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

by

GRAHAM A TOBIN.

A thesis submitted to the University of Strathclyde in fulfilment of the requirements for the degree of Doctor of Philosophy.

Department of Geography, University of Strathclyde 1977.

Volume 2

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.

Acknowledgements

The author wishes to express his thanks to Dr. Keith Smith who has supervised this work throughout, and whose help and guidance have been invaluable. Thanks are also due to Linda McIver for drawing many of the maps and diagrams and to Brian Reeves for all the photographic work. Professor G.M. Howe and the rest of the geography staff at the University of Strathclyde have all been very helpful while contemporary postgraduates provided much constructive criticism, particularly Philip Gatenby and Roddy Fox. Also, Ann Mair of the Social Statistics Laboratory must be thanked for the much needed guidance on computer techniques.

The author would also like to thank all those persons in the research area who helped with this work, in particular Peter Field of the North West Water Authority, Mr. and Mrs. Evans of Carlisle, Mr. Potts of McKenzies Motors, the staff at Carlisle public library, Mr. and Mrs. Whitehead of Appleby, Mr. Hirst of Appleby, Mr. Tyson the editor of the West Cumberland Times and Star in Cockermouth, as well as all those residents and business-men in Carlisle and Appleby who gave up valuable time to answer the survey questions.

Liz Tobin provided considerable help and encouragement throughout the course of the research as well as reading through the preliminary draft of this thesis. Finally, the author acknowledges the financial support of the Natural Environment Research Council who made this research possible.

CONTENTS Page

VOLUME I

CHAPTER FIVE

THE STUDY AREA : CUMBRIA

WITH PARTICULAR REFERENCE TO CARLISLE AND APPLEBY

Introduction

This chapter is concerned with the initial fieldwork in the study area of Cumbria and the research centres of Carlisle and Appleby. The chapter is divided into three sections:

(1) The physical characteristics of Cumbria.

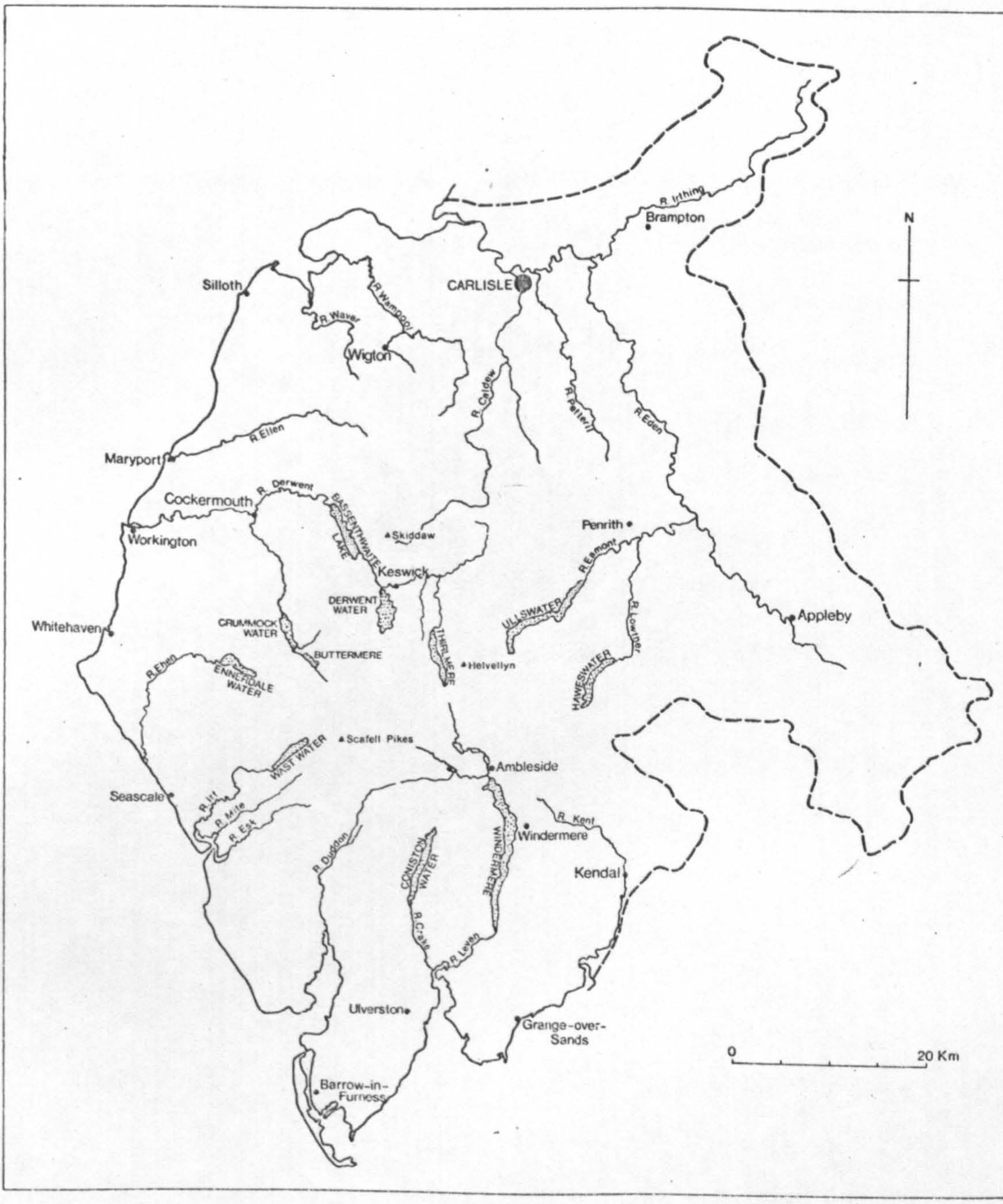
(2) The flood problem in Cumbria.

(3) The characteristics and flood problems in Carlisle and Appleby.

These studies provided the necessary background information for the later studies of perception and response to the flood hazard, by both the authorities and individuals. The data collected here also served to stress the extent of the flood problem in the county and showed how the problem has increased significantly since the early nineteenth century. The evidence procured from these background studies allowed refinements to be made to the research design, particularly in the proposed study of the authoritarian response to the flood hazard. The long history of the flooding in the county was particularly useful in this respect.

(1) The Physical Characteristics of Cumbria

The research area consisted of that part of the extreme north-west of England which lies between the Solway Firth in the north and Morecambe Bay in the south, and stretches between the western coast and the Pennines. This area, at one time divided into Cumberland, Westmorland and North Lancashire, is now known



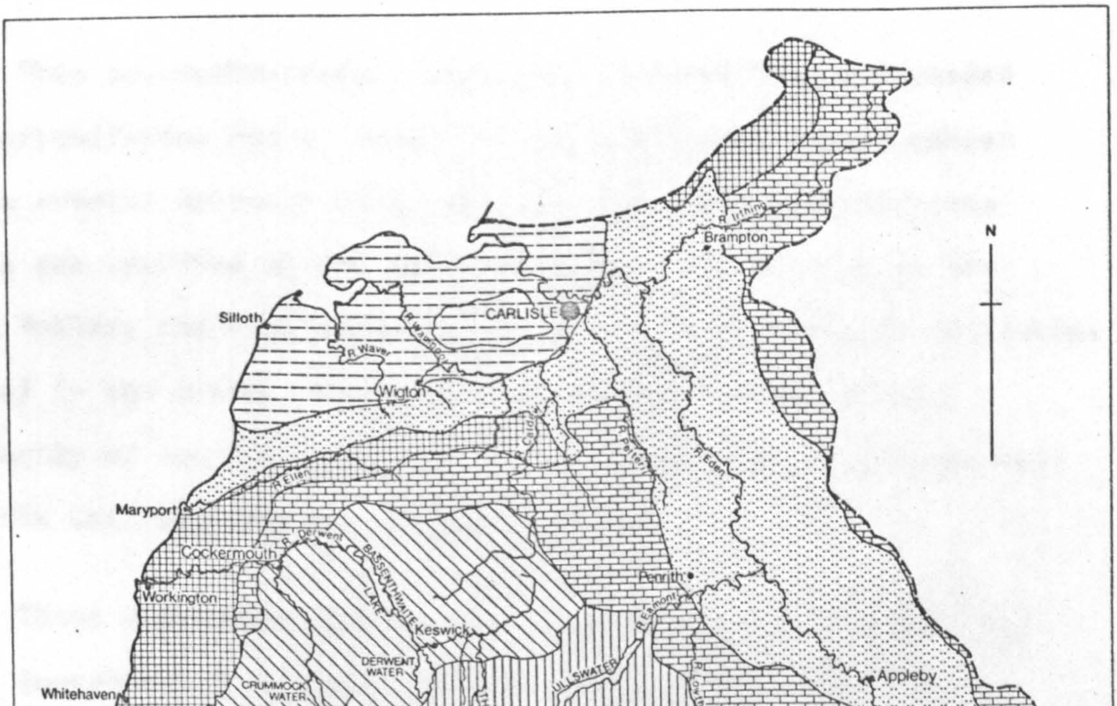
Map. 5-1. Cumbria.

as Cumbria (map 5-1). However, because the county boundaries do not follow clearly defined geographical zones, it was decided to adjust the study area to incorporate complete hydrological units. Thus, using the watersheds as a delimiting factor, a line was drawn along the Pennines embracing all the river basins from the River Eden flowing north to the Solway Firth, to the River Kent flowing south to Morecombe Bay, and including all other streams discharging into the Irish Sea.

The research area was quite large, covering approximately 5,400 km^2 with maximum dimensions of 96 km from north to south and 38 km from east to west. This large area provided examples of a wide range of flood types as well as various responses to the hazard, within an essentially integral unit. However, to counteract any problems of generalisation within such a vast area, two detailed studies were carried out at Carlisle and Appleby. Apart from these variations within the research area, Cumbria represented part of 'Upland Britain' and hence comparisons could be made with the findings from other similar areas. 'Cumbria', therefore, was ideally suited to the research designs decribed above.

Geology

The geology of Cumbria is fairly complex, since it comprises an old core area of pre-carboniferous rocks, surrounded by progressively younger measures of carboniferous and post carboniferous ages (map 5-2). The oldest rocks in the pre-carboniferous series are the Skiddaw Slates, which are up to 1800 metres thick, and the Borrowdale Volcanic Series, which



Map. 5-2. Cumbria: geology.

are over 3,000 metres thick. These two rock types, formed during the Ordovician orogenesis, can be found throughout the old core area of Cumbria. The intense pressures created during these ancient earth movements produced several igneous intrusions around Ennerdale Water and Wastwater, as shown in map 5-2.

This pre-carboniferous core area is completely surrounded by carboniferous rocks, except in the south-west where younger rocks overlap directly on to the old core. The carboniferous rocks are typified by the limestone groups either side of the Eden Valley, the coal measures, and the sandstone/shales (Millstone Grits) in the south. The post carboniferous rocks consist primarily of the Penrith, Kirklinton and St. Bees Head sandstones and the Lias and Stanwix shales.

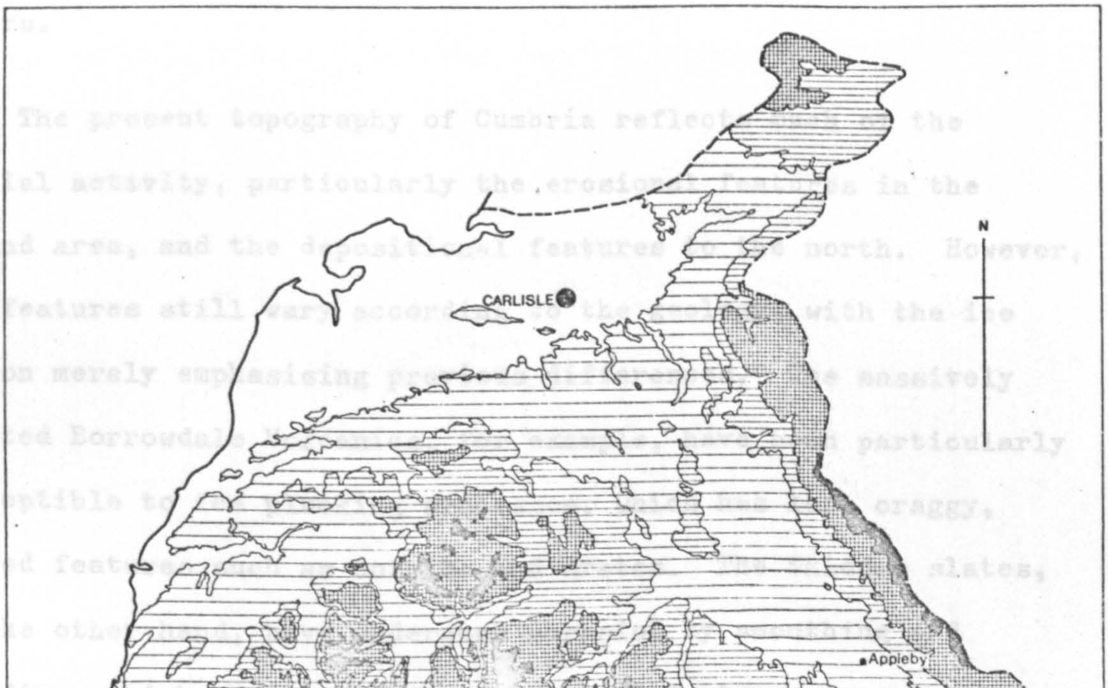
These different rock types are important, because they have been instrumental in producing the topography and drainage patterns of Cumbria and hence should be considered carefully in any assessment of the hydrological characteristics of the area. As far as hydrology is concerned, the principal difference due to geology is found between the pervious and impervious rocks - the old core is impervious to water, while the outer limestones have produced a karstic environment. The implications of these geological features on the topography and drainage patterns are discussed below.

Topography

The topography of Cumbria is intrinsically linked with the underlying geology. The old core rocks have produced a dome feature in the central area while the coastal lowlands to the north-west and south are made up of shales. In the west the area is bounded by the coastline, while the east is delimited by a major Pennine fault. Map 5-3 shows the general relief features of the area. The central dome rises to approximately 978 metres at Scafell Pikes, 950 metres at Helvellyn and 931 metres at Skiddaw, while there are several large areas to the north-west and south where the relief is well below 50 metres. Within Cumbria, Smailes (1968) described several planation surfaces at 610, 490-518, 305-320, 223-244, and 174 metres which are particularly prominent in the west and are common to all rock types.

The geomorphological features have been formed by a variety of processes. For instance, glaciation has been a major factor in modifying the landscape, since the central mountainous area was once the source area of a local ice-sheet. Smailes (1968) suggested that this first cleared away the younger deposits that probably covered the central core at one time, thus exposing the Skiddaw slates and Borrowdale volcanics. The ice centred on the Appleby - Dufton area, according to the evidence of drumlins, flowed out radially from the centre. The northward flowing ice was guided by the Eden Fault and eventually met the southward advancing Scottish ice, which split the Cumbrian ice in the region of Carlisle. This process has been important to the drainage pattern of Cumbria, because valleys were straightened by the truncating of spurs, particularly the Eden Valley, while many lakes were also created.

Post-glacial activity has been characterised by the

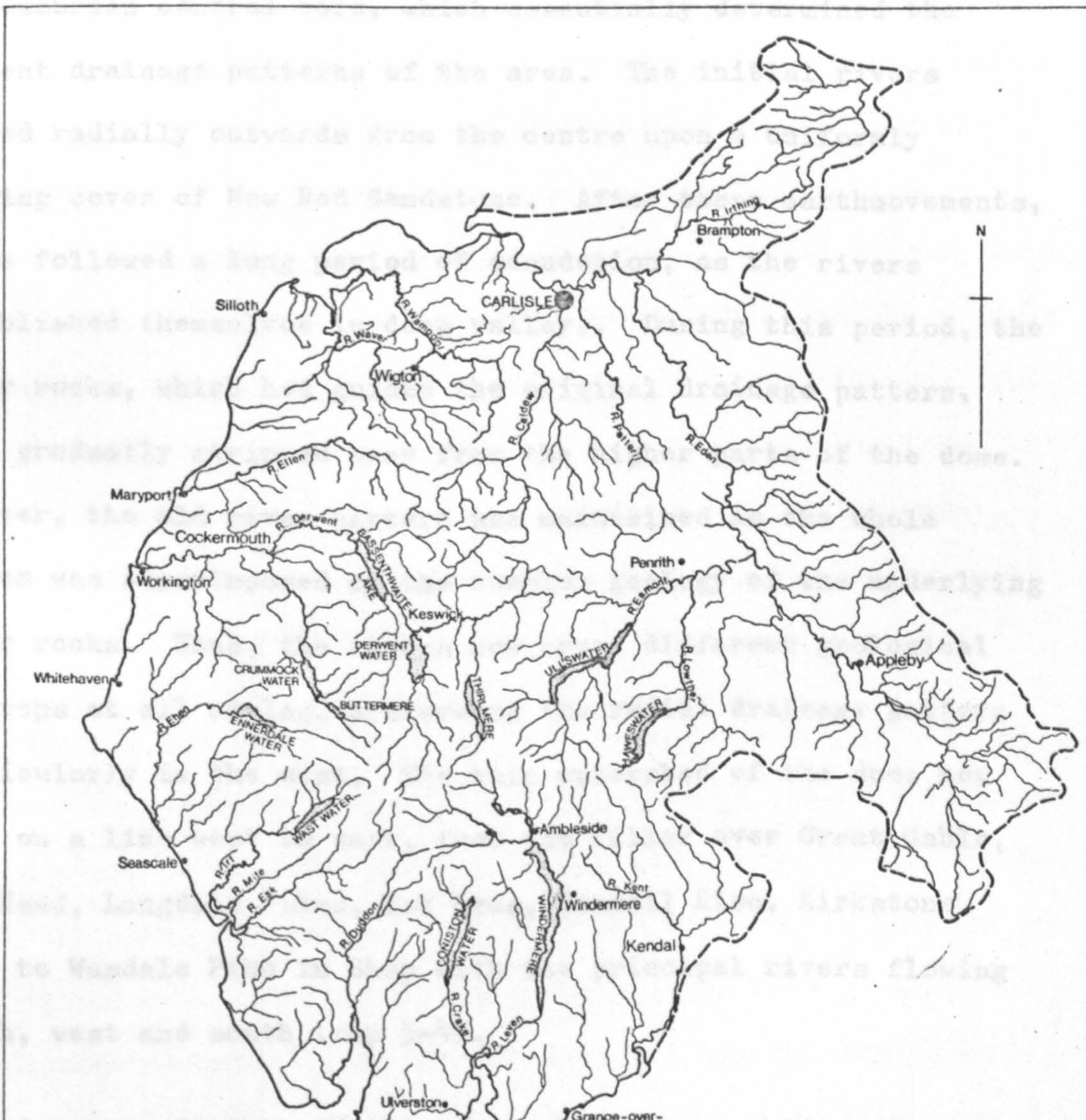


Map. 5-3. Cumbria: relief features.

stripping of the glacial drifts from the area, especially as the land has risen isostatically following the release of ice pressure. This has had a significant effect on the hydrological characteristics of the area, since fluvial erosion, transport and deposition of sediments has altered the timing of certain rivers.

The present topography of Cumbria reflects much of the glacial activity, particularly the erosional features in the upland area, and the depositional features to the north. However, the features still vary according to the geology, with the ice action merely emphasising previous differences. The massively jointed Borrowdale Volcanics, for example, have been particularly susceptible to ice plucking processes, which has left craggy, rugged features such as corries and aretes. The Skiddaw slates, on the other hand, have undergone abrasion by smoothing and rounding, which has produced more conical features.

The limestone rocks of Cumbria have produced different physical features. For example, limestone pavements may be found at Newbiggin Crags and Hutton Roof Crags, which show the typical intermittent drainage and dry valley features of a karst environment. In several places, rivers have cut deep gorges through the limestone such as Scandal Beck, or the River Caldew at Howk. Other limestone outcrops, following major faulting, form the escarpments such as the west facing wall of the northern Pennines, which culminates in the 809 metres summit of Cross Fell. Finally, the shales of the north-west now form an area of coastal lowlands, which are typified by marsh and bog lands often covered in mosses. This area is generally featureless apart from various



Map. 5-4. Cumbria: drainage patterns.

drumlin formations.

Drainage

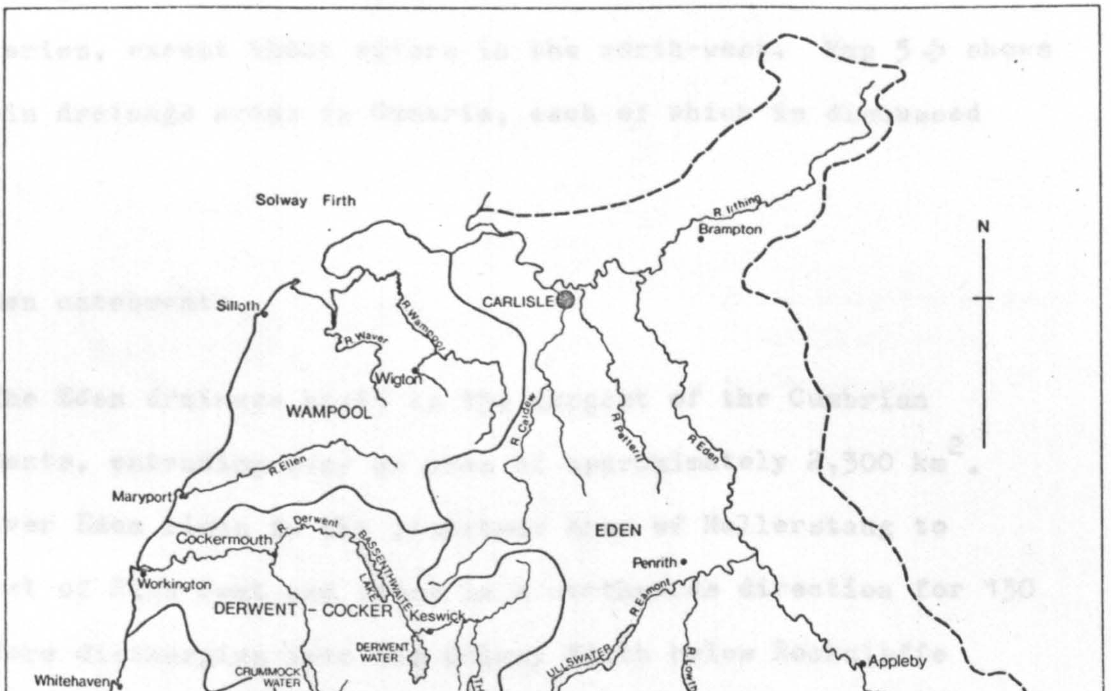
The last Tertiary uplift produced the elongated dome of the Cumbrian central core, which essentially determined the present drainage patterns of the area. The initial rivers flowed radially outwards from the centre upon a uniformly sloping cover of New Red Sandstone. After these earthmovements, there followed a long period of denudation, as the rivers established themselves in deep valleys. During this period, the newer rocks, which had guided the original drainage pattern, were gradually stripped away from the higher parts of the dome. However, the old river pattern was maintained as the whole system was superimposed on the complex geology of the underlying older rocks. Thus, the rivers now cross different geological outcrops at all angles, preserving the radial drainage pattern particularly in the west. The main watershed of the dome now lies on a line west to east, from the Pillar over Great Gable, Sty Head, Langdale Pikes, Esk Haus, Dunmail Rise, Kirkstone Pass to Wasdale Pike in Shap with the principal rivers flowing north, west and south (map 5-4).

A common feature of this general drainage pattern is the straight nature of many of the valleys. This characteristic owes much to the superimposition of the drainage and also to the processes of glaciation and underlying geology. For instance, fairly straight channels would have developed on the original uniform surface, and these would have been enhanced by the later glaciation processes, which would have eliminated any minor irregularities by truncating the minor spurs. Also in Cumbria, many spurs apparently coincided with shatterbelts, and hence were structurally weak, so the straightening process was probably the product of all three factors.

Another consequence of the glaciation was the formation of numerous lakes and tarns; there are sixteen major lakes as well as many smaller ones. Map 5-4 shows the location and features of the larger of these in relation to the general drainage pattern. The largest lakes are principally long and narrow, such as Windemere, Wastwater and Coniston, which have been the product of glaciers straightening and overdeepening the fluvial valleys. Wastwater, for example, is over 80 metres deep with the lake floor well below present sea level. Windermere, on the other hand, was formed by a terminal moraine blocking the valley, now the southern end of the lake.

Changes are occurring in the lakes, especially through the processes of fluvial deposition. Bassenthwaite and Derwent Water were once one vast lake, but deposition has gradually divided the two. The lakes now regain their previous form during periods of high flooding. At Kentmere, two smaller lakes have already disappeared completely due to the transport and deposition of sediment by the River Kent. Even the larger deeper lakes are showing significant signs of infilling, including the north-eastern end of Wastwater.

Hydrologically, the lakes are extremely important in Cumbria because of the storage capacities they add to the various river basins, especially during periods of high flows. The lakes significantly increase the time to peak discharge response of a



Map. 5-5. Cumbria: major catchments and drainage basins.

