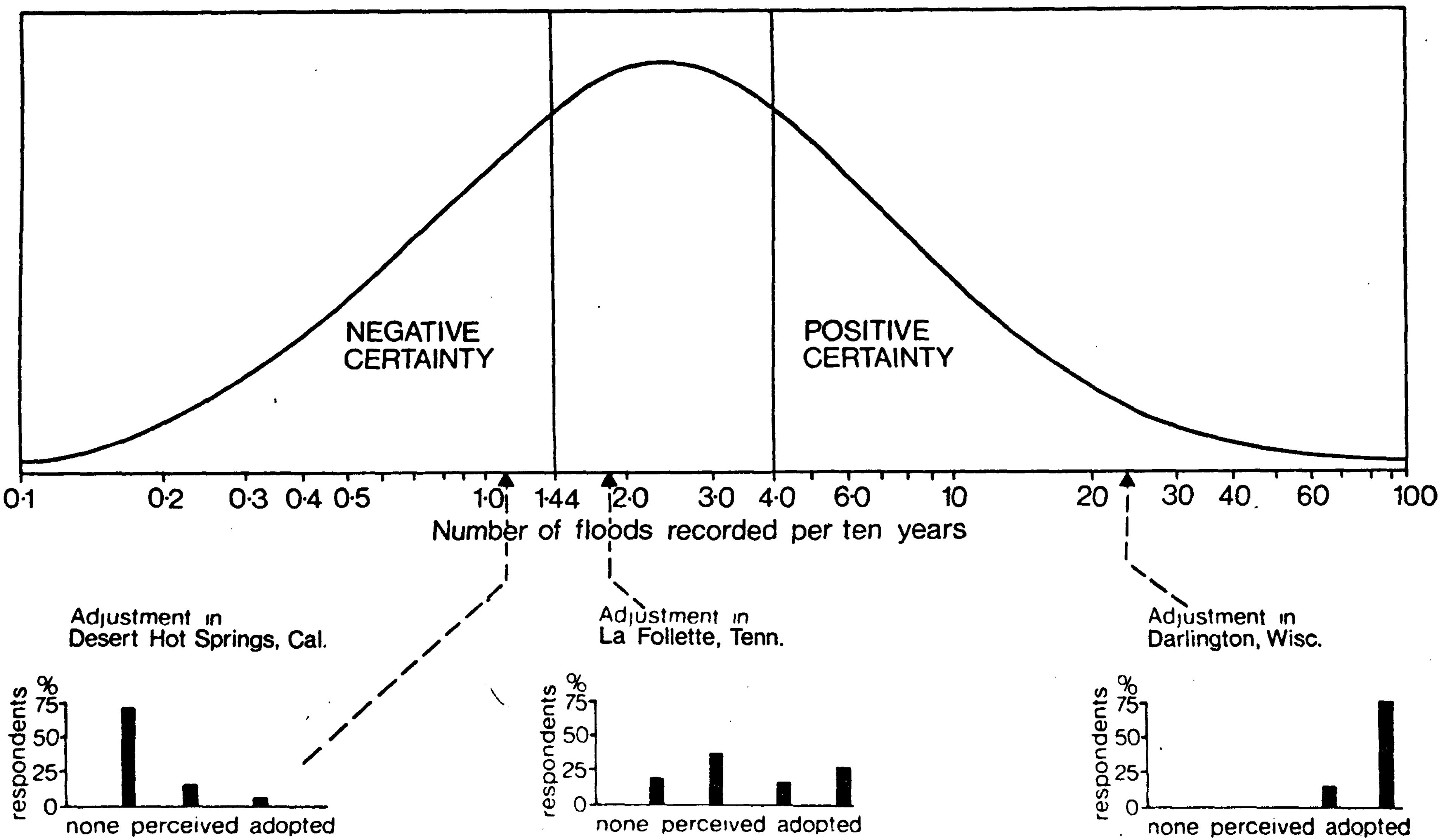
Using these basic hypotheses and concepts, Kates carried out a questionnaire survey of La Follette and further comparison studies at the other five centres, to try and establish the degree of knowledge of the hazard, the range of experience of flooding, and the attitude and response to the flood hazard, of those people who lived and worked on the flood plains. In an analysis of his initial study at La Follette, Kates found that the majority of respondents were aware of the flood hazard, but that only 40% expected any future flooding. There was a tendency to see flooding as 'unique' or 'freak' events that would never happen again at least not within the respondents lifetime. There were, on the other hand, a few who believed that flooding was a serious recurring problem, and the estimates of the frequency of future flooding by this group were higher than those calculated for the area.

Commercial managers were for the most part more aware of the actual risk from flooding than the residential groups, but as was found in Topeka by Roder (1961) there was a tendency towards overall satisfaction and to feel personally exempt from the problem. Several other relationships were discovered by Kates, for example, between the expectation of future flooding and estimates of the frequency of flooding, between awareness of flood protection works and a negative expectancy of future flooding, and between awareness of the hazard and geographical proximity to the hazard. Conversly, he found no relationships, which might have been expected, between the expectation of future floods and such variables as the knowledge of the flood hazard, education of the respondent, and length of residence in the flood prone area.

Following this initial survey, Kates compared his results with similar studies at the other five centres. In the higher risk areas of Darlington and Aurora, the expectation of future flooding was fairly high and the flood plain residents had responded to this by making some adjustments and preparations for future flooding, while in the lower risk areas the expectation of future flooding brought primarily a negative response, and, as would be expected, there had been no individual adjustments to the hazard. In La Follette and El Cerrito however, the respondents were mixed in their outlook, and the expectancy of future flooding was divided almost equally between positive and negative responses. Individual adjustments to the hazard within the communities was similarly mixed, with responses ranging from well planned remedial activity to general uninterest in the problem.

It was from these studies that Kates devised his Certainty-Uncertainty model, which essentially pointed out that environments experiencing more extreme conditions have a tendency towards the certainty end of the scale, while a more mixed environment may well tend towards the uncertainty as far as particular individual elements such as flooding are concerned (figure 2-1). For instance in the survey, Darlington and Aurora were high risk areas as far as flooding was concerned, and hence tended towards the certainty end of the scale; similarly Desert Hot Springs and Watkins Glen, where the flood risk was very low, would also tend towards this end of the scale. Kates saw the certainty end of the scale as producing fairly uniform responses within their own environments as far as perception of flooding and adjustment/non adjustment to the hazard was concerned. The results from the questionnaire surveys conformed to this hypothesis. In the intermediate areas, where there was greater uncertainty about flooding and the

Fig. 2-1. Certainty - uncertainty model of flood plain behaviour (after Kates, 1962).



probable risk, such as in La Follette and El Cerrito, the response to the questionnaire would also be more uncertain and show wide ranges in response to individual questions. It would appear from this that the further along the scale towards uncertainty is an area, so perception and response will become more and more wide ranging. It was this underlying orderliness of perception and response which proved to be one of the most significant findings of Kate's work.

Other major findings from this work by Kates were more specifically concerned with the behaviour patterns of individual flood plain residents. For example, he found that many people did not expect to be flooded in the future, or only expected minor losses from any inundation, and hence continued to live in these hazard areas. Even when someone did perceive a significant loss from flooding, the protective action implemented was often improvised, usually ineffective, and highly inefficient. More often than not the flood hazard was minimised or even totally ignored. However, in general Kates saw individual behaviour as primarily the result of personal experience and unconscious or habitual decision-making, rather than the conscious and rational evaluation of the facts, to produce the most economical decision. This was classed by Kates as the 'prison of experience' and he suggested that only when this was broken down, possibly by education, would individuals achieve a wider perception of the hazard, and hence modify their behaviour. This would hopefully bring about a reduction in flood-losses by a more rational response to the flood hazard. In conclusion, Kates stressed the need for education on the flood plain and further research into the factors influencing human behaviour.

White (1964) published the companion volume to Kates. This book dealt with the same six towns as Kates, but essentially looked at the workings of flood plain management from the aspect of the public decision-makers, rather than the private sector of the community. Using the wide variation in flood frequency between the six towns as the basis for his research, White looked at the workings of flood plain managers to discover what factors were considered, and how rational was the choice in the formulation of a flood plain policy.

White's basic hypothesis was that the efficient use of resources could only be achieved by the development of a cost-benefit analysis technique for guiding projects through public decision-making. In practice, of course, this was not the case since many non-rational decisions have been made in the past and are evidenced today by the ever rising flood losses. White, therefore, attempted to discover which factors influenced decision-makers, in order to explain past decisions as well as to improve future 'rational' decision making. Components he believed to be important were the value criteria set by the particular culture and influenced by public constraints, the political processes, and finally the failure of decision-makers to consider all the relevant facts. White also considered the subjective position of decision-maker and his personal perception of flooding and his own awareness of the range of alleviation schemes, and how these would also affect rational policy formation.

Basically, White saw four factors influencing public decision-making, including both political and psychological criteria.

(i) Perception of the hazard

(ii) Perception of possible adjustments

(iii) Technical feasibility

(iv) Economic feasibility

In his study, White first considered the economic aspects of decision-making by producing stage -damage curves for different types of establishment on the flood plain in La Follette. From this, he established theoretical solutions to the flood problem to test their relative efficiencies. He found, for instance, that engineering structures could prevent up to 40% of the damage accruing from the maximum probable flood, but that this would be too expensive to implement. Emergency action, given an efficient and reliable warning, was estimated to reduce losses by between nine and twenty percent, while other structural measures would be less efficient at five percent(although this would vary tremendously from area to area.) However, flood proofing could be very efficient and reduce losses by up to eighty-five percent, but this would require considerable preparation, as well as financial outlay by large numbers of flood plain residents prior to the flood. Zoning programmes and other alleviation schemes were found to be unacceptable in La Follette. In reality, White discovered that no one scheme could provide better returns than bearing the loss in La Follette, although emergency action did come fairly close. If a combination of schemes were employed then control of the flooding would be considerably more effective, but this would still only provide modest returns for the investment.

In comparing La Follette with the other field centres, White discovered that public response to flooding was very limited in El Cerrito, Desert Hot Springs and Watkins Glen, where there was a general tendency to rely on bearing the losses from the infrequent flooding. The only other 'adjustment' to the flooding in these areas was a general dependence on flood relief funds.

Only in Darlington and Aurora, where the threat of flooding was greater, has there been any public response to the flood hazard. This has taken the form of a dam and levee system in Darlington (as well as an emergency scheme) while Aurora has always relied on flood forecasting, emergency action, and smaller structural adjustments. It was noticeable that this trend of response coincided with Kates findings in the private sector, based on the certainty-uncertainty model .

In conclusion, White saw the La Follette response as perfectly acceptable and justified according to his own economic analysis, which showed that 'Loss-bearing' was probably the most efficient adjustment to the hazard in the town, even if this result had not been obtained by rational decision-making processes. However, like Kates he emphasised the importance of education on the flood plain as a means of achieving more rational flood plain policies. As a further technical point, White suggested that further research should be undertaken into the field of hypothetical flood-losses, so that flood plains could be divided into a series of hazard zones, which delimited different areas of potential losses. From such maps, he suggested, more rational decisions regarding future urban development could be made.

Sewell (1969) has looked at public decision-making on a much larger scale and at a higher level of government than White, with his study of the project for the Lower Fraser river valley. This 800 square mile area experienced widespread and catastrophic flooding in 1948, which effectively cut Vancouver off from the rest of Canada for thirty days. Following this, there was the usual furore and clamour for a flood control policy and eventually a scheme was proposed involving a combination of dams and levees, which would not only control the flooding, but also produce large quantities of hydro-electric power. In fact the scheme appeared, on the surface, to be the product of regional economic optimisation and a triumph for rational decision-making. However, there were serious drawbacks to the scheme which had not been fully investigated, such as the question of financial responsibility, the conflicting interests of both recreational facilities and fishermen with the implementation of dams and reservoirs, and the question of actual demand for the power produced within the region. All these conflicts have led to the indefinite postponement of the scheme.

There were many weaknesses to the decision-making processes involved in the production of the original plan, according to Sewell. Firstly, the concentration on such a narrow range of adjustments led to highly inefficient policies, which, when blocked, resulted in the total stagnation of the project. Secondly, the flood protection offered would have encouraged further flood plain development, and hence any flood plain policy should have taken account of this process, by including some form of land development control. In fact, while the scheme was being considered, the proponents of the flood alleviation scheme were recommending zoning restrictions on the flood plain, while the Development Board were actively encouraging encroachment into flood prone areas. Sewell's final point was one of responsibility. The failure to establish firmly the different responsbilities within the project, especially that of finance, has also led to inaction due to the continuing political and financial wranglings of the various bodies involved. In conclusion, Sewell outlined a few problems of flood plain management particularly relevant to large scale projects; factors other than perception, which should also receive some attention in any flood plain management study.

Other studies into the workings of flood plain management have been carried out in the U.S.A., including those by Pierce (1970) into the flood plain management project for Aitchison (Kansas) and Weathers (1965) into the decision-making problems of the divided town of Bristol (Tennessee) and Bristol (Virginia). Weathers began his work with a short appraisal of the measures available to the flood plain planner to prevent flood damage, and an outline of some of the typical problems of decision-making, such as the lack of liason between river authorities and town planners. This has meant that projects have been selected in the past without due consideration to all the relevant data.

The work by Weathers on Bristol showed how, despite the failings of past techniques, and despite the added problems of two different state governments controlling the two halves of the town, it was still possible to produce a joint scheme involving a combination of adjustments to the flood hazard. Despite these apparently severe handicaps, Weathers pointed out that the decision-makers in the two halves of the city had organised themselves into a Flood Study Committee, which had produced a comprehensive alleviation policy involving two dams, the improvement of river channels, the replacement of some bridges, the strict enforcement of flood plain regulations and the active encouragement of flood proofing techniques. Even the financial requirements had been discussed, with nearly three million dollars coming from the Tennessee Valley Authority, nearly three hundred thousand from the Tennessee part of the city, and three hundred and fifty thousand dollars from the other. Unfortunately, there has as yet been no investigation into the efficiency of the schemes to see how far the decision-makers overcame all the problems, and to what extent a rational decision was made.

More recently James et al (1971, 1974) and his team from Atlanta, Georgia Institute of Technology, have carried the work of White and Kates much further than any previous studies. Essentially, they have looked at the attitudes and perceptions of the private sector of the community, and the implications this would have on the workings of public decision-making. James stated that the goal of the flood plain manager was to reduce the adverse effects of flooding by modifying human behaviour on the flood plain, which he saw as the root cause of all flood losses. The formulation of an effective combination of incentives and control therefore, required an understanding of the particular people involved, the reasons which motivated flood plain settlement, of the perceptions and attitudes towards the hazard, and of the kinds of communications likely to dissuade further encroachment. To analyse these problems, James saw various levels of decision-making affecting flood plain settlement. These were (i) individuals seeking a residential location, (ii) individuals engaged in land development and construction activity, and (iii) individuals charged with the responsibility of formulating and implementing public control policies at various levels of government.

Using Atlanta (Georgia) as a study area, a town which had experienced five recent floods, James carried out a long questionnaire survey of nine percent of the flood plain population. Results of the survey showed that forty-three percent had knowledge of flooding before locating in the hazard zone, and that eighty-nine percent expected to be flooded at some time in the future, or at least within the next fifty years. Despite this, given the same choice sixty-three percent would relocate in the same house, with only fifteen percent positively considering moving away. These figures contrast with the previous results of Burton, Roder and White, where the expectation of future flooding was much lower. The implication of these results according to James was, should people be restricted in their location if they were willing to endure the problem and losses from periodic flooding?

James' work went into even greater details of residential behaviour patterns and characteristics of the flood plain inhabitant than any previous study, to try and establish the real factors governing different levels of decision-making. This extensive questionnaire, with over two hundred questions, was used as a means of assessing these underlying factors influencing perception and decision making. The results of this are too long and involved to consider here, but they are used in comparison with this work in chapter eight.

In conclusion, studies of flood plain management outside the British Isles have been confined almost entirely to North America, from the early sociological research into the behaviour in two communities during the Rio Grande flood, up to the current complex research by James into the workings of perception and response by individuals living in flood prone areas. Roder, Burton and Kates have all looked at the private sector of various communities and have indicated how important perception of the hazard, as well as the actual experience of a flood event, can be in influencing individual decision-making on the flood plain. White, Sewell, Pierce and Weathers on the other hand have considered the public sectors of different communities and have outlined the difficulties of making a rational choice in the selection of flood alleviation schemes. It would seem from these studies that perception may play an important role in decision-making at all levels of government.

In the U.S.A. the importance of these psychological factors in flood plain management has been clearly demonstrated by the American authors. Also, if flood-losses are to be effectively reduced, then further research is generally accepted as necessary to understand fully the workings and processes involved in flood plain decision-making. Similarly, since all schemes will be affected by the actions of flood plain occupants, further research must also be undertaken into the private sector of the community to discover the real factors governing individual decision-making on the flood plain. With further information, then, on perceptions and attitudes towards the flood hazard of both policy makers and individuals, it may be possible, along with the other feasibility studies, to produce a rational choice of flood alleviation schemes, and thus reduce losses accruing from flooding. However, until there is a fuller understanding of these underlying processes, the chances of selecting the optimum combination of flood alleviation scheme must remain to a certain extent in the realms of chance.

Great Britain

Research into the complexities of flood plain management in Great Britain is somewhat restricted, and the important psychological factors, such as perception of, and attitude towards the flood hazard, have tended to be overlooked in favour of research into the physical characteristics or technological feasibility of different alleviation schemes. While there has been some interest in economic criteria by Chambers (1975) Chambers and Rogers (1973) and Penning-Rowsell . (1972), psychological factors have received only scant attention by British workers. However, it is hoped with the increasing emphasis on non-structural alleviation schemes, which rely on correct rational behaviour before, during and after the flood event, the significance of these parameters will become self evident, a situation which has indeed arisen in U.S.A.

Burton (1961) was probably one of the first to consider the problems of flood plain management in this country. His study outlined a few of the problems facing decision-makers in Britain, such as the narrow safety margins of the Medway Letter line and the financial restrictions on any scheme. He was primarly concerned with the workings of the various organisations in Britain and how a flood plain policy was formulated.

Since those early days, two separate studies in this country have looked at the problem of decision - making in greater detail - one at Shrewsbury and the other in the Lower Severn Valley. Firstly, Harding, formerly of the University College of Swansea, has developed research into the Shrewsbury area and has produced several papers to this effect. (Harding and Lillicrap 1973, Harding and Parker 1972, 1975).

In his study, Harding used the physical characteristics of flooding based on his previous work (Howe et al 1967) to define the flood hazard areas of Shrewsbury. Having identified the research area, he proceeded to carry out a full questionnaire survey, similar to that undertaken by Kates, of residents living in flood prone areas. From the initial studies, it was established that the research area was principally agricultural and recreational, although there were nearly two hundred buildings exposed to the flood risk, which had been inundated in 1961 and/or 1964.

Results of the questionnaire survey indicated a very low awareness of the flood hazard in Shrewsbury, with over half of the respondents replying negatively to the question 'Is there a flood problem in the area?' As far as expectation of future flooding was concerned only 26.7% believed the area would flood again. It is noticeable that these figures of awareness differ significantly from those found at La Follette by Kates, and yet the figures regarding future flooding were more alike (27% to 40%). Also in contrast to some American studies, Harding found a strong belief in flood protection works at Shrewsbury, unlike Roder in Topeka where there was apparently very little faith in the protective works. Unfortunately, in Shrewsbury this represented undue faith in the Clywedog Dam. Located 122 kilometres upstream of Shrewsbury and controlling only 2.5% of the drainage basin, the dam would have only minimal effect in reducing flood peaks in Shrewsbury. However, there has been no other major public response to the flood hazard, apart from the implementation of a flood forecasting and warning scheme in the late 1940's, and hence this strong belief in safety could have a catastrophic effect during the next flood, particularly if future flood warnings are not treated seriously.

Individual response to the flood hazard has been minimal, with most residents adopting the negative attitude of relying on remedial action prior to any flooding. This response was not really surprising, since there was such a low assessment of the flood risk in Shrewsbury. The only other response in the town has been the attempt to prevent new buildings having floors below the levels of the 1946 flood limits.

This study is not complete, for a full appraisal of the questionnaire results is necessary to determine some of the characteristics of residents living in flood prone areas. However, the research has already provided some quite significant results, not least being the contrast with American findings on perception. This stresses the importance of further studies to discover the underlying factors influencing decision-making in Britain.

There were several drawbacks to the Shrewsbury study, one being the complete lack of alternative studies for comparison purposes. Nevertheless, the work has provided the impetus for further research and will now stand on its own as an example of research into the workings of flood plain management in Britain.