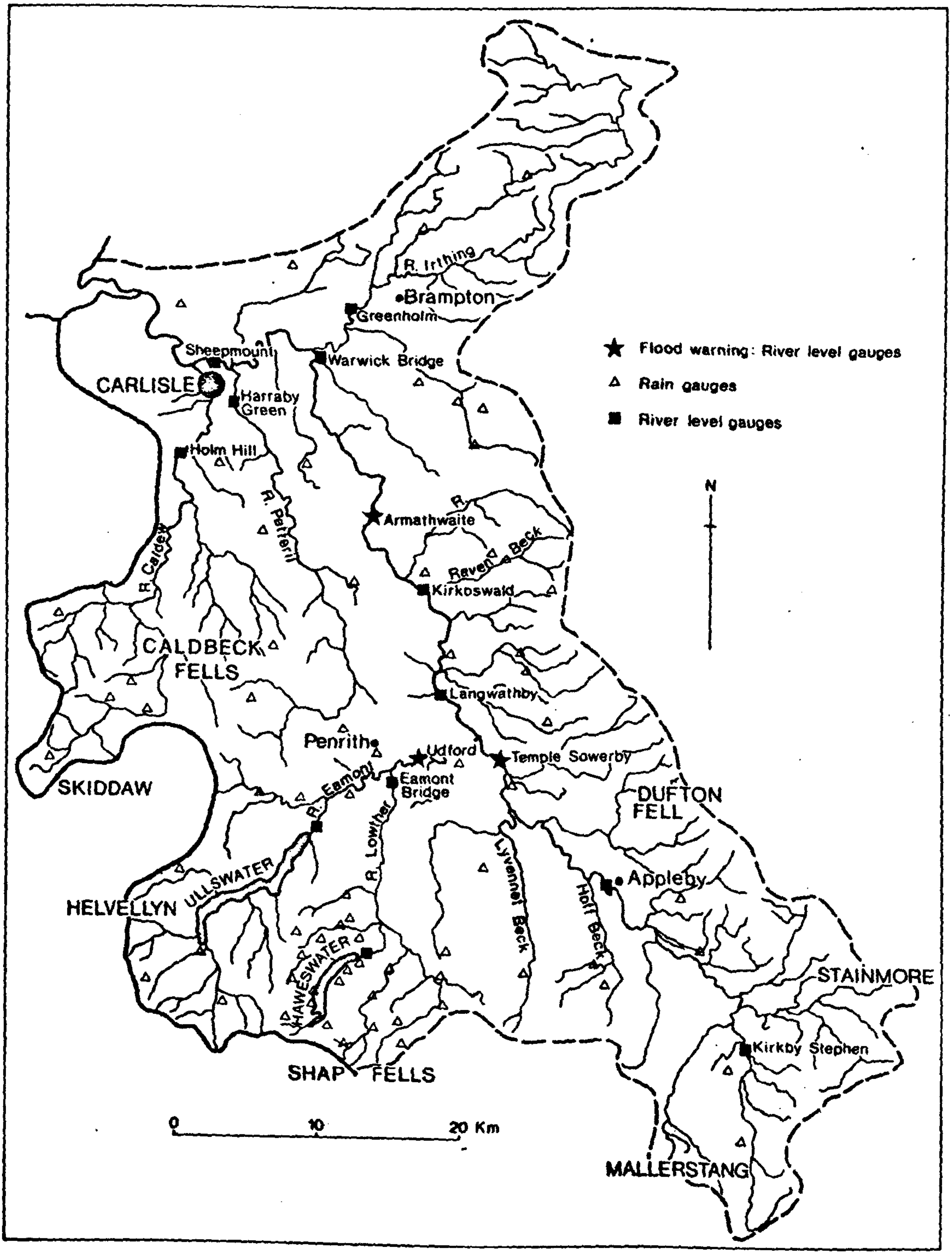
river, and thus can be highly beneficial in providing adequate time for flood warnings in what would otherwise be an extremely flashy environment.

There are seven principal drainage areas in Cumbria, all of which originate in the central core and flow outwards to the peripheries, except those rivers in the north-west. Map 5-5 shows the main drainage areas in Cumbria, each of which is discussed below.

The Eden catchment:

The Eden drainage basin is the largest of the Cumbrian catchments, extending over an area of approximately 2,300 km^2. The river Eden rises in the limestone area of Mallerstang to the west of High Seat and flows in a northwards direction for 130 km before discharging into the Solway Firth below Rockcliffe (map 5-6). During its course, the river falls approximately 715 metres, at an average of 5.5 m/km, although the largest falls occur within the first 50 km. The stream frequency for the catchment is 1.59 junctions/km^2, which, according to the Flood Studies Report (1975) is fairly typical of Upland Britain. (Various theoretical calculations have been made on the Eden basin with data gathered from the 1:25,000 O.S. maps. Details of these calculations can be found in appendix IV).

There are four principal tributaries of the Eden, the River Irthing on the right bank and the Rivers Caldew, Petteril and Eamont on the left bank. The majority of the right bank tributaries are generally short because of the steep escarpment slope of the



Map. 5-6. Eden Valley drainage basin showing the instrumentation for the flood forecasting and warning system.

Pennines. Only the Irthing flows for any distance and this river rises in the far north-east of Cumbria. Other right bank tributaries include the Croglin, Ravensbeck, Milburn Beck, Troutbeck and Swindal Beck. However, the major source of drainage into the Eden is supplied by the left bank tributaries. The Caldew, for instance, rises as two streams from Caldbeck Fells and north of Skiddaw, from where it joins to become the Caldew, cutting deeply through the pervious rock, to flow northwards to join the Eden at Carlisle. The Petteril follows a similar pattern, rising near Greystoke, crossing the limestone area and finally joining the main river immediately west of Carlisle.

The River Eamont is not as long as the other main tributaries but, along with the River Lowther, drains a much larger area. The River Eamont is dominated by Ullswater reservoir, into which flow many smaller streams which originate at Helvellyn, Grisedale and Kirkstone Pass. The Lowther drains the area to the east of Ullswater and is also dominated by another reservoir - Haweswater. The tributaries flowing into this lake rise in the Shap Fell and High Street areas. There are several other left bank tributaries of the Eden, such as the Leith and Lynnett which also flow northwards from Shap.

The Wampool drainage area:

The Wampool catchment area to the west of the Eden, consists of the complex drainage patterns of the coastal lowlands in the far north-west. The River Wampool and River Waver are fairly short, but tend to meander across relatively low lying land from the limestone and sandstone areas in the north to Moricambe Bay.

In this area, particularly the Cardunock Penninsula, there are considerable bogs and marshlands. The River Ellen, further south, rises on the periphery of the central core at Uldale Fells, but flows for only thirty kilometres to the Irish Sea. The area drained by the Ellen is very small, and it is principally fed by short left bank tributaries, flowing off the upland foothills. The Wampool drainage area, in general, is characterised by lowland drainage problems and the associated aspects of flooding, and hence provides several examples of lowland flood problems in contrast to the rest of Cumbria.

The Derwent-Cocker catchment:

The second major catchment in Cumbria is the Derwent-Cocker system, which drains most of the north-west central core. The Derwent rises as several tributaries at Great Gable, Sty Head and Bow Fell on the northern slopes of Scafell Pikes, from whence the main river and the two tributaries, Stonethwaite Beck and Greenup Gill, flow north into Lake Bassenthwaite and on to Derwent Water. At this point the river course turns west to flow into the Irish Sea at Workington. Both Derwent Water and Bassenthwaite Lake drain extensive areas. Newlands Beck, for example, drains most of Derwent Fells before flowing direct into Lake Bassenthwaite. The River Greta is another major river in this system, which rises at Bowscale and Matterdale Common in the east of the catchment. This river is joined by St. John's Beck, which rises at Wythenburn, and is dominated by Lake Thirlmere.

Further downstream the River Derwent is joined by the River Cocker, a major left bank tributary. The Cocker rises near

Honister Pass on Buttermere Fells as Gatesgarthdale Beck, flows down through Lake Buttermere and Crummock Water, then through the Lorton Valley to Cockermouth, which is situated on the confluence of the Cocker and Derwent rivers. A further tributary feeds Crummock Water draining Loweswater Fell and emanating from Loweswater Lake.

The Derwent-Cocker catchment, therefore, drains a considerable area of the upland core, and includes five of the larger Cumbrian lakes. But for the delaying processes of these and other smaller lakes, the catchment would be exceedingly responsive to any given input of rainfall. The behaviour of this river system is critical to the understanding of flooding in settlements throughout the catchment (see below).

The Ehen catchment:

South of the Derwent-Cocker system is a smaller catchment, comprising of the Rivers Ehen and Calder, which together drain the western section of the central core. The Ehen, the larger of the two rises at Great Gable and flows westward to Ennerdale Water receiving water from both banks. After the lake, the river flows in a gradual curve in a southward direction, where eighteen kilometres later it reaches the Irish Sea. The only tributaries of any significance are the Keekle and Dub Beck which flow south from Dean Moor to join the Ehen at Egremont. The other river, the Calder, flows directly south from Ennerdale Fells.

The Duddon drainage area:

The south-west of Cumbria is drained by a series of small rivers - the Irt, Mite and Esk drainage basin which discharges into the Esk ria, and the Duddon basin which flows into the Duddon Sands ria between Barrow-in-Furness and Millom. All four rivers drain the south-west central core area, rising in the Copeland Forest and Langdale Fells. The River Irt flows through a deep valley, reputably one of the deepest valleys in Britain, to Wastwater. This valley, although fault assisted, represents an area of intense glacial erosion, which has resulted in a deep trench along the valley currently filled by Wastwater. The overall depth from the peak to valley floor is nearly 700 metres. Subsequent freeze-thaw action on these slopes, particularly those facing north, has created spectacular scree slopes falling several hundred metres into Wast water. However, as with many other lakes, Wastwater is now experiencing a degree of infilling at the upper end.

The River Mite is the smallest of the Esk ria rivers and drains the area of Miterdale to the south-west of Scafell. The river Esk itself, is much larger and drains the area known as Eskdale. The river rises at Bow Fell as Lingcove Beck and at Scafell Pikes as the Esk, from where the river flows south-west to the coast. These rivers essentially drain the Borrowdale Volcanics and Eskdale granitic intrusions.

The River Duddon catchment is another small south-west basin dominated more by the large ria of Duddon Sands than the drainage pattern. The river system drains many of the small fells in this area, including Thwaites Fell and Ulpha Fell to the west, and

Furness Fell and Dunnerdale Fell to the east. The river Duddon rises at Wrynose Pass and flows almost directly south to the coast, receiving drainage from many small left and right bank tributaries throughout its course.

The Leven drainage area:

The Leven drainage area is also located south of the central core, but differs hydrologically from the previous catchment, because the river systems are dominated by several lakes, in particular Windermere and Coniston. The smaller of the two rivers, the Crake, rises in Furness Fell as Yewdale Beck and flows directly south through Lake Coniston, emerging as the Crake for the short distance to the sea. Tributaries from both east and west drain parts of Furness Fell and Grizedale Forest. However, the Crake is quite clearly dominated by Lake Coniston.

The River Leven catchment drains a larger area of the south and south-east central core, rising as many small tributaries north of Lake Windermere. The Micklen and Oxendale rise at Bow Fell, and together form Great Langdales Beck which flows south-east to join Elterwater. This small lake is also fed by the Little Langdale river system to the south, which drains the area of Tilberthwaite Fells. The River Brathay rises on the opposite side of Wrynose Pass to the Duddon and flows down through Elterwater to Lake Windermere. To the north of Langdales is the River Rothay drainage system which flows south through Grasmere Lake and Rydal Water to join the Brathay immediately above Windermere. Many small tributaries drain the area of Grasmere Common, Wytheburn Fells and Fairfield. Two further tributaries flow directly into Lake

Windermere : Troutbeck which flows from Caudale Moor to the east bank, and Cunsey Beck on the west side, draining Grizedale Forest and Esthwaite Water. The River Leven itself represents the outflow from Lake Windermere down to the ria at Leven Sands, to the east of Ulverston.

The Kent drainage area:

The final catchment in the Cumbria research area is the Kent river system, which drains the area to the south-east of the central core. The main river Kent and its tributaries the Sprint and Mint rise at Kentmere, Longsleddale and Bannisdale respectively, from where they flow south to the ria at Milnthorpe Sands. These rivers are typical of the southerly flowing streams in Cumbria, particularly at the coast where the changing sea level in Morecambe Bay is a predominant feature. The immediate post-glacial period produced deeply incised valleys, and as more temperate conditions returned sea levels rose thus flooding the lower valleys. Siltation has since led to the partial or even complete infilling of the bays with deposits brought down by the rivers and redeposited by the sea movements in Morecambe Bay.

The drainage systems within Cumbria, therefore, are quite varied, although they all represent a part of the overall radial pattern. Catchment areas vary between the large Eden basin in the north-east and east of the region and the smaller systems found in the south-west. Most of the basins represent upland river systems, often incorporating large lakes or reservoirs, except in the north-west where a lowland drainage pattern has evolved. This variation of hydrological characteristics within Cumbria has led to many different flood problems, throughout the county (these are described in detail in part 2 of this chapter).

Settlement Patterns

The general settlement pattern of Cumbria consists of small villages and hamlets in the upland valleys, particularly in the central mountainous area, with a few larger towns on the peripheries. This pattern has evolved following a series of invasions by various people, including the Romans and later the Scandinavians and Norse-Irish settlers, who have left their mark in many place names throughout the country. (Details may be found in Chancellor 1954). During a later period defensive settlements developed because of the assaults from Scots across the border, but the necessity for these diminished following the Act of Union in the eighteenth century. Larger towns have since developed on the Lower land, principally as ports, route centres or market places. For example, Carlisle, with a current population of 71,582 (Census, 1971) was originally an old defensive site dominated by the castle and cathedral and central market place, but since the early nineteenth century, has developed into the major centre in the north-west. Other large settlements in Cumbria include Whitehaven (27,000) Workington (28,500) Millom (14,000) Kendal (21,500) Barrow in Furness (64,000) Maryport (11,500) Dalston (11,000) Ulverston (12,000) and Penrith (11,000). These settlements emerged as defensive sites and market centres or were the product of the industrial revolution. Indeed, Maryport was created in 1748-1749 because the Senhouse Coalmines required a port from which to export coal and somewhere to house the work force.

Smaller centres such as Cockermouth (6,500) Keswick (5,000) Windermere (3,500) Ambleside (2,000) Appleby (2,000) Brampton (4,000) Wetheral (4,000) Egremont (7,000) Aspatria (3,000) Silloth (2,500) and Wigton (5,000) may incorporate some industries but their main livelihood comes from tourism or agriculture. These settlements have changed least in the last 200 years in comparison with the larger centres.

Figures of population increases in Cumbria show that by far the greatest expansion occurred between 1801 and 1900, although the process has continued in some areas though at a slower rate (see table 5-1).

Table 5-1 Population of Cumberland and Westmorland - census data

	1801	1901	1971
Cumberland	117,230	266,933	292,187
Westmorland	40,805	64,409	72,836

Between 1801 and 1901 the population of Cumberland increased by 127.7% while in the following 70 years it only expanded by 9.46% Figures for Westmorland indicate a similar trend, 57.85% and 13.08% respectively. The present population for Cumbria, including Cumberland, Westmorland and the relevant areas of North Lancashire is 472,589. During the past 200 years the smaller settlements have remained relatively stable or even experienced a decrease in populations, while the lowland towns have expanded rapidly.

The settlement pattern is critical to any consideration of flood problems in the area, because the increase in population and the resulting expansion of urbanisation has meant that more people are now at risk from flooding than in the past. Thus, given that there has been little change in the physical characteristics of the area, the development of settlements would appear to have been instrumental in aggravating the flood problem, particularly in the lowland flood plains where urbanisation has been greatest. The studies of Carlisle and Appleby (see part 3) show the contrast between upland and lowland sites in this respect.

(2) The Flood Problem in Cumbria

The flooding in Cumbria does not produce the large damages which are experienced in other parts of Britain, and seldom poses a serious threat to life. On occasions people have been killed during high flows, but this is nothing like the large numbers who die annually in such places as India, Pakistan and Bangladesh. However, the flood problem is significant enough to warrant further consideration, particularly in the larger centres of population such as Carlisle, Penrith, Cockermouth, Keswick and Kendal, which frequently suffer losses from flooding. Flooding is also a widespread feature throughout the county, causing damage and inconvenience in both rural and urban environments.

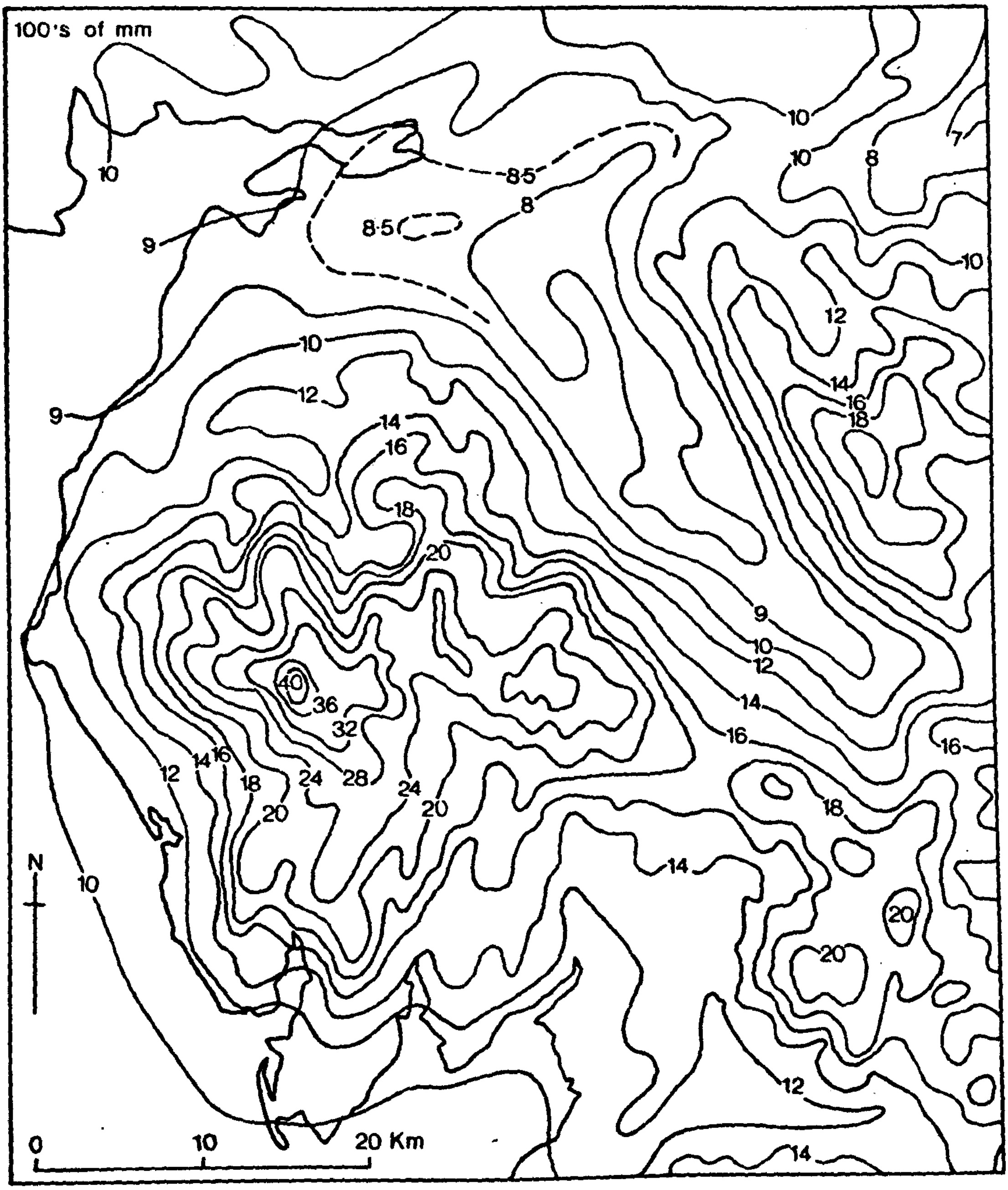
The flood hazard in Cumbria takes three basic forms: the flash flooding of small settlements in the upland valleys caused by thunderstorms on highly responsive streams; the downstream flooding of urban and rural areas by less responsive streams generally as a result of more prolonged frontal storms; and the flooding of coastal settlements usually from a combination of large river discharges and high tides. Thus, the differences in flood types may be the product of different meteorological and hydrological features, as well as determined by the geological and topographical characteristics. The land-use patterns may also influence the extent of flooding within settlements.

Meteorological characteristics

The meteorological characteristics in Cumbria are conducive to flood producing conditions with heavy storms and a high average annual rainfall frequently recorded for large areas of the county.

Precipitation is exceedingly high, amounting to over 2,500 mm a year in a large part of the central mountain area (Flood Studies Report, 1975). This situation is a product of the location and topography of Cumbria. The western approaches naturally experience many depressions crossing the area, while at the same time the Cumbrian mountains act as a barrier, thus causing orographic rainfall. Away from this central core the precipitation falls off rapidly. Most of the northern coastal strip, for example, receives less than 1000 mm, and there is even a small enclave at the head of the Solway Firth, near Bowness, where the average annual precipitation drops below 750 mm a year. Similarly the Eden Valley is in the rain shadow of the Cumbrian mountains, and as a consequence only receives between 800 and 900 mm in the main part of the vale. Significantly, however, the catchment area for the Eden receives considerably more than this, rising in the east at Cross Fell to 2000 mm (Map 5-7 shows the mean annual isohyets for Cumbria).

The type of rainfall varies between heavy storms and prolonged rain. During the summer, the central core in particular is subject to thundery conditions with very heavy and intense falls of rain. These storm events can cause extensive flash flooding in many of the upland valleys such as Borrowdale or Langdale. For instance, in August and again in September 1966 between 100 mm and 130 mm of rain fell in little over an hour in Borrowdale (Cumberland River Authority personal communication, 1974). However, since heavy falls of rain are very common to mountainous region flood producing storms are liable to occur at any time of the year.

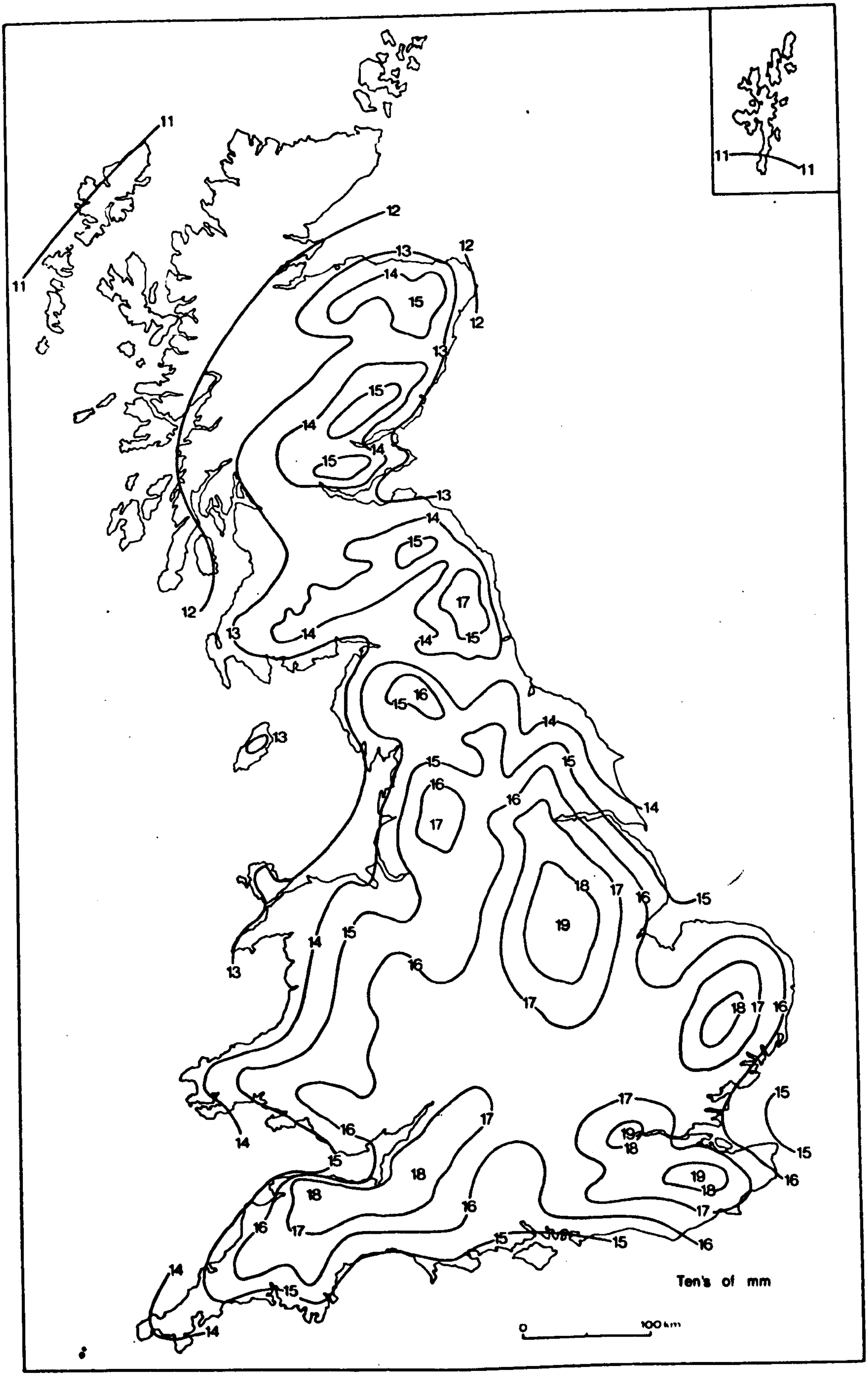


Map. 5-7. Cumbria: mean annual precipitation.