Other weaknesses in the study could be the lack of depth in the investigation, but since this was such original work in Britain, this criticsm would be unfair. However, further thought, particularly in follow up studies, should be given to other relationships, and the establishment of other trends. For instance, would there be a difference between the responses of people from areas of different flood frequency; is there a significant difference between the behaviour patterns of different socio-economic groups; what factors control the decision-making processes of the industrialist or small business man, and finally what really governs the decision-making of the public flood plain managers in Britain? There is, therefore, considerable scope for further research in this field.

The second major research contribution in Britain, to this aspect of flood plain managment, has been undertaken by the Middlesex Polytechnic Research Team under the leadership of Penning-Rowsell. This team has produced a series of Reports, Penning-Rowsell (1972), Penning-Rowsell and Underwood (1972), Penning-Rowsell and Parker (1972, 1973) and an article in 'The Planner', (1974) in conjunction with their work on the Lower Severn Valley. This work, again, is very much in the early stages and does have a tendency towards the economic aspects of decision-making, rather than the psychological criteria currently being considered.

A pilot study was originally carried out into the Lower Severn - Tewkesbury area, and like Harding's work utilized the Kates survey as the basis for the questionnaire design. The questionnaire in fact included four types of questions: (i) questions on general environmental problems to put flooding in its true perspective for the area; (ii) questions on past flooding to provide basic statistical information on details such as depth, duration and damage; (iii) questions on the adjustments to flooding and the faith the residents have in these schemes, and finally (iv) questions on the social and economic characteristics of the respondents. The pilot survey included a seven percent sample of the flood plain population, which resulted in nearly seven hundred interviews.

The results of this survey are biased to economic considerations, but several other significant considerations have arisen from the study. For instance, Middlesex Polytechnic found certain comparisons between their own work and the work of Harding in Shrewsbury. Both studies, for example, exhibited a very low awareness of the flood hazard, and a correspondingly low perception of future flooding. It would appear, therefore, from these initial results, that residential behaviour patterns are different in Britain from those in the U.S.A., where apparently awareness of flood problems is considerably greater. However, further evidence is required to confirm, or refute, this thesis, since to date, research has not been undertaken in strictly comparable settlements in terms of flood frequency and severity.

The results of Middlesex survey have still not been fully analysed to give any indication of the controlling influences behind the individual decision-making processes in responding to the flood hazard. This research, however, appears to be moving away from the psychological aspects of flood plain management towards the economic factors - another area of flood plain research which has received only limited attention in Britain in the past. It is quite likely, therefore, that this work will not develop into a more complex analyses of the workings of those parameters which influence decision making. However, as with the Shrewsbury study, there are several drawbacks to the research, but the Lower Severn pilot study will stand as an important case study for comparison with future research projects. Both Harding and Penning-Rowsell therefore have set the scene for further research, and provided case studies and examples, which later researchers may follow in any appraisal of flood plain management techniques. The most recent survey undertaken in Britain, which has only recently become available, was carried out by Parker (1976). This extensive work shows a logical development to the previous British studies, described above, examining the various aspects of flooding not previously considered in this country. These included the problems of flood damage assessments and studies of residential perception of the flood hazard. Parts of this survey are directly comparable to this research, particularly those aspects of residential behaviour, and hence are included in chapter eight for comparison purposes rather than a direct review here.

PART II

THE BRITISH CONTEXT

CHAPTER THREE

THE FLOOD PROBLEM AND THE RESPONSE TO THE FLOOD HAZARD IN GREAT BRITAIN

Introduction

On the national level several fundamental differences can be seen between the flood environments of the U.S.A. and those of Great Britain. These differences range from the physical characteristics of the flooding, particularly regarding 'time to peak' and 'duration' parameters, to the human response to the hazard. The response in the U.S.A. has involved a wide range of flood alleviation schemes, especially in more recent years with the emphasis on combined projects which may incorporate a variety of measures. In Britain a more limited attitude to flood alleviation has developed, incorporating only a few of the many adjustments available. Nevertheless, this somewhat narrow approach to the flood hazard has produced, in flood forecasting and warning systems, a highly developed and technically advanced alleviation scheme.

This chapter, therefore, examines the problem of flooding in Britain, followed by an analysis of the response to the hazard to show how trends in flood plain management have changed in recent years, particularly in the development of non-structural measures. This entails an investigation of the physical characteristics of the hazard as well as the particular social, financial and legal restraints involved. The whole range of flood alleviation schemes is considered, with a general assessment of the extent of utilization of each in this country.

The physical environment

When considered on a general level, the flood hazard in Britain differs from that in the U.S.A. in several ways. The flooding in North America is very often large scale and extensive, covering wide tracts of flood plains, and lasting for considerable periods of time. In Britain, the reverse tends to be the case; small upland basins, often intrenched due to post-glacial uplift, produce highly responsive streams which cause flooding of the narrow flood plains downstream, but only for a short duration. Naturally, there are many exceptions to these observations, but on a superficial level the most damaging floods in the two countries do have the above characteristics. The important differences would appear to be 'time to peak discharge', 'duration' and the spatial 'extent of the flood', although there may be significant variations between other factors, such as 'velocity', 'wave-action and turbulance', and 'sediment yield' on a more local level (see Appendix I for definitions).

Other factors have also combined with these physical characteristics of flooding to bring about the differences in response. For instance, the general environment in the U.S.A. is far more diverse than in Britain, and thus lends itself to a more varied response; the limited conditions in Britain appear to have produced a very narrow response. Even the materials used in buildings may have had some effect. For example, in the U.S.A. wood was for a long time the predominent construction material, and hence houses subjected to flooding would suffer serious damage. There are even reported cases of houses floating away during larger floods. On the other hand, the brick and stone buildings of Britain can withstand both greater depths of flood water and higher velocities. These differences may have resulted in calls for large scale structural measures in the U.S.A., while in Britain there was considerably less concern by flood plain residents.

Management of the flood plain environment

Management of flood hazard areas also varies between Britain and the U.S.A. The U.S.A. has fewer restrictions on flood plain development, although a flood zoning policy may encourage fairly strict administrative control of flood prone areas. In Britain, where planning laws have been implemented since the 'Town and Country Planning Act' (1947) and where water bodies, beginning with the Drainage Boards have operated since the 1930's, a comprehensive structure for flood plain management has, with a certain degree of reorganisation, gradually evolved. Unfortunately, this planning structure has proved largely ineffectual to date, because of the inadequate consideration of drainage problems, and the blatant disregard for liaison between the various responsible bodies. While the structure exists for potentially efficient flood plain management, the present policies are generally ineffective.

Financial sources have also differed. In the U.S.A. finance is obtained for alleviation schemes from three levels of Government : Local, State, and National, as well as from other inter-state organisations such as the Tennessee Valley Authority. This authority was in fact responsible for many of the large scale structural alleviation schemes implemented during the 1930's. In Britain, the funding of schemes has always been considered the responsibility of the Local Authority, unless of national significance, when the Central Government has helped. Large cities with major flood problems have frequently come into this category, such as London, when joint funding of projects has been proposed. However, recently certain Government departments have actively encouraged flood alleviation works; for example the Ministry of Agriculture Fisheries and Food has provided a fifty percent grant for flood forecasting and warning instruments since the late 1960's. Nevertheless, the lack of any organised body responsible for overall flood plain management, like the Tennessee Valley Authority, has undoubtedly been one of the reasons for the ad hoc response to the hazard in this country. Current changes in Local Administrative boundaries, and the reorganisation of the twenty-nine River Authorities into ten Regional Water Authorities may well allow more comprehensive policies to be implemented in the future.

The ever changing social, financial and political factors have played an important role in determining the management policies towards the flood hazard in Britain over the years, although it should be remembered that this has only been the result of the stimulus of a long history of flooding. For instance, major floods have been recorded as long ago as the ninth century on the River Thames (Brookes and Glasspoole 1928) while other significant events have occurred in the years 1663, 1852, 1875, 1877, 1894 and 1928. Brookes and Glasspoole also quoted the catastrophic flooding on the River Severn in 1770 and 1886, and in Scotland in 1829, 1849, 1863, 1892, 1914 and 1920. Radley and Simms (1971) similarly studied the flood problem in Yorkshire between 1315 and 1968. However, probably the most significant flood years in any consideration of the current response to the flood hazard have been those of the twentieth century, and in particular 1947, the early 1960's and 1968.

These have produced not only the most damage in monetary terms, but also the biggest response to the hazard.

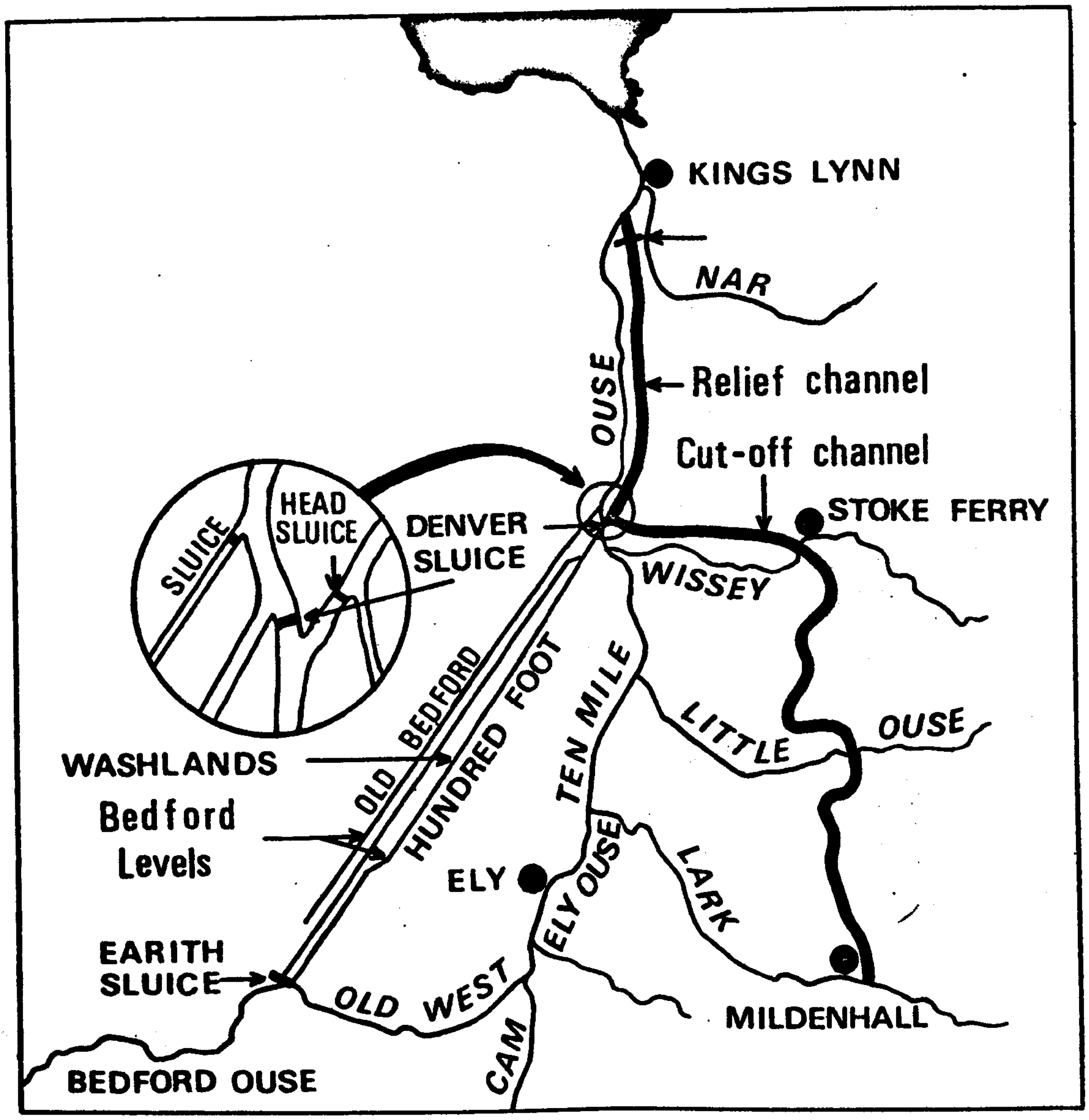
In conclusion, the response to the flood hazard has varied to a certain extent, although there has been a definite emphasis on small scale structural adjustments, such as embankments, and more recently a trend towards more sophisticated non-structural adjustments. This variation in response has developed because of contrasts in the physical parameters of the flooding and the changes in administration and politics. Thus, there now follows a brief discussion of both structural and non-structural flood alleviation schemes, which can be found in Britain.

(A) Structural Alleviation Schemes

(i) Channel modifications

These schemes have received very little attention in the past, although there are examples of each of the types described by Nixon (1966) in the country (see figures 1-3, 1-5 and 1-6). For example flood relief channels have been cut on the River Welland at Spalding and on the River Lee at Walthamstow , while intercepting channels have been constructed at Dunster and Minehead (Nixon, 1966). Morgan (1969) also quoted the example of the Fens drainage works where there have been two attempts at flood alleviation through channel adjustments. The first in the seventeenth century was constructed by Vermuyden and involved two channels approximately thirty-four kilometres in length which intercepted the flow of the main river (see map 3-1). The second scheme, undertaken this century, cost £8 million and involved the construction of a relief channel from the sluices at Denver to the sea beyond Kings Lynn; the straightening of the Ten Mile River and the Ely Ouse, and the cutting of a channel to intercept the waters of the Lark, Little Ouse and Wissey. This response to the flood hazard is fairly expensive and is normally only justified where large populations are at risk and the physical environment restricts the implementation of schemes, or by protection of valuable agricultural land. As a result, all the examples of such schemes in Britain can be found in the lowland areas, where the topography is relatively flat with wide flood plains.

Channel enlargement and channel straightening are more common, and many of the major British rivers have been adapted,



Map. 3-1. The Fens flood relief schemes (after Morgan, 1969).

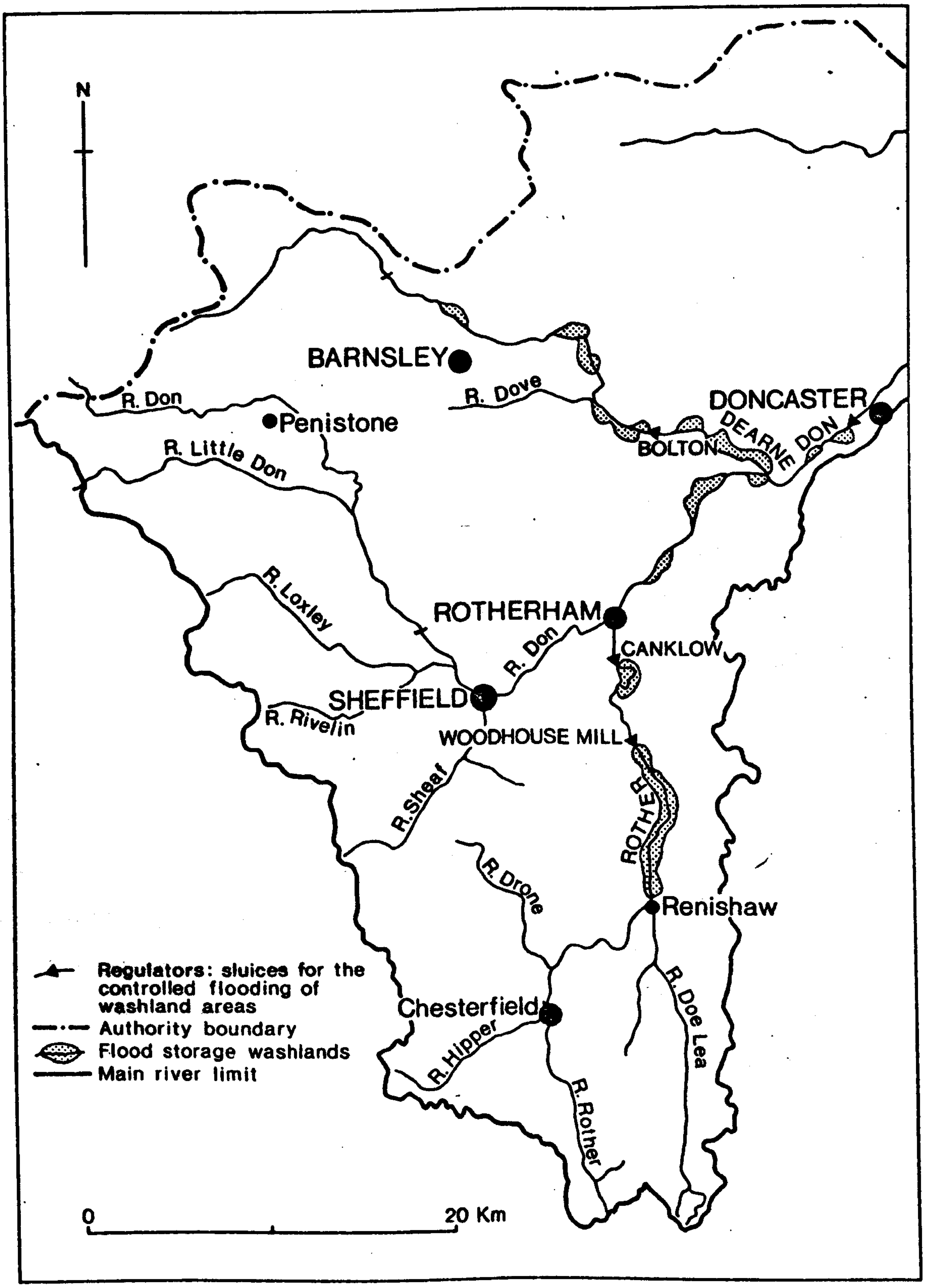
to some extent, by such alleviation policies. For example, the River Don at Doncaster, the Avon at Bath and Bristol, the Tame at Birmingham, the Leen at Nottingham, Bentley Brook at Matlock and the River Thames at London show the various scales on which such canalisation schemes have been carried out in this country. The more complicated adjustment incorporating compound channel cross-sections are also fairly common. Sibbald (1970) described the case of the River Crouch in Essex, Butler (1972) the example of Chelmsey Wood, while Skeat (1969) examined the case of Pymme Brook at Tottenham.

These channel adjustments typify the ad hoc policies of the past, where small administrative units with only limited responsibility and restricted finance, implemented individual structural measures to protect their respective areas. These policies showed little or no concern for the effects on other parts of the drainage basin. In fact, in many cases these policies must have exacerbated flooding downstream by pushing the water rapidly downstream during periods of peak discharge. Thus, it would appear that no general policy has evolved in Britain for two reasons. First, the administrative structure has been limited to small parts of the catchment and hence no general policy could be easily developed, and secondly, financial sources have frequently been inadequate for such expensive schemes.

(ii) Embankment, levees and washland schemes

Embankments levees and washland schemes have been utilized in a variety of ways, and on a larger scale than any other structural flood alleviation measure in Britain. The rapidly rising floods of short duration inherent in the country, added to the physical nature of the flood plain, and the necessity to prevent flood waters spreading much further than the main channel because of the high degree of urban development on other parts of the flood plain, has encouraged the employment of levee systems. Embankment schemes are also ideally suited to the British administrative structure, because they are both cheap and relatively simple to construct; they can be used to protect quite small areas, and providing they are well maintained will operate most effectively up to the design standards of the project. The problems of land-ownership and 'rights of way' are also kept to a minimum because such schemes do not require large tracts of land.

Embankment schemes have a very long history and can be found throughout the country ranging in scale from the large features in several major cities, to smaller works protecting towns and villages or even fields. For example, London has been protected by such an adjustment since 1874, when the present defensive structures were completed. Other large settlements protected in this way include Nottingham, Sheffield, Doncaster, Gainsborough and Newtown in Wales, although these represent only a small proportion of the total number of embankment schemes in Britain. The Doncaster scheme is a fairly extensive project, which incorporates both flood embankments and washland areas to control flood flows through the town (map 3-2). Poor drainage policies in the seventeenth century, and more recently the subsidence of land due to the collapse of old mine workings had aggravated an already serious flood problem in Doncaster. To combat this, old flood banks, remnants of an earlier nineteenth century adjustment to the hazard, were raised and strengthened, while new banks were



Map. 3-2. The Doncaster washlands scheme (after the Yorkshire River Authority).

constructed upstream to form washland areas, where water could be stored during times of peak flows. The Doncaster scheme also involved some river course alterations below the town, which combined with the 64 kilometres of embankments cost £1.6 million. The Yorkshire River Authority (personal communication 1974) estimated that these washland areas could store approximately 9,500,000 m^3 of water, which would reduce peak flows in Doncaster by 113 m^3/second. In the natural state, without proper water management incorporating controlled flooding of the washland areas, it was estimated by the River Authority that the effect would be less than 14 m^3/second.