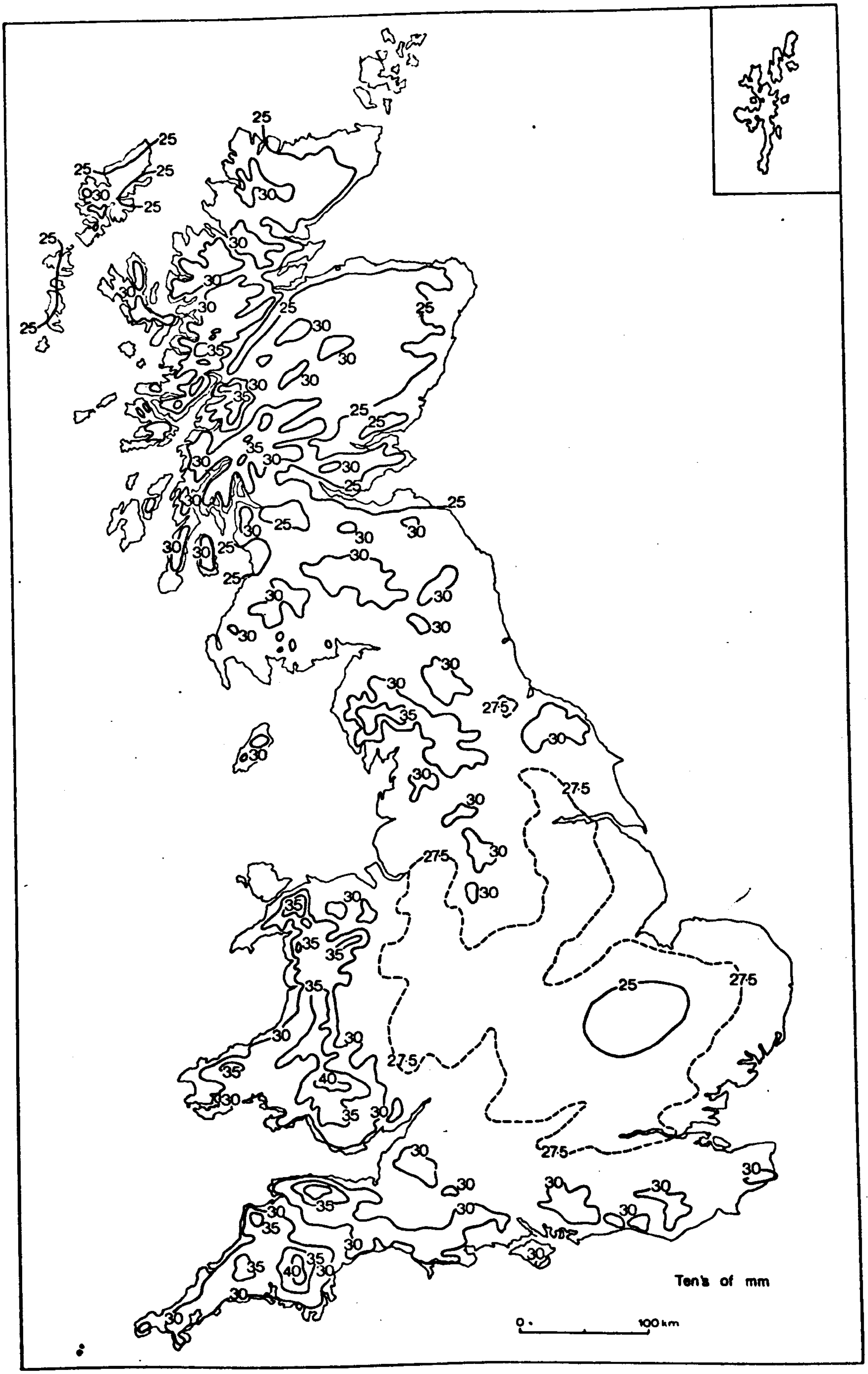
Further studies (Flood Studies Report, 1975) have calculated the maximum potential rainfall for a two hour and a twenty-four event. These events have an exceedingly low probability of occurrence, but if they did occur would cause unprecedented flooding throughout Cumbria. Maps 5-8, and 5-9 indicate that Cumbria is typical of upland Britain with respect to the two maximum precipitation calculations. The storm events in Borrowdale in 1966 would appear to be fairly close to the maximum two hour event proposed by this map evidence.

The prolonged rainfall in Cumbria probably causes more serious flooding throughout the county. Since most of the Cumbrian rivers originate on the central core area where the annual rainfall is fairly high, the rivers are particularly prone to high discharges. The catchment area for the River Eden, for instance, incorporates both a large part of the central area, as well as the western slopes of the Pennines. A widespread storm over the central mountains, therefore, could cause flooding in many parts of Cumbria.

Snowfall may also add to the problems of flooding in Cumbria. On the coast, snow falls on average for only ten days in the year and seldom lies for any length of time, except when an intense anticyclonic weather pattern settles in following a snowfall. Further inland, however, the duration of snow cover increases so that the mountain areas are covered for three months most years. Snowmelt during the spring period, when the soil moisture deficit is zero, can be a particularly hazardous time since the melting snow may add significant quantities of water to any heavy rainfall and thus exaggerate flooding downstream. In fact, most major floods in Cumbria have incorporated some degree of snowmelt,



Map. 5-8. Great Britain: 2 hour potential maximum precipitation (after Flood Studies Report).



Map. 5-9. Great Britain: 24 hour potential maximum precipitation (after Flood Studies Report).

including those of 1925 and 1968 (see below).

Hydrological characteristics

The hydrological aspects of flooding in Cumbria are highly individualistic to the particular catchment, and specific examples of these variations are discussed below. In general, Cumbrian rivers show the typical contrasts in hydrological characteristics, between the upland and lowland reaches. Such factors as time to peak discharge or the response time of the stream to a given input, the duration of flooding, the velocity of flood water, the extent of flooding, and the sediment yield of the stream during high flows, all change significantly from the source to the mouth of a river. For instance, in the narrow upland valleys, streams tend to be very responsive, produce floods of short duration but often of high velocity, and to have a low sediment yield. The steep sided valleys combined with the heavy rainfall events produce the flash flooding which is typical of these areas. Further downstream the reverse condition may be found, with the flood waters more extensive spatially because of the wider flood plains, and flood flows lower in velocity but of greater duration. The sediment yield may increase also, because of the accumulation of material by the river throughout its course. The different conditions prevailing between upstream and downstream areas quite clearly produce different flood conditions.

These differences, between the upper and lower reaches have been somewhat idealized, since no account has been taken of the effects of local characteristics on the flood hydrology. For instance, the presence of lakes along the course of a river can delay the response of the river and may lead to complex timing of rivers within the same system. The Derwent-Cocker catchment illustrates how lakes can affect river response times. The flows of the River Derwent are delayed by the presence of Bassenthwaite and Derwent Water, whole flows of the River Cocker are retarded by Crummock Water and Buttermere, and Thirlmere, being a controlled reservoir, stabilises the flow of St. John's Beck. The timing of these rivers is critical to Cockermouth situated at the confluence of the Derwent and Cocker, for if the peak discharges coincided at the town then major flooding could ensue. Fortunately, the flood flows from the Cocker have normally passed through the system before the Derwent flows arrive. However, one of the major flood dangers to Cockermouth is that a heavy storm will at some time fall first over the Derwent catchment then later over the Cocker so that high peak discharges from both systems will coincide at the confluence (Hudleston, 1935).

In contrast to the Derwent-Cocker system, the Eden basin is not affected by lakes to any great extent, although the Eamont and Lowther are retarded by Ullswater and Haweswater respectively. The danger from flooding is obviously greatest if the flood peaks from the main river and the tributaries coincide, although either system can cause flooding downstream. In the major flood of 1968, the contribution of water from the Eamont and Lowther was equivalent to that of the Eden, approximately 500 m^3/sec (for details see below). In 1974 however, the peak discharge from the Eamont and Lowther reached similar levels to that in 1968, but because the Eden was only a little above average only minimal damage from flooding was reported (Cumbrian River Authority, personal communication 1974).

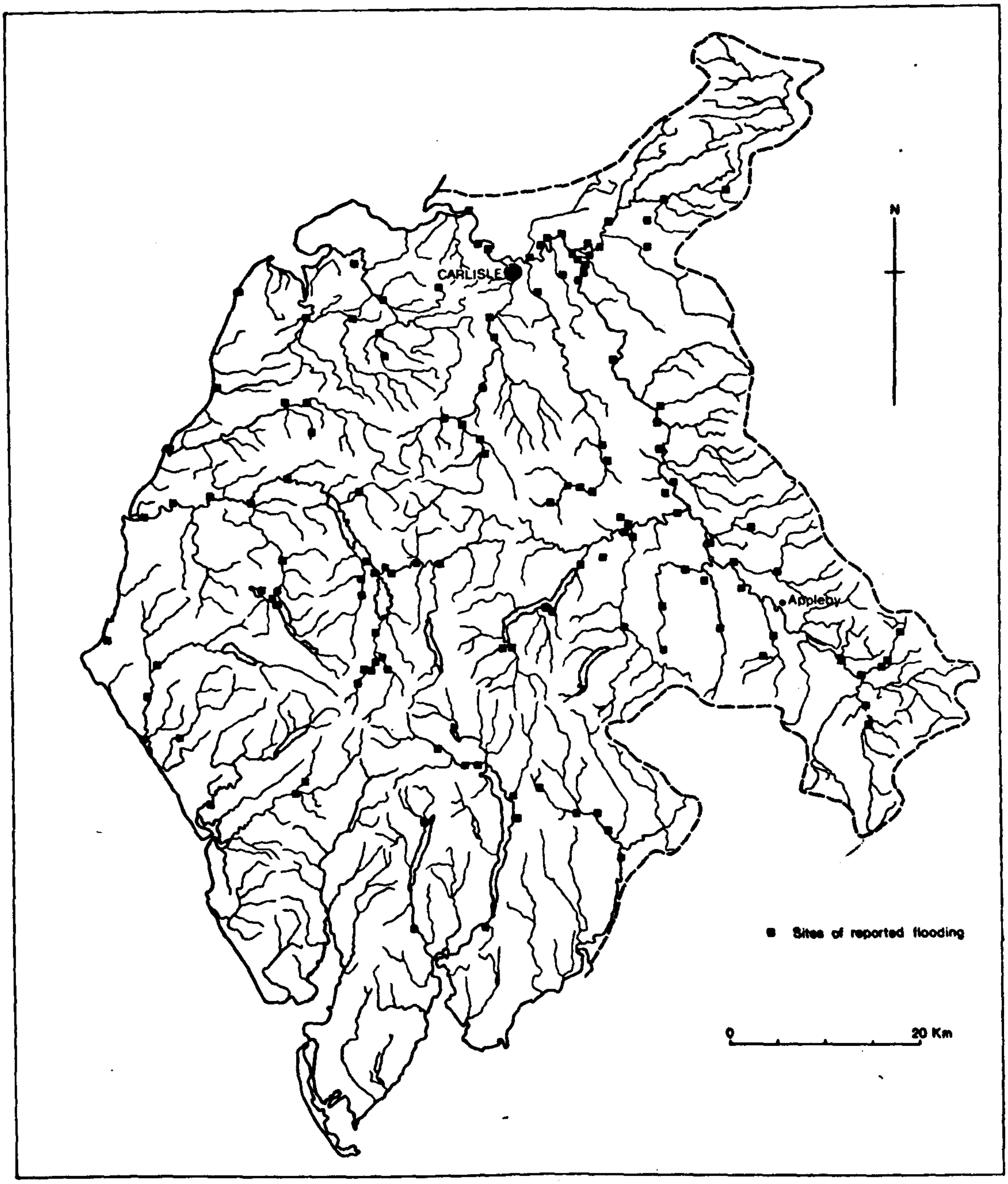
Extent of flooding in Cumbria

Different meteorological and hydrological conditions have produced a variety of flood environments throughout Cumbria, ranging from the uppermost forms in the central mountains, to the ports at the mouths of the larger rivers. The distribution of known flood sites is shown in map 5-10 while a full list appears in appendix III. These sites have been collected from a variety of sources, although primarily the data have been obtained from old newspaper reports.

Upland flooding:

The small farms and hamlets in the upland valleys are particularly prone to flash flooding from heavy thunderstorms. In these cases, water tends to sweep rapidly down through the narrow valleys causing extensive damage. The Borrowdale flood in 1966, for example, was caused by a thunderstorm and the resulting runoff swept down the valley damaging buildings and bridges, and moving large boulders along the stream bed. On this occasion many of the small villages suffered losses, including Stonethwaite and Rosthwaite (Cumberland and Westmorland Herald, 20.8.66) while on other occasions the villages of Seathwaite, Seatoller and Borrowdale have also suffered.

Many other valleys undergo periodic flooding similar to that in Borrowdale. Newlands Beck, which flows into Bassenthwaite, frequently floods the villages of Newlands, Portinscale, and Braithwaite. Great Langdales is another valley system particularly susceptible to flash flooding, which has in the past caused damage



Map. 5-10. Cumbria: sites of recorded flooding, 1800 - 1968.

to the villages of Ambleside, Grasmere, Clappersgate and Elterwater. The Buttermere valley also floods, affecting the settlements of Crabtree, Scalehill, Loweswater and Kirkhead. Even the head waters of the Eden suffer from flash flooding as a result of thunderstorms, and damage has been reported at Spurrig End Farm, Kirkby Stephen, Brough-under-Stainmore and Warcop.

While the incidence of flash flooding is fairly common to these upland valley sites, such events may, on certain occasions, occur in other areas. For instance, if a particular intense storm affects a settlement elsewhere in the catchment, the drainage network may prove inadequate for the sudden flows of water and hence flooding may result. This situation occurred in Appleby in 1965 when 76.5 mm of rain fell in 90 minutes, which caused flooding throughout the town (Whitehead papers).

Lowland flooding:

More extensive flooding can be found further down the valleys where the natural flood plains become wider. Unfortunately, these flat flood plain areas are ideal for urban development and as a result towns have expanded on to the flood prone areas. Many houses and business properties are now subject to flooding in Cumbria because of this process. For example, nearly all the towns and villages along the Eden Valley from above Appleby to the Solway Firth, including the City of Carlisle, have experienced flooding at one time or another. Other larger settlements which have suffered quite frequent flooding include Cockermouth, Keswick, Kendal and Penrith (see map 5-10). Details of the flooding at these sites are discussed below.

Coastal flooding:

Coastal flooding, the product of high tides and high river levels can be found extensively round the Cumbrian coastline. The larger towns particularly prone to this type of flooding include Silloth, Maryport, Workington and Whitehaven.

In conclusion, the spatial extent of the flood problem in Cumbria is both extensive and varied. As shown by map 5-10, the hazard occurs in all environments, from the narrow upland valleys to the wider coastal plains, affecting small hamlets and large settlements. Appendix III lists those places with flood experience over the last 200 years.

Flood frequency in Cumbria

The significance of the flood problem in Cumbria should not be measured purely by the spatial extent of the hazard throughout the county, but should incorporate an indication as to the degree of risk at each site. A town which experiences flooding on average once every ten years is more likely to rank the hazard higher than a town flooded only once every fifteen years. For this reason old newspaper reports, local records and archives were consulted to give some idea of the frequency of flooding at various sites in Cumbria (Carlisle and Appleby are examined separately in part 3 of this chapter).

References to flooding in Cumbria have been found dating back to the November flood 1771 and has been confirmed by several independent sources (Garret, 1818; Carlisle Patriot 9.2.1822). Information on floods previous to this has not been verified by alternative sources, and hence is difficult to assess. One reference was made to a major flood in 1571 which changed the course of the Eden and this event is apparently confirmed by map evidence (Smith Kenneth, 1973).

More reliable evidence is available from the early years of the nineteenth century with the publication of regular newspapers, and the reporting of local news and events. It was from this source that a great deal of information was obtained, both on flood frequency and the spatial extent of the hazard between the years 1809 to 1975. For instance, according to various newspaper reports, Penrith has experienced flooding on fourteen occasions and while not all these were major events, they still warranted reporting. Similarly, references to flooding indicated that Cockermouth had been flooded fourteen times, Keswick fifteen, Kendal fourteen and Kirkby Stephen ten. Other settlements had been flooded less frequently according to the reports, although they could well have been flooded on other occasions and the events not recorded. For example, flooding was reported six times at Langwathby, four times at Temple Sowerby, five at Brampton, four at Carleton, seven at Plumpton, four at Broughham, six at Eamont Bridge, four at Pooley Bridge, four at Brampton, six at Maryport and three times at Whitehaven.

Many other settlements, particularly in the upland valleys, are flooded quite frequently, but the events are not always reported. In Borrowdale flooding has always been a problem, although it is only in recent years that reports have appeared in the newspapers and that the River Authority has acknowledged the problem. This century flooding is known to have occurred on at least eight occasions in the small villages on the River Derwent, at Grange, Longthwaite, Seatoller, Thornythwaite and Seathwaite, and on the Langstrath Beck at Stonethwaite and Rosthwaite. It may be conjectured from the evidence of the last 75 years that a similar number of floods occurred during the preceeding 75 years given that climatic conditions have remained relatively stable.

The data collected from the newspapers and other local sources, therefore, are not complete, although every attempt was made to reduce errors by cross-checking. However, errors in this case represent floods not reported rather than over-representing the flood problem. Also, it is reasonable to assume that the accuracy of information has increased since the 1920's when newspapers became increasingly orientated towards local events, rather than national problems. Even so, enough evidence exists from the past 200 years to suggest that many areas have been subjected to quite regular flooding, while others may be affected only during the major events.

During the historical research, it was discovered that flooding was recorded for 75 separate occasions during 51 of the 204 years of record from 1771 to 1975. Of course, there may have been other years when flooding occurred but was not reported, or was overlooked during the newspaper survey. Nevertheless, the large number of floods found gives a clear indication of the extent of the problem in Cumbria. Table 5-2 lists the years of flooding between 1771 and 1975 and the number of separate events reported for each year. Clearly 1891 is the worst with five, but none of these was a serious as many of the other events.

Table 5-2 Years of recorded flooding in Cumbria 1771-1975

1771	1891 (5)	1924 (3)	1947 (2)
1809 (2)	1892	1925	1952
1815	1894	1926 (2)	1954 (3)
1822	1895	1927	1962
1831	1896	1928 (3)	1964
1851	1898	1929 (2)	1965
1852	1899 (2)	1930 (2)	1966
1856	1903 (3)	1931 (2)	1967
1857	1914 (2)	1932	1968
1861	1916	1933 (2)	1972
1868	1918	1938	1974
1874	1921	1941	1975
1883	1922 (3)	1945	

Total flood events = 75 (numbers in parentheses represent
Total flood years = 51 total floods in year).

From this list of flood events, several years stand out as major episodes in the history of flooding in Cumbria. During these particular years flooding was usually of such a scale that many places experienced their largest floods for many years. While not all the Cumbrian rivers would have been reached major flood proportions, the floods of these particular years were sufficiently large enough in both spatial extent and volume to warrant special consideration. On this basis, the years of 1771, 1822, 1856, 1925 and 1968 stand out as particularly important. The approximate return period for such major events would appear to be once every forty years, although the period between floods actually varies between thirty-four (1822-1856) and sixty-nine years (1856-1925). However, during this latter period the flooding in 1903 was almost as large as the other events. It should also be noted that not all settlements have experienced their largest floods on these occasions. Kendal, for instance, was reported to have been most seriously flooded in November 1898 (Flood Studies Report, 1975) and Cockermouth in 1938 (Cumberland River Authority personal communication 1974).

1771:

The flood event of 1771 caused widespread damage throughout the whole of Northern England including Cumberland, Westmorland, Northumberland and Durham (Garret, 1818). In writing about the flooding of the Eden, Garret quoted the case of a whole mill being washed away at Bolton, while on the Kent at Kendal three men were drowned when the Wennington Bridge collapsed. At Betham he stated (page 23) 'that graves were washed open and corpses and coffins were floating for some time.' Although the 1771 flooding was a major event in Cumbria the lack of evidence prevents any detailed examination.

1822:

The 1822 flooding was featured in the Carlisle Patriot (9.2.1822) under the heading 'Storm and Flood'. On this occasion the River Eden was said to be 'higher than in 1771' and was reported to have caused much damage and destruction throughout its course. For instance, the bridges at Eastfield Wath, Kirkby Stephen, Church Brough and Cliburn were all destroyed by flood waters, while others at Coupland Beck, Kirkby Thore, Longmarton and Bolton were damaged quite seriously. At Keswick, floods completely destroyed several houses and at Cockermouth and Penrith many parts of the towns were inundated.

1856:

In 1856 flooding occurred in Cumbria of a similar nature to that in 1822, although in several areas the flooding was of even greater magnitude. The Carlisle Patriot (13.12.1856) and the Carlisle Journal (12.12.1856) reported widespread flooding throughout the county.

1925:

The flooding of 1925 was given even wider coverage by the newspapers than any previous events, although compared to 1856 the flooding was not as great. The flooding in 1925 was the culmination of three floods in December 1924, building up to the major event in the following January. During this period much of Cumbria experienced widespread flooding and particularly high flood losses were reported from the catchments of the Eden, the north-west lowlands, the Derwent-Cocker and the coastal areas of the south.

The River Eden apparently flooded many of the settlements along its course from Kirkby Stephen to Warcop, Langwathby, Lazonby and Kirkandrews. Many of the tributaries were also in flood, including the Caldew, Petteril, Eamont and Lowther, which inundated the settlements of Lannercost Priory, Kirkoswald, Hesket-New-Market, Millhouse, Carleton, Penrith, Plumpton, Brougham, Eamont Bridge, Pooley Bridge and Thrimby Grange. The rivers of the north-west were also in full spate flooding many small villages such as Wigton, Gamelsby, Kirkbridge and Lessonhall. Along the west coast high tides and full rivers added to the problems, and Maryport, Whitehaven, Workington and Silloth all experienced major flooding. The Derwent-Cocker river system caused extensive flooding from the upper villages of Borrowdale to the coastal flooding at Workington. Reports of flood losses were received from Stonethwaite, Rosthwaite, Seathwaite, Seatoller, Borrowdale, Grange, Portinscale, Cockermouth, Cammerton and Braithwaite. The Leven drainage areas were also in high flood, especially above Lake Windermere where the Brathay and Rathay caused considerable damage down through the Langdales Valley. The settlements of Ambleside, Grasmere and Elterwater were inundated as well.

The 1925 flooding may not have produced the largest recorded flood levels, but the extent of flooding throughout the county warranted particular attention. For instance, the local newspapers indulged in headlines such as 'New Years Day Havoc' (Cumberland and Westmorland Herald, 3.1.25) and 'Torrential Rains over Christmas - Flooded Rivers' (Cumberland News, 3.1.25.) The Herald went on to describe the flooding as the worst for many years, stressing the widespread flooding throughout Cumberland and Westmorland.

1968:

The most recent major flood event in Cumbria took place in

March 1968, when again a considerable number of towns and villages suffered the most serious flooding for many years. Because this event occurred so recently, there is considerable information available on the meteorological and hydrological characteristics of the flooding, as well as details on the spatial extent of the flooding in the county.

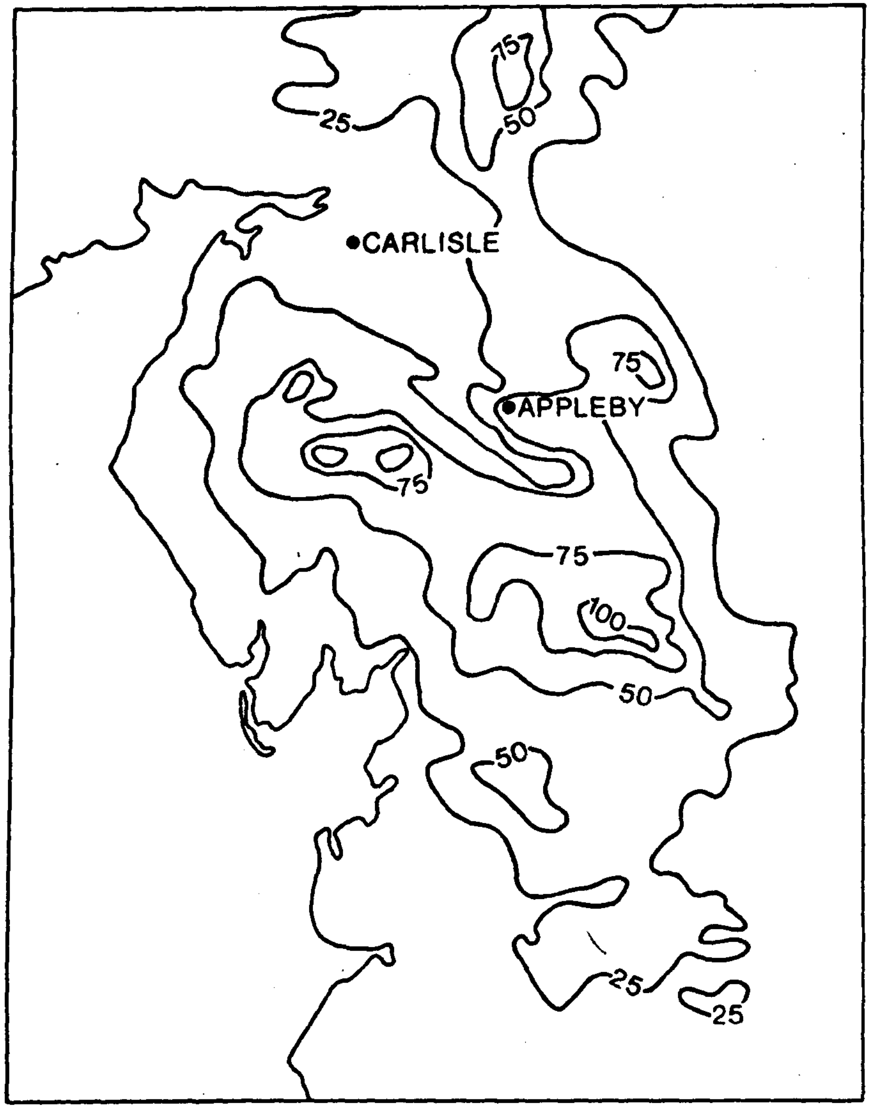
The meteorological conditions which led up to the event of March 23rd 1968 were such that a flood occurred almost immediately in the upper reaches of the catchment. Four days earlier there were several heavy falls of rain in excess of 50 mm which produced high flowing rivers (map 5-11). However the storms of the 22nd and 23rd March brought even heavier falls of rain which on the already saturated catchments rapidly reached the river channels. Map 5-12 shows the extent and intensity of these storms, which brought the heaviest storms of the year to many places, such as Borrowdale, Keswick, Thirlmere, Braithwaite, Eden Place, Appleby, Patterdale, Burn Banks and Spadeadam (British Rainfall, 1968). Several of these places received over five percent of their average annual rainfall in one day (Table 5-3).

Table 5-3 Sites with more than five percent of mean annual rainfall during 23rd March 1968

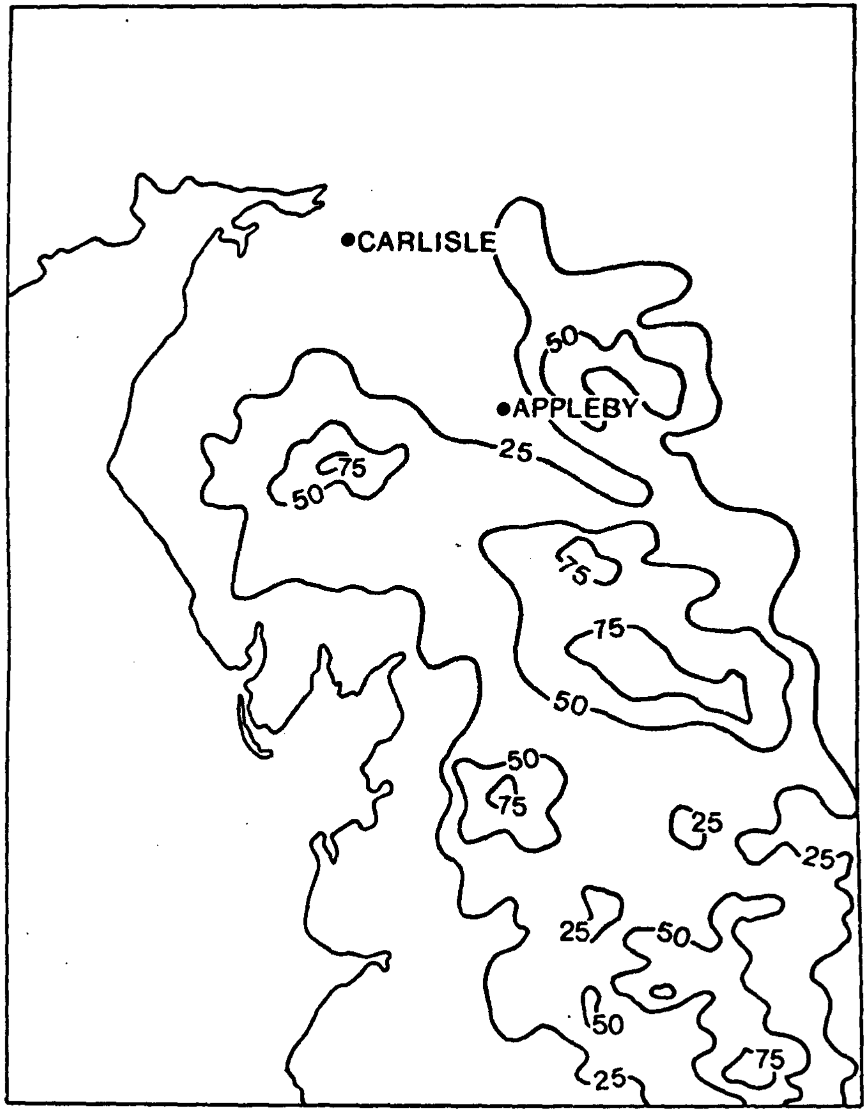
(Source : British Rainfall 1968)

	mm	% Annual Average
Eden Place	54.1	5.1
Appleby Castle	50.8	5.5
Appleby Highfield	58.4	6.5
Burn Banks	96.5	5.3
Spadeadam	67.1	6.1

Map. 5-11. Cumbria: isohyets for the storm on 19th. March 1968.



Map. 5-12. Cumbria: isohyets for the storm on 23rd. March 1968.



Apart from rainfall, other meteorological factors were also involved in creating the very high flows on the 23rd March. The soil moisture deficit would have been minimal, which meant that rainfall would soon become runoff. Potential evapotranspiration would also have been very low and hence would have no effect in reducing flood levels. Snowmelt, on the other hand, significantly increased the flood peaks of many streams. Snowfall, for instance, was recorded in parts of the Lake District during March on seven occasions with snow remaining on the ground for between two and five days. Maximum accumulations of up to 8 cm of undrifted snow were found on the 20th and 21st March at Ashey Croft, Dale Head Ennerdale, Patterdale, Haweswater and Langdales (British Rainfall 1968). These snow accumulations disappeared following the storms on the 22nd and 23rd March and hence were presumed to have added to the runoff during this period.

The hydrological characteristics in 1968 varied between the different catchments, although in general the rivers in the east were the worst affected. The River Eden, for example, reached its highest level since 1856 with a peak discharge of approximately 1400 m^3/sec, measured immediately above Carlisle. Contributions from the main tributaries amounted to 274.92 m^3/sec and 231.55 m^3/sec for the Eamont and Lowther respectively (Cumberland River Authority personal communication, 1974). The Caldew and Petteril rivers were also at their highest for many years. In the south, the River Kent experienced a major flood, discharging 188.23 m^3/sec at the peak of the flood at Kendal, where the channel capacity is only 76 m^3/sec. The rivers in the south-west were less severely affected and flood levels failed to attain the peaks reached the previous October.

Table 5-4 shows the corresponding flows for the October and March events on three of the west and south-west rivers.

Table 5-4 Measured river flows for three Cumbrian rivers (Source: Flood Studies Report 1975).

River	At	9.10.67	23.3.68	Channel Capacity
		m^3/sec		
Leven	Newby Bridge	121.39	71.4	46.3
Crake	Low Nibthwaite	29.68	11.51	10.0
Derwent	Camerton	245.73	180.99	113.5

As with other significant flood years, 1968 did not represent major flooding for all areas of Cumbria. The worst hit areas on this occasion were the north and east of the county. Newspaper reports for these areas described the considerable devastation particularly down through the Eden Valley. The Cumberland Journal (29.3.68) reported the destruction of two bridges, one at Longwathby which had stood for 280 years and the other at Appleby, as well as damage in the settlements of Kirkby Stephen, Warwick Bridge, Eden Hall, Crosby-on-Eden, Brampton, Lanercost, Wetheral, Brampton, Grange and Penrith. There was also considerable agricultural damage in the Vale of Eden.

Example Sites

(a) Kendal:

From the various newspaper reports and local records, it would appear that Kendal has been flooded on at least fourteen occasions between 1831 and 1970. This frequency represents a a return period of approximately one in ten years for floods large enough to warrant a report in a newspaper. While the lower areas of the town, including the Main Street are quite frequently flooded, the higher areas are only affected during the very large floods. The worst flood on record in the town occurred in 1898, when Stramongate was inundated to a depth of 1.6 metres, and a small wooden bridge was swept away. The total losses at the time were estimated to be over £10,000 (Carlisle Journal, 4.11.98). Other large floods, which also caused significant damage in the town, occurred in 1874, 1927 and 1954. A feasibility report on the River Kent, Kendal Improvement Scheme (undertaken by C.H. Dobbie 1970, and quoted by the Flood Studies Report, 1975) marked the top seven floods in the town according to peak flows (table 5-5).

Table 5-5 Seven largest Kendal floods.

Date	m^3/sec	Rank
2.11.1898	368	1
7.10.1874	280	2 =
2.12.1954	280	2 =
27.10.1927	280	2 =
26.11.1861	248	5
9. 2.1831	222	6 =
2. 2.1852	222	6 =

(b) Keswick:

Keswick has been flooded on many occasions between 1822 and 1970, and, like Kendal can expect to be inundated once every ten years on average. However, the last major event appears to have been the 1924-1925 flood for since then only the lower parts of the town have been flooded. Previous to 1924, the largest floods on record were the 1894 and 1898 events; the latter was particularly significant because not only was extensive damage caused in the town, but also in the Braithwaite Pencil Mill, when a small dam structure failed (Carlisle Journal, 4.11.1898)

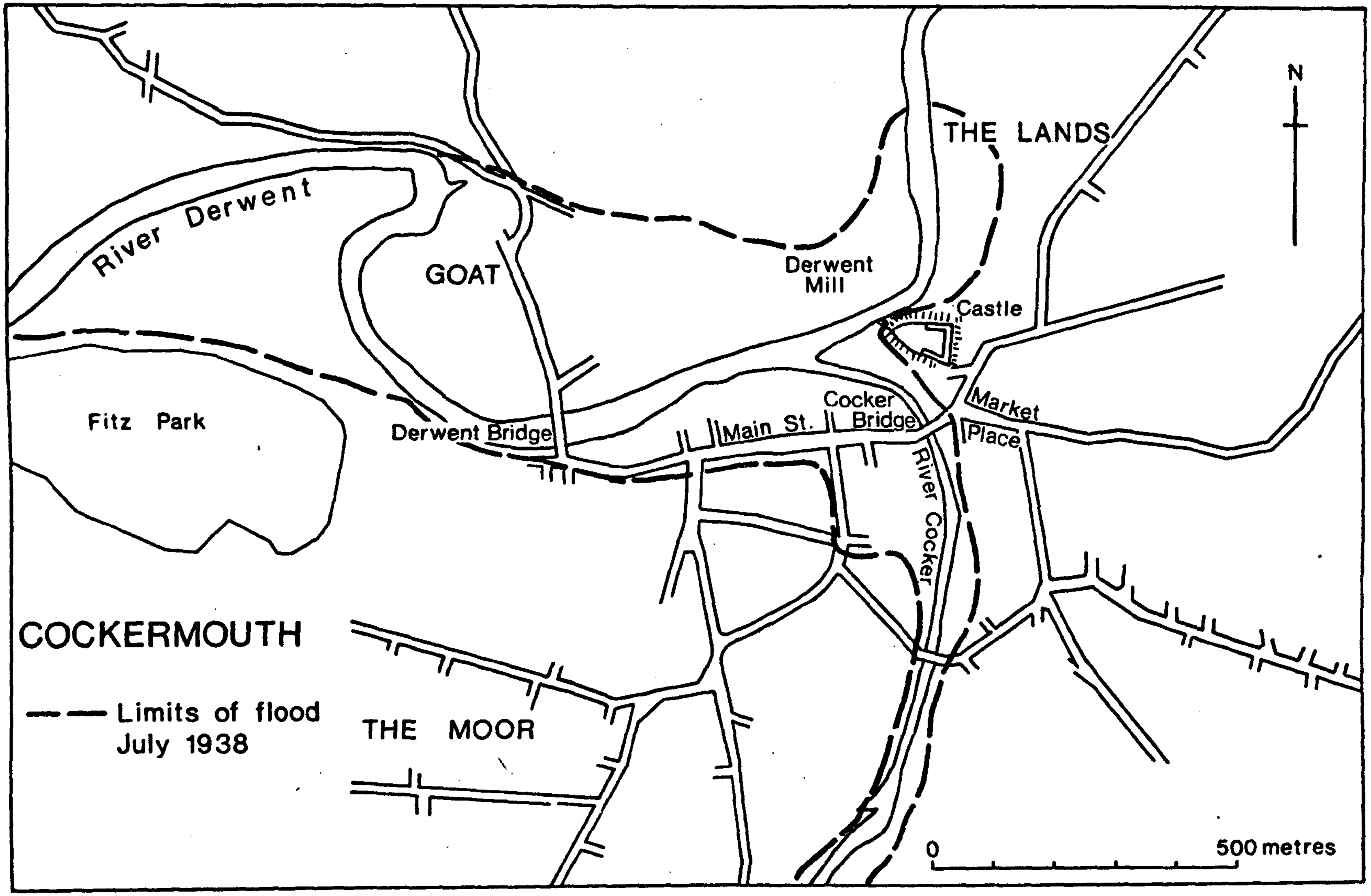
(c) Penrith:

Penrith experiences less extensive floods than either Keswick or Kendal although the frequency of events in the town is quite high. At least fifteen references were found to flooding in the town between 1809 and 1970. However, the two small streams, which have now been culverted under the town, tend to produce minimal flooding compared to the larger rivers in Cumbria.

(d) Cockermouth:

Cockermouth has suffered very severe losses from flooding for many years, from both the River Derwent and the River Cocker (see above). A particularly bad period of flooding occurred during the 1930's when three major floods and one of smaller magnitude inundated the town. The worst of these was the 1938 event, of which the limits of the flood are shown on map 5-13, when Main Street was under one metre of water at the flood peak (see plates 1 and 2). A large part of the town experienced flooding on this occasion with many houses and shops damaged, while the old Quaker Bridge was cracked and Barrel Bridge totally destroyed (West Cumberland Times, 3.9.38). In 1932, flooding in

Map. 5-13. Cockermouth: extent of flooding in 1938.



Main Street rose to 0.75 metres and over 200 people were affected by flood waters in the Goat area of the town (Carlisle Journal, 20.12.32). In the previous year, 1931, the Main Street had again been flooded (Cumberland News, 7.11.31) while in 1933 only lower parts of the town were inundated. Other notable floods have occurred in 1874, 1898, 1918 and 1924-1925, and altogether the town has been affected by flooding on at least 14 occasions in the last 150 years. However, it is significant that Cockermouth has not been flooded seriously since 1938, a point which is discussed in detail in chapter six.

In conclusion, there is a long history of flooding in Cumbria, which in some places recurs with remarkable frequency, causing considerable damage to both urban and rural environments. The flood problem has, if anything, increased in significance over the past 200 years due to the activities of man. Many settlements for example, have encroached onto the flood plains as the towns have expanded during the rapid developments of the late nineteenth century. This process has naturally put greater areas at risk from flooding and hence given the appearance of an increase in flood frequencies. Losses from flooding have also increased because of the greater property at risk and hence flooding has become more important during the years. The problem, though has been created entirely by man occupying flood prone areas. Whellan (1860) also suggested that the frequency of flooding in Cumberland had actually increased due to improved field drainage techniques which accelerated runoff and increased both flood peaks and flood frequencies downstream. This is probably unrealistic on any large scale, because the vast majority of the Fells or

Plate I. Cockermouth: Flooding in Main Street, 1938.

Plate 2. Cockermouth: Flooding at Victoria Bridge, 1938.

catchment areas have been left undrained. However, the effects of the current afforestation programmes may have led inadvertently to greater peak discharges particularly during the initial stages of ploughing, planting and saplings.

(3) Carlisle and Appleby

Many of the general physical and human characteristics associated with flooding in Cumbria can be seen clearly in the two case studies - Carlisle and Appleby. Between them, the two towns have experienced a large number of the problems described above, and thus in many respects are typical of many other settlements in Cumbria. These case studies not only provided examples of upland and lowland flooding, but also illustrate different meteorological and hydrological features. The development of the two settlements and the adjustments made to the flood hazard have also differed. More detailed surveys of Carlisle and Appleby, therefore, are useful in explaining and analysing the general flood problems in Cumbria.

Both towns are situated on the River Eden in the east and north-east of Cumbria. Appleby is located approximately 41 km from the source of the river, and is 125 m above sea level. At this point the Eden is deeply incised, having already fallen 590m (Millward and Robinson, 1972). Carlisle, on the other hand is located 113 km from the source of the river, and is only 14 m above sea level. However, although the river is only 17 km from its mouth at this point, the tidal effects do not reach as far as Carlisle. The geological structure of the two locations is predominantly sandstone (Kirklinton at Carlisle and the Penrith type at Appleby) although lias and shales can be found in the western part of Carlisle and small limestone deposits are visible to the west of Appleby. The main vale of the Eden consists of sandstone while to each side are the limestones of Caldbeck Fells, Great Mell Fell, Mallerstang and the West Pennines (map 5-6).

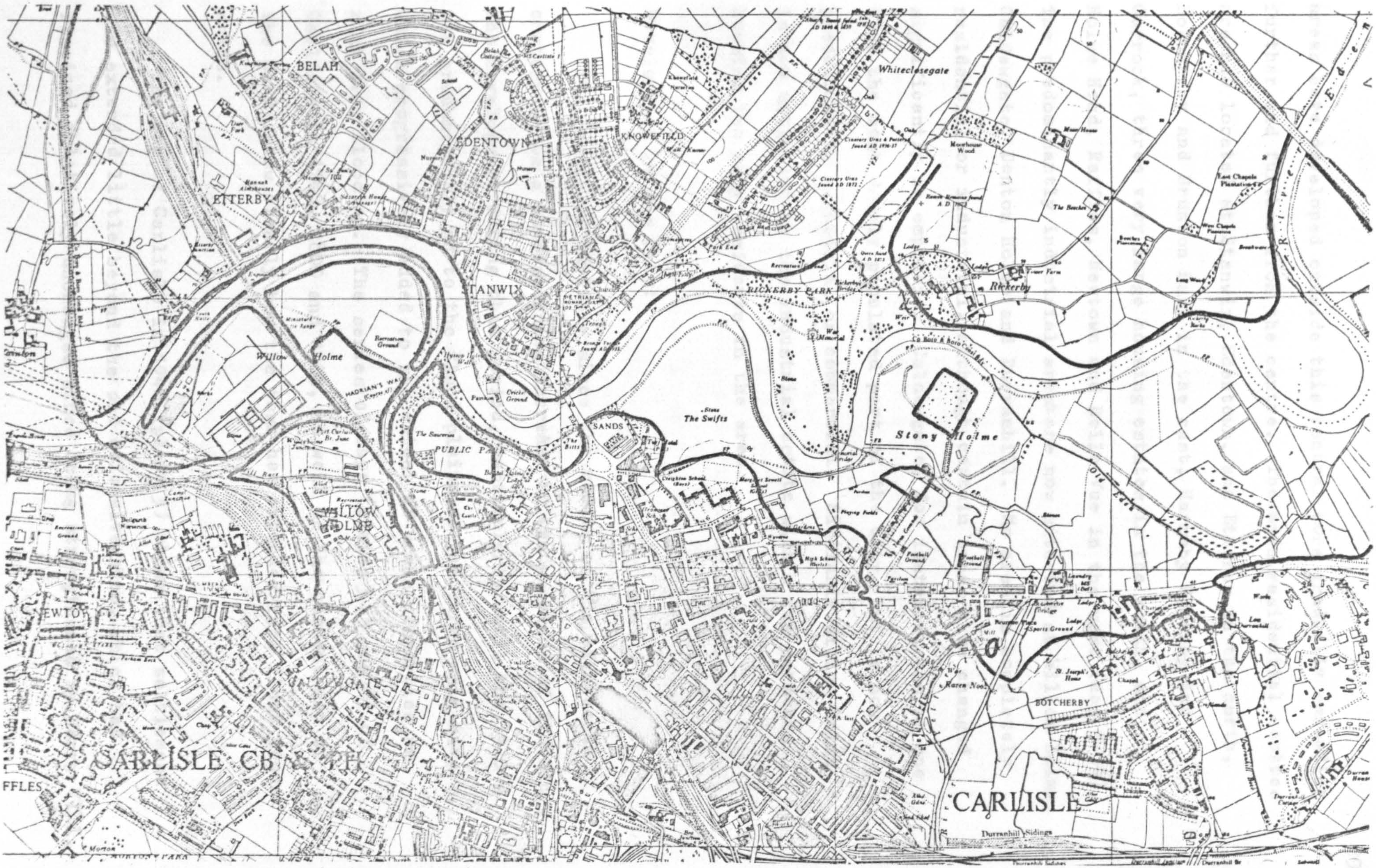
Carlisle

The modern city of Carlisle is the largest settlement in north-west England. It covers an area of approximately 2465 hectares and at the 1971 census had a total population of 71,582 The City is situated upon three rivers, the Eden which bisects the town from the east to west, and the two left bank tributaries which flow in from the south, the Caldew and the Petteril. The Caldew which rises in the Caldbeck Fells, flows into Carlisle through the southern residential and industrial suburbs of Denton Holme, Caldewgate and Willow Holme, eventually reaching the Eden at the Sauceries. The Petteril, which also flows into the south of the city meanders through principally residential areas to join the main river in the far east of the City at Stony Holme. The Eden is fairly large by the time it reaches Carlisle and winds its way through the lower Holmes of the City. The river effectively separates the residential suburbs of Stanwix, Edentown, and Etterby from the main City area (map 5-14).

Apart from the three main rivers, there are several small streams which run through various parts of the City. Parnham Beck and Dow Beck, for example, rise to the west of Carlisle and flow eastwards through Newtown and Raffles to join the River Caldew at Caldewgate. The Old Eden, a former course of the main river, flows into the Eden east of Stony Holme, while Brunstock Beck flows south to join the Eden at Rickerby.

The old core of the City, incorporating the castle, cathedral and market place has remained the focal point of the town, although large shops and businesses have replaced many of the small traders who used to occupy the site. The major residential and industrial

Map. 5-14. Carlisle: the extent of flooding in 1968.



areas have developed outside this central core gradually spreading further and further from the centre. The main residential centres are now located at Stanwix, Edentown, and Etterby in the north, Botcherby and Brunton Park in the east, Harraby Upperby and Currock, three very large housing estates in the south, and Holme Head, Raffles, Newtown and Belle Vue in the west (map 5-14). The predominantly industrial areas are now situated at Willow Holme, Caldewgate, Denton Holme and Durranhill. No area is completely residential or industrial, although certain areas have changed significantly in emphasis. Caldewgate, for instance, was at one time the most densly populated part of the City, but is now predominantly industrial or commercial. Similarly Willow Holme is now dominated by the industrial estate with a few caravans housing the only residents in the area.

Development of the City:

The growth of Carlisle since the middle of the eighteenth century shows a corresponding increase in the problems of flooding. The development during this period, particularly until the 1920's was predominantly on to the flood plains of the three main rivers, which progressively added to the extent of urban properties at risk from flooding. The series of maps (plates 3, 4 and 5) of Carlisle in 1746, 1800 and 1900, as well as the current map of the City, show clearly how the town has expanded into flood prone areas.

The map of Carlisle in 1746 (plate 3) shows that settlement had extended little beyond the old defensive site, which had remained relatively unchanged since being strengthened by Henry VIII.

Only a few dwellings can be seen outside the walls, at 'Cauda Gate' (now Caldewgate) Shaddongate and Rickergate. However, these few houses were indicative of the development that was to follow, and represented the beginning of the expansion onto the low lying area around the old town. At this time, the River Eden still occupied the two channels around the north of the City, which had been formed by a particularly high flood in 1571 creating the new Prestwick Beck (Smith Kenneth, 1973).

By the beginning of the nineteenth century, the town had undergone several major changes due primarily to the doubling of the population. In 1763, the town was estimated to have a population of 4,158 (Whellan, 1860) while in the first official census (1801) this figure had risen to 9,521. The maps of this period (plate 4) show the tremendous expansion of buildings outside the city walls. For example, in 1801 Caldewgate was already supporting a population of 1,990, which by 1821 had virtually doubled to 3,915. The Botchergate population also doubled during this period to over 2,000 and Rickergate increased by 50% to 1,235 (Censuses 1801, 1811, 1821). This period, from the late 18th to the early 19th centuries, saw the beginnings of the industrial revolution in Carlisle. Thus, flooding of the main rivers from this time on would represent a threat to urban properties rather than the agricultural damages experienced in the past.