Other flood embankment schemes have also involved more sophisticated forms of water management than required by a straight forward levee system. For instance, pumping stations may be used to return water to the channel side of the defensive structure, thus reducing flood levels in the area to be protected. Nixon (1966) quoted the case of the River Birket and River Fender pumping schemes. Another example of the use of washland/storage areas was described by Thompson (1966) concerning the River Gray. On this river during flood flows, excess water is channeled into two disused ballast pits, where it is stored until the threat of flood has passed. Although these two schemes may add to the efficiency of embankment systems, they both require careful water management to be entirely effective.

(iii) Flood storage reservoirs

Reservoirs have never been implemented in Britain for the express purpose of flood alleviation, although certain water supply reservoirs have an element of flood control written in to their operational procedures. Several factors account for this general lack of attention to flood storage reservoirs, not least being the very high construction costs associated with such single purpose schemes. A second factor is the scarcity of suitable reservoir sites, since there is little advantage in inundating a large area of land to protect other areas of only slightly more value. In Britain only the headwaters of certain rivers fulfil this requirement, and a dam located in such areas would only have a minimal effect on the flows any distance downstream. Also in eastern England, where the need for flood protection is high, neither the terrain nor geology are ideal for reservoir construction.

Multi-purpose reservoirs do operate in Britain, although there are still only a few which have incorporated flood control into the design of the project. It is only in multi-purpose schemes that flood storage reservoirs may be justified on economic grounds. However, very few such schemes can be found in Britain, despite the advantages of controlling floods in this way. The Bala Lake system on the River Dee in north Wales is one example (Cooke and Dornkamp, 1974) although the effectiveness of the flood control aspect is somewhat impaired by the long term strategy which gives priority to water supply. The Thames Water Authority (1975) also use urban reservoirs to retain water during flooding.

One further aspect of reservoirs is the inadvertent effect of water supply and hydroelectric stations on the river flows downstream. The construction of a dam across any river will alter the timing of the river automatically, and according to Laurenson

(1973) reduced the frequency of smaller floods, especially in those areas immediately below the dam. Thus, a certain amount of flood protection is probably forthcoming from other apparently unrelated structures. Nevertheless, it is unlikely that reservoirs will ever be constructed purely for flood control in Britain, because of the recent trend away from these large scale structural measures, to smaller more flexible non-structural schemes.

(iv) Flood proofing

Flood proofing has never really been considered a viable flood alleviation scheme by flood plain managers in Britain. As a result, there have been no flood proofing programmes, where proofing techniques are actively encouraged by the local authorities to counteract rising flood losses, and examples of independent actions are also quite rare. Shell House in London (described in chapter one) is the only major project which can compare with the American proofing policies for the comprehensive protection of a single building (Porter 1970). Other minor schemes have been undertaken, such as the flood proofing of a factory wall at East Butterwick, although this was really part of the Trent River Authority flood alleviation programme rather than purely to protect the factory (Butler 1972, b). Harding and Parker (1975) described the more permanent proofing measures in Shrewsbury, where new buildings in the flood prone areas are required to raise floors above a minimum level.

Examples of flood proofing can also be found in the private sector of the community, with individual adjustments to the hazard.

Butler (1972) cited the case of a house with a low retaining wall at Fiskerton on the River Trent, while a similar example has been noted near Drymen on the River Endrick flood plain in Scotland (Smith K. (1976) personal communication). Relph (1968) found further examples of flood proofing in the villages of Devon, such as the blocking of air vents or sealing of floor boards. Some residents had even prepared their doorways with slots into which boards were placed prior to a flood.

In general, flood proofing has received only cursory attention as a flood alleviation measure, which is somewhat surprising considering that proofing could be a most effective adjustment in 'typical' British flood conditions. There are three probable reasons for this. Firstly, to employ temporary flood proofing measures an adequate flood warning must be given to the flood plain inhabitants, which unfortunately was not always available, particularly in the past. Secondly, there is generally a complete lack of awareness of the range of possibilities in flood proofing, by both the authorities and individual flood plain residents. Thirdly, many flood proofing measures may not be undertaken because of the behavioural attitudes of those persons living in the hazard areas. For example, Burton et al (1968) classified flood plain residents into certain types according to how they perceived the flood problem, (see table 3-1).

Table 3-1 : Common Responses to the Uncertainty of Natural Hazards (after Burton et al 1968).

RESPONDENT TYPE	ATTITUDE
Eliminate the hazard	
Deny or denigrate its existence	"We have no floods here only high water".
	"It can't happen here".
Deny or denigrate its recurrence	"Lightening never strikes in the same place twice".
	"It's a freak of nature".
Eliminate the uncertainty	
Making it determinate and knowable.	"Seven years of great plenty... After them seven years of famine".
	"Floods come every five years".
Transfer uncertainty to higher power	"It's in the hands of God".
	"The Government are taking care of it".

It is fairly clear from this, that those respondents who deny the existence, or recurrence of flooding will perceive little necessity for permanent flood proofing measures, and that the majority would be unprepared for temporary proofing procedures. Even those repondents who perceive future flooding may be surprised if the hazard recurs more frequently than the expected regular interval. Thus, the lack of attention in flood proofing adjustments appears to have been the product of early technical difficulties, unawareness of the different schemes, and general behaviour problems of flood plain occupants.

The limited measures undertaken by residents to date, would indicate a certain willingness to protect personal property, although the efficiency of some of these adjustments may be in doubt. Nevertheless, an active policy of education in this sphere could prove beneficial in these otherwise unprotected areas, and encourage others to adopt similar schemes.

(v) Flood abatement

Flood abatement policies, like those of flood proofing and storage reservoirs, have never been fully considered as a viable means of reducing flood losses, in the British context. Studies have shown quite conclusively that programmes, such as afforestation, will reduce flood peaks by delaying the transfer of water into the channel system (Watson et al, 1955; Molchanov, 1963; Law 1957). Initially, it might be added, that during the ploughing, seeding and tree sapling stages, flood peaks may well be exaggerated by a more rapid runoff, but this situation will exist only until a full canopy of leaves has developed. Further studies of the inadvertant effects of the recent massive afforestation programmes undertaken by the Forestry Commission would be most interesting.

Some River Authorities have considered the effectiveness of flood abatement policies, but none of them has implemented such a programme. The York (1974), Trent (1974) and Cumberland (1973) River Authorities (in personal communications) all intimated that flood abatement schemes would not be a viable alleviation policy for their particular areas. The general concensus amongst these River Authorities, was that such a programme would have to be so extensive as to cover virtually the whole of the catchment. The hypothesis was substantiated further by the findings of Crawford (1969) who suggested that major land-use changes would be required to alter the volume of run-off even by five percent.

In conclusion, the response to the flood hazard, in the form of structural alleviation schemes in Britain, has been restricted to a limited range of measures, notably flood embankments and levees, and channel straightening programmes. This contrasts quite significantly with the response in the U.S.A. where the diversity of flood environments has generally encouraged a wide range of adjustments. Other factors have also restricted the response in Britain, such as the administrative structure or financial sources, although the reorganisation of these now means that more attention can be given to the whole river basin rather than tackling, in an ad hoc fashion, the individual flood problems as they arise.

(B) Non-Structural flood alleviation schemes

It is in the field of non-structural flood alleviation schemes that Britain, in recent years, has established a more advanced pattern of adjustments to the flood hazard. Even in this sphere, though, the range of non-structural schemes employed has been restricted to one or two measures in particular, and these have not always been as efficient as was first anticipated. Nevertheless, the popularity of non-structural adjustments is increasing in Britain primarily because of two independent factors - the technological advances in recent years and the reorganisation of the administrative structure. Both these factors emerge from a review of the use of non-structural measures in Britain, especially the employment of flood forecasting and warning schemes. (The second half of this chapter is devoted entirely to flood forecasting and warning schemes because of the current importance of such measures in Britain).

(i) Loss bearing and flood relief funds

Loss bearing and the dependence on flood relief funds are still two very common responses to the flood hazard in Britain. This response is prevalent particularly in those areas where the River Authorities have not implemented other alleviation schemes, which generally entails those areas away from the main rivers and large urban centres. A second possible factor, which also may have encouraged this somewhat negative attitude to flooding, is the placing of unwarranted faith in certain structural measures, which may subsequently reduce the number of individual adjustments to the hazard. Alternatively a flood plain resident may have great faith in flood relief funds to compensate completely for any losses.

Flood relief funds are not very effective, in general, in alleviating flood losses, for according to Relph (1968), they rarely achieve even thirty percent of the total reported losses. Also, very few Local Authorities maintain funds for such disasters, and hence authoritarian aid is usually limited to emergency relief, such as accommodation, food, heating and other essentials for the flood victims. In the past, however, a few relief funds have collected money in excess of total damages; Chambers (1975) quoted the example of the Lynmouth Flood Disaster Fund of 1952. This fund eventually raised £2 million, which provided adequate compensation for the victims of the flood, but more significantly allowed the construction of a highly protective, structural alleviation scheme. According to calculations made at the time, the design standards of the project were so high that the benefit-cost ratio suggested the scheme was not economically feasible. Another major flood in 1962, not only proved the effectiveness of the scheme, since very little damage was caused, but also called for a reassessment of the return period calculations for such floods.

A loss-bearing approach to the flood hazard, although a negative attitude, is not necessarily an unsatisfactory response. Harding (1974) for example, claimed that loss-bearing was the only economically viable response to flooding in Shrewsbury. It would appear that in given situations, such as a fairly low flood frequency, where there are no large residential or industrial areas at risk, the benefit-cost ratio of any individual measure may be smaller than that obtained from loss-bearing. However, as was shown in the case of Lynmouth, these calculations are subject to a certain degree of error, and hence could produce a false result. Also, they take no account of the suffering and mental stress associated with living in a flood prone environment, and Harding did add that if a combination of measures were considered at Shrewsbury then a more effective benefit cost ratio might be obtained.

Loss bearing and flood relief are generally unsatisfactory responses to the flood hazard, since even individual remedial actions will reduce losses to some extent. However, if this approach is to be utilised, then advice should be given on how to cope with damage and losses from flooding. Cooke and Doornkamp (1974) suggested the guide for accepting loss from flooding produced by the U.S. Department of Agriculture, 'First Aid for Flooded Homes and Farms'.

(ii) Flood insurance

Flood insurance has been available in Britain since the 1920's, although it is only since the early 1960's that there has been an active policy to promote such a programme of flood alleviation. Flood insurance has developed fairly rapidly since 1929, when the general 'Household Coverage' was extended to cover storms, tempests and burst pipes, but not flooding, and by the 1940's there was a tendency to insure against various weather perils (Doublet 1966). In 1961, following extensive flooding throughout the country, the Ministry of Housing and Local Government approached the British Insurance Association in an effort to encourage flood insurance policies, and at the same time, Building Societies began to require flood insurance on certain mortgaged property. This provided the stimulus for an active flood insurance policy, which by the end of the 1960's included a large number of households throughout Britain. Currently, there are only a few areas in the country where flood insurance is not available; these include those areas subject to frequent inundation where there had been no structural response to the hazard by the authorities.

The standard rate for household insurance, which includes cover for flooding, tends to vary between different companies, although the British Insurance Association (1974 personal communication) quoted figures of £0.125% for buildings and £0.25% for contents. This cover excluded damage to fences and gates and the first £15 of any claim. Porter (1970) found similar figures for insurance premiums, and added that industrial and commercial properties would have to pay even more. For the payment of flood losses the official definition of a flood (according to Doublet 1966) is,

> "The destruction or damage by (a) the escape of water from the natural confines of any natural or artificial water course (other than water tanks, apparatus or pipes) or lake, reservoir, canal or dam, or, (b) inundation from the sea".
>
> (Doublet 1966, 18)

These standard flood insurance rates will vary, not only between different insurance companies, but also, to a certain extent, between areas subject to different flood frequencies. Porter stated that rates could increase by as much as fifty pence per one hundred pounds dependent on whether the area had been inundated or not. However, perhaps somewhat surprisingly, there has been little attention to accurate rating of the flood risk, particularly since flood frequencies can be relatively easily predicted, at least in comparison with other hazards such as fires. Hempsell (1962) pointed this out at an early stage in the flood insurance programme;

> "It is surprising that this state should exist in these progressive times, when of all the hazards accepted by material loss insurers, the risk of flooding is the one which can be assessed with some precision for any particular location".
>
> (Hempsell 1962, 115)

Hempsell further believed that 'the underwriting of loaded risks called for the calculated assessment of such risks.' Nevertheless, despite the early indication of the potential of flood insurance schemes, very little has been done to relate the premium to the risk. Indeed, the Policy Holder Insurance Journal (1974) recently published an article entitled 'Can the risk of floods ever be underwritten with scientific precision?' The article proceeded to point out that they actually developed a policy to do this. The paper ends,

> "To anyone who believes that the mathematical rating of risks must eventually come, the fact that anything so seemingly unpredictable

as floods can come down to a formula is a very big step forward indeed". (13.5.74).

Despite the general failure to relate flood insurance premiums with the degree of risk, flood insurance still appears to be quite profitable, for after thirty years there is no sign of companies relinqishing this business. Flood insurance cover is now fairly extensive, although Relph (1968) estimated that only fifty percent of the households in his research area of Devon were covered.

Accurate details of the value and effectiveness of flood insurance are very difficult to obtain in Britain, because insurance companies do not keep records for longer than three months, due to the expense of storage. Even the British Insurance Association (1974 personal communication) do not maintain records, because of the difficulties involved in comparing the various policies of the insurance companies. As a result, very few figures are available, and the best are only estimates of the compensation paid out by the insurance companies. Porter (1970) quoted a series of estimates for the East Coast floods in 1953, the West Country and Welsh floods in 1960 and the more widespread 1968 floods:

Porter (1970, 117)

	Actual damage	Estimated insurance paid
1953	£30 - 50,000,000	£6,500,000
1960	£10 - 11,000,000	£6,000,000
1968	£ 5 - 6,000,000	£3,000,000

These figures, although rough estimates, would indicate a general increase in the use of flood insurance, since the proportion covered by insurance has increased during this period.

In conclusion, flood insurance is now a fairly popular adjustment to the flood hazard, although the programme could be even more efficient if greater attention was given to accurately rating the flood risk by the companies themselves. A flood plain education policy would also make residents and industrialists aware of the availability of the scheme, and would probably encourage greater cover. Both the companies and the Ministry of Housing have placed the onus on individuals to take out insurance in the past(Porter, 1970) although it is conceivable that an active programme encouraging flood insurance would probably lead to even greater flood plain cover.

(iii) Flood plain zoning:

Conventional flood control measures can only serve to reduce damage after flood plain development, whereas flood plain zoning policies offer a more positive approach directed towards the modification of flood plain usage so that danger potential from the hazard is reduced or eliminated. Zoning, therefore, attempts to divide the flood plain into separate areas of equal flood probabilities, so that authorities can plan flood plain development according to the risk. Thus zoning and flood plain management policies are inextricably linked with the planning laws and the administrative structure of the country. In Britain, this structure has gradually evolved since the first Town and Country Planning Act in 1947, and now there exists a potentially strong administrative system for strict control of flood plain development. Despite this, a comprehensive programme of flood plain zoning has never been undertaken in Britain, primarily because of the attitudes of the two responsible organisations - the River Authority and the Local Authority. The short sighted policies of certain town planners in permitting further flood plain development in known hazard areas, and the almost total lack of communication between the Local Authorities and River Authorities has brought about the ineffectual policies of the past. These programmes of urban development have put even more property at risk from flooding and has been a principal cause of the rising flood losses.

Initially a crude form of zoning was followed by the authorities in adhering to the Medway Letter Line (1933) which proposed the restriction of new development in known hazard areas. However, this policy was only followed very loosely, and failed to promote any association between the two responsible authorities. It was not until 1947 that liaison between the Planning Authorities and Drainage Authorities was actively encouraged (Ministry of Town and Country Planning, First circular 1947). This circular stated,

> "There are many points on which Drainage and Planning Authorities can help each other in formulating their plans for future works, and there is a need for regular exchange of information between the two sets of authorities. The Minister is anxious therefore that Planning Authorities should at an early stage consult the local Drainage Authorities in order to find out which parts of their new development are likely to raise problems of drainage".

The second circular of the Ministry of Housing and Local Government (1962) reiterated the remarks of the other ministry on closer liaison, and also encouraged the River Boards to take the initiative and contact the Local Authorities; "River Boards should indicate where development would upset drainage and state their plans for alleviation, while Planning Authorities should consult the River Boards about their development plans". Further circulars (Number 76, 1969) by the same ministry on 'Natural Emergencies', called for similar liaison between the River Authorities and Local Authorities, while another (Number 94, 1969) called on Planning Authorities to consult the River Authorities concerning drainage problems.

While the Central Government has actively encouraged liaison between the responsible organisations in flood plain management, periodic circulars appear to have had little effect. As recently as October 1973, the Guardian newspaper (1973) reported the lack of co-operation between the various authorities.

> "Householders are being unnecessarily put at risk because some local authorities are allowing new housing development in areas liable to flooding. A call for Government designation of risk areas and tighter control of development is likely to provoke a political row between planning authorities and river boards and other interested bodies".
>
> (30.10.73).

Flood plains, therefore, have continued to be inefficiently managed, despite the continued attention of the Government, because of a blatant disregard for the flood problem by some

Local Authorities, and the inability of the responsible authorities to work together. Penning-Rowsell and Parker (1974) put much of the blame on the planners' poor appreciation of the flood hazard, rather than on the River Authorities. Application for developments in flood prone areas are frequently referred to the River Authorities (following the two Government circulars 52/62 and 31/47) but as Penning-Rowsell and Parker pointed out, this procedure is entirely voluntary and the Planning Authorities have no obligation to act on the findings of the River Authorities. They could not see this situation improving following the administrative reorganisations, for it will entail 10 Regional Water Authorities liaising with 332 District Planning Authorities and 45 County Authorities.

Consequently, flood plain encroachment by urban development has been fairly widespread in Britain. For example, on the River Thames, Maidenhead, Oxford, Reading and Windsor have all seen residential expansion on to lands flooded in 1947. In contrast, there are very few examples of flood plain zoning policies, although some authorities are now begining to exhibit more control. In Nottingham, a zone designated as prone to periodic flooding has been excluded from further development plans, while Harding and Parker (1975) noted the restrictions on further development in Shrewsbury, although this only put a limit on minimum flood levels. Flood plain zoning would be a relatively easy policy to adopt in Britain, because the machinery and structure for implementing such measures is already in operation. Only a positive flood plain management programme is required so that flood plain regulations could be strictly enforced. Since the rising flood losses have been partially blamed on flood plain encroachment, zoning would seem to be an immediate requirement to stop this trend.

(iv) Flood forecasting and warning schemes

Flood forecasting and warning schemes have become progressively more prominent in Britain, particularly over the last fifteen years, and now must rate as one of the most important forms of flood alleviation in the country. The recent emphasis on this response has put Britain ahead of other nations, both in terms of technological developments and sophistication of flood forecasting and warning systems. It is perhaps surprising that such developments should take place in this country, where the physical environment, and, in particular the flashy nature of the rivers means that highly advanced technology is required to provide sufficient warning time for remedial action. However, instead of acting as a restrictive influence, the reverse has been true, and technological developments have apparently been stimulated.

A second aspect of flood forecasting and warning schemes, to be considered, is the various roles played by the different authorities involved in the schemes. The River Authorities have always accepted a moral obligation to provide flood warnings, a policy which was reiterated at the Authorities' 'Elephant and Castle Conference' (1968), while other organisations have accepted various roles within the system, including data transference and emergency procedures. The significance of these other organisations was exemplified at the 1968 Conference, which was attended not only by representatives from the twenty-nine River Authorities, but also by members of the Ministry of Agriculture Fisheries and Food (both headquarters and regional engineers) the Home Office, the Meteorological Office, the Water Resources Board, the Post Office, the Greater London Council, and the chief constables of two police forces.

The final aspect of flood forecasting and warning schemes to be considered is the use of such schemes in Britain. These include a wide range of examples currently in operation with probable plans for future improvements. Thus, because of the importance of flood forecasting and warning schemes in Britain, and their probable increased use in the future, a great deal of attention is devoted to such schemes. They are reviewed under three broad headings

(a) Development of instrumentation.

(b) Responsible organisations.

(c) British flood forecasting and warning schemes.

(a) <u>Development of instrumentation</u>

One of the initial problems in Britain was how to issue early flood warnings, given that many streams in the country have extremely short lag times. To solve this problem it was essential to develop a technique of monitoring characteristics such as rainfall, river levels and soil moisture conditions in the upland areas of catchments, and to relate those to downstream flow discharges. If a stable relationship could be established between one or more of the upstream characteristics and downstream river levels, so that the response of a catchment to a given input could be accurately forecast, then a warning scheme could be operated for downstream communities. The major drawback to such a scheme was the lack of understanding of catchment processes, and insufficient hydrometeorological data. The instrumentation, such as rain gauges and river level gauges were inadequate for the demands of such schemes.