Two major changes within the town also encouraged the physical expansion of the town. Firstly, the defensive walls had been removed by 1821, which permitted greater development away from the central core. Secondly, the southern channel of the River Eden (the original course before 1571) was filled in to leave

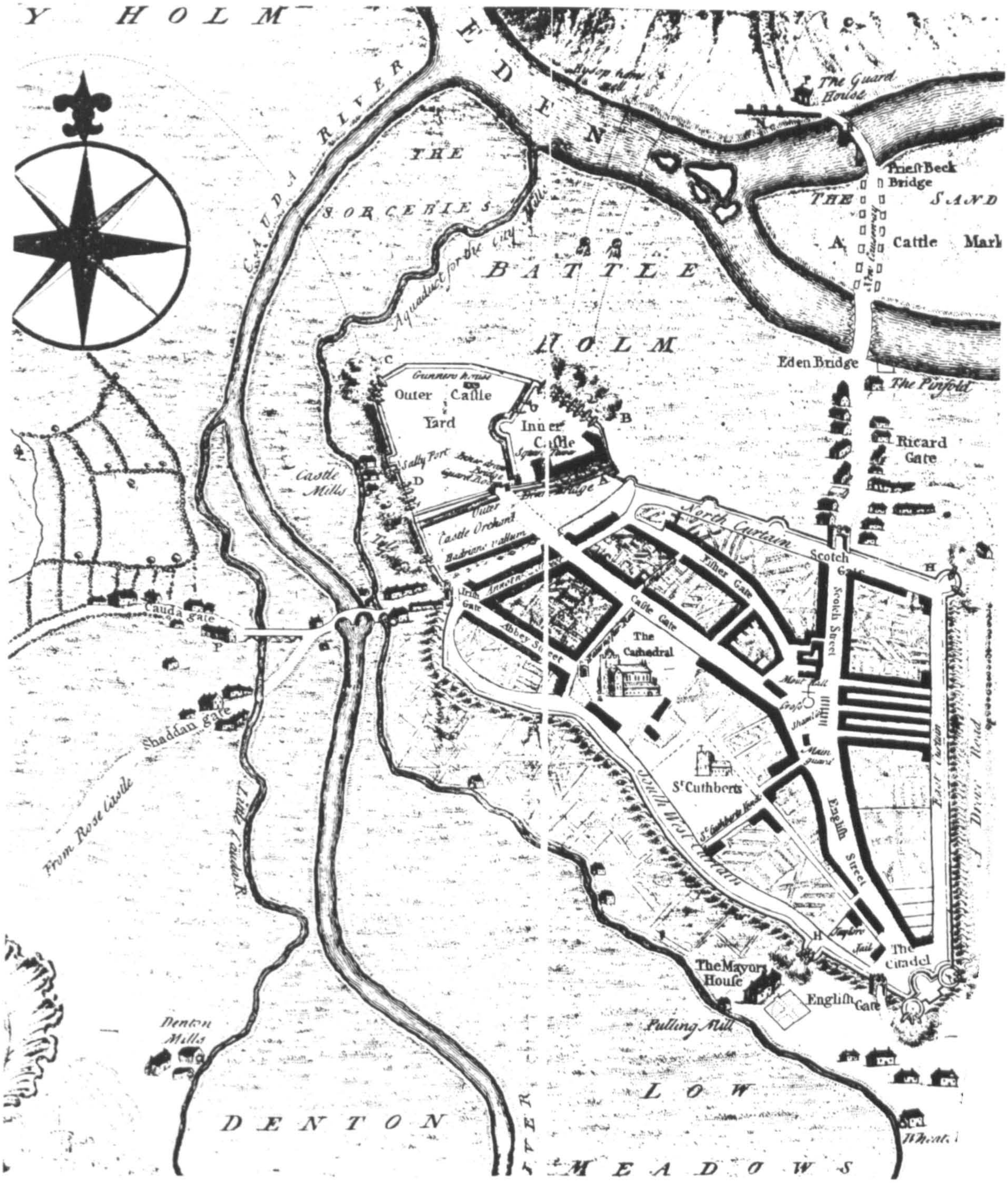


Plate 3. The City of Carlisle in 1746.

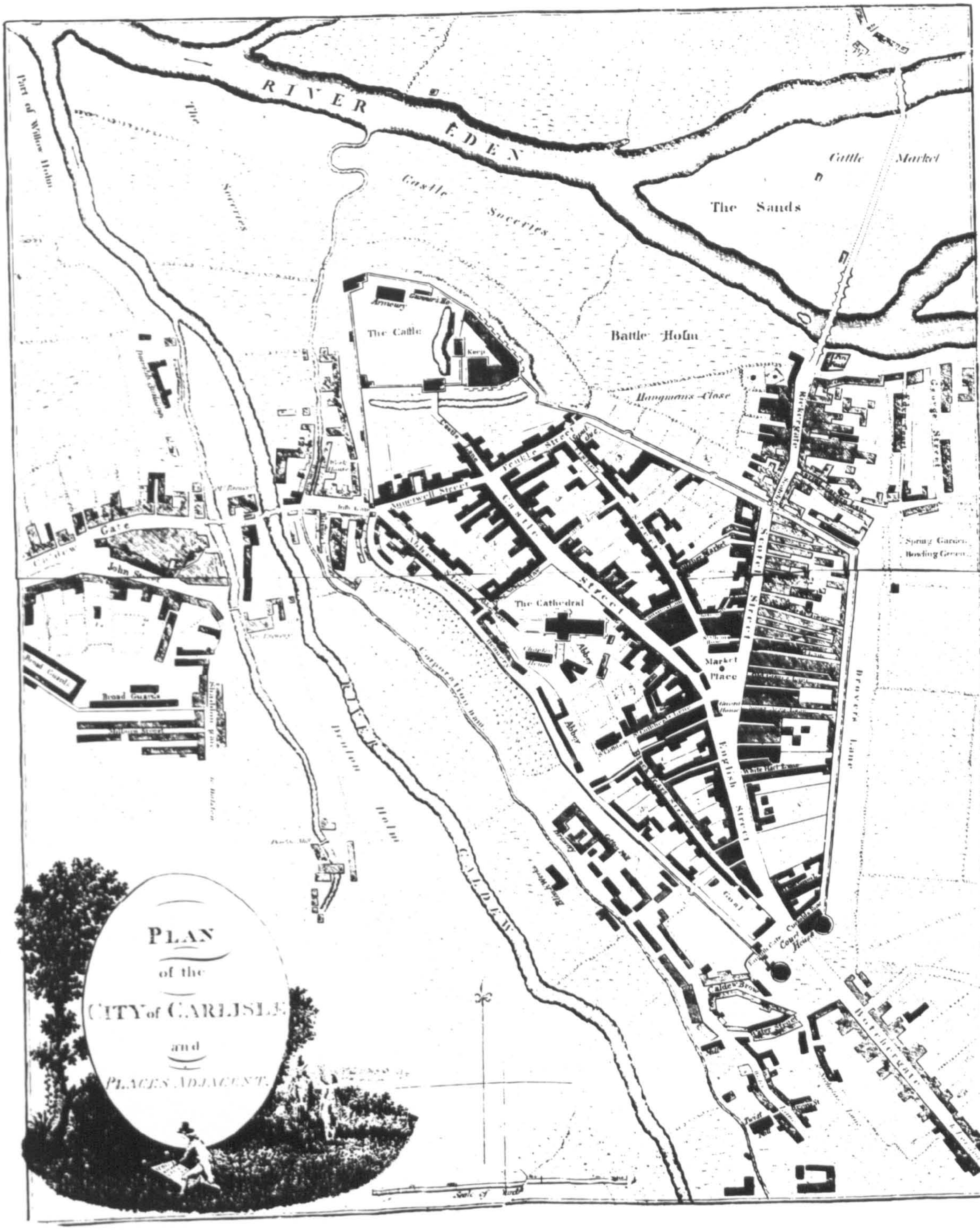
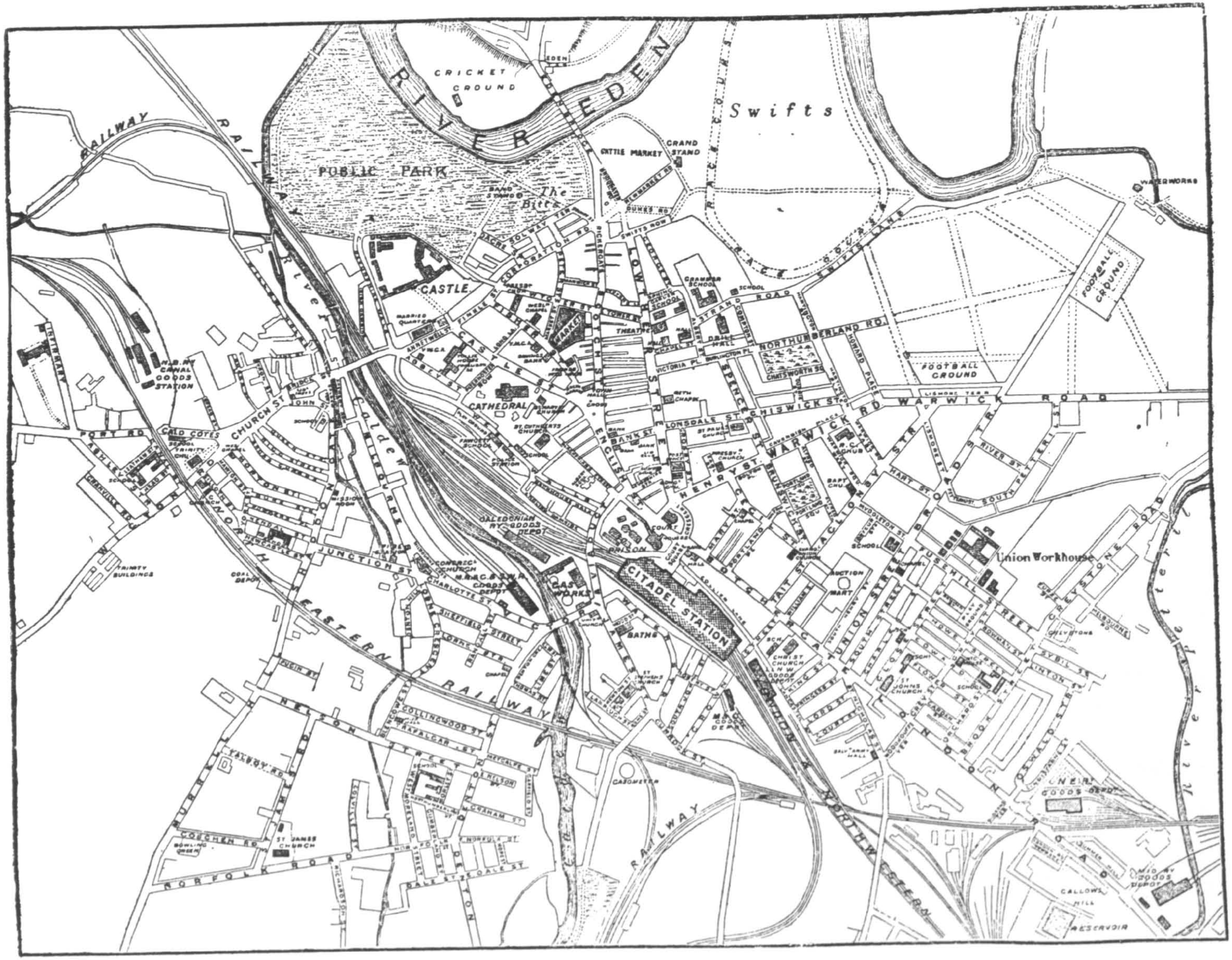


Plate 4. The City of Carlisle in 1800.



MAP OF CARLISLE IN THE PRESENT DAY (From *Beaty's Guide to Carlisle*).

Plate 5. The City of Carlisle in 1898.

Prestwick Beck as the main river course (compare plates 4 and 5). The development of this area was further encouraged by the construction of a new bridge across the Eden which cost £70,000 (McIntire, -). All these factors enhanced the flood problem in Carlisle. The removal of the walls and the new bridge served to promote further development of the flood plains, while restricting the river to a single channel would naturally aggravate the frequency of flooding.

Throughout the whole of the 19th Century there was an immense growth of the City of Carlisle, for by 1901 the population had already reached 45,480, an increase of 378% in a hundred years (census, 1901). By this time, Caldewgate had become a densly populated area surrounded by the factories of the industrial revolution. Shaddongate had expanded southwards to Denton Holme, while to the east there had been some development towards Botchergate, along Warwick Road and London Road. The plan of 1900 (plate 5) essentially shows the built up areas of Carlisle at this time.

The development of the Brunton Park and Botcherby areas of the City occurred during the late 19th and early 20th Centuries and has been traced with the aid of the first three editions of the Ordnance Survey Maps, 1:2500 and 1:10,560. For example, in the first editions, which were published in 1868 (1:10,560) and 1876 (1:2500) there was very little building to the east of the central core (these maps were surveyed in 1861 and 1865 respectively). Development was only just proceeding along the two main arteries, London Road and Warwick Road, from the City centre, although there was a small block of housing at Brunton Crescent built in 1832-5.

By 1901, with the second editions of the map, a certain degree of urban infilling was visible. Charlotte Terrace, Victoria Terrace plus a few houses on Warwick Road had been built east of Botcherby Bridge over the Petteril. To the west of the bridge, Warwick Road was almost fully developed on the north side, and intermittently on the south. The London Road had also been developed and there was further infilling between the two. This included Greystone Road, Petteril Street and Eldred Street. In the west of the city there was less change because the area was almost fully developed by this time. Caldewgate, Shaddongate and Willow Holme were supporting large populations housed in densly packed dwellings and working in the nearby industries. Carrs Biscuit Factory and Alexandra Saw Mills, two factories developed during the mid 19th Century, have remained to the present day on the original sites.

By 1925 the third editions of the Ordnance Survey maps show many further roads had been developed including those along Warwick Road, such as St. Aidan's Road, Brunton Avenue, Brunton Crescent, Short Street, Tullie Street, Greystone Road, Waller Street, Thirwell Avenue, Eldred Street and Petteril Street. In the west of the city expansion continued outwards although the Caldewgate and Shaddongate areas remained relatively unchanged.

Development up to the 1930's therefore continued the trend of the previous century with growth gradually expanding outwards from the city centre. Detailed consideration has been given to the Caldewgate, Shaddongate, Warwick Road and Botcherby areas in particular because this is where expansion on tb the flood plain was greatest. These areas also figure most prominently in the later discussion of flood problems in Carlisle.

Since the 1940's and 50's there has been a general slowing down in the urban expansion of Carlisle. Probably the most significant as far as the city was concerned was the construction of large residential estates to the south and east, including Harraby, Upperby and Currock. During the 1960's, Caldewgate became progressively more industrial and less residential as the old densely packed housing was permitted to decline and to be taken over by industries. However, much of this may have been the result of planning blight since in 1954 the area was designated for industrial and commercial purposes, but, to date, nothing has been done with the area. Planning authorities are still unsure of what is to become of the area, although a new road is planned to serve Willow Holme (Carlisle Planning Department, personal communication, 1975). The Caldewgate area now represents one of the poorest areas of the city, with a mixture of derelict property, small businesses and a few residential dwellings. One positive product of this period was the building of the Willow Holme Industrial Estate, which has brought many new industries to Carlisle, but is also situated in a flood prone area.

Future plans for the city are not very extensive as far as expansion is concerned, and most changes are anticipated within old areas rather than developing new. Apart from the new road to supply the Industries of Willow Holme, the only other planned development is a residential estate in Brunton Park which is to be sited between the Petteril and Greystone Road. Plans for 250 to 300 new dwellings have already gone before the ministry and county council for final approval.

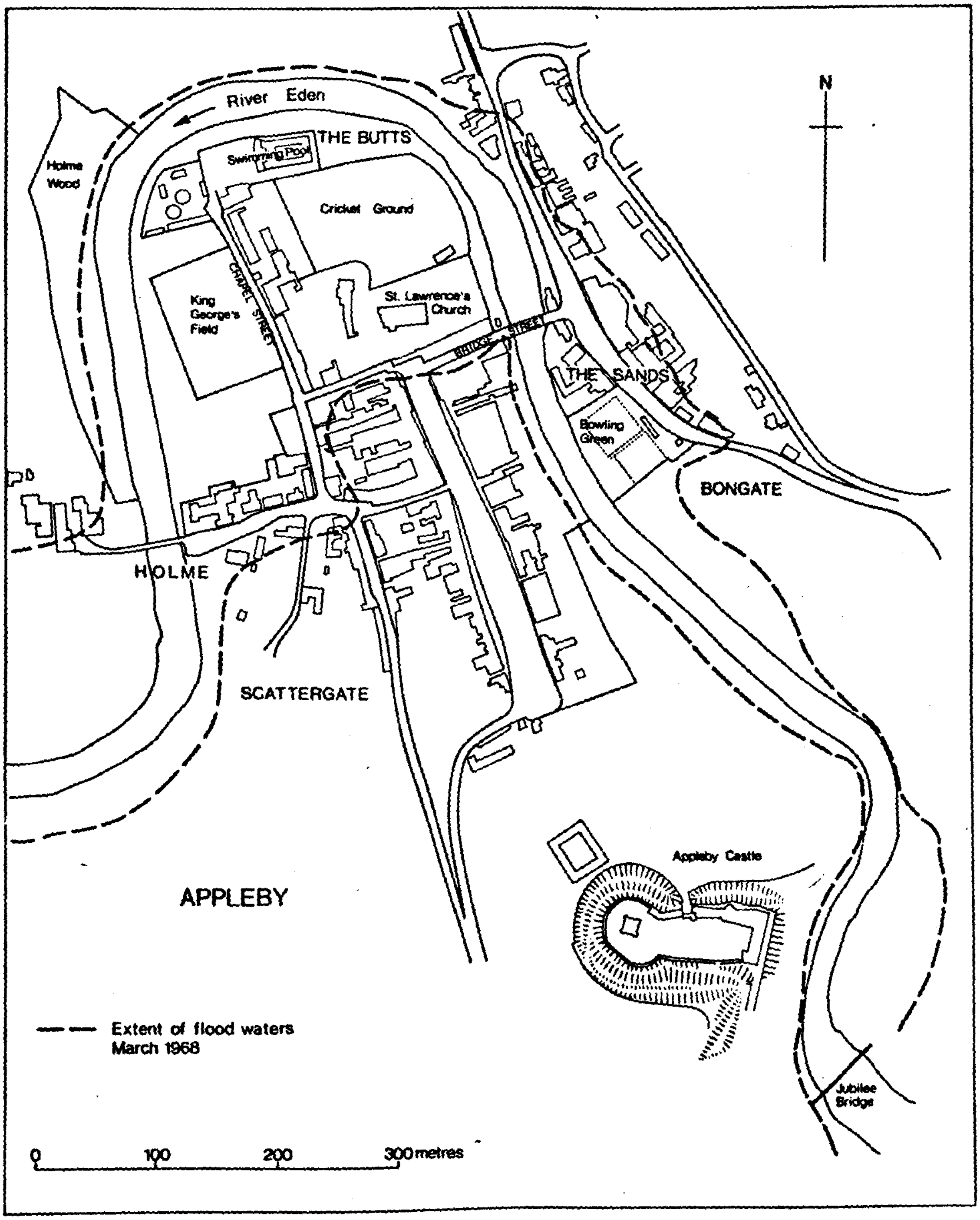
It is obvious from the evidence of the maps that the flood problem has been created by man during the past 200 years. The gradual expansion of both residential and industrial areas on to the flood plains of the Eden, Caldew and Petteril has put increasing amounts of property at risk. No doubt some of the rapid expansion of the 19th century or even early 20th century may be excused in the blind rush for industrial achievements, technological break-throughs and general progress, the result of which has been the legacy of flood prone property. However, that the trend of flood plain development has continued, thus increasing the flood problem still further, is purely the result of poor planning policies implemented by the flood plain managers, including the town planners and other local authorities. The most blatant disregard of the flood hazard in recent years was the promotion of Willow Holme Industrial Estate in an area known to have been flooded on numerous occasions. Even future plans for the City are little better, for the new housing estate is to be situated in the old course of the River Petteril at Raven Nook, another area of periodic flooding. It would appear, therefore, that Carlisle, like many other cities, has already forgotten the lessons of the last flooding.

Appleby

In contrast to Carlisle, Appleby is a much smaller settlement with a total population in 1971 of only 1,949 people, although until the administrative reorganisations in 1974 it retained the status of county town of Westmorland. The town itself is situated on an old defensive site, with the castle on a bluff surrounded on three sides by a large bend in the River Eden (Described in detail by Simpson, 1950). The town extends down from the castle to the inner side of the bend, and across the river to the east, to an area known as the Sands. Since the name 'Sands' implies proximity to water (Gibson, 1877) this provides an early indication of the flood problem. From the Sands, a residential area extends up the steep bank to the railway station, while a further residential area can be found at Scattergate, to the south-west of the castle (map 5-15). Another part of the town includes the ward of St. Michael which extends from the top of Drawbriggs to the Jubilee Bridge.

Development of the town:

The development of Appleby did not follow the same pattern as Carlisle. In the 14th Century Appleby had an estimated population of over 3,000, but due to a series of invasions by the Scots and devastation by bubonic plague, this figure was reduced radically. In 1778, Ferguson (1894) reported that there were only 80 families, although this was probably for the St. Lawrence ward only. By 1801 (census) the population of the combined wards of St. Michael and St. Lawrence amounted to 1,619. The population at this time occupied the old core of the town, including Boroughgate, Doomgate, High Wiend, Low Wiend, Bridge Street and part of the Sands. By 1860, the first edition of the Ordnance Survey showed that Chapel Street and Holme Street had been developed, while by the 1920's a certain degree of infilling had taken place along the Sands and in Chapel Street, and the residential area below the railway station was developed. The most recent development has been the construction of a housing



Map. 5-15. Appleby: the town in 1968 showing the extent of the March flooding.

estate at Scattergate, primarily for older people. Very little has changed in Appleby, therefore, particularly in the older centre and along the flood plain where much of the housing is over one hundred years old and a considerable number of dwellings over two hundred years.

The population of Appleby experienced some growth during the 19th Century as numbers rose to 2,824 in 1869 which represented a 75% increase since the turn of the century. However, this trend did not continue, as it had in Carlisle, for by 1951 the population had fallen to 1705. It is only in recent years with the movement from large towns that the population has risen to its present size.

Appleby, therefore, is different from Carlisle in that the flood problem is not really the product of rapid urban expansion during the industrial revolution, but is instead the legacy of a much earlier period. In fact the areas particularly prone to flooding, such as Bridge Street, Sands, Cloisters, Low Wiend, High Wiend and Doomgate were established well before 1800. Even the development of Chapel Street, Holme Street and the rest of the Sands was completed fairly early in the 19th century. Recent development has avoided these flood prone areas in favour of the higher areas, except for an old peoples' home, located next to the Eden at the bottom of Holme Street.

The 1968 Flood in Carlisle and Appleby : Hydrological Aspects

In March 1968, both Carlisle and Appleby suffered extensive flooding, which in Carlisle, at least, was the largest since 1856. The estimated losses accruing from the flooding were also of record proportions, being the highest ever recorded in both communities. The meteorological and hydrological characteristics which caused this flooding, have already been discussed above. However, the implications of the hydrological features of the flooding are now considered in greater detail with reference to Carlisle and Appleby.

The flow at Appleby began during the early evening on Saturday 22nd March and reached its peak sometime after midnight. By 3.00 am the following morning the water had started to recede and by 8.00 am the town was virtually free from water. The volume of the peak discharge has never been estimated officially, although the maximum flood levels at the two Appleby Bridges were recorded (table 5-6). These figures suggest that the River Eden rose by 6.1 metres during the night of the 22nd-23rd March.

Table 5-6 Maximum recorded flood levels : March 1968

(source Cumberland River Authority)

		metres above sea level
Jubilee Bridge	upstream	129.68
	downstream	129.67
St. Lawrence Bridge	upstream	128.68
	downstream	128.5

The flood peak was transferred gradually downstream, reaching Warwick Bridge between 5.00 and 6.30 am and the Motorway Bridge just outside Carlisle at 8.00 am. By this time, a great deal of Carlisle was already inundated, and the arrival of this peak merely enhanced the flood problems. Carlisle is subject to flooding by any of the three main rivers, although individually they cause more localised flooding. However, on this occasion all three rivers were in full spate. The River Caldew was probably at its highest since 1925 and caused flooding of houses and businesses in Caldewgate and Shaddongate as well as the industries of Willow Holme. The River Petteril was also very high, and, like the Caldew, was blocked by the Eden which caused the Petteril to flood parts of Brunton Park.

The River Eden rose to its highest level for over one hundred years and caused widespread flooding throughout the lower Holmes of the City. Official estimates of the peak discharge through Carlisle have varied because no river level gauging station remained operational throughout the flood event. The Cumberland River Authority (records, 1968) originally quoted figures of 1557.42 m^3/sec but this was later reduced to 1415.84 m^3/sec. Although estimates of the peak flows have varied, the River Authority now assumes that the latter figure is probably the most accurate (personal communication, 1974). In order to reach a flood of this magnitude at Carlisle, a certain degree of synchronisation is required between the main river and the tributaries. The Cumberland River Authority estimated the peak flows for the Eden and more accurately measured flows from the Eamont and Lowther (table 5-7).

Table 5-7 Peak river flows : March 1968

River	Station	Max. flow (m^3/sec)
Lowther	Eamont Bridge	231.55
Eamont	Udford	274.92
Eden	Temple Sowerby	400.97 (estimates)
Eden	Warwick Bridge	860.00 "
Eden	Carlisle	1415.84 "

(Source : Cumberland River Authority)

However, since the peak flow at Warwick Bridge reached only 860 m^3/sec it would suggest that the maximum flows did not entirely coincide. All figures on the River Eden were estimates because of failures of the gauging stations during the flooding. Some controversy developed over estimates of the Warwick Bridge flows for an early River Authority estimate put these as high as 1135.5 m^3/sec. This may have been reduced on reflection of the total contributions from the Petteril and Caldew. The only large tributary, the Irthing, reached its peak at 2.00 am (193.97 m^3/sec) and so did not add significantly to the peak flows on the Eden. The different timing of these rivers probably increased the duration of the flood, which was reported to have lasted for most of the Sunday (see questionnaire results in chapter seven).

The Cumberland River Authority estimated the frequency of floods of this magnitude in Carlisle to be 1 in 60 or 1 in 100 years. However, this was later revised, following a more careful assessment of the flooding, to a recurrence interval of 38.5 years

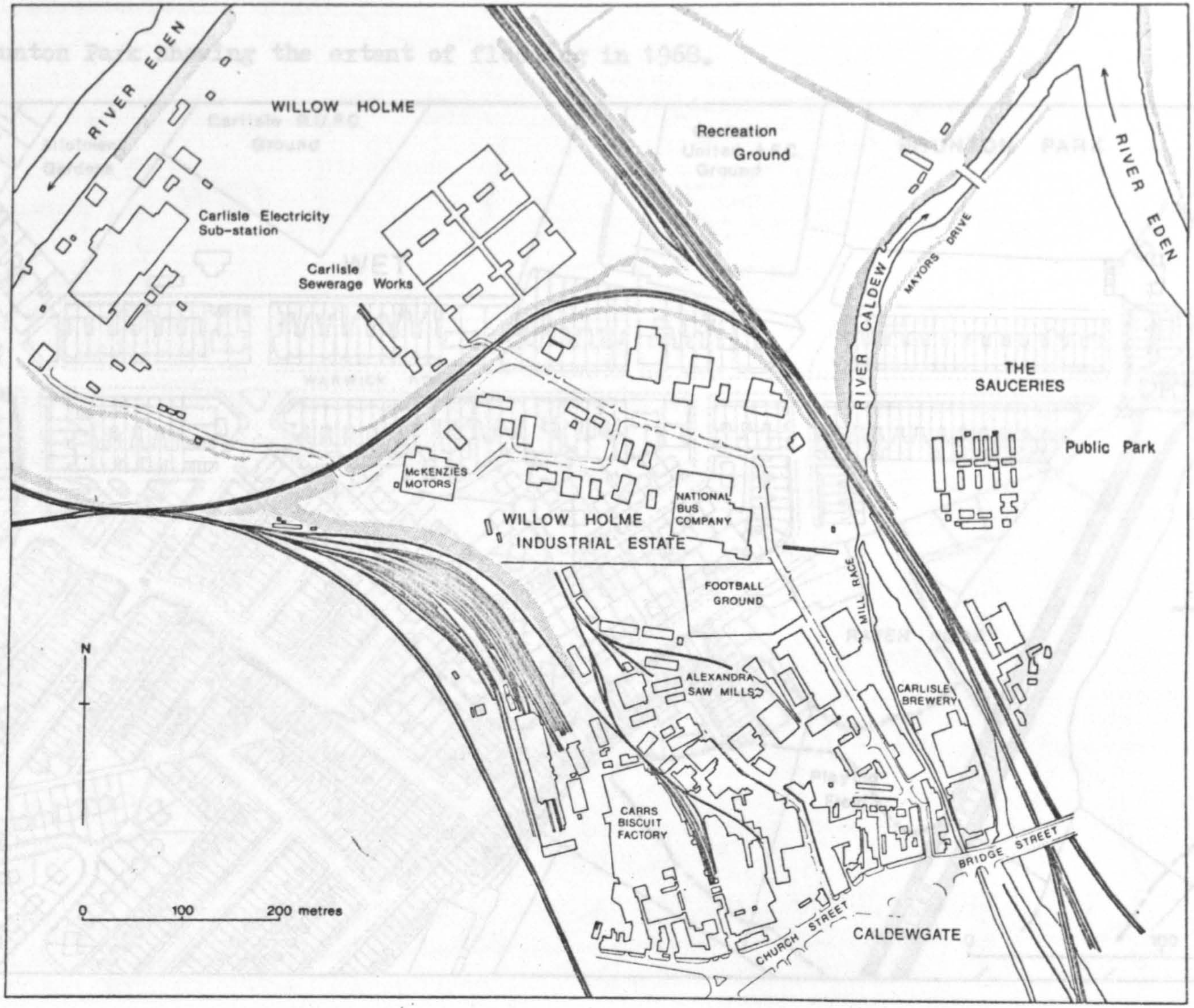
(Cumberland River Authority - Records).

Flood damage in Carlisle

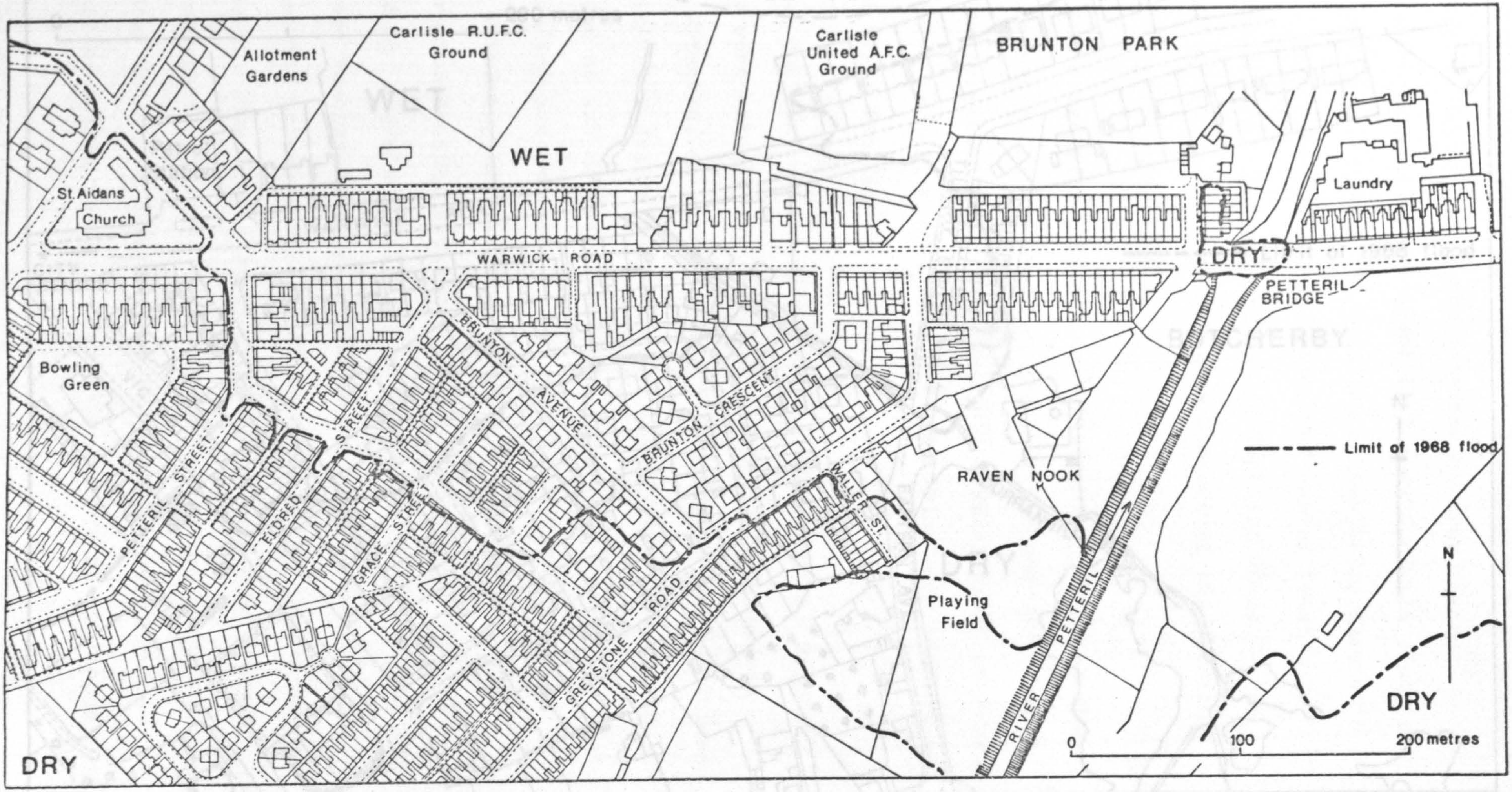
The 1968 flood in Carlisle inundated over eleven percent of the land area within the City boundaries, and caused damage to residential and industrial properties, as well as to recreational parkland facilities (map 5-14). Local newspapers reported at the time that over 6,000 people in the City were affected by the flood in one way or another, and that 150 families had to be evacuated temporarily from their homes (Cumberland Journal, 29.3.68). The newspaper went on to point out that losses due to the flood were expected to reach £500,000, without including consequential losses or uninsured property.

The Caldewgate area of the City suffered very high losses because several large commercial properties were inundated (map 5-16). The Cumberland Journal (29.3.68) reported that the manager of Carrs Biscuit Factory estimated losses to the company to be as high as £25,000 while Alexandra Saw Mills and the Carlisle Brewery were reported to have suffered thousands of pounds worth of damage. The Willow Holme Industrial Estate experienced even greater damage, especially in the west of the site where flood waters rose to nearly two metres. McKenzies Motors, for instance, lost everything, including fifty new cars and many spare parts, and immediate losses were assessed by the company to be approximately £30,000. Plates 25 and 26 show the depth of water at McKenzies after the flood peak had passed. (Further details of the Willow Holme flooding can be found in chapter nine). The Cumberland Journal (29.3.68) also reported that Adamson and Company

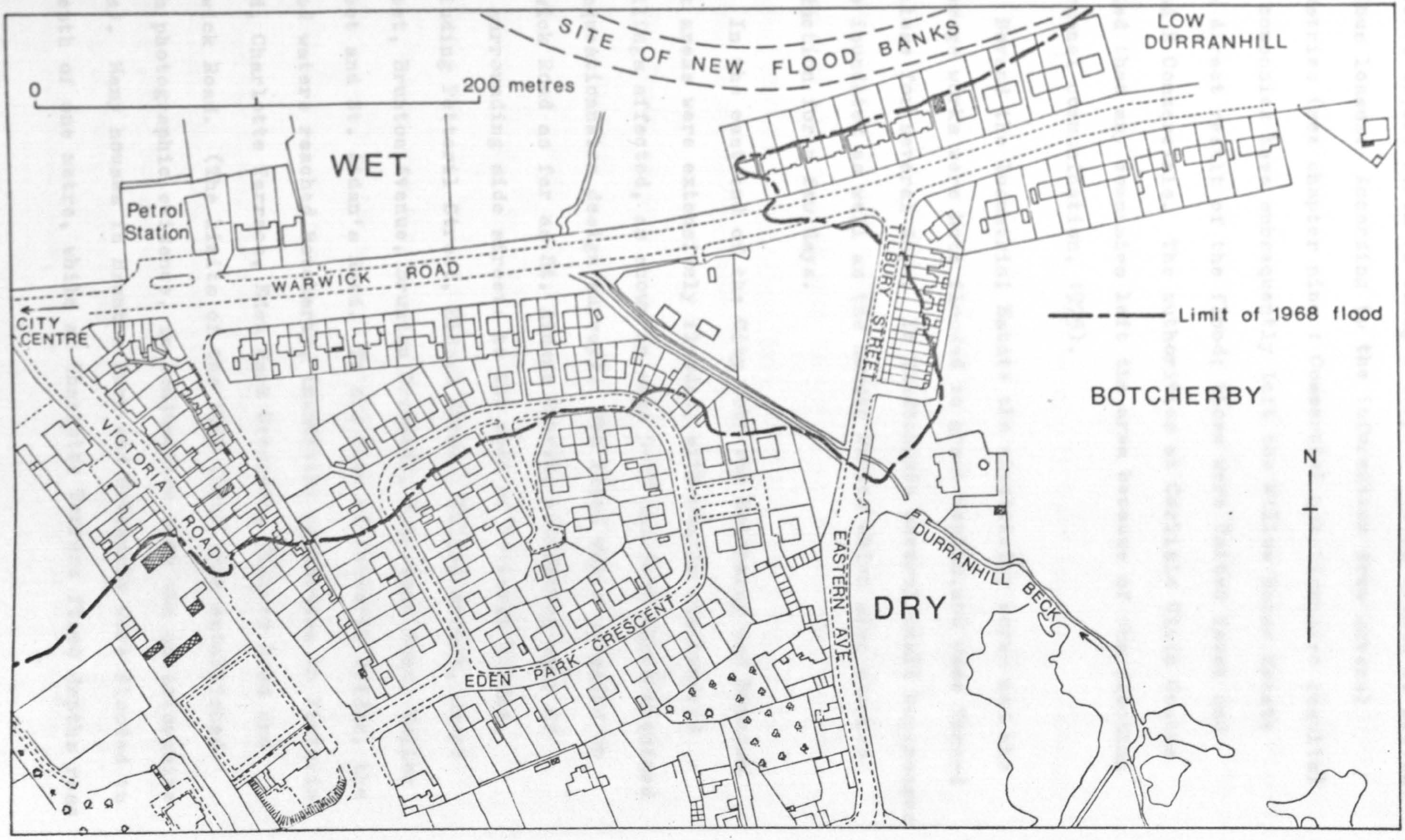
Map. 5-16. Caldewgate and Willow Holme Industrial Estate showing the area flooded in 1968.



Map. 5-17. Brunton Park showing the extent of flooding in 1968.



Map. 5-18. Botcherby showing the extent of flooding in 1968.



suffered £8,000 worth of damages despite taking action to prevent serious losses. According to the information from several industries (see chapter nine : Commercial questionnaire results) two companies have subsequently left the Willow Holme Estate as a direct result of the flood; those were United Yeast and S and B Commercials. The authorities at Carlisle Civic Centre denied that any companies left the area because of the flooding (personal communication, 1975).

Beyond the Industrial Estate the electricity works and the Sewerage works were both flooded to great depths,and were forced to close for several days. In Shaddongate several small businesses were inundated as well as the Border Daries which also stopped production for a few days.

In the east end of the City, both the Botcherby and Brunton Park areas were extensively flooded, with nearly six hundred dwellings affected, as shown in maps 5-17 and 5-18 (Data obtained fromquestionnaire design survey). The flood water extended up Warwick Road as far as St. Aidans Church, inundating many of the surrounding side streets to the west of Petteril Bridge, including Petteril Street, Eldred Street, Tullie Street, Short Street, Brunton Avenue, Brunton Crescent, Greystone Road, Waller Street and St. Aidan's Road. To the east of Petteril Bridge, the flood waters reached Botcherby, inundating properties in Victoria Road, Charlotte Terrace, Eden Park Crescent, Tilbury Road and Warwick Road. (The limits of the 1968 flood were established from photographic evidence, in conjunction with the questionnaire data). Many houses in Brunton Park and Botcherby were flooded to a depth of one metre, while at Charlotte Terrace flood depths rose to 1.5 metres (Details obtained from the questionnaire survey, see chapter seven). Many residents suffered considerable losses during the flood both to personal possessions and to the structure of their properties. The rugby football ground and Carlisle United AFC pitch were also flooded to depths of approximately two metres.

The Flood damage in Appleby

In Appleby the damage caused by the flood was quite extensive and resulted in considerable monetary losses, despite the relatively small amount of property at risk. The Mayor of Appleby launched an appeal immediately after the flood to recompense some of the victims. A council official estimated at the time of the flood that losses in the town were expected to reach £250,000 (Cumberland News, 29.3.68). The full extent of flooding in Appleby is shown in map 5-15.

The Sands, an area of frequent flooding, was inundated in 1968 to a depth of 1.5 metres with water extending from Burnes Garage in the north to Bongate in the south (Cumberland and Westmorland Herald, 30.3.68). Plate 6 shows the extent of flooding along the Sands hours before the peak passed through the town. In this area alone, three garages, several shops, some houses, as well as the Methodist Church and the police station were all flooded to various depths.

From the Sands, the flood spread across the Butts, covering the cricket pitch and inundating St. Lawrence's Church, the swimming pool, the gas works and the whole of Chapel Street. The flooding at Chapel Street was aggravated by a brick wall between the road and Broad Close, which retained water in the houses.

This wall was eventually demolished at one section to allow the water to recede. Plates 8 and 9 show the conditions in Chapel Street the morning after the flood. At the peak of the flood the buildings in Holme Street, High Wiend, Low Wiend, Doomgate and finally Bridge Street were affected. The Jubilee Bridge upstream of the town centre was totally destroyed (Details of the flooding were obtained from the questionnaire survey - chapter seven).

Plate 6. Appleby: The Sands during the 1968 flood (taken several hours before the peak discharge).

Plate 7. Appleby: St. Lawrence Bridge during the 1968 flood. At the flood peak water reached to the top of the bridge arches.

Plate 8. Appleby: Chapel Street the morning after the 1968 flood.

Plate 9. Appleby: Chapel Street the morning after the 1968 flood.

Historical record of flooding

There is a very long history of flooding in both Carlisle and Appleby, which fortunately has been reported quite regularly by the local newspapers or recorded in local records and archives. Although this historical record of flooding is not complete, an analysis of the more notable events, in conjunction with the study of urban development, provides an interesting picture of the increasing flood problems. Table 5-8 lists the dates of flooding in Carlisle and Appleby for which references have been found. Appleby appears to be under represented in this table, which is probably the result of newspapers not reporting the smaller floods in the town, whereas this has occurred in the large centre, Carlisle. However, it is reasonable to assume that all the floods of greater significance have been reported, since these would have greater news value for the newspapers.

Carlisle : historical record

The first recorded account of flooding at the site of Carlisle was during January 1571 (Smith Kenneth,1973) when the River Eden was reported to have burst its banks and created a secondary channel, which became known as Priest Beck. In fact the Eden remained as two channels at Carlisle until early in the nineteenth century when the older of the two channels was filled in to improve the northern approach to the City. However, it was in 1771 that the first recorded evidence of flood damage to property was recorded at Carlisle. Garret (1818, 22) stated that "On Sunday (16th November) they had there the greatest flood ever known". He went on to describe how the flood waters were nearly

Table 5-8 Dates of known flooding in Carlisle and Appleby (1571-1970)

(Source - Newspapers and Local records)

1571	JAN	C		1903	JAN	C		1933	FEB	C	
1771	NOV	C	A	1903	OCT(8)	C		1941	MAR	C	
1809	FEB	C		1903	OCT(29)	C		1947	JAN	C	A
1809	SEPT	C		1914	NOV	C		1947	APL		A
1815	DEC	C	A	1914	NOV	C		1954	OCT(18)	C	A
1822	FEB	C	A	1916	JAN	C	A	1954	OCT(24)	C	A
1851	JAN	C	A	1918	JAN	C		1954	OCT(29)	C	A
1852	JAN	C		1921	DEC	C		1954	DEC	C	A
1856	DEC	C	A	1924	DEC(27)	C		1964	DEC	C	A
1868	JAN	C	A	1924	DEC(30)	C	A	1965	JULY		A
1874	OCT	C	A	1925	JAN	C	A	1968	MAR	C	A
1883	JAN		A	1926	SEPT	C					
1891	AUG	C		1926	NOV	C					
1891	DEC(6)	C		1928	JAN	C					
1891	DEC(10)	C	A	1928	FEB	C	A				
1891	DEC(13)	C	A	1928	AUG		A				
1891	DEC(15)	C	A	1929	NOV	C	A				
1892	SEPT	C	A	1929	DEC	C					
1894	FEB		A	1930	JAN(14)	C	A				
1895	NOV		A	1930	JAN(18)		A				
1896	OCT	C	A	1931	JAN	C					
1898	NOV	C		1931	NOV	C	A				
1899	JAN(18)	C	A	1932	DEC	C					
1899	JAN 27		A	1933	JAN	C					

Reference of known flooding C = Carlisle

A = Appleby

two metres deep in Rickergate, how a house was entirely demolished in Caldergate (now Caldewgate) and how a whole mill was washed away in Botcherby. Despite this major flooding of both Caldewgate and Botcherby, these areas still became the first areas to experience the rapid development of the industrial revolution just a few years later.

The next reported cases of flooding occurred in 1809 (in February and September) and again in 1815, when the same areas of the town were inundated. On these occasions even greater damage was caused in Caldewgate and Rickergate because further development had already taken place. (Plates 3 and 4 illustrate these developments). In September 1809, many houses in Caldewgate were washed away while others were flooded to depths of two metres (Carlisle Journal 23.9.1809). In 1815, the new bridge over the Eden was damaged by flooding while the Petteril Bridge at Botcherby was destroyed completely, as were several acres of wheat (Garret, 1818).

In February 1822,Carlisle experienced the first major flood following the initial development of the town on to the flood plain. On this occasion Rickergate was the worst affected area with flood waters reaching first floor ceilings of some houses. Gross damages in Rickergate were reported by the Carlisle Patriot (9.2.1822) to be in the region of £1000. As a result of this, several subscriptions were started to help flood victims, and the Carlisle Patriot appealed on the behalf of one sufferer;

> "Three pigs and a donkey belonging to poor
> Hughy, the coal leader, were drowned:

> We trust the benevolence of the public will
> be exercised on this occasion for the sufferer
> is a deserving object".

This is the first reported case of a flood relief fund being set up in Carlisle, and it typifies much of the responses to later flooding.

The next serious flooding in the town occurred in the 1850's by which time Carlisle had expanded to support a population of 26,310 (Census, 1851). The combination of this development and large-scale flooding naturally brought a corresponding increase in the level of flood losses. In January 1851, over 1000 acres were reported inundated including Rickerby Holme, Stony Holme, Willow Holme, The Swifts and the Sorceries, as well as many houses in Caldewgate, Willow Holme and Botcherby (Carlisle Journal, 3.1.1851). The following year a flood of similar magnitude flooded the same areas of the City causing similar damage (Carlisle Patriot, 9.1.1852). Four years later in 1856, Carlisle experienced its largest flood on record with many areas suffering extensive damage. On this occasion, a Relief Committee was established to distribute coal, blankets and financial support to the flood victims (Carlisle Patriot, 13.12.1856; Carlisle Journal 12.12.1856).

Flooding again occurred during February 1868 (Carlisle Patriot, 1868) and October 1874 (Carlisle Journal, 1874) when houses in Caldewgate, Shaddongate and Warwick Road were affected. This was the first time that flood damage was reported in Brunton Park (that is, Warwick Road). In 1891, Carlisle was flooded on five separate occasions, although flood levels never attained those recorded for

1868. During the December, the flooding was particularly persistent, inundating the lower parts of the City on the 6th, 10th, 13th and 17th (Carlisle Journal, 8th, 11th, 15th, 18th December 1891). The following year, Caldewgate experienced a flash flood caused by a heavy thunderstorm, which produced flood depths sufficiently deep to stop work at Carrs Biscuit Factory (Carlisle Journal 6.9.1892).

In November 1898, the highest floods since 1856 were recorded in Carlisle, and all the usual areas of the City suffered losses, particularly Caldewgate (Carlisle Journal 4.11.1898). During the following January another flood caused more damage, this time in the east end of the City. The Carlisle Patriot (20.1.1899) reported damage to houses in Warwick Road, Greystone Road, Brunton Place, Petteril Street and Botcherby, and further inundation of the football grounds at Brunton Park. Further floods were recorded in 1903 on three occasions, and once in 1916, 1918 and 1921. These were reported in various editions of the Carlisle Patriot (30th January, 6th February and 9th October in 1903) and the Carlisle Journal (30th January, 9th October 1903, 4th January 1916, 26th January 1918 and 27th December, 1921). None of these was a major flood event, but they all caused damage to various parts of the City. The Petteril was particularly high during this period and frequently inundated property in Brunton Park and Botcherby, while in 1916 the Eden flooded the new electricity works in Willow Holme. By the 1920's most of Brunton Park and Botcherby were fully developed, while Caldewgate had reached its peak some years earlier. Therefore, it can only be assumed that in spite of quite frequent flooding, the development of properties in these areas went on regardless.

The next major events occurred in December 1924 and January 1925, when a series of floods between the 27th December and 4th January intermittently inundated the City. On the 27th all the main Carlisle rivers were in flood and as a result Caldewgate, Shaddongate, Willow Holme and Warwick Road were all flooded Carlisle Journal 30.12.24). A second flood on the 30th saw the Eden rise 15 cm higher than 3 days previously, to 6.63 m. The same parts of the City were flooded including the electricity station where the water was 4.27 m deep (Cumberland News 3.1.25). On January 3rd the Eden rose again, this time to 6.96 m which produced the largest flood for 69 years. The east end of the City was extensively flooded including the newer houses in Greystone Road, Brunton Avenue, Thirlwell Gardens and Botcherby, while the older premises in Brunton Place, Eldred Street, Tullie Street, Short Street, Warwick Road and St. Aiden's Road were also inundated. The football grounds were again under two metres of water. Plate 10 shows a view near Petteril Bridge during this flood.

The River Caldew at this time rose to its highest ever recorded level and the resulting floods caused thousands of pounds worth of damage. One shop keeper was reported by the Carlisle Journal (6.1.25) to have losses of between £1500 and £2000. Willow Holme was also severely flooded with many houses inundated to a depth of one metre. This flooding was covered extensively by the Carlisle Journal who issued a special flood supplement (9.1.25) depicting the whole sequence of events. Plate 11 from this supplement shows the inundation at the new

Plate IO. Carlisle: Flooding of Warwick Road near Petteril Bridge in January I925.

Plate II. Carlisle: The new electricity works under construction at Willow Holme - flooded in January I925.

Plate I2. Carlisle: Flooding of Church Street in Caldewgate in January I925.

Plate I3. Carlisle: Flooded property in Church Street and Byron Street, Caldewgate in January I925.

electricity works, still under construction, while plates 12 and 13 show the extent of the flooding in two parts of Caldewgate.