Development of instrumentation up until the 1960's was fairly limited. Indeed, apart from minor alterations, there had been little technological advance since the tipping-bucket and recording rain gauges invented by Wren and Hooke in the latter half of the seventeenth century (Biswas, 1970). The Digital Raingauge Company admitted that one of the early models, currently in the South Kensington Science Museum, inspired the design of one of their models (1974, personal communications). By the 1950's there was still no full flood forecasting scheme operating which relied on data from the upper parts of the catchment. At this time, the nearest to an automated system was that implemented by the Mersey and Weaver Authority in the late 1930's. This scheme employed simple river level gauges, which when raised to a certain level would trigger off an alarm mechanism, thus alerting a local resident, who then was requested to telephone the Authority. This arrangement provided the initial procedures for several such warning schemes throughout the country (Flood Warning Conference, 1968, comment by Davidson of the Mersey and Weaver River Authority). Various other schemes were employed, although essentially all of these relied on local observers to some extent.

Following the violent storms and serious flooding in 1960, a Conference of River Authority engineers was called for further investigations into flood forecasting technology, (this was to be the first of the now annual Cranfield Conferences). More serious flooding in various parts of the country in 1961 and 1963 stimulated further interest in flood forecasting and warning schemes as a means of alleviating the flood losses. These various stimuli eventually led to the development of the recording gauge, either for river level or rainfall, which could be interrogated by telephone. This was a most significant break-through for flood forecasting schemes, since it gave greater freedom to gauge siting. Gauges could be located virtually anywhere, and could still provide frequent readings of river levels or rainfall, without the requirement of a local observer. Thus, even the most inaccessible places could be monitored and hence more accurate predictions of stream discharges could be made, because of the greater data on which to base the calculations.

The Meteorological Office were instrumental in developing these telemetry gauges, and after several years of research and testing finally accepted a system based on the standard 150 cm^2 tipping-bucket rain gauge connected by a low voltage cable to an electronic recorder and telemetry transmitter. The two earliest models were purchased by the Yorkshire Ouse and Hull River Authority in July 1966, for use as a flood warning device on a very flashy river (Hindley 1968). Several minor faults were found with the gauges when incorporated into an actual alleviation scheme. The message tape in the recorder presented some problems and the rain gauge soakaways proved inadequate during heavy rainfalls, becoming water logged and thus short-circuiting the electrical mechanism. The only major fault to arise was the use of G.P.O. overhead transmission lines, which proved unreliable in storm conditions. Hindley (1968) pointed out that during the initial trial period these gauges averaged one fault every two weeks. Nevertheless, during the mid 1960's a great many of these problems were overcome as gauges were improved.

Although the technological developments in rainfall and river level gauges had made flood forecasting schemes a more viable proposition, the operation of the system still required constant surveillance if all floods were to be accounted for. Naturally, this presented difficulties during the weekends and at night when there may be no one actually on duty at the River Authority. To be really efficient, therefore, flood forecasting and warning schemes needed further automation. Bussel and Jackson (1968) stated that forecasting schemes required either automatic rainfall alarms to alert local observers or a system of continuous telemetry, to account for even the unexpected flood.

The problem of continuous telemetry was eventually solved by the joint co-operation of several River Authorities, the Meteorological Office and the instrument manufacturers, in particular Plessey Electronics. A fully automatic interrogable rainfall (and river level) recording gauge was produced, which could also instigate a warning alert to a series of persons remote from the gauge site. The gauge was designed to telephone a series of numbers at any time, if any preset critical limits were exceeded. This constituted the second major break-through in flood warning instrumentation in the 1960's, and gave the opportunity for whole areas to install flood forecasting and warning schemes.

Rainfall and river level gauges have now reached a quite sophisticated stage of development, due primarily to the research undertaken in the 1960's. The Plessey Company Limited have been actively involved in such work for several years and now market various kinds of gauges. The river level gauge works on the principle of a recording gauge (Fischer and Porter) which is based on the float and balance mechanism and allows recordings every fifteen minutes. This information is then fed into a store where it is retained in an electronic memory until replaced by fresh information. The gauge is further equipped with an alarm comparator, which is activated if any preset level is reached. Similar processes are involved with the rainfall gauges, which are normally based on one millimetre tipping bucket mechanisms. Again, information is transferred to a memory, which when interrogated, returns the data as rainfall levels. Both rainfall and river level gauges may be interrogated at any time, which releases the memory producing a tone control of pulses to generate the required information. The rainfall gauge can also be linked to an alarm mechanism which operates in the same way as the river level gauge. The alarm system for these gauges - the Telephone Answering Unit - is designed to operate on magnetic tape cassettes which are pre-recorded with verbal statements and telephone dialling information. When an alarm arises, the T.A.U. calls up the first of five numbers and repeats the warning message; it will then wait for two minutes to be rung back, which will cancel the message. If there is no reply the T.A.U. will move on to the other telephone numbersin turn repeating the procedure. (Details supplied by The Plessey Company Limited, 1973).

The development of flood forecasting and warning scheme instrumentation appears to have been the product of a stimulus - response mechanism. Bleasdale (1973) pointed out that the initial stimulus to flood warning schemes in Britain was provided by the Lynmouth flood in 1952. However, it was the notable flood years of 1960 and 1968, which stimulated the greatest period of technological advance, while smaller and less concentrated events in various parts of the country during 1961, 1963 and 1964 maintained the research impetus. By 1970, Porter reported that fifteen River Authorities had incorporated some form of flood warning system.

The efforts to improve the effectiveness of flood forecasting and warning schemes have not been restricted to developments of rainfall and river level gauges. Other aspects of flood forecasting have also been investigated to try and improve the accuracy of forecasts and at the same time issue earlier warnings. For example, several alterations to overhead transmission lines in the telemetry system have received attention, because of the susceptibility of such lines to failure during storms. Both the laying of lines underground, and the use of radio as the means of data transmission have been tried. Although radio links are frequently used for schemes which need to cover large distances (see chapter one), they do have certain advantages over overhead transmission lines. Radio links are generally more reliable and are less likely to fail during adverse weather conditions, while at the same time radio units are easier to install and operate in particularly remote areas. The equipment required for radio transmission is generally less expensive than telephones, and can scan and collect data from substations considerably quicker. However others, such as Body (1969) claimed that radio links were generally less reliable and more expensive. . It would appear, therefore, to depend on the particular environment, and particularly the distances involved.

Flood forecasting and warning schemes have also been improved by more efficient-evaluation of the data collected, by the use of computers. In fact, computers can now run the complete flood forecasting system, by constantly monitoring gauging stations, reviewing any changing conditions and issuing the appropriate warnings of any impending flood. With this development, flood forecasting schemes have become fully automated. Although very few River Authorities use computers to this extent, by 1972 nine had started to use computers within the systems. (Local Authorities Management Services and Computer Committee, 1972). These were Lancashire, Mersey and Weaver, Gwnedd, Severn, Bristol Avon, Somerset, Sussex, Trent and the Dee and Clwyd River Authorities.

Again, the Meteorological Office has been partially responsible for integrating computers into flood forecasting and warning schemes. At their own headquarters, a computer is employed in the data transmission system, operating between Beaufort Park and the Meteorological Office, to display remote meteorological data (Sands and Wilkinson 1974). This system, the Continuous Automatic Remote Display System, and the mark two version for working over greater distances, the Meteorological

Office Weather Observating System, could easily be adapted for forecasting schemes. Salter (1972) also described the Meteorological Office system known as CARP (Comprehensive Areal Rainfall Programme) which through computer mapping techniques would produce areal assessments of rainfall. All these schemes would be beneficial to the operation of a flood forecasting and warning system.

Future improvements to flood warning systems will undoubtedly take place in the quantitative measurements of precipitation, on the principle that earlier rainfall data will provide even earlier flood warnings. At present, of all the techniques considered (see chapter one) radar appears to have the most potential for flood forecasting and warning schemes. Several authors have intimated that early results from the radar studies are most promising (Kelway and Warner, 1973; Harrold etal, 1973). The most significant work on radar has been carried out by the Dee Weather Radar Project, a joint undertaking by the Water Resources Board, the Meteorological Office and Plessey Radar. The project has examined the potential use of radar as a means of accurately measuring precipitation as it falls over the catchement. Initial results indicated an average error in rainfall measurements of less than twenty percent, which is equivalent to the accuracy attained from using a rain gauge network of one gauge for every fifty to one hundred square kilometres (Dee Weather Radar Project, Report, 1974). Radar, it may be added, is also capable of measuring snowfall, although the level of accuracy is reduced. Further studies have shown that a countrywide radar system would be cheaper to run than a full

Table 3-2 Estimated annual costs of five rainfall measuring systems and their relative abilities to meet the specified user requirements.

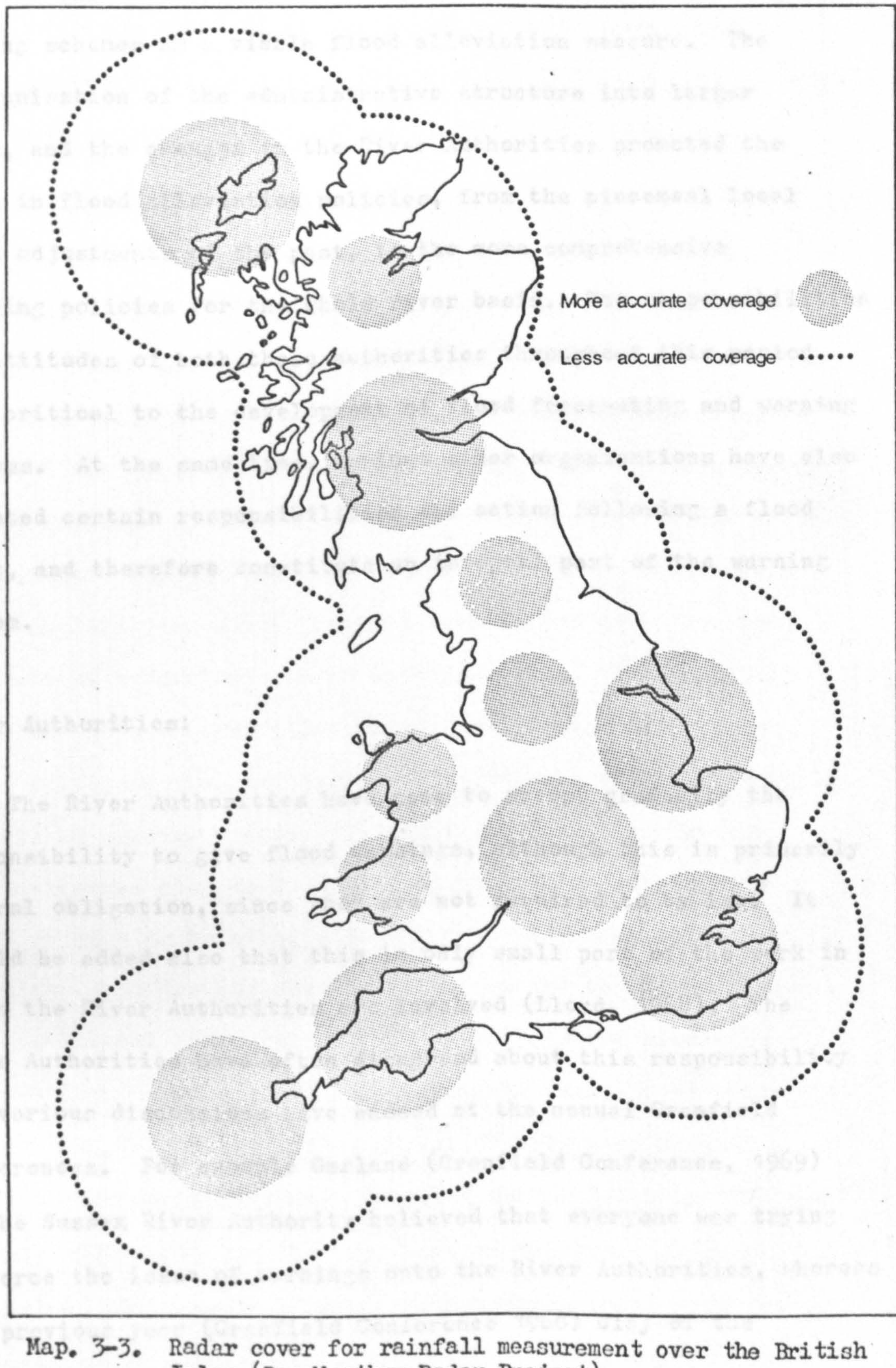
	Annual Cost	Measurement Potential		Forecasting Potential	
	£	Areas of major interest	Other areas	Areas of major interest	Other areas
Radar network	9,000,000	G	G	G	G
Gauge network (1/100 km^2)	1,720,000	M/G	M/G	M	M/P
Partial radar network	470,000	G	G/NIL	M/G	M/NIL
Partial gauge network	380,000	M/G	NIL	P	NIL
Existing system	220,000	P/NIL	P/NIL	P/NIL	P/NIL

G - Good
M - Moderate
P - Poor

gauging station network, and would incorporate a greater measuring and forecasting potential, as shown in table 3-2 and map 3-3 (Doc Weather Radar Research - Report 1974). It is significant that only twelve years ago the River Authorities, at one of the earlier Cranfield Conferences, rejected radar as having no application to flood warning purposes (Reported at Cranfield Conference 1971).

Several authors have shown the value of radar to flood forecasting and warning systems. Taylor (1974) and Taylor and Browning (1974) have described a prototype system, developed at the Royal Radar Establishment, which can supply data within thirty seconds of its acquisition by radar. The display in this case is through standard post office lines on to a modified colour television screen, and is presented as a series of shaded maps indicating the intensity of rain almost as it is falling over a wide area. Other data outputs are available and the whole system can be linked to a computer for analysis of the meteorological and hydrological statistics.

Thus, during the last fifteen years, there has been great technological advance made in the field of instrumentation and data handling. This development has made flood forecasting and warning schemes a viable proposition in Britain, where frequently rapid systems are required if the warning is to have any meaningful effect. The first stage of the flood forecasting and warning system, collection and evaluation of the relevant data (full details can be found in chapter one) therefore, is potentially very efficient.



Map. 3-3. Radar cover for rainfall measurement over the British Isles (Dee Weather Radar Project).

(b) Responsible organisations

During the 1950's and 1960's there were other changes, which affected the development and acceptance of flood forecasting and warning schemes as a viable flood alleviation measure. The reorganisation of the administrative structure into larger units, and the changes in the River Authorities promoted the trend in flood alleviation policies, from the piecemeal local flood adjustments of the past, to the more comprehensive planning policies for the whole river basin. The responsibilities and attitudes of both these authorities throughout this period, were critical to the development of flood forecasting and warning systems. At the same time, various other organisations have also accepted certain responsibilities for action following a flood alert, and therefore constitute an integral part of the warning system.

River Authorities:

The River Authorities have come to accept gradually the responsibility to give flood warnings, although this is primarily a moral obligation, since they are not required to by law. It should be added also that this is only small part of the work in which the River Authorities are involved (Lloyd, 1968). The River Authorities have often disagreed about this responsibility and various discussions have ensued at the annual Cranfield Conferences. For example Garland (Cranfield Conference, 1969) of the Sussex River Authority believed that everyone was trying to force the issue of warnings onto the River Authorities, whereas the previous year (Cranfield Conference 1968) Clay of the

Lancashire River Authority suggested that River Authorities should be statutorily obliged to give flood warnings. The Government, for their part, have actively encouraged the River Authorities to adopt flood forecasting and warning schemes. This has taken the form of grants for flood forecasting equipment, from the Ministry of Agriculture Fisheries and Food.

The reorganisation of the water industry has also aided the development of flood warning schemes, by creating larger and potentially more efficient administrative units. The various 'water bodies' have amalgamated gradually since the 1944 White Paper entitled 'A National Water Policy', which culminated in the 1948 Act setting up the River Boards, The Proudman Report (1962) followed by the Water Conservation in England and Wales (1962, White Paper) replaced the River Boards by twenty-nine River Authorities, which provided even larger units for more comprehensive developments in water planning. The fact that these authorities controlled larger areas meant there were fewer administrative problems associated with the implementation of a flood warning system. The full effects of the recent administrative changes into ten Regional Water Authorities still remains to be seen, although hopefully they will stimulate even greater consideration for the total environment. Penning-Rowsell and Parker (1974) do not see the situation improving as regards flood plain planning (see above) while the Thames River Authority (1975, Annual Report) have already praised the reorganisation. Flooding during November 1974 and January 1975 stretched the resources of the local drainage divisions, but because of the reorganisation there were few administrative problems in supplementing resources from other divisions.

In conclusion, River Authorities, and now the Water Authorities have accepted the responsibility for flood forecasting and warning schemes. The reorganisation of these authorities and the active encouragement by the Government have been two of the more important factors, which have made this form of response feasible.

Local Authorities:

The responsibilities of the Local Authorities in flood forecasting and warning systems require a close liaison with the River Authorities, various Government Offices and local police forces, as well as many other voluntary help organisations. By law Local Authorities are obliged to, (i) maintain public services, (ii) to help local residents in distress, and (iii) to play a major part in co-ordinating the actions of various local organisations offering relief during the emergency. A certain degree of preplanned action, therefore, is required of the Local Authority, if flooding is not to catch people unprepared. The Ministry of Housing and Local Government issued a circular on Natural Emergencies (1969) which suggested certain preparations for flood events which were likely 'to disrupt public services and adversly affect the normal routine of daily life'. The Ministry went on to recommend that each River Authority should carry out a review of the flood problem in their area, and in consultation with the Local Authority and the police force, determine what extensions in flood warning were desirable and feasible.

As far as the health and welfare of residents were concerned, the Ministry recommended that the Local Authority should review their plans for emergency action. The Local Authorities were advised to contact the Civil Defence from whom equipment may be borrowed in the event of a flood. Similarly the local water suppliers, the gas board, and the electricity companies should also be encouraged to prepare for emergency action. The Local Authority itself should make similar plans for relief centres, for food and clothing distribution, and for the immediate dispensation of financial assistance to the flood victims.

In spite of the advice circulated by the Central Government, very few Local Authorities have made provisions for a flood emergency, and many are apparently unconcerned about, or unaware of, the flood problem within their area. Some councillors, for instance, from the East End of London, refused to participate in a recent GLC flood prevention exercise even though that part of the City is particularly susceptible to flooding (Cox, 1976). A further circular from the Home Office (Number 1, 1972) on Emergency Services, recommended the appointment of Emergency Planning Officers in every one of Britains fifty-four county councils. However, because of the local government reorganisation this was not acted on until 1974. The effectiveness of these Officers and their staff (there is usually a staff of four, to which the Home Office pays a seventy-five percent grant) depends to a great extent on the character and ability of the individual members, but at least preparations have been made to deal with emergencies.

The Meteorological Office:

The Meteorological Office has been closely connected with flood forecasting and warning schemes for a long time, encouraging much of the early development of the telemetry gauges, and is currently involved with the Dee Radar Research Project (Harrold et al 1974). Since 1962, the Meteorological Office has developed two national services particularly relevant to flood forecasting, and these now form the basis of many flood warning schemes run by the River Authorities. Firstly, the Meteorological Office will issue forecasts of heavy rainfall either as a general indication or as more specific local information. The general forecast provides details of expected heavy or more prolonged rainfall, with details on the likely duration and severity of the storm and the probable areas affected. The more detailed forecast provides information on intense rainfalls, which are likely to affect small river basins prone to flash flooding and urban storm water drainage systems. These forecasts are used frequently by River Authorities as a general flood alert.

The second service offered by the Meteorological Office is the provision of soil moisture deficit maps for the whole country. These maps, revised every two weeks, are used by the River Authorities to estimate the potential runoff during periods of heavy rain. The Meteorological Office hopes to expand this facility to include other parameters relevant to runoff calculations, such as actual evaporation rates or effective rainfall maps. Overall, therefore, the Meteorological Office plays an invaluable role in flood forecasting and warning schemes by providing the initial alert mechanism and statistics on catchment characteristics, as well as actively encouraging such schemes and promoting the development of instrumentation.

Police Forces:

Police Forces throughout the country play an integral part in flood forecasting and warning schemes. While River Authorities have accepted the moral obligation of flood warning, the process of disseminating the warning message is generally left to the police. Naturally, this system requires close co-operation between the police forces and the River Authorities, which in the past the River Authorities have found quite satisfactory. Only a few complaints have been raised about this situation (Cranfield Conference, 1969). The Kent River Authority and the Thames Conservancy both complained about the Metropolitan police force which refused to undertake work similar to other forces.