The period between 1925 and 1933 saw the recurrence of flooding in Carlisle with increasing frequency. In 1926, Carlisle was flooded twice, and on each occasion Caldewgate suffered most severely (Carlisle Journal, 21.9.26, 9.11.26). Flooding returned to the City twice in 1928 (Carlisle Journal, 17.1.28, 7.2.28) and again in 1929 when houses in Brunton Park and the football grounds were flooded (Carlisle Journal, 27.12.29). In January 1931, the Brunton Park and Botcherby areas were once again inundated by the Eden and Petteril (Cumberland News, 3.1.31). Following this flood, some straightening work was carried out on the River Petteril, and the part of Warwick Road extending to Botcherby was raised, but this did not prevent another flood in November of the same year. On this occasion, the River Eden rose to 6.89 m which caused flooding similar in magnitude to the event in 1903 and 1924. Extensive flood damage was reported in Brunton Park, but fortunately for the residents of Caldewgate, the peak flows from the Caldew passed through the river system two hours ahead of the Eden peak. However, even this did not prevent substantial flooding in Caldewgate, Shaddongate and Willow Holme. Plate 14, taken from the Cumberland News (7.11.31) shows various flood scenes in Warwick Road, Caldewgate and Botcherby.

After 1931, there were a series of floods which caused little more than superficial damage. These included the events of December 1932, January and February 1933, as well as those of March 1941 and January 1947, reported by the Carlisle Journal (20.12.32, 6.1.33, 3.2.33, 7.3.41, 18.1.47) and the Cumberland

News (17.1.47). Many of these events flooded parts of Warwick Road and the football pitches, but only the 1947 flood caused any real concern. October 1954 brought the worst flooding since the early 1930's and inundated all the usual lower parts of the City. It is significant that the Willow Holme Industrial Estate was promoted at this time, just when the area was under one metre of water (Cumberland News, 22.10.54, 3.12.54; Carlisle Journal, 19.10.54, 22.10.54). The only other flood of note before 1968 occurred in 1964 and was similar in magnitude to the October 1954 event (Cumberland News, 11.12.64).

In conclusion, there is a long record of flooding in Carlisle dating from the late eighteenth century to the present day. There have been several very large floods during this period, notably those of 1822, 1856, 1925 and 1968, but neither these, nor the smaller more frequent events appear to have had any significant effect on the City builders or developers. Since the very early days of development at the end of the eighteenth century, Carlisle has gradually spread onto the surrounding flood plains with a total disregard for the consequences. As a result, the flood problem has increased, and flood losses have continued to rise, not because of any hydrological reason, but because of the occupation of flood prone land. The selection of Willow Holme as a site for major industrial development, and the planned residential estate next to the Petteril indicates that the Authorities still do not consider the implications of the flood hazard. Admittedly, since 1968 some alleviation work has been undertaken in the City but this only provides protection up to limited design standards (see chapter six).

Plate 14. Carlisle: Flooding November 1931. (1) Warwick Road under water despite being raised by over one metre earlier in the year. (2) Botcherby. (3) and (4) Warwick Road.

A second feature to emerge from this consideration of the flood record at Carlisle is the variability of flooding within the City. For instance, a high flowing River Eden does not necessarily entail extensive flooding throughout the City, for a great deal will depend on the hydrology of the two tributaries, the Caldew and Petteril. Caldewgate is prone to flooding primarily from the River Caldew, but if the Eden is also in full spate, then backing-up by the tributary can cause even more serious flooding. Hence, in 1925 Caldewgate experienced its worst flood ever, whereas the Eden was still fifteen centimetres below that of 1856. Similarly, the magnitude of floods in Brunton Park and to a certain extent Botcherby can depend on the relative levels of the Eden and Petteril. Thus, the extent of flooding in Carlisle is dependent not only on the actual flows of the three main rivers, but also on the timing of the peak discharges.

Appleby : Historical record

Appleby has experienced more damaging floods in the past than Carlisle, although the newspaper reports and local records of the events are less comprehensive than was the case for Carlisle. The news value of a small flood in Appleby is not as great as a small flood in Carlisle because of the relative number of dwellings affected. However, discussions with local residents in Appleby and with the Cumberland River Authority employees would suggest that the frequency of flooding is greater in Appleby than Carlisle.

The earliest reference to flooding in Appleby was that of 1771 when it was reported that "the water ran with a strong current along Bridge Street and on the high side of Low Cross". (Garret, 1818, 22). Throughout the history of flooding in Appleby, it was significant that Bridge Street, the Market Place and Low Cross were only inundated during the major flood events. In 1822 another large flood inundated the town, and caused extensive damage to all low lying areas. Bridge Street and Low Cross were again affected with many houses, particularly those on the Sands flooded, some up to depths of 1.75 m (Chancellor, 1954). During the same flood the Carlisle Patriot (9.2.1822) reported that the old Gothic Bridge across the Eden was also damaged.

The next major event did not occur until 1856, although there was reference to a smaller flood in 1851 which according to the Carlisle Journal (3.1.51) caused damage to property on the Sands, Butts, Chapel Lane and Doomgate. The 1856 flood inundated all the low areas of the town including Bridge Street and the Market Place. The town was again flooded in 1868 and 1874 (Cumberland and Westmorland Herald, 28.1.1868, 31.10.1874). On both of these occasions the flood levels were only high enough to inundate the cellars of the property along Bridge Street. The most damage was caused on the Sands, Butts, the Vicars Croft and Chapel Lane.

In the 1880's and 1890's Appleby experienced a series of flood events (Whitehead papers). In 1883, the Cumberland and Westmorland Herald (30.1.1883) reported 'the largest flood for nearly thirty years' which inundated the lower parts of the town. The Sands, Butts, and Chapel Street were also flooded in 1891, 1892, 1894, 1895 and 1896 (Cumberland and Westmorland Herald, 15.12.1891, 19.11.1895, 13.10.96; Carlisle Journal, 6.9.1892; and the Whitehead papers). In 1899 Appleby suffered from two larger events, and the Cumberland and Westmorland Herald (28.1.99) reported that water in Bridge Street was several centimetres deep, and houses and shops in the Sands and Chapel Street were inundated to a depth of one metre.

In 1903 (Cumberland and Westmorland Herald, 31.1.03) and 1916 (Carlisle Journal, 4.1.16)flood damages were again reported along the Sands and Chapel Street. In 1924-25, Appleby experienced another large flood, although on this occasion water levels were not high enough to affect the property on Bridge Street. The Cumberland and Westmorland Herald (3.1.25) however, described the flooding on the Sands from Burnes Garage to the south of Bongate, which inundated all the intervening shops and houses apart from the Co-operative which is slightly elevated. The houses in both Chapel Street and Holme Street were also flooded. Three years later there was an even larger flood in the town with water over two metres deep on parts of the Sands (Whitehead papers). Both Bridge Street and the Low Cross market area were flooded and the property on the Sands, Chapel Street and Holme Street suffered considerable damage.

Smaller floods occurred in 1929 (Cumberland and Westmorland Herald, 16.11.29) twice in 1930 (Whitehead papers) and again in 1931 Cumberland News, 7.11.31). In 1947 the town suffered from flooding on two occasions, the January event being the largest for many years. This flood inundated over 100 houses along the Sands, Chapel Street, Holme Street, Doomgate and Low Wiend, as well as St. Lawrences Church, the cricket pitch, football pitch and bowling green (Cumberland and Westmorland Herald, 18.147). Chapel Street the

Sands and the Butts were flooded again seven years later (Cumberland and Westmorland Herald, 4.12.54), while a larger flood in 1964 caused more extensive damage to all the usual areas in the town. Plate 20 shows the flooding of the Sands at this time. In 1964, the structure of the Jubilee Bridge was twisted by the high flood flows (Cumberland and Westmorland Herald, 12.12.64) and further weakening occurred the following year when a violent thunderstorm, which produced 76.5 mm of rain, caused flash flooding in the town (Whitehead papers). The Jubilee Bridge was finally destroyed in March 1968.

In conclusion, the flood problem at Appleby has existed for many years and given more comprehensive records would show an even longer history than Carlisle. Unlike Carlisle, Appleby did not experience the rapid development during the nineteenth century and only Chapel Street and Holme added significantly to the problems of flooding. The basic pattern of lower parts of the town were established long before this, and hence given this later evidence, it is reasonable to assume that flooding has always been a constantly recurring problem in the town. The hydrological aspects of the flooding at Appleby are also fairly straight forward with only one river to consider. However, the situation of the town means that flood waters, during particularly high floods, tend to meet at the Market Place with water flowing from both sides within the river meander. In general, the floods in Appleby are usually of short duration, rising to a peak in less than six hours and receding in two to three hours.

Assessment of the flood risk in Carlisle and Appleby

In an assessment of the flood risk in Carlisle and Appleby several hydrological characteristics are quite similar while others illustrate the differences between upland and lowland flooding. For example, the frequency of flooding is very high in both towns according to the data collected from newspapers and other local records. The floods in Carlisle and Appleby between 1800 and 1970 have been ranked according to the approximate extent of flooding in the two settlements (tables 5-9 and 5-10). In Carlisle, the recurrence interval for flooding affecting the Lower Holmes of the City is once every 3.5 years, while in Appleby floods

occur just as frequently, although missing data has prohibited a full evaluation of these non-damaging floods in the City.

The historical data would indicate that major floods occur more frequently in Appleby than Carlisle. In Appleby, since 1815, there have been five very large floods in 1822, 1856, 1899, 1928 and 1968, which would suggest a recurrence interval of once every 31.2 years. Carlisle, on the other hand, has only experienced four major floods during this period, the largest in 1856 followed by three floods of equal magnitude in 1822, 1925 and 1968, at a frequency of once every 42.75 years. Clearly, the probability of a major event occurring is greater in Appleby than Carlisle.

In Carlisle, the first four classes of flooding in table 5-9, which included the fifteen largest floods since 1800, invariably caused extensive damage throughout the City. Floods of this magnitude may be expected to recur on average once every 11.4 years.

Table 5-9 Magnitude of flooding in Carlisle (1800-1970)

Major floods (known) since 1800. Ranked according to the approximate extent of flooding in the City.

		No. of floods	Recurrence Interval
1	1856	1	171 years
2	1822, 1925, 1968	3	42.75 years
3	1809, 1852, 1874, 1903, 1924 1931.	6	17.1 years
4	1809, 1815, 1868, 1899, 1924	5	11.4 years
5	1851, 1891, 1891, 1891, 1892, 1903, 1914, 1916, 1918, 1921, 1926, 1929, 1933, 1947.	14	5.9 years
6	1891, 1891, 1896, 1898, 1903, 1914, 1926, 1928, 1928, 1929, 1930, 1931, 1932, 1933, 1941, 1954, 1954, 1954, 1954, 1964.	20	3.49 years

$$\text{Recurrence Interval} = Tr = \frac{n + 1}{m}$$

n = years

m = magnitude

Total number of floods = 49

Years of record = 170

The fifth ranked floods have generally produced more localised flooding, while the sixth resulted in little more than superficial damage and inconvenience. In Appleby, all the floods ranked in table 5-10 caused some damage in the town, although by far the greatest losses resulted from the top two categories. Quite serious flooding, therefore, may be expected once every 8.5 years and floods which cause some damage once every 4.22 years. Thus, the frequency of damaging floods is much greater in Appleby than Carlisle.

These figures compare favourably with the estimates of flood probabilities made by the Cumbrian River Authority. For instance, the revised estimate of the return period for the 1968 flood was once every 38.5 years (Cumberland River Authority records 1975) which compared to once every 42.75 years from the historical records. Thus, the probability of such a flood occurring in any one year would be approximately 0.025. The official estimates of flood frequencies in Appleby also compared favourably for the larger floods, 30.6 years by the River Authority and 31.2 years from the historical survey. However, these calculations made by the River Authority were not undertaken until early 1975, before which the return periods for such floods were considered to be much greater. For example, at one time the return period for the 1968 magnitude of flooding was thought to be once every sixty years, or even once every one hundred years (Cumberland River Authority records, 1968). Calculations on flood frequencies based entirely on catchment characteristics suggested that these earlier estimates of recurrence intervals may be correct. However, this theoretical technique was thought to be less reliable than actual historical records. (For full details of these calculations,

Table 5-10 Magnitude of flooding in Appleby (1815-1970)

Major floods (known) since 1815. Ranked according to the extent of flooding in the town.

		No. of floods	Recurrence Interval
1	1822, 1856, 1899, 1928, 1968	5	31.2 years
2	1815, 1868, 1883, 1892, 1899, 1924, 1925, 1928, 1930, 1930, 1947, 1964, 1965.	13	8.67 years
3	1851, 1874, 1891, 1891, 1891, 1894, 1895, 1896, 1903, 1916, 1924, 1928, 1929, 1931, 1947, 1954, 1954, 1954, 1954.	19	4.22 years

$$\text{Recurrence Interval} = Tr = \frac{n + 1}{m}$$

n = years of record

m = magnitude

Total number of floods = 37

Years of record 155

based on a technique proposed in the Flood Studies Report, 1975, see Appendix IV).

Despite the differences in flood frequencies both settlements experienced flooding at the same time of the year. Flooding of the two towns appears to be a winter phenomenon, with ninety-two percent of the floods in Carlisle and eighty-nine percent in Appleby occurring between October and March (figure 5-1). In fact, over half the floods since 1800 have occurred in December and January, fifty-five percent in Carlisle and fifty-seven percent in Appleby. The few floods which have occurred during the summer months were primarily the result of exceptionally intense thunderstorms causing flash flooding.

There does not appear to be any significant link between the seasonality of flooding and flood magnitudes except that the major events usually occurred between January and March. For instance, in Carlisle the four major floods occurred in December, January, February, and March, while in Appleby two occurred in January and one each in December, February and March. These larger floods in January to March may reflect a degree of snow melt, which can significantly increase the magnitude of flooding. However, this has been recorded only for the events of 1925, 1947 and 1968.

Other differences between the flood problems of Carlisle and Appleby were found in the hydrological features of duration and velocity of flood waters. At Appleby, the flooding is normally of short duration but of relatively high velocity as flood waters virtually sweep through the town. The River Eden, at this point, can rise from normal levels to peak discharge and

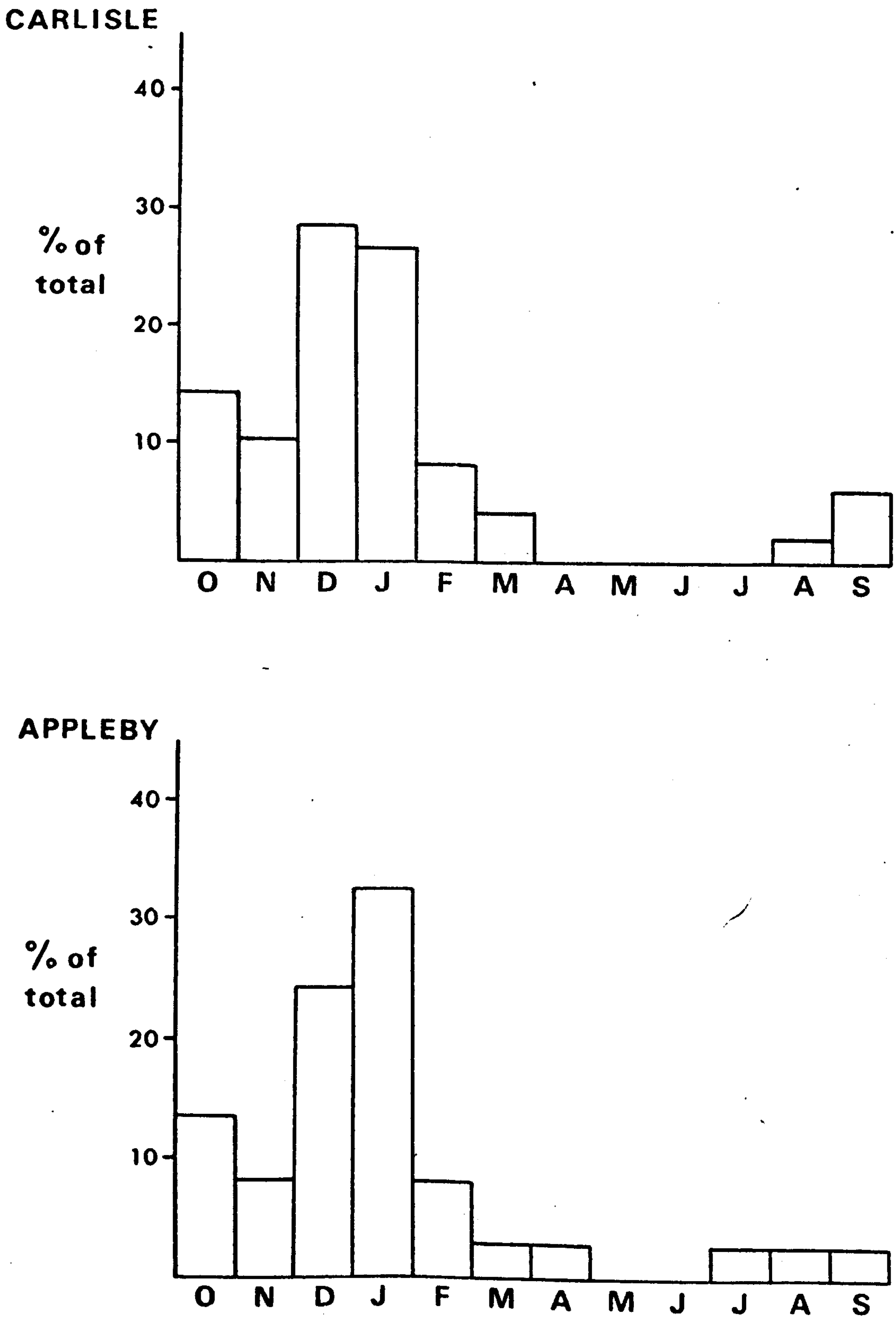


Fig. 5-1. Seasonality of flooding in Carlisle and Appleby.

fall back to normal again within eight to twelve hours. A flood such as this can cause considerable damage by sweeping rapidly through the town. Plate 7 shows how a car has been carried along the Sands and dumped on the river bank. At Carlisle, the flooding is a slower more prolonged affair. Flood waters often take many hours to rise and gradually spread over the wider flood plain areas, where the water may remain for up to twelve hours before receding. In this respect, Carlisle and Appleby typify the flood characteristics of lowland and upland flooding respectively.

Apart from the hydrological differences, the major conclusion to emerge from the historical flood review was the contrasting ways in which the flood problem has developed at the two sites. In Carlisle, the flood problem was created almost entirely during the nineteenth and early twentieth centuries by the rapid development of flood plain properties. This intensive urbanisation process continually aggravated the flood problem and has caused a general rise in flood losses throughout the period. The process has even continued to the present day, although at a much slower rate, with the promotion of the Willow Holme Industrial Estate and the planned estate at Ravens Nook. In Appleby, the flood problem is a remnant of pre-Industrial Revolution Britain, since the town has changed very little in form for several hundred years. Only Chapel Street and Holme Street houses have added significantly to the flood problem in the last 150 years. Any new development has been away from the flood prone areas such as the old peoples estate at Scattergate.

Thus many differences exist between the flood hazard at Carlisle and the hazard at Appleby. The following chapter examines these differences with respect to how the various responsible authorities have responded to the problem.

CHAPTER SIX

THE AUTHORITARIAN RESPONSE TO THE FLOOD HAZARD

Introduction

The official responsibility for alleviating flooding in England and Wales lies with the River Authorities (now the Regional Water Authorities) and the local councils in the areas where the flooding occurs. It is the combined policies of these organisations which provide the basis of the authoritarian response to the flood hazard. While there are numerous constraints on both these authorities, not least being the economic restrictions, they are legally obliged to review the flood problem regularly and if necessary to implement measures to alleviate the hazard. However, whereas Local Authorities are responsible for the whole of their area, the River Authorities are only officially responsible for designated main rivers.

Other official bodies, for example the police force or fire brigade, may play an active short-term role in flood alleviation programme, but are rarely called on to implement such policies. For instance, the police are normally requested to participate in the operation of flood forecasting and warning schemes by dissemination of the warning message to the flood plain population, but are seldom required to evaluate the probability of flooding. Voluntary organisations, such as the Womens' Royal Voluntary Service are not usually concerned with either the implementation or the running of flood alleviation programmes, although they frequently provide valuable assistance during an actual flood.

The strategic response to the flood hazard, therefore, is essentially a product of the combined policies of the Local Authority and the River Authority. This chapter examines the official response to the flood hazard in Cumbria based on the historical record of flooding described in the previous chapter. Firstly, the chapter considers the general response of Local Authorities and the Cumberland River Authority (in places the Lancashire River Authority) to the various flood problems throughout the county. Secondly, the authoritarian adjustments to the flood hazard in Carlisle and Appleby are examined. This includes not only the historical development of the present flood alleviation schemes, but also the proposals for future schemes in the two communities. In this way the overall efficiency of the authoritarian response is reviewed.

(A) Cumbria

In spite of the great variation in the hydrological characteristics of flooding throughout Cumbria and the different Local Authorities involved, the authoritarian response to the flood hazard has been remarkably narrow. There are essentially only three types of alleviation scheme to be found in the county, apart from the more negative non-structural measures of accepting the loss or maintaining public relief funds. These are:

(i) the construction of flood embankments.

(ii) channel improvements such as canalisation and straightening.

(iii) flood forecasting and warning schemes.

Thus, despite the wide range of structural and non-structural alleviation schemes available (described in chapter one) very few schemes have been tried in Cumbria. Although many of these adjustments would be unsuitable on physical or economic grounds, others would probably have proved feasible alternatives to those implemented. However, in general the attempt to alleviate the flooding in Cumbria has been a piecemeal approach to individual flood problems, rather than a comprehensive flood alleviation programme. It is only in recent years that some degree of overall flood plain planning has been considered. This is a trend which has developed along with the technical advances made in flood forecasting and warning systems.

A second factor, common throughout Cumbria, as in much of the world, is the way that authoritarian response invariably follows immediately after a flood event. In general, the greater the flood the greater is the response by the authorities to the hazard. The response by the Cumberland River Authority and the various Local Authorities in Cumbria show that inadequate attention has been given to these aspects of the flood problem. Also the lack of co-operation between the various authorities has clearly made flood alleviation a bigger problem. This was illustrated in chapter five with the expansion of settlements into known flood hazard areas.

In Cumbria, much of the responsibility for the failure to control flooding, at least during the 1950's and 1960's, must be attributed to the River Authority (originally the River Board). During this period the River Authority repeatedly stated that no flood problem existed in Cumberland. For instance, in 1962 the Engineer (Cumberland River Authority records, 1962) stated:

> "The Cumberland River Board are peculiar in not having a great flood risk, and in fact it is many years since there was any flooding of urban areas. In consequence my Board have not considered the problem to be a very serious one here."
>
> (Letter to Ministry of Agriculture Fisheries and Food 14.6.62).

Examples of this general lack of concern by the River Authority can be found throughout the county in spite of directives from several Government Ministries encouraging the close liaison between River Authorities and Local Authorities (see chapter three).

During the 1960's several councils approached the River Authority for help on matters relating to flooding. For instance, the Ennerdale Rural District Council required information on the safety of a new housing estate in Egremont. The somewhat terse reply from the River Board suggested that this was the responsibility of the District Councils own consultants (Cumberland River Authority records, February 1964). In 1961 the Whitehaven Borough Council requested advice over repairs to a surface water culvert, but also received no help (Cumberland River Authority records, November 1961). In the same year, the Penrith Urban District Council required information on the probability of flooding to a new industrial estate, and were told that this was of no concern to the River Board because flooding would not be caused by a designated main river (Cumberland River Authority records, August 1961).

Thus, during the early 1960's it would appear that some Local Authorities in Cumbria were becoming increasingly aware of the flood hazard and saw the need to consider the problem in relation to urban development. Unfortunately, at this time the Cumberland River Board remained unwilling to accept any responsibility for flooding, even in an advisory capacity, and continued to advance the view that no real flood problem existed within its area. This belief is clearly disproved by the historical evidence of flooding outlined in the previous chapter.

By the mid 1960's, after flooding had occurred in Carlisle in 1964, the River Board showed greater concern over flood problems. For instance, following the severe flooding of the Upper Derwent Valleys in September 1960, the Cumberland River Board agreed to join a meeting to discuss the flood problem with the National Trust, which owns large areas of Borrowdale, and the Borrowdale Parish Council. The Council wanted the designated main river extended one mile upstream so that help could be obtained with alleviation schemes for several small villages. Although this meeting failed to produce any positive action, it was indicative of the role the Cumberland River Authority were to play during the following years.