In general, it is accepted that the police are the best equipped, most authorative and reliable body available to issue flood warnings. However many flood warning schemes, which do rely on the police, are highly inefficient, and fail to provide the rapid warnings anticipated by the River Authorities. This aspect of flood forecasting and warning schemes represents the second part of the system, dissemination of the warning message, and unlike the first stage has received only scant attention in the past. Clearly, the improvements in forecasting techniques, which have been described above, are of little value, unless the rest of the system also operates smoothly and efficiently. The evidence of past failures would suggest that improved warning dissemination techniques could significantly improve the effectiveness of the alleviation scheme. In fact, there are very few examples in Britain of set procedures being implemented to improve warning dissemination, and most systems normally rely on police touring the flood risk areas with loud-hailers. The Cumberland River Authority implemented a telephone pyramid calling system amongst residents and industrialists, but this has yet to be fully tested (for detail see chapter six). Other River Authorities, such as the Severn, use local flood wardens to issue warnings which reduces the police responsibility, but unfortunately these are only used in the rural areas.

Other organisations:

There are several other organisations which play a part in the operation of a flood forecasting and warning scheme. For instance, the army and civil defence forces may be called out in cases of major flooding, while the local fire brigades are generally on standby with pumps and sand bagging equipment during and immediately after a flood. Other voluntary organisations such as the Salvation Army, the Womens' Royal Voluntary Service and the British Legion all mobilise their forces during flood emergencies, to bring various forms of relief to the flood victims. These other organisations, therefore, may play a smaller role in the overall flood forecasting and warning systems, but they provide essential emergency relief on the local scale, and thus should be considered in no way insignificant to the workings of the scheme.

The current stage of development of flood forecasting and

and warning schemes represents a very great advance on the situation fifteen years ago. The technological developments in instrumentation, described in section (a), and the changes in the administrative structure, as well as the joint co-operation between the various responsible organisations discussed above, have made flood warning schemes a viable flood alleviation measure. These advances have improved in particular the initial stage of the system, the process of data collection and evaluation, while the problems of the second stage, warning dissemination have also been recognised. The third stage, response to the warning message, is examined in detail in the case studies described in chapters seven and eight.

(c) British flood forecasting and warning schemes

There are three basic types of flood forecasting and warning schemes currently operating in Britain, ranging from elementary techniques, through to highly sophisticated technological schemes. The first rudimentary type relies on simple equipment, such as river staff gauges and local observers to communicate any warning message to the River Authority. Most River Authorities employed schemes similar to these before the mid 1960's, and indeed many still have such arrangements in some localities. The second, and now most common type of scheme, dispenses with the local observer and substitutes an automatic sensing device, which monitors data remotely by radio or telephone links, and in some instances automatically interrogates the rainfall and river level gauges. The third and most advanced scheme is a completely automated system controlled by a computer. Sensing, data transmission, monitoring and evaluation of the data are all fully automatic, which has added to the efficiency and reliability of at least the first stage of warning systems.

Flood forecasting and warning systems do not only vary in the technical complexity of the equipment, they may also differ according to the forecasting procedures of the particular schemes. Thus, some areas will rely on river level relationships, between the upper and lower reaches of the catchment to forecast flood flows, while others will incorporate a measure of rainfall and soil moisture deficits to determine river flows downstream.

Until the early 1970's the attitude of the River Authorities towards flood forecasting and warning schemes, varied from a general lack of interest and non-participation, to one of active involvement in the development of such schemes. Because of this, there exists now a wide range of warning schemes through Britain. Some Authorities have made very little progress in this sphere, for example, Wye, Glamorgan, South-West Wales, Hampshire and the Avon and Dorset River Authorities. As late as 1969, the Sussex River Authority believed that the responsibility for flood warning should not be forced on the River Authorities, but that Local Authorities should receive weather forecasts and then ask the River Authorities to assess the likelihood of flooding (Cranfield Conference, 1969). At the other extreme, the Mersey and Weaver, Bristol Avon and Devon River Authorities have worked out detailed arrangements for fully automated flood warning schemes.

Several River Authorities with only rudimentary flood warning systems have recently considered developing these measures. The Welland and Nene River Authority, for instance, has contemplated the installation of more sophisticated equipment, to enhance the river stage relationships on which the original scheme was based. The Usk River Authority has realised also the potential of telemetry and has considered implementing a warning scheme based on these instruments (Cranfield Conference, 1969, 1970). The Northumbrian River Authority has planned a more detailed programme of flood warning (Storey, 1974, personal communication). This Authority proposed to use unit hydrograph techniques for the respective catchments, by forecasting future flooding on the basis of past storm events. River levels are to be correlated for selected sites downstream, and the time of arrival of peak discharges estimated, so that in future accurate flood forecasts can be made. These plans have still not been implemented, because certain difficulties have not been resolved with the Ministry of Agriculture, Fisheries and Food, and also because the necessary prediction techniques have still not been completed.

The Lancashire River Authority has only elementary warning procedures in its area, but, like the Northumbrian Authority has made a full review of the flood problems and proposed quite major changes to the flood forecasting and warning policies. (Details of these proposals were obtained from the 1971 Cranfield Conference reports, although personal communication - 1974- with the River Authority intimated that the scheme was only out to tender three years later). The Lancashire River Authority proposed a two phase scheme; phase one incorporated all those flood prone areas where more than two hours warning could be given, and phase two all the other areas, which would be considered for flood warning in the future. Phase one includes the provision of eight interrogable rainfall gauges, seven interrogable river level punch-tape recorders with automatic alarms to the police and the Authority's Control Centre, and six alarm only river level indicators with a direct link to the police.

The Lancashire scheme will be operated on the basis of river level relationships, although the Meteorological Office warnings of heavy rain from Barton Hall, and the data received from the interrogable rain gauges will provide the background information for the flood forecasting. The rainfall statistics will enable the River Authority's engineers to assess the likelihood of flooding of different areas, and thereafter advise the appropriate police headquarters of where flooding is probable and which communities are at risk. Where the time between heavy rain and subsequent flooding is short, then the rain gauges may be utilized directly for initiating the flood warning, while the river level alarms will also alert other areas to the likelihood of flooding. Studies within the Authority have shown that economically the most efficient means of communication with the interrogable gauges is attained by radio links, while telephone lines will be used for the straightforward alarm gauges. (Figures 3-1 and 3-2 show the workings of these gauges). The use of a dual communication link is seen as increasing the reliability of the scheme.

Other River Authorities have suggested plans which, although less comprehensive in their details, are similar to those of the Lancashire River Authority. For instance, the Lincolnshire River Authority has proposed installing a new instrument to measure the 'rate of rise' of water levels at Lough, since other techniq

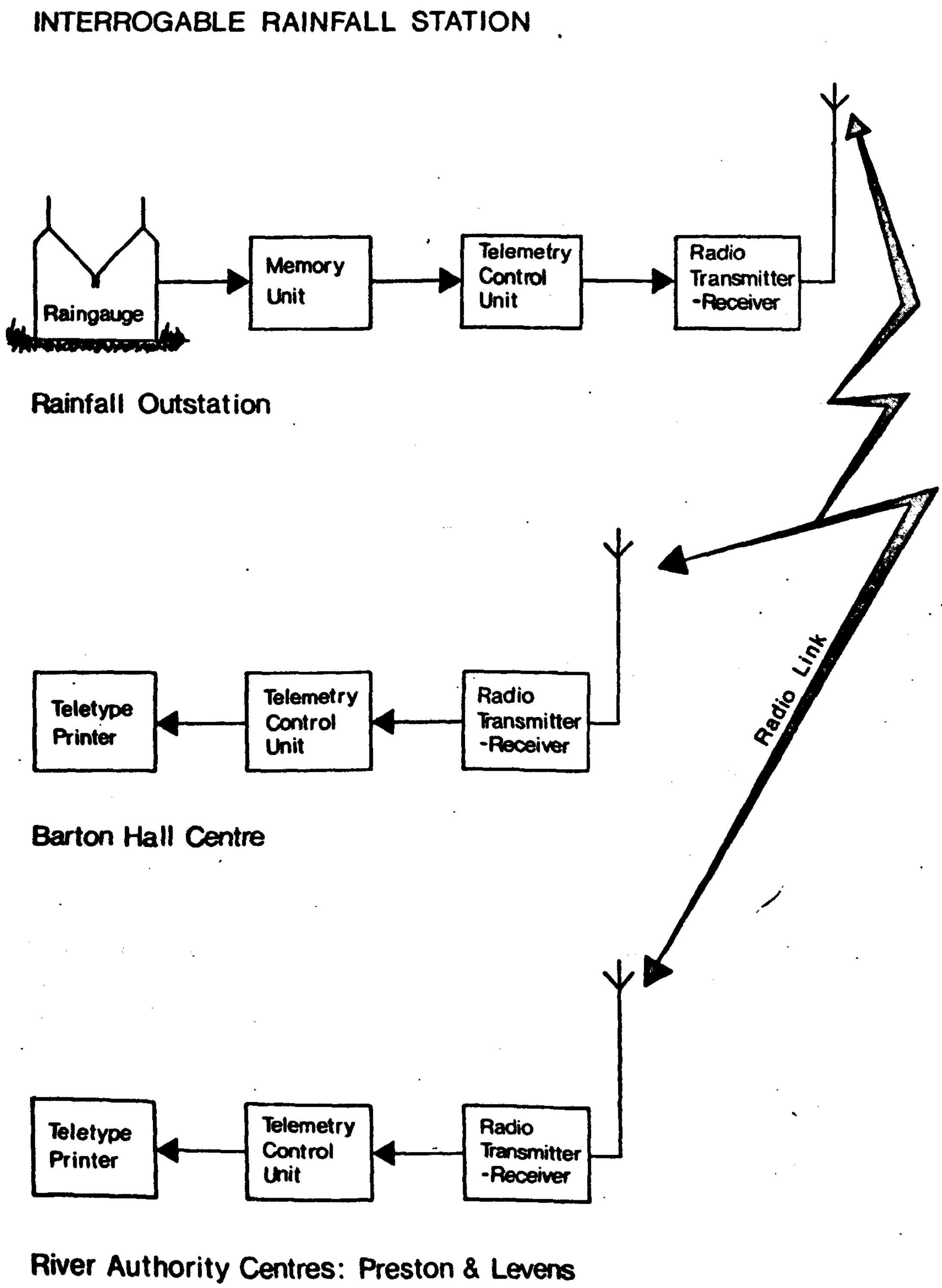


Fig. 3-1. Lancashire River Authority interrogable raingauge system for flood forecasting and warning procedures.

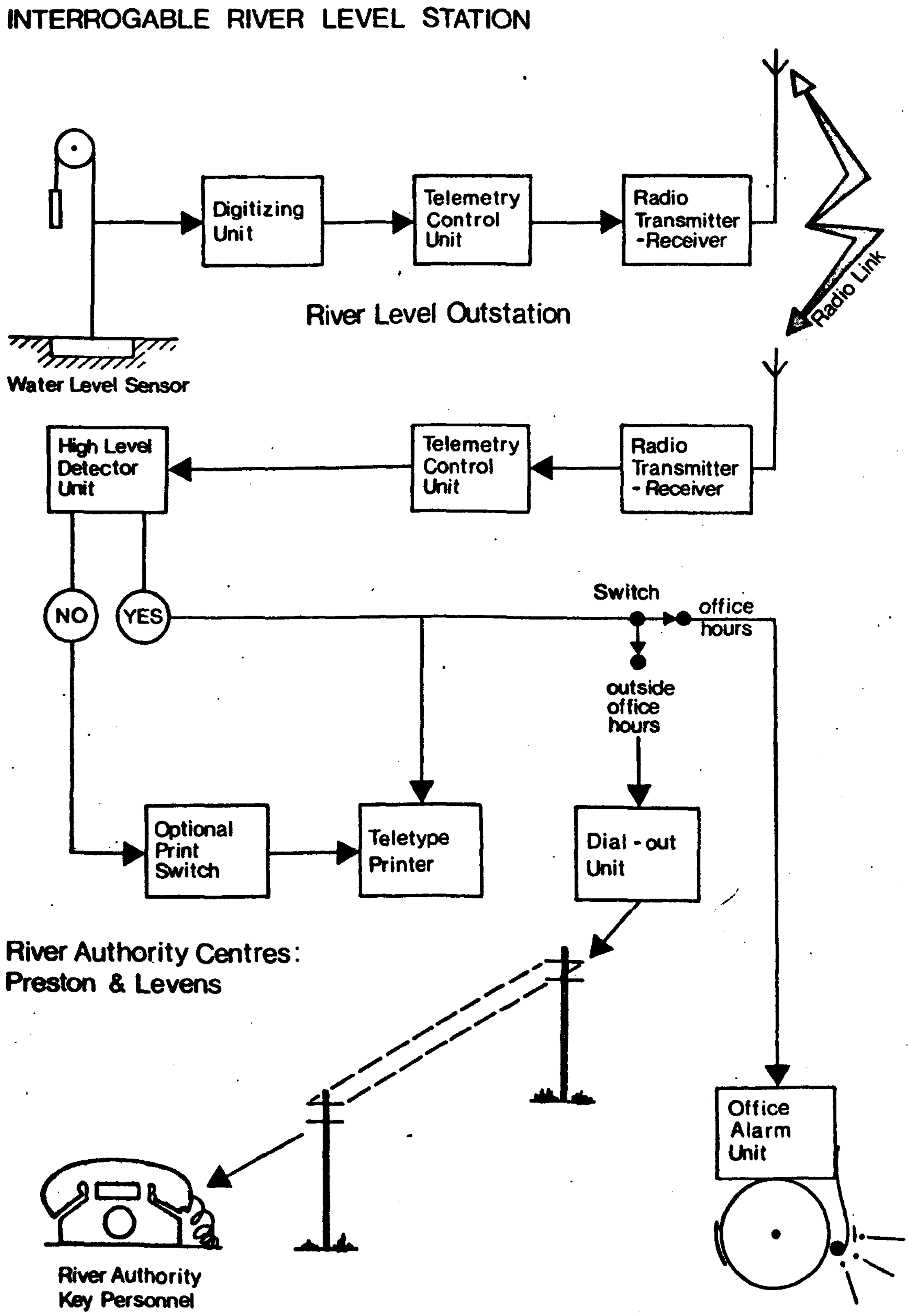


Fig. 3-2. Lancashire River Authority interrogable river level system for flood forecasting and warning procedures.

such as river level relationships have not been that helpful. A rainfall based scheme, it was believed, would institute too many false alarms (Cranfield Conferences, 1968, 1971). The Yorkshire Ouse and Hull River Authority has already installed several telemetry gauges, although not on the scale anticipated by Lancashire. The present scheme in Yorkshire incorporates both manually operated and automatic gauging stations, which provide the river engineers with the first indications of likely flooding. If flooding is assessed as a possibility, then upstream river levels will be monitored through a telephone linked telemetry system, and if rivers reach certain limits, which previous experience has shown causes flooding downstream, then warnings are issued to the local police stations. The Yorkshire River Authority is typical of many others in this respect, since both manual and automatic gauges are employed in the same warning system, and a certain degree of experience and local knowledge is relied upon. However, the Yorkshire River Authority is currently reviewing the whole flood warning procedures in the area. (Details were obtained by personal communication with several divisions of the River Authority 1974, and with the Yorkshire Water Authority 1975).

The Severn River Authority has a more advanced flood warning system than Yorkshire, with greater automation. The River Severn scheme is based on the warnings of heavy rainfall issued by the Meteorological Office; which puts the River Authority on a general flood alert. 'Telytone' river level and rainfall gauges on the smaller catchments are then consulted to determine whether a flood is likely to result from the rainfall. For this purpose there are eight interrogable rainfall gauges and twenty-four river level gauges installed throughout the catchment. From this information, and the statistical data compiled from previous flood events, assessments are made of the extent and time of occurrence of flooding downstream. If flooding is imminent the police are contacted, who then issue flood warnings to the appropriate areas. In contrast to most British flood warning systems, speed of communication is not generally at a premium, because of long times of concentration and peak wave travel. The Severn River Authority has found this procedure satisfactory in the past and has no plans to change these policies. Nevertheless, the Authority still emphasised the importance of local knowledge acquired over many years, as a valuable asset in flood forecasting (Haines, 1974 personal communication).

The Essex River Authority has, like the Severn Authority, already incorporated telemetry equipment into flood forecasting and warning schemes (Jeeps, 1971). The Essex scheme is also initiated by heavy rainfall alerts, this time from the London Weather Centre who distinguish between heavy intense falls and moderately prolonged rain. The rain, if it exceeds certain preset limits, will activate twenty burglar alarm type gauges which have been developed by the Authority for this purpose. The operators at these sites are required to transmit the information through to the headquarters. The Duty Engineer will consider this information in conjunction with data already received from four interrogable rainfall gauges, sixteen other manual gauges, and three interrogable river level gauges. If the situation is conducive to flooding he will issue a warning to the local police.

The Essex River Authority has made several proposals to improve this scheme, including the installation of eleven new interrogable rainfall stations and twenty-five more interrogable river level stations, linked by telephones to the Authority's Headquarters. These would provide even more information on a regular fifteen minute interval, which would help in stage routing procedures, as well as on demand through the telemetry system. Others will add to the automatic warning processes with preset limits activating an alarm at headquarters.

The Kent River Authority has also incorporated modern telemetry equipment into flood forecasting and warning schemes, although, as is the case with many Authorities, the initial alert is provided by the warnings of heavy rainfall from the Meteorological Office. The Kent River Authority has installed nineteen 'Plessey' automatic alert rainfall gauges, twelve interrogable rainfall gauges (Thorn-Bendix) and ten interrogable water level gauges (Lea-Telytone). The system operates on alerts from the 'Plessey' rainfall gauges, followed by an analysis of catchment characteristics. Data for this are obtained from the other interrogable gauges and from estimates of the soil moisture deficits, received from the Meteorological Office, so that the likelihood of flooding can be forecast. If a flood is imminent the police are notified of the probable areas of inundation and the time of arrival of the peak discharge. Despite this fairly advanced approach to flood warnings, the River Authority still has plans to improve the system by transferring to radio links rather than telephone lines (Cranfield Conference, Kent River

Authority Report 1971).

The Mersey and Weaver River Authority has one of the longest records concerning automated flood warning systems. The original scheme was implemented by the Mersey and Cheshire River Boards following severe flooding on the Mersey, Weaver and Dane in 1946. It was one of the first to install burglar-alarms in river level gauges to provide local residents with some form of advanced flood warning. The present scheme, although more technically advanced than the 1946 system, still incorporates burglar-alarms within the system. The warning scheme now operates on three levels: (a) warnings of heavy rain from the Meteorological Office; (b) a few automatic burglar alarms triggered by river level gauges which alert local observers who then transmit the information to the River Authority, and (c) general observations by Divisional and Hydrology Staff, which includes the monitoring of several telytone gauging stations. If these staff confirm the initial alert then a series of bank patrols may be made prior to issuing a definite flood warning. There are several weaknesses in this scheme which are fully recognised by the River Authority. For instance, at present only a limited warning time can be given to a very restricted area, and the scheme only operates outside normal office hours if heavy rain is forecast a long time in advance.

To overcome the difficulties of the present system, the Mersey and Weaver River Authority has proposed a three stage programme of improvements. Stage I includes (i) the installation of interrogable instruments to observe both rainfall and river levels; (ii) the introduction of a formal and reliable organisation for observations, forecasting and warning outside normal office hours; (iii) the preparation of required documentation describing the scheme, and (iv) a detailed survey and consideration of all flood risks throughout the area, including those away from designated main rivers. Stage II of the proposed scheme provides warnings for those residents in flood prone areas away from the main rivers, although primarily these will incorporate the old burglar alarm type system. The longer term aims of the Authority are outlined in Stage III, and include suggestions for a fully automated flood forecasting and warning system based on telemetry and on-line computing (Lloyd, 1971).

The Devon River Authority has also run a flood forecasting and warning scheme for quite a long time. The scheme has developed gradually since 1952 and is now based on several hydrological and meteorological parameters, an antecedent precipitation index, rainfall estimates and river level measurements. The present scheme normally commences with a warning of heavy rainfall from the local Meteorological Office at Plymouth, although, since this service does not operate at weekends, the system is not entirely reliable. However, following this initial alert, the Duty Officer monitors several telemetry rainfall and river level gauges and, in conjunction with an antecedent precipitation index, determines the probability of flooding. If flooding is likely then the River Authority will notify the local police, certain engineer contractors and the Ministry of Agriculture Fisheries and Food. If a major flood is expected then the County Secretary of the National Farmers Union, the Devon County Council Emergency Officer, and the County Council Surveyors Department will be notified. Other River Authorities may also be informed of the threat of flooding, including Cornwall, Somerset and Avon and Dorset River Authorities (Gosling, 1974 personal communication). It is noticeable though, that none of these other Authorities has instigated any efficient warning systems of their own. Oates of the Cornwall River Authority even believed that flood warning systems were meant to cater for catastrophic flooding which would lead to a national disaster, and hence, since there was no such risk in Cornwall, there was no need for a flood forecasting and warning system. In plans for the future, the Devon River Authority anticipate the introduction of a fully automated forecasting and warning system covering most of the major flood risk areas within the boundaries of the Authority.

The Bristol Avon River Authority has made similar proposals and is currently pursuing the policy of a fully automated flood forecasting and warning system. The overall strategy is to provide rapid and accurate flood warnings to a defined 'direct warning' area in the Bristol Avon catchment employing the most reliable methods available. For this purpose, modern interrogable rainfall and river level gauges, as well as complete weather stations, will be installed with direct links by radio to the office headquarters. The system will be controlled by a small computer which will constantly scan the gauging stations at fifteen minute intervals and continually update the flood forecast for various points within the catchment. The system will be quite flexible since any alterations in the scanning sequence or alarm levels can be made by changing the computer program rather than converting any hardware. Warnings of flooding will be issued by the computer and relayed to the local police and broadcasting corporations (Whitaker, 1974). One of the major drawbacks to the scheme is that some flood prone communities will not be included in the 'direct warning' area. However, the River Authority has considered issuing informal warnings to these communities.

Other River Authorities have considered extensive alterations to their flood warning schemes. For example, the Trent River Authority has proposed a scheme similar to the Bristol Avon, based on the computer scanning of telemetry gauges (Wood, Personal communication 1974). The Gwynedd River Authority is currently testing the reliability of flood forecasting on the basis of data received from one strategically placed rain gauge (Johnson, Personal communication). The Dee and Clwyd River Authority has also installed telemetry gauges, but instead of using the Meteorological Office warnings of heavy rain as an alert to the system, considerations are being given to the Dee radar research project (Cranfield Conference 1971). In Scotland there are no advanced warning schemes for flooding, and the only official scheme on Speyside is run essentially by the police. The system works on river level relationships and provides flood warnings for several communities along the Spey (Poodle, 1974 personal communication).

In conclusion, flood forecasting and warning schemes have become a highly sophisticated alleviation measure, which involve quite advanced technology. Warning schemes now represent a major response to the flood hazard by the river authorities, and can be found in a variety of forms throughout the country. These schemes have developed rapidly over the past fifteen years, and undoubtedly, by following the reorganisation of the water industries, even further changes will take place in the future. While this will probably not involve any more technological breakthroughs, the next stage may well see the expansion of such schemes around the country. Perhaps the most obvious failing of this whole period, however, has been the failure to improve the second and third stages of flood forecasting and warning schemes. While considerable attention has been devoted to improving the collection and evaluation of hydrological and meteorological data, there has been very little consideration of warning dissemination techniques, and the behavioural response to the warnings. Clearly, further studies of these latter two aspects of warning systems are required to make the schemes more efficient.

PART III

THE FLOOD PROBLEMS IN CUMBRIA

CHAPTER FOUR

HYPOTHESES AND METHODOLOGICAL BASE

PART A : HYPOTHESES

Introduction

> "All land surfaces are in a watershed. The runoff from all watersheds collects in channels found every few miles over land surfaces. All channels occasionally flood. This means that an urban area cannot grow to any size without being criss-crossed by a number of flood producing channels. Urban areas would be less compact if no development were permitted in these areas. The reduction of flood damage and urban development must be considered against the greater gross urban spread and the additional costs incurred from transportation, communications and public utility systems."
>
> James _et al_ (1971, 17).

This description is applicable to many countries throughout the world, and especially in Britain, where the high proportion of urbanisation and the great density of drainage channels mean that numerous settlements are prone to flood damage. Part of the aims of this research, therefore, was to look at some of the causes of the current flood situation in Britain. This included studies not only of the decision-making process which have culminated in the urbanisation of flood plains, but also of the behaviour patterns of those persons living and working on the flood plain. The research was designed to study all levels of decision-making, from the Central Government policies, through the activities of Local Authorities and other responsible organisations such as the River Authorities, down to the decision-making processes of individual flood plain residents and business-men. Chapter three has shown already the general causes for flood plain encroachment due to the lack of liaison between the Local Authorities and the River Authorities, while the two preceding chapters examined the problems of rational project selection to alleviate flooding. This chapter, therefore, puts forward the various hypotheses which stimulated the research into the flood problem, while the second part of the chapter describes the methodology by which the work was undertaken.

In Britain, flood protection is considered to be the responsibility of the various organisations, especially the River Authorities and Local Authorities, who have attempted to solve the problem in the past by the implementation of structural alleviation schemes (described in chapter three). This somewhat narrow response developed because flood plain planners were (i) unaware of the wide selection of non-structural schemes available, and (ii) if aware, only perceived minimal benefits accruing from such schemes. Since non-structural alleviation measures now represent viable means of flood loss reduction, with often greater economic feasibility than large scale structural measures, neither of these attitudes are satisfactory. Flood plain managers, before implementing any alleviation programme, should ideally obtain accurate information on the physical aspects of flooding, consider the full spectrum of effects of such policies, and evaluate the effect on the behaviour of flood plain residents. However, most of these aspects, except the physical, are rarely considered in detail, although admittedly such data are not easily collected, largely because much depends on human attitudes and feelings. Nevertheless, the significance of the human element is becoming increasingly important, due particularly to the gradual introduction of non-structural alleviation schemes.

In the past, further assumptions were made that the individual would act rationally to optimise his location, and thus minimise his losses accruing from flooding. Unfortunately, this is not always the case, for even non-structural schemes have failed to prevent the general rise in flood losses. Thus, further studies are required of human characteristics so that the effects of different alleviation schemes on the individuals within the community can be accurately predicted.

A second problem is the apparent standardisation of non-structural alleviation schemes. Apart from the initial stages of flood forecasting and warning schemes, very little attempt is made to adjust non-structural measures to the particular environment, and hence schemes are seldom used to maximum advantage. This of course contrasts significantly with schemes incorporating structural measures, where considerable attention is given to the physical factors and design standards of each individual project. Of the non-structural measures, only flood insurance is ever adjusted to local conditions, and even this is frequently only a crude division of the flood plain into zones of high and low premiums, based on whether an area had been flooded before or not. However, for both structural and non-structural schemes there is a general tendancy to ignore the social implications of such policies.

Flood plain planners in the U.S.A. have devoted some attention to these social factors, but generally alleviation schemes are implemented on the basis of an assumed 'Community-norm'. Unfortunately, very few people would appear to conform to this norm, and hence many schemes have been less efficient in reducing flood losses than was initially anticipated. Theiler (1969) described the example of farmers who failed to fulfil the expectation of the planners in Coon Creek, Wisconsin. Planners would be greatly assisted by a more accurate survey of flood plain residents, particularly one that produced a model to predict future responses to given alleviation schemes.

In conclusion, this present study was developed to examine some of the variables which are normally deliberately ignored or unwittingly passed over in any assessment of flood plain management programmes. It was planned to look at both the social characteristics and the physical parameters, to determine the response and attitudes of different groups and individuals to the flood hazard. It was hoped that, in a broader context, such a study would help to explain why some previous alleviation schemes had failed to reduce flood losses, and also to pinpoint certain significant variables which should be considered in any future flood studies.

General aims - Flood plain management

This research was designed to study various aspects of flood plain management policies. Initially, two general questions were posed, (i) what factors were responsible for the spread of urbanisation on to the flood plain?, and (ii) what factors were responsible for the failures of many flood alleviation schemes? The first question was the more straightforward of the two and was considered in terms of the decision-making processes of the Central Government, Local Authorities, River Authorities and the public and private sectors of the communities. The Central Government in Britain has not been particularly strong in preventing flood plain encroachment and several Government directives and circulars, as well as the Medway Letter Line (see chapter three) have been totally ignored. As a result widespread development of flood plains has continued. Responsibility for such development rests essentially with the Town Planners and the Local Authorities, although the Water and Drainage Authorities over the years must take some of the blame for failing to point out the fallacy of such policies. (The various responsible organisations are examined in chapter three in the section on Flood forecasting and warning systems : Responsible authorities). Further liability for flood plain encroachment must be placed on those concerned with the supply and demand aspects of urban development, especially where residential property is concerned. A house with a view of a river is frequently considered an additional selling point as far as the building contractors and estate agents are concerned, and a major attraction of residential location by many buyers. As Troop (1976) pointed out:

> "Just having a view of a river from an upstairs bedroom can add £1000 or £2000 to the value of

the house. And if the river is navigable or offers fishing rights that counts double."

Sunday Times (16.5.76)

However, the apparent acceptance of such locations by some members of the community does not absolve the planner, local government or river authority employee from the responsibility of aggravating the flood problem. Many houses, for instance, will have no such attractive setting, but will still be liable to flooding. Flood plain development, therefore, may proceed because of ignorance or underestimation of the flood hazard, due to inadequate examination of the physical characteristics in the area. At the same time these social pressures may actively encourage residents to purchase property in known flood hazard areas.

The second general consideration of flood plain management took into account the feasibility studies of project selection (described in chapter one). These studies should be undertaken before any alleviation programme is implemented, so that ideally the most efficient scheme in every respect is adopted. However, while physical, political, financial and economic feasibility tests are invariably carried out, the social implications of project selection are usually ignored, on the assumption that any scheme designed to reduce flood losses would be favourable to the flood plain community. The perceived flood hazard should be distinguished from the scientifically measured hazard in order to model the human response to flooding with any success. It was proposed that all groups living or working on the flood plain would perceive the hazard in different ways, whereas, ideally everyone should make an objective assessment of the hazard. However, since the various organisations responsible for flood plain management frequently disagree about the hazard, it is unreasonable to expect an accurate perception of the hazard by individuals within the community. The responsible authorities should evaluate the problem and convey the general strategy to alleviate the hazard in clear terms to the public.

Alongside these perception studies must come the perceived effects of different alleviation schemes, which may obscure the more objective evaluations made by the feasibility tests. For instance, the flood plain planner would invariably select scheme A if the benefits outweighed those of scheme B. However, the benefits could be invalidated if the individuals living and working on the flood plain have little or no faith in the scheme. This could prove particularly unfortunate if the scheme incorporated non-structural measures, which required a positive response to be effective. Alternatively, too much faith in flood alleviation works could lead to the 'levee effect' and hence even greater flood losses.

In conclusion four basic areas of research were proposed concerning the more efficient management of the flood plain. They included,

(1) Perception of the flood hazard

(2) Response to the flood hazard.

(3) Awareness of the authoritarian adjustments to alleviate the flood problem.

(4) Effect of the authoritarian response on individual behaviour.

These aspects were believed to be particularly relevant to flood plain residents and business-men, since it is their behaviour which can determine the overall efficiency of any flood alleviation scheme.

Individual hypotheses

Apart from the general themes of behaviour outlined above, there were many other more specific aspects which were identified for study. For instance, individual hypotheses were developed on the perception and response to the flood hazard by the community, the various authorities, business-men and residents. The case of the flood plain residents was one of the most critical aspects of the research and hence was examined in great detail.

Ideas and hypotheses were formulated about the behaviour of the flood plain resident, which were later translated into a simple model to be tested by the research strategy (figure 4-1). This model assumed the general principle that most residents would require freedom from flooding, or freedom from flood anxiety as a prerequisite of residential location. It was accepted that for many inhabitants this would not be a conscious decision, nor would it rank very highly in the decision-making processes, since other, more everyday, factors would assume greater importance. Nevertheless, it was purported that given input variables would significantly affect the residential perception of the flood hazard, which would cause the inhabitant to adjust his beliefs accordingly, through his 'degree of fear'. If the perceived hazard generates considerable anxiety, the response of the flood plain resident would probably be to move away from the hazard altogether or, alternatively, attempt to reduce the effects of flooding either by personal remedial actions or by pressurizing the authorities to undertake a flood alleviation programme.

The model distinguished three major input factors, which it was postulated would influence residential attitudes and beliefs:

(1) Structural factors.

(2) Environmental factors.

(3) Social factors.

It was hypothesised that in combination these factors would control the perception of the flood hazard and the awareness of authoritarian schemes, which in turn would determine residential behaviour.

Structural factors :

It was proposed that factors such as area of residential location, house type and the geographical proximity to the hazard could influence the residential perception (and thus behaviour) in various ways. For instance, a resident living close to a river would more likely be aware of the hazard than a resident living some distance away. A resident living in a bungalow or ground floor flat would conceivably show more anxiety of flooding than a resident with upstairs rooms to which property could be evacuated.

Environmental factors :

These factors included the physical parameters of the area, especially those characteristics of flooding, such as frequency, depth, duration and velocity. It was anticipated that experience of these factors could produce a wide range of hazard perceptions. For example, it was believed that a great deal would depend on the number of floods experienced, and the extent of flooding in terms of depth and duration. From these environmental factors, which were believed to be partially responsible for flood plain behaviour patterns, three categories of residential attitudes were proposed: (a) Ignorance or unawareness of the flood hazard, (b) Knowledge of the hazard, and (c) direct personal experience of flooding. These three categories should not be considered as separate entities, but rather as basic types within a continuum of experience. For instance, there would be some variation within each category dependent on different levels of knowledge and various degrees of flood experience. The categories were necessary, however, to simplify a complex relationship between certain residential types and flood plain behaviour. It was purported, therefore that these three types would elicit significantly different perceptions of the flood hazard.

Social factors :

These included the social characteristics of the flood plain inhabitant, such as age, sex, family structure, religion, length of residence, education and occupation. These factors have frequently been overlooked in the past, or assumed to be of only secondary importance to the environmental variables. An early study by Kates (1962) in the U.S.A. suggested that these variables may not be relevant to the flood hazard perception. Nevertheless, because of differences between the two countries it was decided to test these factors in the British context. (It was also believed that social traits could play an important role in response to the flood hazard - see below).

Several hypotheses were put forward pertaining to the influence of social characteristics on perception and awareness of the flood hazard. For instance, it was purported that different age groups would perceive the hazard differently. An older person would be more likely to be aware of the problem, because of greater experience, than a younger person. Similarly, because of greater flood experience, length of residence in a flood hazard area was believed to be directly related to greater awareness of the flood problem. It was also hypothesised that different occupation types could lead to various degrees of awareness of the hazard. For example, a person intricately involved with the land, such as a farmer, would probably perceive the hazard more accurately than a factory employee in a large urban area. Education would also appear to be an important factor, with levels of flood awareness directly linked to greater education.

The two factors of sex and religion were believed to have significantly less influence in perception and awareness studies. Sex was tested, although it was unclear what the true effects of this factor would be. Religion was purported to be only of minor significance, affecting a relatively small number of flood plain residents. It was suggested that residents who saw flooding as an 'Act of God' or product of some other higher power would perceive flooding differently from those residents who considered the problem from an assessmeht of the scientific facts.

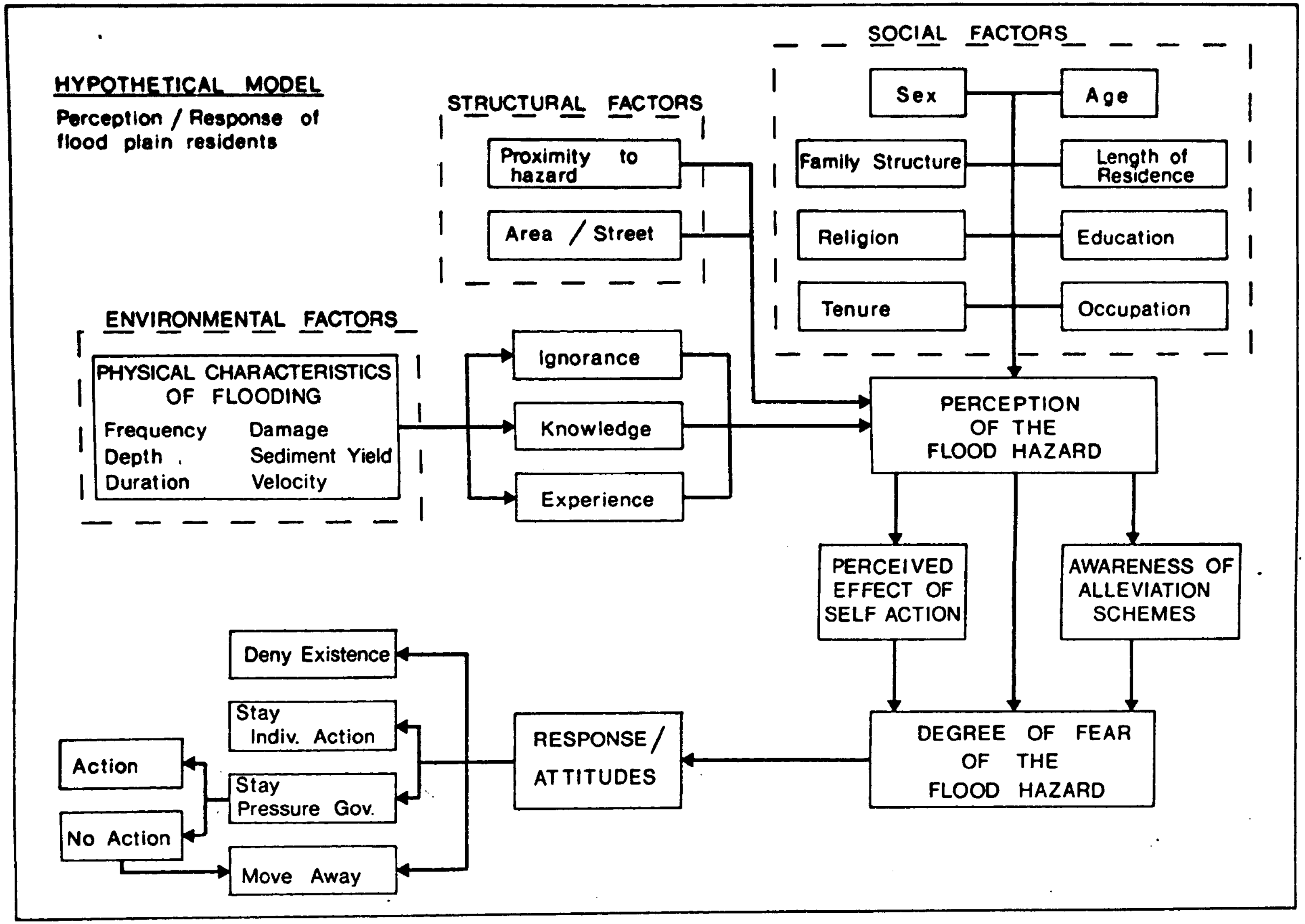
Other social factors were possibly relevant to this study, but were not included for a variety of reasons. Health may be important, but because of measurement problems, it was decided to accept that health would be generally related to age. Income of residents could possibly affect perception, but again was rejected in favour of occupation studies.

The perception of the hazard, therefore, is believed to be the product of structural, environmental and social factors which interact in a complex manner to produce a perceived reality. The association between these variables, as hypothesised, is shown in figure 4-1.

Anxiety of flooding

The hypotheses concerning residential behaviour suggested that perception and awareness of the flood hazard was the principal factor in generating the degree of fear of the hazard (figure 4-1). This perception may be modified by the perceived effectiveness of either individual or authoritarian adjustments, but the degree of fear is still controlled by the various aspects of perception. This degree of fear may range from a complete dread of flooding to an acceptance of the hazard.

Fig. 4-1. Model to explain research hypotheses on residential flood plain behaviour.



The hypotheses in this respect stated that those extremely alarmed by flooding would probably move out of the hazard area following a flood, while others less frightened may take preventive action to reduce future losses. Those individuals completely unconcerned with flooding could be expected to continue living in the hazard area, do nothing to reduce future losses, and to accept other floods as little more than a minor inconvenience.

Several factors were thought to be particularly significant in determining the residential anxiety of flooding. Of the environmental factors, experience and frequency were believed to be most important in this respect. Most texts (Burton, 1962; James, 1974) stated that fear of flooding is greatest immediately following a flood event, and this gradually decreases afterwards, until another flood renews the anxiety. This is linked with personal experience of flooding which was generally seen as adding to the anxiety of flooding, while residents with less experience would express less fear, and those ignorant of the hazard would not be worried at all.

A second factor was perception of the future flood hazard. If a resident perceived frequent flooding in the future, then the associated fear of the hazard may be very great, while another resident who foresaw no future flooding would live totally unconcerned about the problem. Again, the knowledge and experience of previous flooding would probably affect the perception of the future hazard. For instance, a person who successfully prevented serious flood losses on previous flood occasions may express less fear than a person who has suffered considerable flood losses in the past. Geographical proximity to the hazard may be related to the fear of flooding. A view of the river may be a pleasant attraction to a residential location but this could add to the degree of fear during periods of heavy rain, when the river can be seen rising towards the building.

Social factors were believed to govern the degree of fear through perception of the hazard in a variety of ways. It was suggested, for instance, that differences in sex may constitute a difference in the degree of fear. The age of the flood plain respondent was thought to be another significant factor regarding flood anxiety. It was suggested that since increasing age generally reduces personal mobility this could generate increased anxiety, whereas on the other hand, older residents may have learned to accept the hazard calmly because of their experience of the flood environment. It was also expected that a family with young children would express greater anxiety about flooding than a family with no young children. Higher levels of education may prevent extreme fear, but it was anticipated that more general anxiety would be generated because of greater awareness of the hazard by this group. Degree of fear, therefore, was believed to be directly related to the perception of the flood hazard, as well as to various structural, environmental and social factors.

Response

To complete the above model, the 'degree of fear' of the flood hazard was believed to stimulate the individual response to the hazard. Response was thought to be based entirely on the perception of the hazard and the perceived effectiveness of any alleviation schemes through the medium of fear. This represents a further stage of the research, the study of those variables influencing the response to the hazard, rather than those variables controlling perception of the hazard. For example, it was suggested that an individual who perceived flooding as a frequent hazard would respond in one or more ways. He may move from the area altogether, remain but undertake individual flood adjustments, or press the authorities to take some form of remedial action. If the authorities had already responded to the hazard then the behaviour of the individual would depend on the perceived effectiveness of the scheme.

The perceived effectiveness of individual measures may also significantly influence the response of individual residents to the flood hazard. This was thought to relate to the experience of flooding, for if successful measures had been implemented in the past, then the perceived effects of future floods may be minimal, because of the faith in individual actions to prevent flood damages. Naturally, this is also linked with fear of the hazard (described above) since experienced residents may feel more confident of coping with the hazard.

Another factor associated with the degree of fear of flooding was age, which could also restrict response to the hazard. It was purported that younger residents would be able to undertake more vigorous activity to reduce flood losses. However, it was further suggested that the actions undertaken by the elderly may be more effective, because of the greater experience of this group.

Tenure of the building was another variable thought to have some influence on the residential response to the hazard. The hypothesis suggested that flood plain tenants would behave differently from owner-occupiers in that the former would seek to save personal possessions from damage, whereas the latter would try to protect the property.

In conclusion, the model outlines the basic variables believed to influence the residential response to the flood hazard. First, perception of the hazard was analysed through certain structural, environmental and social factors to establish the attitudes and beliefs of the flood plain residents. From these perceptions studies, a degree of fear factor was developed, which was believed to be directly related to individual response to the flood hazard. It was believed that through this simplified model of residential decision-making a greater understanding of flood plain behaviour could be established.

Response to authoritarian adjustments

The general hypotheses, described at the begining of this chapter, suggested that the inadequate consideration of the social implications of flood alleviation schemes had contributed significantly to the past failures of these measures. For this reason, therefore, a series of hypotheses were produced to examine this aspect of flood plain management in greater detail. It was anticipated that through a better understanding of the residential perception of, and response to, the authoritarian alleviation schemes, a more accurate prediction of future flood plain behaviour as a result of similar schemes could be made.

Flood forecasting and warning schemes, because of their widespread distribution in Britain, were specifically selected for the detailed analysis of the social implications of flood alleviation projects. An efficient residential response to this measure is essential if the scheme is to be successful in reducing flood losses and hence is particularly applicable to this type of survey. The basic hypothesis developed from this was that not everyone would necessarily believe or respond to a flood warning. It was suggested that responses would vary due to the differences in structural, environmental and social factors influencing the individual resident. Mileti and Krane (1973) distinguished four variable groupings to describe the residential response to warning schemes:

(i) Variables related to evaluation and dissemination of the warning.

(ii) Variables related to warning confirmation.

(iii) Variables related to warning belief.

(iv) Variables related to response

The first group of variables are related to the physical aspects of flood warning and the problems of accurately forecasting statistics on flooding such as the time of arrival and peak discharges. The additional problems of disseminating the warning message to all flood plain residents are also considered in this group. The importance of these variables is not particularly relevant to flood plain behaviour and have already been discussed in chapter three, with a further case study in chapter six.

The second group of variables described by Mileti and Krane reflected the tendency of flood plain residents to seek confirmation of the warning message. For instance, individuals who receive a hazard warning may check on the accuracy of the warning with other organisations or with their neighbours.

This group is closely related to the third category, variables related to warning belief. It was purported that a variety of factors would combine to influence the perceived faith of individuals in warnings. Variables thought to be significant in warning confirmation and belief were : the warning source, warning content, the method of communication, the number of warnings received, the perceived certainty of the event, warning confirmation, the observed action of others, hazard perception, personal experience, the experience of others, the geographical proximity to the hazard; and socio-economic factors such as sex, age, education and occupation. For example, it was hypothesised that warnings received from an official source were more likely to be believed than the casual dissemination of information through the flood plain residents. Also, the more warning messages received the more likely an individual is to believe the message, and if others respond immediately to the warning, then by observation the message may be confirmed. Socio-economic factors may make some groups more receptive to warning messages with some individuals accepting authoritarian action and others rejecting it. Thus, it was planned to test these variables in the British context to discover which variables were most significant in generating warning belief.

The last group of variables, those related to response, were similar to the previous category; source of warning, content of warning message, means of dissemination, number of warnings received, perception of the hazard, the perceived time to impact, personal experience, geographical proximity to the hazard, socio-economic factors, but also included warning confirmation and belief. Response to the warning was thought to be related to the characteristics of the warning techniques, the message, the mode of communication, the source, and number of warnings received. Again, official warnings were believed to be more likely to induce a high response rate than unofficial channels. The perceived effect of flooding, and previous personal experience may also affect response rates. For instance, if earlier warning had not resulted in flooding, or had failed to reduce flood losses, future warnings could well be ignored by these groups. Belief in the warning message and faith in the ability to undertake remedial action, thus reducing flood losses, are essential ingredients of a flood forecasting and warning system.

The research hypotheses also suggested that flood forecasting and warning schemes, as well as other non-structural adjustments, would be less effective in areas of low flood frequency than in areas of considerable risk. Residents in low risk areas would be less prepared for remedial action and have less experience than residents in higher risk areas, and hence this may significantly reduce the effectiveness of the scheme.

In conclusion, as far as the individual was concerned, the research aimed to look at those characteristics which affect the perception of the hazard by the flood plain resident, and how in turn, through the degree of fear, this affects the response of the individual to the hazard. The theory was to establish certain categories with similar ideas, perceptions and views. For example, was there one group with greater faith in government adjustments and another group with more faith in individual measures?

Another important aspect of flood hazard research is the constantly changing perceptions over time. For instance, in a flood environment a pattern of behaviour develops which suggests an increasing feeling of security over flood free periods, but that this can be changed instantly by renewed flooding. The temporal aspects of flood hazard research, therefore, would indicate where individuals within the flood prone community were on this scale. Each major flood will result in greater, more accurate perception of the hazard and further response to alleviate the problem.

The commercial sector

As well as the individual inhabitants, there were other groups on the flood plain, who were considered important in an assessment of flood hazard perception and flood plain behaviour, namely the industrialists and small business-men. The general hypotheses concerning the business-men were much the same as for the residents, particularly the perception studies and perceived future flood plain behaviour. Both structural and environmental factors were believed to be significant in effecting the response of business-men to the hazard, while social factors suggested in the residential proposals were replaced by business characteristics. For instance, the research hypothesis stated that certain industries, such as road haulage companies, could withstand flooding without suffering significant losses, while other industries, for example food processing plants, would suffer considerable losses even from minimal flooding. A survey of industries and businesses, therefore, was necessary to consider the extent and damage of flooding throughout the flood plain, as well as to establish the effectiveness of any flood alleviation scheme. It was also proposed that different business concerns would react differently to authoritarian adjustments, and again particular attention was devoted to the response generated by a flood forecasting and warning scheme.

The decision-makers

The research hypotheses also proposed that the characteristics of the decision-makers themselves could play a significant part in flood plain management. It was purported that the decision-makers, in formulating a flood plain policy, would be influenced not only by the physical factors of hydrology and meteorology, but also by the perceived threat from flooding and the perceived effectiveness of various alleviation schemes. Naturally, flood events tend to stimulate flood adjustments, but the actual process of project selection may be influenced by the mental attitudes of the decision-makers. Hence, further studies of characteristics of flood plain managers was deemed important.

The whole process of flood plain management was seen by James et al (1971) as the result of six factors, which together culminated in 'community action'. These were:

(1) The physical characteristics of flooding

(2) Perception of the hazard by the decision-makers.

(3) Perception of the effectiveness of various alleviation schemes.

(4) Political motivation.

(5) Pressure groups.

(6) Economic appraisals

Economic appraisal is probably most significant since this often determines the likelihood of a scheme being implemented.

Unfortunately the technique of benefit-cost analysis is not always accurate and can frequently omit major factors from the final evaluations (see chapter one). The factors of perception may play an important role in flood plain decision-making, and several hypotheses to this effect have been outlined above. Political motivation and pressure groups may also effect the processes of flood plain management. Pressure groups have become more important in recent years and may in future lead to different forms of adjustment. It is of interest to note that pressure groups had warned of the dangers of building the Teton Dam on the River Snake prior to the collapse. Political implications of flood plain management have been described in the feasibility tests (chapter one).

Community response, therefore, is seen as the process of altering unacceptable flood plain behaviour by employing means acceptable in terms of the feasibility studies described in chapter one. Ideally, this should entail a combination of measures so that behaviour is 'controlled' by non-structural adjustments and the physical aspects of flooding by structural schemes. However, before any scheme is implemented the social acceptability of the measure should be assessed.

A further aspect of flood plain behaviour considered important to this research was the necessity for prepared emergency action. The research proposed that considerable damage and stress could be avoided by planned community action at times of flooding, particularly in the physical relief of the flood victims. Control of sightseers may also help in some respects. Fritz and Matthewson (1957) described the general tendency of people to drift towards the source of disasters. An example of such behaviour occurred during the Trident air disaster in Staines, when sightseers blocked the access of emergency vehicles.

In the final analysis, the research hypotheses centred on studies of perception of the flood hazard by all those concerned with the flood plain, the flood plain managers, business-men and the local residents. Second to this was the consideration of those factors affecting the response of these different flood plain groups to the hazard. Factors believed to be important to these studies of behaviour were classified as structural, environmental and social characteristics. These were incorporated into a proposed model of residential decision-making to study general flood plain behaviour patterns. Further hypotheses were proposed on the perceived effectiveness of certain flood alleviation schemes and especially the perceived response to flood forecasting and warning schemes. Once having established these general research hypotheses, it was necessary to set up a research strategy which could be used to test these theories.

PART B METHODOLOGICAL BASE

Introduction

The various techniques of data collection in this study incorporated both primary and secondary sources, and provided information on a wide range of issues. The collected data was then analysed, and used in testing the research hypotheses described in the first part of this chapter. Two basic sources of information were utilized during the course of the research, the hydrological data obtained from the River Authority, and the social characteristics procured from the questionnaire survey. However, to supplement this information, many other records were consulted, whilst further primary data were collected from additional sources. Because the research was so wide ranging, incorporating both the physical aspects of flood hydrology and other drainage parameters, and human studies of response and behaviour in a known hazard area, considerable information was required on a variety of factors. This second part of the chapter, therefore, in examining the research design, discusses the relative merits of the various data sources. These include the literature review, the field study area, various maps, newspaper reports, photographic material, Local Authority archives, River Authority records and finally the questionnaire survey.

The Literature Survey

The literature reviewed in chapters one and two provided much of the background details for the present study by promoting and encouraging the formulation of ideas and theories on the behaviour of various flood plain groups. One of the most significant findings to emerge from this early study was the apparent lack of detailed surveys undertaken in Britain. Only the preliminary considerations put forward by Harding and Parker (1972) and the Middlesex Polytechnic Research Team (Flood Reports 1972, 1973) were exceptions to this. Studies, such as those engaged by White (1961, 1964), Burton (1962), Kates (1962), James et al (1971) and James (1974) have never been implemented in this country. The general literature survey, therefore, suggested several important aspects of flood plain management, particular social implications, which should have been considered in a British context.

The literature coverage of the hydrological aspects of flooding was quite extensive, particularly on the design standards of structural alleviation schemes, while there was only minimal concern of the response to the flood hazard, or the implications of non-structural alleviation measures. Also questionable was the applicability of the American work to Britain, and hence a survey on the 'Response to the Flood Hazard' was believed to be relevant, if not essential.

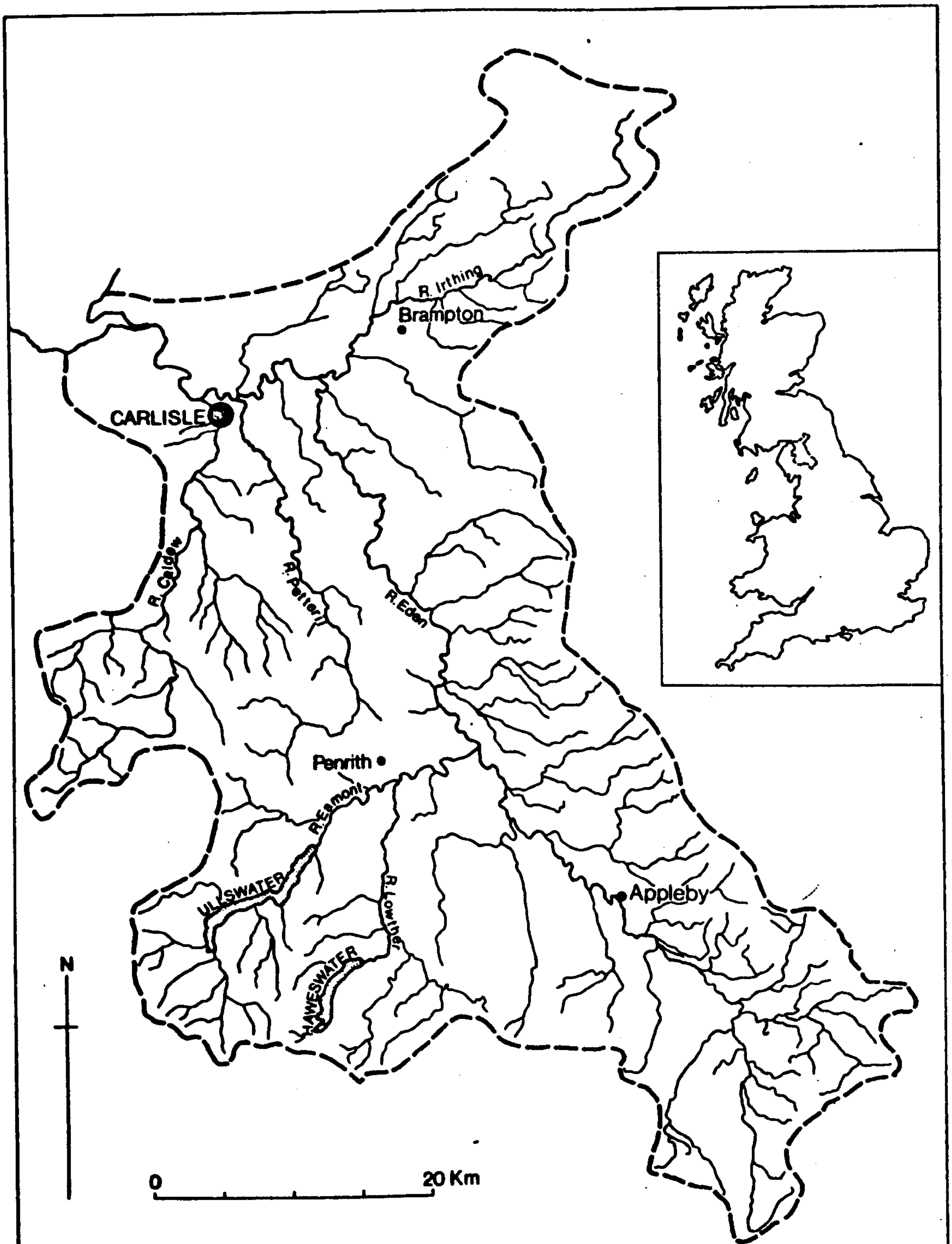
Research Centre

The theories developed following the literature review required practical testing and hence a study area was selected which provided scope for these tests. The general survey of the authoritarian response to the flood hazard in Britain (chapter three) provided an indication of areas with particular flood problems. Basically, this entailed studying an area which experienced different types of flooding, and where the authoritarian response to the hazard had taken more than one form. It was also necessary to select an area of manageable size for an individual survey such as this, where a wide range of factors had to be followed up. Another consideration was convenience, for, with limited resources, the research was restricted to reasonably accessible centres. With all this in mind, it was finally decided that Cumbria suited all the necessary requirements and provided various types of flood environments and authoritarian response (see chapters five and six for details). Cumbria was also accessible from Glasgow and had not experienced any previous investigation into the flood hazard.

Two particular centres were selected for further in-depth analyses, following a general survey of the research area, namely Carlisle and Appleby (map 4-1). Again, the details may be found in the following two chapters, but essentially the two centres experienced not only different types of flooding, but also different authoritarian responses to the problem. Thus, the research area, and in particular the research centres, were ideally suited for the proposed study, and the testing of the research hypotheses.

Maps consulted

Maps of Cumbria were, of course, a fundamental requirement in tracing the physical characteristics of the research area. The majority of the maps consulted were obtained from the Ordnance Survey, and ranged in scales from 1:625,000 to 1:2500. The



Map. 4-1. Location of research centres: Carlisle and Appleby.

smaller scale maps were utilized for various catchment characteristics, although more specific information for the theoretical calculations of flood risk in Carlisle and Appleby was gathered from the 1:63360 and 1:25,000 maps (see appendix IV). Communities at possible risk from flooding in Cumbria were established from the 1:10,560 scale maps in conjunction with other data, while the more detailed delimitation of flood boundaries in Carlisle and Appleby were undertaken with aid of 1:2500 maps.

The Ordnance Survey maps were also of value in the historical survey, especially in tracing the development of settlements within the study area. In particular, the morphological changes in the settlements of Carlisle and Appleby were examined from the last quarter of the nineteenth century to the present day with the aid of various editions of the 1:2500 and 1:10560 maps (1:2500 maps 1876, 1901, 1925, 1952 and 1:10560 maps 1868, 1901, 1927, 1952, 1964). These maps helped to show the effect of flooding on urbanisation over the last hundred years, when used in conjunction with other hydrological data.

Other maps were also consulted besides the basic Ordnance Survey. These included geological surveys, historical maps of Carlisle, and more specific maps of the hydrological characteristics provided by the Cumberland River Authority. The historical maps of Carlisle provided evidence of the gradual encroachment on to the flood plain, and are shown in plates three, four and five (1746, 1800 and 1900).

Newspaper Reports

Another major source of data was the old newspaper reports of flooding. Local newspapers provided detailed information on both the extent of flooding throughout Cumbria and on the frequency of flooding over the years. More recently, particularly with the important flooding of the 1960's, the reports were useful in establishing the spatial extent of flooding and more specifically those areas of greatest risk within settlements. However, probably the greatest value of the newspaper reports was that a long history of flooding could be traced back in both Carlisle and Appleby.

Naturally, there were some disadvantages in using newspaper reports as a research technique. Firstly, not all floods may have been reported in the newspapers, or the researcher may have overlooked some events which would give a false estimate of flood frequency. Secondly, there was the danger that any flood event could have been exaggerated by a reporter trying to make a good story. Nevertheless, many floods were reported by the newspapers, and particularly with recent flooding, the accuracy of the reports compared favourably with the records consulted at the River Authority. Also, in the past several newspapers stressed various aspects of 'inclement weather' which probably encouraged the reporting of even small localised flooding. A second factor which added to the accuracy of this research source was the availability of a wide selection of newspapers (see below) at least until recently, which meant that reports of flooding could be cross-checked between papers. A third factor was the tendency to produce very local editions of more general papers, which tended to concentrate on purely local problems, for example the Appleby edition of the 'Cumberland and Westmorland Herald'.

The local newspapers have a long history and several such as the 'Carlisle Journal' and the Carlisle Patriot' date from the first two decades of the nineteenth century. Other newspapers with long records include the 'Cumberland News' the 'Carlisle Pacquet' and the 'West Cumberland Times and Star'. More recent newspapers consulted were the 'Cumberland Journal' and the Carlisle and Cumberland Journal'. Fortunately, many of these papers have been stored at the library in Carlisle, while others have been retained by the local newspaper offices at Penrith and Cockermouth. All these were made available for consultation, which greatly enhanced the accuracy of the historical flood survey.

Photographs

Another valuable source of information was photographic evidence of different flood events. Photographs, taken from the air, of the 1968 flooding throughout the Eden Valley were particularly useful since they provided a good record of the extent of flooding (plates 17-19). It was unfortunate that these had been taken after the flood peak had passed through the system, and hence they do not portray the exact limits of the flood. Other photographs were forthcoming from local residents and business-men of various floods in Carlisle, Appleby and Cockermouth. For example, a local photographer in Appleby provided photographs of the two most recent floods in the town (plates 6-9 and 20), the editor of 'West Cumberland Times and Star' found copies of photographs from the 1938 flooding in Cockermouth (plates 1 and 2) and the manager of McKenzies Motors in Carlisle provided visual evidence of the damage in Willow Holme Industrial Estate (plates 25 and 26). Photographic evidence such as this was particularly useful in delimiting the extent of flood events, and especially when used in conjunction with the air-photographs, were employed to determine the small undulations on the flood plains not always apparent from the maps survey.

The earliest visual record was obtained from old newspaper photographs of the 1924 December floods in Carlisle, although other photographs were available for the floods of January 1925 (plates 10-13) 1926, 1928, 1929, 1931 November (plate 14) 1933, 1938, 1941, 1947, 1964 and 1968. In Appleby, photographs of flooding were available for 1931, 1954, 1964 and 1968 (plates 6-9) while in Cockermouth there was extensive coverage of the catastrophic flooding in 1938 (plates 1 and 2).

Other Archives

Several other record offices and archives were also visited to obtain additional background material. The libraries, particularly at Carlisle, provided considerable information on local history with records dating back two hundred years or more. There were several references to the recurring problem of flooding especially in the 'Carlisle Sewerage Reports' (1850-1880). The City Surveyor (Gordon 1861) described in detail the causes of flooding in several areas of the City, and the proposed measures to deal with the problem. Also in Carlisle, the County Record Office, situated in the castle, provided valuable information on the development of Carlisle on to the flood plains. These archives contain details of buildings erected in the City during the last one hundred years or more. Since development on to the flood plains was somewhat sporadic, a sample of properties was taken to check the exact dates of construction. Within the same street considerable differences in development were found. This evidence was checked by the map evidence, described above.

Local Authority

The present Local Authority Offices were not very helpful. The Town Planning Department, for example, could give no definite description of the future plans for the City, apart from producing a very old town plan map, showing many schemes which had been completed or either postponed or cancelled. For instance, very little was known about the final plans for the residential part of Caldewgate (the town plan showed this as a designated industrial area) or for the new road link to Willow Holme Industrial Estate. In general, there was little consideration of the flood problem, for the only firm plans made, were for the development of residential properties on the flood plain of the River Petteril.

River Authority

The River Authority - originally the Cumberland River Authority, but later, following the reorganisation of the water industry, the Cumbria Division of the North West Water Authority - supplied much of the hydrological data for the research. Estimates were obtained for the recent flood flows, while more recent data were available for rainfall and river level relationships. Unfortunately, the River Authority did not have long detailed records of rainfall or river levels, because accurate gauges were not installed until the early 1970's, after the last major flood. Nevertheless, the River Authority did provide a guide to the spatial extent of flooding in Cumbria as well as an indication of the expected frequency of flooding. These data were later compared with the theoretical calculations of flood frequency based on techniques described in the Flood Studies Report (1975). The major disadvantage, however, was the complete lack of historical data, but in general the River Authority was quite helpful and even provided evidence of a flood report by the Derwent Catchment Board in the 1930's.

Other Sources

Many other surveys were undertaken on an informal, unstructured interview basis, to allow individuals to talk freely about flood experiences. These included organisations such as the police forces, fire brigade, Salvation Army, the Womens Royal Voluntary Service and estate agents. This led to some valuable information on the flood hazard, which was later cross-checked with data from other sources. For example, in Appleby one family had maintained a scrap book of notable events in the town for the past 150 years. Other interviews provided supplementary information to the questionnaire survey (see below) and although not statistically comparable, they did provide valuable insights into the trends and beliefs of various organisations. Finally, many contacts were made with other research workers at various university departments and River Authorities which helped to set this research in motion.

In conclusion, many sources of information were examined during the course of this study; some of these provided valuable primary data, while others were used for purposes of checking results. Problems of comparison arose between some data sources, particularly between quantitative and non-quantitative material, but this was to be expected given the variety of data sources consulted. Probably the basis of the whole research was the questionnaire survey, which supplied the primary data for the studies of perception and behaviour. For this reason the questionnaire design, construction and implementation is discussed in detail below.

The Questionnaire Survey

The questionnaire survey was carried out in order to collect primary material, which was unobtainable through alternative sources. The very nature of the study into human behaviour, attitudes and perceptions precluded most alternative techniques, and so it was established finally that a questionnaire survey would best serve the designs of the research. The information collected by the questionnaire survey was utilized in conjunction with other data obtained from the other sources, and so formed the basis of the research, balancing the physical aspects of the hydrological parameters with the response of various flood plain groups to the physical environment. The questionnaire survey was extremely important to the research proposals and hence it was essential to design a survey that would most accurately reflect the attitudes of the flood plain residents, industrialists and business-men. It was necessary, therefore, to eliminate as many errors as possible, both of the interviewer and respondent, so that valuable and representative data would be collected. For this reason,considerable attention was devoted to all aspects of questionnaire surveying, from the preliminary aims and initial design of the questionnaire to the sampling techniques employed, the interviewer methods, the pilot study, and the final analyses techniques. Much of this planning was based on the work of Cannell and Kahn (1965) Peak (1965) Simon (1969) Moser and Kalton (1971) and James (1973).

Aims of the questionnaire survey

At first it was important to establish the exact aims of the questionnaire survey, so that pertinent questions could be formulated to test the research hypotheses. According to Cannell and Kahn (1965) the questionnaire serves two prime purposes. Firstly, it must translate the research objectives into specific questions, the answers to which will provide the necessary data to test the hypotheses or explore the area set by the research objectives. Secondly, the questionnaire must assist the interviewer in motivating the respondents to communicate the required information. The immediate aim of the questionnaire, therefore, was to collect primary data, which was unobtainable through alternative sources, on the characteristics of various flood plain groups in relation to response to the flood hazard. The principal objective was to collect information on the choice processes of flood plain locations and the adjustment processes of learning to live with the hazard. The emphasis was not on the physical aspects of accommodation, although flood proofing was considered, but rather on the mental processes of adjustment and rationalisation. With these general aims in mind, it was decided to test the research hypotheses in two areas of contrasting flood frequencies and where the authoritarian response had been different. For these reasons, the two communities of Carlisle and Appleby were selected from the general research area of Cumbria (map 4-1).

There were many general aims of the questionnaire survey, although of particular importance were those associated with the flood plain residents. For example, the research hypotheses suggested several characteristics, which, it was believed, were influential in governing flood plain behaviour. For instance, a questionnaire survey could be used to discover to what extent residents were aware of the hazard, whether they had personal experience of flooding and how much risk they were willing to tolerate. Other factors, such as social characteristics of the flood plain population, could also be assessed in this way. The fundamental question to be tested was whether or not flood plain residents exhibited certain characteristics which could be used to classify them according to their response and perception. Other objectives considered important were knowledge of flood alleviation schemes, attitudes towards flood adjustments and the perceived effects of future flooding. Again, from an analysis of the views expressed to questions such as these, estimates on flood plain behaviour and predictions of future actions could be made.

Thus, the basic aim of the questionnaire survey was to collect information on the characteristics of flood plain residents and business-men, so that more detailed analyses could be made of flood plain behaviour. An immediate objective of the survey was to establish which factors were most significant in determining flood plain behaviour patterns, and to gauge the efficiency of various alleviation schemes based on the social acceptability of such measures.

Design of the questionnaire

Having established the aims of the questionnaire survey, the next stage was to translate them into meaningful questions. This involved designing a questionnaire which was both clear and concise, and well structured so that an accurate response would be obtained and any errors would be reduced.

There are certain principles, which should be applied to any questionnaire, including such factors as the ease of handling in the field, the efficiency of lay out, the clarity of definitions, and naturally the adequacy of the questions themselves. The objective of the design stage, therefore, is to produce a questionnaire which would be clearly understood in the same way by the majority of people.

Wording :

The wording of individual questions was extremely important. Questions should be clear, unambiguous and free from technical terms so that, as far as possible, the majority of respondents would interpret the question in the same way. Poorly worded questions would create both confusion and errors in the response, while others could actually lead the respondent to give an answer which he believed the researcher required. Thus careful question wording was necessary to prevent these errors.

Form :

The type of question employed could help to reduce bias, and hence several question forms were considered, such as restricted and unrestricted questions (closed and open). Restricted questions normally limit the respondent to a few choices, whereas the unrestricted type allow the respondent to talk freely about the subject. While restricted questions are ideal for purposes of comparison, because every response is neatly classified, they are probably less accurate than the unrestricted type. For this reason both types of questions were employed in this survey.

Order :

Arrangement of the questions was also an important aspect in questionnaire design. For example, at the begining of an interview several 'warm up' questions should be included to put the respondent at ease, and thereby build up a rapport between the interviewee and interviewer. These questions should be of general interest which the respondent would have little difficulty in answering, and should avoid controversial issues in case this terminates the interview. The following questions should then proceed in a logical manner, moving from topic to topic in a way that indicates a relationship between the questions. Any obvious breaks should include a few words of explanation, and in essence the question order should funnel down from the broad based questions at the begining to more specific items at the end.

The questionnaire designed for this survey followed these general principles, begining with general open ended questions and gradually funnelling down to more specific closed questions. The final questions were opinion type, while possibly the more controversial social aspects were asked immediately before these (appendix II). The layout of the questionnaire permitted easy marking in the field, while technical terms were defined in straightforward language. For example, flood could mean a variety of things to different people, and hence it was defined in terms of effect; 'A building is considered flooded when flood water either enters it , or rises around the outside walls without getting inside'.

The final questionnaire design was based not only on these general principles, but also on the work of two similar surveys. The Middlesex Polytechnic carried out a pilot study of the Lower Severn area, and this was employed as the general basis of the questionnaire (Penning-Rowsell, Progress Report, 1972) A second survey carried out by James (1974) also helped with respect to the perception studies and opinion type questions. It was anticipated that by employing some similar variables as had previous studies, comparisons could be made later between the research area and these other studies.

Two questionnaires were designed, one for the flood plain residents and the other for business-men. The commercial survey was very similar to the residential questionnaire and is considered in greater detail below. The residential questionnaire incorporated four basic question types:

(i) Social characteristics - these included the personal details of age, sex, family structure, education, occupation, length of residence in the area and tenure of household. These were necessary to distinguish the different characteristics of flood plain residents. (Questions 30-35).

(ii) Flood statistics - these were questions on past flood events and in particular the characteristics of the 1968 flood. Since these questions relied on the capabilities of respondents to recall certain events a certain degree of error may have been incurred. However, the questions were important in establishing those residents with flood experience and those without (Questions 6-13).

(iii) General environmental perceptions - these questions were used both in the warm-up procedure, and also to put flooding into perspective as far as other environmental hazards in the area were concerned (Questions 1-5).

(iv) Behavioural aspects - these questions on residential behaviour and perceptions were probably the most important in the survey and certainly constituted a major part of the research. These questions were quite wide ranging, investigating not only the previous behaviour of residents, but also their perceived future activities in the event of another flood. Perception of the hazard was included also, to test the accuracy of the evaluation of flood risk by the residents, while other questions were used to assess the perceived effects of various flood alleviation schemes (Questions 14-29, 36-39).

Sampling

A further problem regarding the questionnaire survey was whom to interview. It was decided to question the flood plain residents on the basis of households, where any adult member of the family would be acceptable, since it was reasonable to assume that any of the adults would be likely to take any decisions during a flood. This policy was satisfactory in Appleby, where all the flood plain households could be interviewed, but in Carlisle the large number of households and the limited time and resources available, precluded a hundred percent survey. Thus some form of sampling was required which automatically introduces a degree of error into the survey technique. Cochran, Mosteller and Tukey (1970) pointed out that the measurement and sampling involved in questionnaire surveys would be imperfect in almost every case and that any appearance of perfection would be an illusion. They in fact stressed several systematic errors involved with sampling : (i) the failure to include all possibles from which the sample has been taken, (ii) persons perenially not at home or samples lost, and (iii) refusals to answer which represent the hard-core of systematic errors. However, Grebenik and Moser (1970) suggested that these errors would be reduced significantly by careful sample design.

The actual techniques of sampling are fairly well documented (for example Parten, 1950; Kish, 1965; Conway, 1967; Moser and Kalton, 1971; and the Social Community Planning Research 1972) and have proved acceptable to all surveys, providing the relevant technique and correct procedures are followed. There were several sampling techniques from which to select the research methodology, from a simple random sample, where each respondent has the same probability of being selected, to more sophisticated techniques which involve the stratification of data, or the clustering and systematic techniques of selection. After due consideration, it was decided that a proportional, stratified random sample was necessary on the Carlisle flood plain. This procedure incorporated several of the standard sampling techniques, which together reduced much of the error resulting from sampling bias. The flood plain properties in Carlisle were first organised into strata, which for the purposes of this survey involved individual streets, or parts of streets subject to flooding. The houses, which were to be included in the survey were then selected on the basis of a given proportion from each of the strata. In this way the whole of the flood plain was represented in the survey, while the proportional selection procedure reduced any bias towards the smaller streets. The final house selection was carried out through random numbers, which prevented any bias in this aspect of the sampling technique. Each house in each strata was first given a number, and then random numbers were employed to select houses up to the required proportion. The anticipated result of this somewhat complicated procedure was the production of an unbiased and representative random sample.

In practice, the sample size, and hence the proportion of households selected from each strata, was determined by the response rate generated by the pilot survey (see below) and the agreed acceptable error associated with sample surveys. Details of the calculations of sample size are given in chapter seven.

Interviewing

A further problem with the questionnaire survey was how the interviews should be carried out. Having decided to employ a structured questionnaire, observational techniques and unstructured interviewing were immediately discounted. These would have been of little value since the former would require complete observation of the communities before, during and after a flood event, while the latter would make accurate statistical comparisons very difficult and possibly invalid. However, there were still several other methods which warranted some consideration, each with relative advantages and disadvantages. The choice of technique rested essentially between a telephone survey, mail questionnairing, and face-to-face interviewing. Telephone surveys were considered unsatisfactory because of the obvious bias towards telephone receivers and hence probably towards the more affluent people in the communities. The expense of such a long questionnaire survey was also prohibitive. Mail questionnaires were eliminated for several reasons. Firstly, the response rate generated by such techniques is notoriously low, and usually requires a series of follow-up letters to reach a response rate of twenty to thirty percent (Berdie and Anderson 1974). If this technique had been used, a full flood plain survey would have been attempted, but with such low response rates, the resulting bias would probably have been greater than with a controlled sample survey. Secondly, to allow for strict comparisons, a mail survey in Carlisle would have necessitated a similar procedure in Appleby, which given the low response rate would have produced statistically invalid results. Thirdly, and probably of most importance was the actual nature of the survey study - perception. This entailed answering the questions in sequence with no prior knowledge of the following questions, since this could influence certain responses. Naturally, this could not be guaranteed in a mail questionnaire survey. Thus, because of these problems the face-to-face interviewing technique was employed.

Questionnaire interviewing also has several disadvantages

For example, there are problems with how the interviewer interprets the questions, and the extent of interviewer bias. Cannell and Kahn (1965) suggested that one of the limitations of the interview was the involvement of the individual in the data and the consequent likelihood of bias. Many of these systematic errors, however, were hopefully eliminated by the researcher not only designing the questionnaire but also carrying out the interviews, and hence being aware of these particular problems. The objective of the formal interview, therefore, was to maximise the reliability and validity of the results by simplified questioning.

The formalities of the interview itself were carried out along tried and accepted methods in order to encourage as high a response rate as possible (described by Atkinson 1967, and the Survey Research Centre 1966). For instance, at each interview, the researcher explained the purpose and objective of the research, described briefly how the respondent was selected, emphasised the strict confidentiality of the survey, and also identified himself. However, to avoid leading the respondent, there was no reference to flooding in the introductory talk or in the initial questions. Flooding was not introduced formally until section two of the questionnaire.

These interview techniques were found to be quite successful and despite each interview taking up to thirty minutes a response rate was generated which compared favourably with other studies. In a discussion of response rates Grebenik and Moser (1970, 191) stated;

> "As regards non-response, improvements in survey techniques have in fact considerably improved levels of response. Response rates of 70-90% are customary in well administered questionnaires and rates of over 90% are not uncommon."

However, it should be noted that the higher rates relate principally to shorter more concise questionnaires. Moser and Kalton (1971, 171) agreed;

> "A more typical non-response rate is probably nearer 20% and these refer to straight forward interview surveys with few questions."

Some surveys have produced very low response rates, such as the National Expenditure Survey in 1941 with a positive response of forty-five percent and the Food Survey in 1955, with fifty-five percent.

The response rate generated by the Carlisle residential survey was 79%, which represented 218 interviews out of a planned 277. In Appleby, of the total 49 households on the flood plain interviews were obtained from 44, which represents a 90% response rate. Details of these figures can be found in the questionnaire results in chapter seven.

The pilot survey

A full questionnaire survey plan was prepared on the basis of the preliminary research aims, the questionnaire design, the sampling techniques and the interviewing techniques discussed above. However, before proceeding with the proposed research, the basic plan was tested in a small pilot survey. This is generally considered an essential part of questionnaire studies. The pilot survey is used to test the qualities of the research plan and to allow amendments before starting the full survey. On the basis of response rate, the pilot survey was also used to determine the final sample size. This systematic testing should incorporate all the ingredients of the main survey to provide guidance on : (i) the adequacy of the sampling technique, (ii) the variability within the population, (iii) the non-response rate likely to be expected, (iv) the suitability of the method of collecting data, and (v) the adequacy of the questionnaire itself. The pretest may also give an indication of the probable duration of the main survey.

In the present research, the pilot survey was undertaken on the Carlisle flood plain, and as a result, the research design and questionnaire form were amended in several ways, before beginning the full survey. For example, the sampling technique was found adequate, although it was decided to replace empty or unoccupied housing with other randomly selected households. The variability within the population showed up the inadequacy of several questions and accordingly new categories had to be incorporated into closed questions. The non-response rate was acceptable, but as it turned out higher than during the actual survey. This difference was probably attributable to improvements in the technique of the interviewer. The questionnaire wording also appeared to be satisfactory since no leading questions were found, nor any questions which were too sensitive for the respondent. In general, therefore, the research proposals were quite sound apart from the minor alterations required in the questionnaire.

Several other important points did emerge from the pilot survey; for instance, the actual timing of the interview was significant. The pretest showed the fallacy of interviewing only during the day, since this produced predominantly female respondents. While this is reasonable because flooding may occur at any time, a more balanced sex component was required for the studies of perception. Thus, interviews in the main survey were carried out both during the day and in the evenings. A second point to emerge from this pilot study was the necessity for frequent call-backs to ensure a high response rate. In many cases the sampled occupants would be out at the first or second times of calling, and hence to raise the response rate and attain a reliable sample survey call-backs were made. Campbell and Katona (1965) stressed the importance of re-interviewing. Even so, there were still twelve households in Carlisle where no contact was made throughout the period of the survey. In general, however, the pilot study was a valuable tool in the overall research design.

Analyses of results

One of the final considerations before any questionnaire survey should be attempted is the final analyses of the collected data. That is, what form should the analyses take and what statistical tests should be employed. This is an important aspect of questionnaire surveys, since both the lay-out and design of the questionnaire should be orientated towards the anticipated analyses techniques (Rosenberg, 1970). This is particularly important if computers are to be used since some form of computer compatible coding should be incorporated. In this study both computer and hand calculating techniques were envisaged because of the great versatility this would offer over other methods, such as machine reading.

The analysis of questionnaire data is one of the most important aspects of the whole survey. The questionnaires must be first checked and coded, and then the whole mass of data must be reduced to more manageable proportions. The data should be summarised in tabular form, and otherwise analysed to bring out the salient features, before the results are interpreted and finally presented in research conclusions. In this case, the aim of the survey was to test the various hypotheses on perception and response of the flood plain resident. In analysing the results from the two centres, several statistical tests were employed, principally the chi squared test to assess the differences between variables, and correlation and regression techniques to evaluate the relationships between variables. However, despite the advantages of statistical testing, it should be remembered that many of these questions represented opinions, and hence should not be accorded with scientific fact, but rather with trends or probabilities. Several basic texts were consulted for the purposes of the statistical analyses, such as Fisher (1970) Blalock (1972) and Hammerton (1975) on the general requirements, while more specific information was obtained from Siegel (1956) on non-parametric statistics, and from Ezekiel and Fox (1963) on correlation and regression techniques.

The Commercial Survey

The questionnaire survey of flood plain business-men was very similar to the residential survey, although because of the limited numbers, sampling procedures were not required. Also, the questionnaire was reduced to a more factual level, with most of the early questions omitted, and the social questions orientated towards the business rather than the individual (appendix II). However, the questionnaire was of utmost importance for collecting primary data on the industries, particularly on the response to previous flooding, the damages caused in 1968, and the perception of the future flood hazard. The response rates of the commercial surveys were also very high:

76.71 in Carlisle and 94.29% in Appleby.

Details of the commercial survey, response rates, results and analyses can be found in chapter nine.