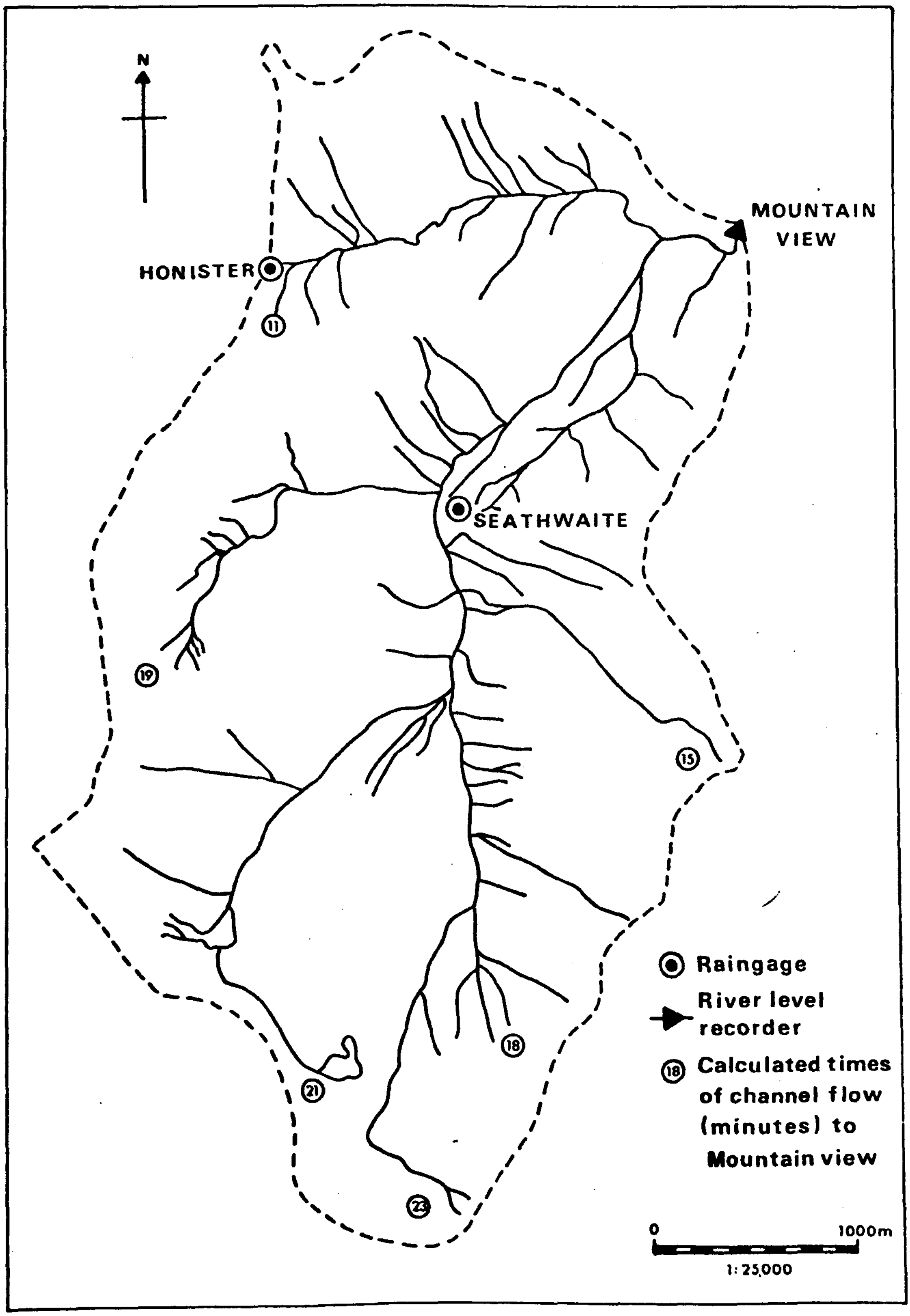
Authoritarian response to the flood hazard : Case studies

Borrowdale

After the 1966 meeting, there were further calls for a flood alleviation programme in Borrowdale in 1967 and 1973 following more flooding. A flood forecasting and warning scheme was considered for the area but was found to be impractical, because the extremely flashy nature of the streams would leave insufficient time to disseminate any warning message. Field (1974) calculated that for Mountain View the maximum river lag time would be twenty-three minutes and considerably less from other parts of the catchment. Map 6-1 illustrates the estimated peak flow times for Seathwaite, Honister and Mountain View in Borrowdale. Clearly with these flow times a flood warning scheme would not be feasible, and hence because of the added economic restrictions of implementing any structural measure, no adjustment has been made by the authorities to the flood hazard in Borrowdale. Figures 6-1 and 6-2. show the response rates of the River Derwent to two storm events.

Kendal

The town of Kendal has a long history of flooding and it is only recently that any major scheme has been implemented in the town to alleviate the problem. The present scheme consists of an



Map. 6-1. Borrowdale: estimated channel flow times to Mountain View.

Fig. 6-1. Borrowdale: river response rates.

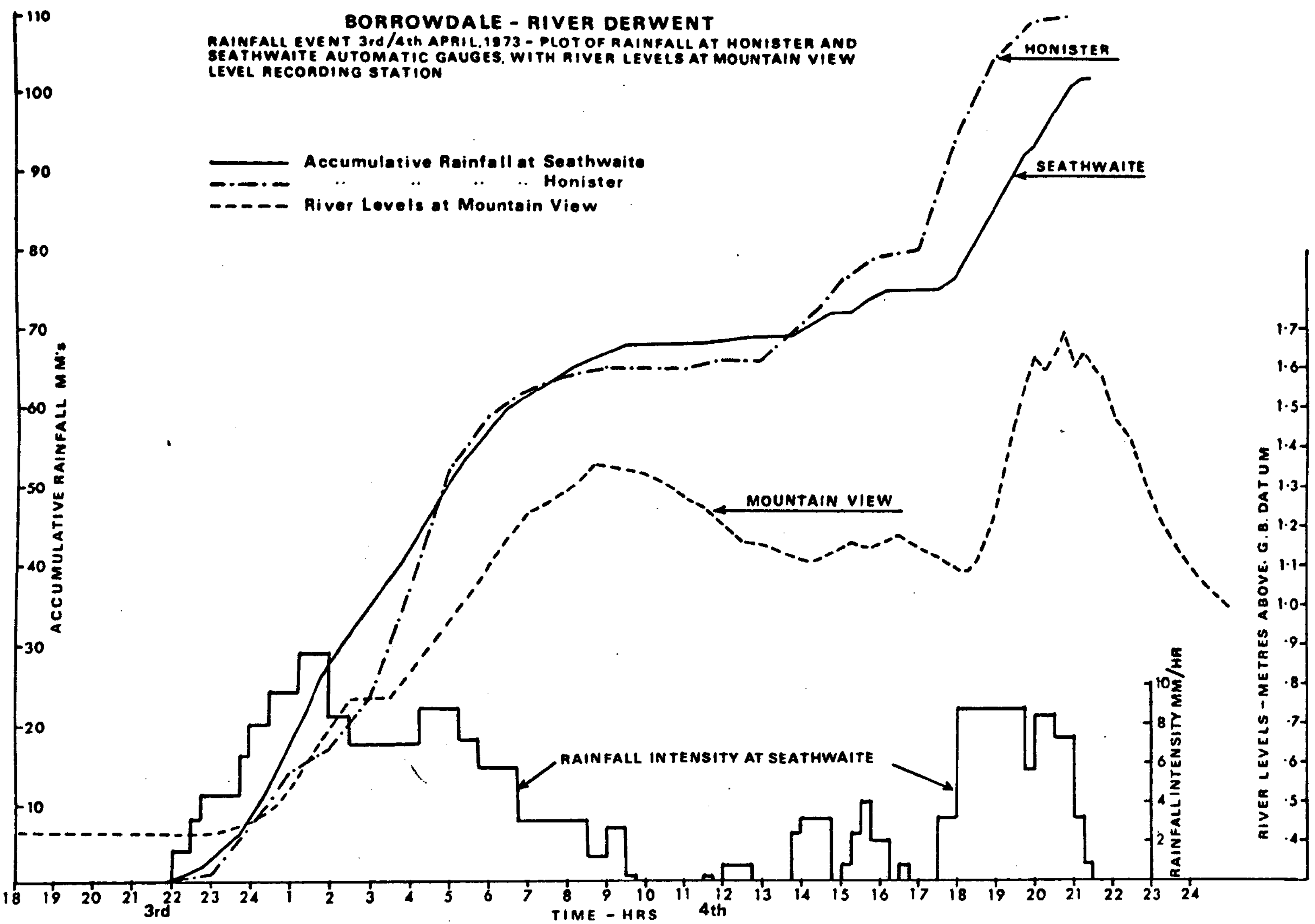
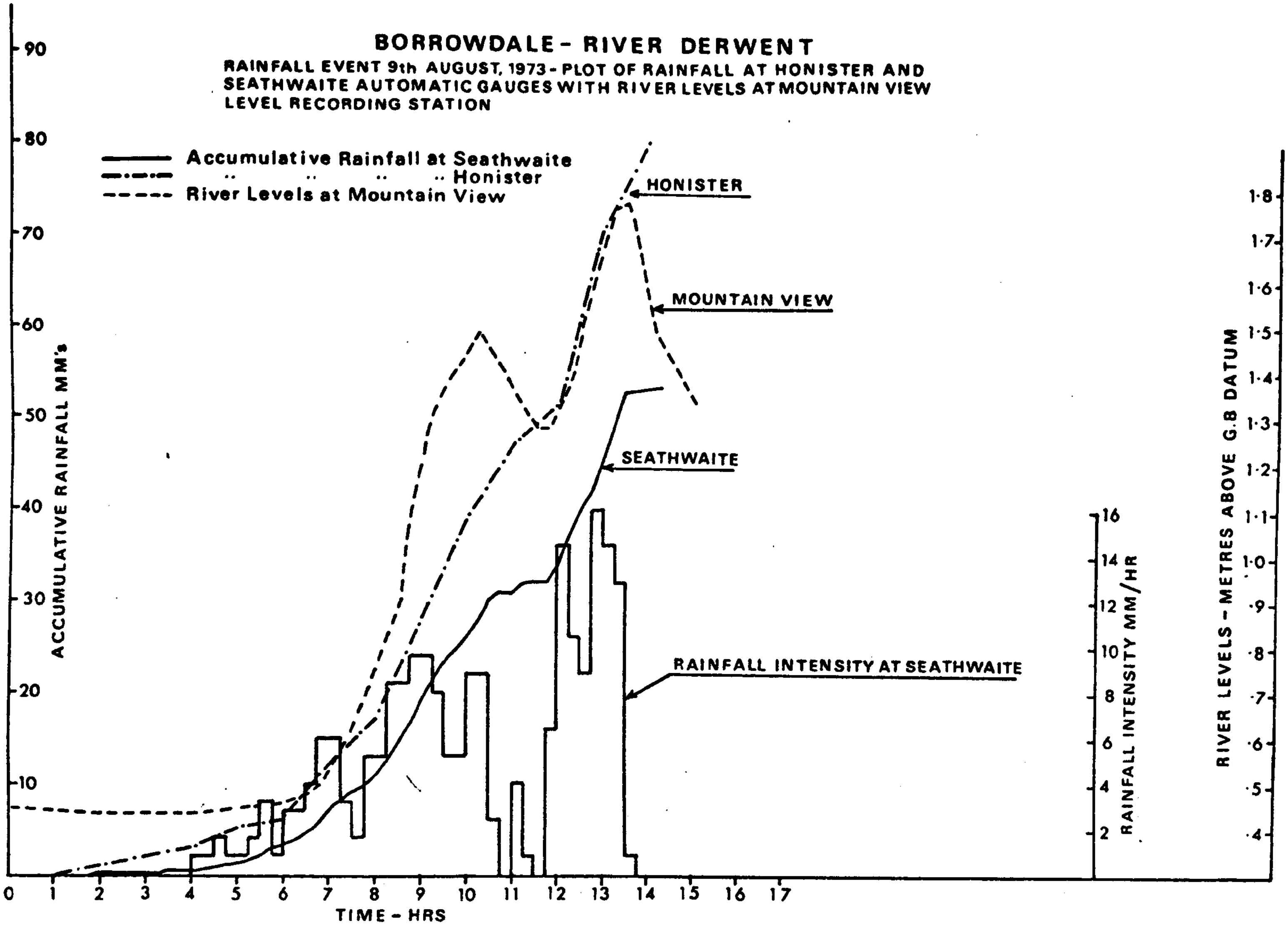


Fig. 6–2. Borrowdale: river response rates.



extensive channel system throughout the built up area. Although constructed with concrete and stone, the banks have been successfully designed to blend with the surrounding landscape. This work was originally proposed by the Lancashire River Authority in 1970 and, according to the design standards of the project, should significantly reduce the incidence of damage producing floods.

Langdale Valley

Another responsibility of the Lancashire River Authority was the Great Langdales Valley which used to suffer severe flash flooding. Flood alleviation works in the valley were undertaken as early as the 1950's, which included the straightening, regularising and dredging of the upland stream. In this way several small settlements in the valley have been protected at least from smaller floods.

Keswick

Keswick also has a very long record of flooding but has still not received adequate protection from a full alleviation programme. Flood banks were constructed at the Bullfield area of the town early in the 1930's, to protect the main Carlisle Road and some new residential property. However, Hudleston (1935) believed that these banks had in fact increased flood levels by 0.6 metres, because by raising the banks the greater cross-sectional area of the channel had encouraged further deposition on the stream bed. In turn, Hudleston suggested that this would lead to higher flood levels and larger flood banks. To solve this problem he suggested the construction of a flood relief channel to be used when the main channel became over charged. However, no such scheme was forthcoming, and the authorities continued to 'solve' the Keswick flood problems as and when they arose.

In 1939, the Keswick Urban District Council put forward further suggestions for alleviating the flooding in the town. For instance, it was suggested by the council to the Clerk of the Catchment that the water level of Lake Thirlmere should be maintained one metre below the sill during winter months to allow a degree of flood storage in the system (Cumberland River Authority records, March 1933). Nevertheless, the principal aim of the reservoir is water supply and this has generally been adhered to. Large flows of water have been reported over the spillways in October 1954 and again in October 1960 (Cumberland River Authority records 1954, 1960).

Cockermouth

The authoritarian response to the flood hazard in Cockermouth clearly illustrates the changing views towards the flood problem in recent years. In 1933, the Carlisle Journal (3.2.33) reported that discussions were taking place on a proposed flood alleviation project for Cockermouth following several floods during the preceding years. However, nothing was accomplished to alter the flood problem, and the town was inundated again in 1938. In 1936, the stream at Derwent Bridge had been widened and two new archways constructed in the bridge to accommodate high flows and thus prevent backing-up of flood waters. This work had little effect on the 1938 flood when both the River Derwent and the River Cocker were in full spate. Map 5-13 shows the extent of this flood in the town. Following the flood, the local council constructed several embankments to try and prevent flooding in the Goat area of the town.

In 1954, following more flooding in Cockermouth, further discussions took place between the Cumberland County Council, the County Surveyor and Bridgemaster, and the Cumberland River Board. On this occasion it was suggested that the lowering of the outlet of Bassenthwaite Lake would alleviate the flood problem in Cockermouth. However, the River Board pointed out that this had been done in the past but had since silted up and there were no immediate plans for the future (Cumberland River Authority records, December 1954).

The lower parts of the town were flooded again in 1960, when the Fitz weir was destroyed. This was believed to have aggravated flood levels by backing up the waters, although the effect would be relatively insignificant during a major flood, such as occurred in 1938. However, a further small flood occurred in the Goat area of the town in 1968 when the flood embankments were breached.

In the 1970's the attitudes of the two responsible authorities in Cockermouth had changed significantly. The Cumberland River Authority proposed a flood warning scheme for the town in 1971, but was forced to delay these plans due to the attitudes of the Cockermouth Urban District Council. The Cockermouth Council would not commit itself to any expenditure towards the scheme, because it believed the probability of flooding from rivers to be too remote (Cockermouth Flood Warning Scheme - Cumberland River Authority, Engineers Report, 24.8.72). Because of this delay, the scheme was postponed for two years, by which time the estimated costs had risen to over £10,000. However, by 1974 a flood forecasting and warning scheme was operating for Cockermouth based essentially on river flows of the Derwent and Cocker.

Before 1974, Cockermouth had experienced many floods which had produced only a minimal response from the authorities. Any remedial action was usually small scale and dealt with the problem in one particular part of the town. It was not until the introduction of the flood warning scheme that any more general alleviation policy was proposed. Although this scheme will do nothing to reduce the physical characteristics of the flooding, efficient action can reduce flood losses. The weaknesses of such a scheme have been discussed in chapter three. One significant aspect of the Cockermouth scheme, however, is that it has been proposed and implemented at a time when the last major flood in the town occurred nearly thirty years previously. This is unusual since most alleviation schemes are implemented immediately following a flood event.

(B) The Authoritarian response in Carlisle and Appleby

The responses of the Cumberland River Authority and the Local Authorities to the flood problems in Carlisle and Appleby were examined in several ways:

(i) as detailed examples of different authoritarian adjustments to the hazard.

(ii) as a means of assessing the efficiency of certain authoritarian responses.

(iii) through an analysis of the development of particular schemes as a means of indicating the important factors influencing authoritarian response.

The two settlements also provided the contrast between authoritarian responses in upland and lowland flood environments.

Carlisle

In Carlisle the authoritarian response to the flood hazard can be divided into two totally different periods - the response before 1968, and the response following the 1968 flooding.

(i) The authoritarian response before 1968

The alleviation schemes currently employed in Carlisle are the culmination of many years flood experience and the result of various adjustments made in the City to the flood hazard. Nevertheless, the development of the authoritarian measures at least until 1968, consisted of piecemeal attempts to control local flooding in various parts of the City.

The earliest recorded response to flooding in Carlisle was in 1809 and again in 1822, when subscription funds were started by 'young ladies' for aiding the flood victims in those years (Carlisle Journal 23.9.1809, Carlisle Patriot, 9.12.1822). However, these relief funds were not strictly authoritarian responses, but really the philanthropic gesture of the upper classes to the poorer sector who suffered in the Caldewgate area of the City.

The first evidence of authoritarian response to the flood hazard was small embankments constructed at Rickergate, sometime prior to 1851. These were reported by the Carlisle Journal (31.1.1851) and the Carlisle Patriot (13.12.1856) to have saved the Rickergate area from extensive flooding in both 1851 and 1856. Also in 1856, another relief fund was set up, this time on a more official basis and was run by a Committee of 'responsible' persons in the City. On this occasion relief to the flood victims amounted to 8 cwt of coal, 36 blankets and £70 which was distributed to over 200 families.

In the second half of the nineteenth century, the City Authorities showed greater concern for the now frequent flood problem in various parts of the city. However, the attitude prevailed that the floods should be controlled, rather than that further development of these low lying areas should be prevented. For example, in 1861 the City Surveyor made a report to the Local Board of Health on the problem of flooding in certain parts of Carlisle (Gordon, 1861). This report noted three particular areas of flooding, Caldewgate, Water Street and Botchergate.

In Caldewgate, the report referred to the construction of embankments at Willow Holme and the use of sluice gates on the River Caldew as it flowed through the land owned by the brewery. The Surveyor could not see any material improvements which could be made to this system to prevent future flooding. Suggestions, though, were made for the culverting of Dow Beck, or even for enclosing the stream completely in an underground sewer, because during dry weather over one third of the flow was sewerage. While these measures failed to eliminate the flooding in Caldewgate and Willow Holme, at least some attention was being devoted to the problem as early as 1861.

In the second area, Water Street, the City Surveyor could see no immediate remedy for the flooding because county magistrates had refused permission for the gaol culvert to be incorporated into a new system, which was essential for the alleviation of flooding in the area. Of the third area, Botchergate, the report added:

> "This District is the only remaining one amongst those liable to flood, besides those already reported, that can be relieved, if not entirely cured of the inconvenience of flooding at a cost compatible with the improvement of the system of sewers carried out so as to make them available for extraordinary storms without materially interfering with existing arrangements."

(Carlisle Sewerage Report, 29.10.1861).

Thus, even in 1861 consideration was given to improvements in the City sewer system to cope with extraordinary storms and hence reduce the flood risk.

By the end of the nineteenth century, the City Authorities were more appreciative of the frequency of the flood hazard. For example, it was reported in the Carlisle Patriot (20.1.1899) that flooding on both sides of the Petteril Bridge was a recurrent problem seen once every ten to fifteen years. Early in the twentieth century several large embankments had been completed around Bitts Park and the Sorceries, probably as a result of the relative success of similar structures in Rickergate. The two new embankments, Mayor's Drive and Weavers Bank were reported by the Carlisle Journal (30.1.03) to have reduced the extent of flooding in the City and to have removed the possibility of flooding in Bitts Park and the Sorceries, as they were in the 'great floods of former days'. While this was not strictly accurate, the apparent success of the measure promoted similar structures at Sheepmount and Willow Holme. At the turn of the century, therefore, there is ample evidence to suggest that the flood problem was being treated seriously by the Carlisle Authorities.

Further response to the flood hazard by the authorities occurred in 1931 following flooding in the January of that year. During the year, the authorities widened the river channel at Petteril Bridge and straightened part of the river course. At the same time the height of Warwick Road was raised one metre from the Bridge to the Star Inn at Botcherby to prevent flooding of the road (Cumberland News 17.1031). Unfortunately, these measures were soon discovered to be grossly inadequate, for in November of the same year the whole area was again flooded including the raised part of Warwick Road (plate 14, Cumberland News 7.11.31).

This piecemeal approach to the Carlisle flood problem continued until 1968, particularly during the 1950's and 1960's when the Civic Authorities and the River Board paid little attention to the hazard. For example, in 1954 following a series of petitions from Carlisle residents, the Engineer of the River Board stated that the River Eden had already been lowered by over one metre, which had increased the channel flow by twenty-five percent, which he concluded must reduce flood peaks to some extent (Carlisle Journal, 29.10.54). The City Authorities also provided little help or compensation and were reluctant to accept any responsibility for the flooding. The Carlisle Journal (22.10.54) reported:

> "As to who is responsible for the flooding itself, a City Councillor told me yesterday that it was suggested at a special meeting of the City Council on Tuesday morning that the bill might be sent to Mr. Eisenhower or Mr. Malenkov - or to any person who had been exploding hydrogen bombs recently."

The general lack of authoritarian concern for the flood hazard persisted until the late 1960's despite the quite serious flooding in 1964. For example, the Willow Holme Industrial Estate was developed at this time by the Civic Authorities in a area known to be prone to flooding. In fact, the area was inundated in both 1954 and 1964. The Cumberland River Board also ignored the hazard, and in 1961 was the only authority not to attend the first conference on flood warning schemes held by the Ministry of Agriculture Fisheries and Food. In a written reply to the Ministry's invitation, the Engineer of the River Board stated; "My Board feel that no useful purpose would be served by my attending as there is little flood danger in this area where warnings would be possible or useful" (Cumberland River Authority records, April 1961). By 1963, the River Board appeared to accept that parts of Carlisle were subject to infrequent flooding (Response to Ministry of Agriculture, Fisheries and Food questionnaire on flooding, 14.6.62) although it was stressed that this was strictly under control. The Engineer's Report (Cumberland River Authority records, September 1963) made it clear that the River Board could cope with the problem without the need for the new flood warning instruments which were being developed at the time.

> "Upstream river levels will give adequate warning of possible flooding in Carlisle and this would be partly the case in flooding from the Caldew and the Petteril. But in Carlisle flooding from the river is not extensive and in the past a close watch on local river levels has proved quite sufficient for everyone concerned to be warned. On the balance it is felt that flooding of a serious proportion within this area which would cause material damage is comparatively rare and has been reduced by channel improvements. Therefore any elaborate flood warning system is not really necessary."
>
> (Engineers report, 10.9.63).

In 1963, therefore, the Cumberland River Board clearly underestimated the flood risk in Carlisle and failed to appreciate the future potential of flood forecasting and warning schemes in reducing flood losses.

In November 1963, the River Caldew inundated the Industrial Estate at Willow Holme and Denton Holme, which produced a response from the River Board in the form of emergency work on the Caldew at a cost of £1860 (Cumberland River Authority records, December 1963). However, despite further flooding throughout Carlisle in 1964, the River Board still denied there was a flood problem in the City. The River Board believed that work on the Eden between 1947 and 1952 which cost £200,000 (primarily on reducing the channel level) would control the flooding. The authorities, therefore, appeared totally to ignore the smaller floods since the early 1950's and the River Board paid little attention to circulars from the Ministry of Agriculture, Fisheries and Food to review the problem. This situation, however, could not remain and the major flooding in March 1968 completely reversed all previous policies and views of the various authorities.

The situation in Carlisle in 1968 was probably the most critical ever as far as flooding was concerned, for never before had so much property been exposed to the dangers of flooding with little or no protection. All previous warnings had been ignored, including several small flood events, petitions from local residents and circulars from the Ministry. The Civic Authorities had even continued the process of flood plain encroachment by establishing the Industrial Estate at Willow Holme. On previous occasions when large floods had inundated the City, the same areas were flooded but there was less property at risk from flooding.

The 1968 flood caused extensive damage throughout the City and brought widespread criticism from a variety of quarters. The Ministry of Agriculture, Fisheries and Food, for example, accused the River Authority of 'Leaving the back door open' with respect to the Caldew flooding Willow Holme (Cumberland River Authority records, April 1968). There were also many complaints from residents in Brunton Park and Botcherby areas which involved the local M.P. However, it was this major flood event which finally stimulated a more effective response from the Local Authorities.

(ii) The authoritarian response to the flood hazard since 1968

Following the serious flooding of March 1968, two separate alleviation schemes have been implemented in Carlisle. The first, a structural measure, was constructed by the Civic Authorities, and consists of a system of flood embankments throughout the City, designed to restrict flood water to an artificially defined flood plain. The second scheme was installed by the Cumberland River Authority and provides forecasts and warnings of impending floods.

(a) The structural scheme:

The structural scheme employed in Carlisle was essentially an extension of the existing measures in the City, which had been constructed seventy years earlier. The new scheme incorporated the old flood banks into a more comprehensive embankment system

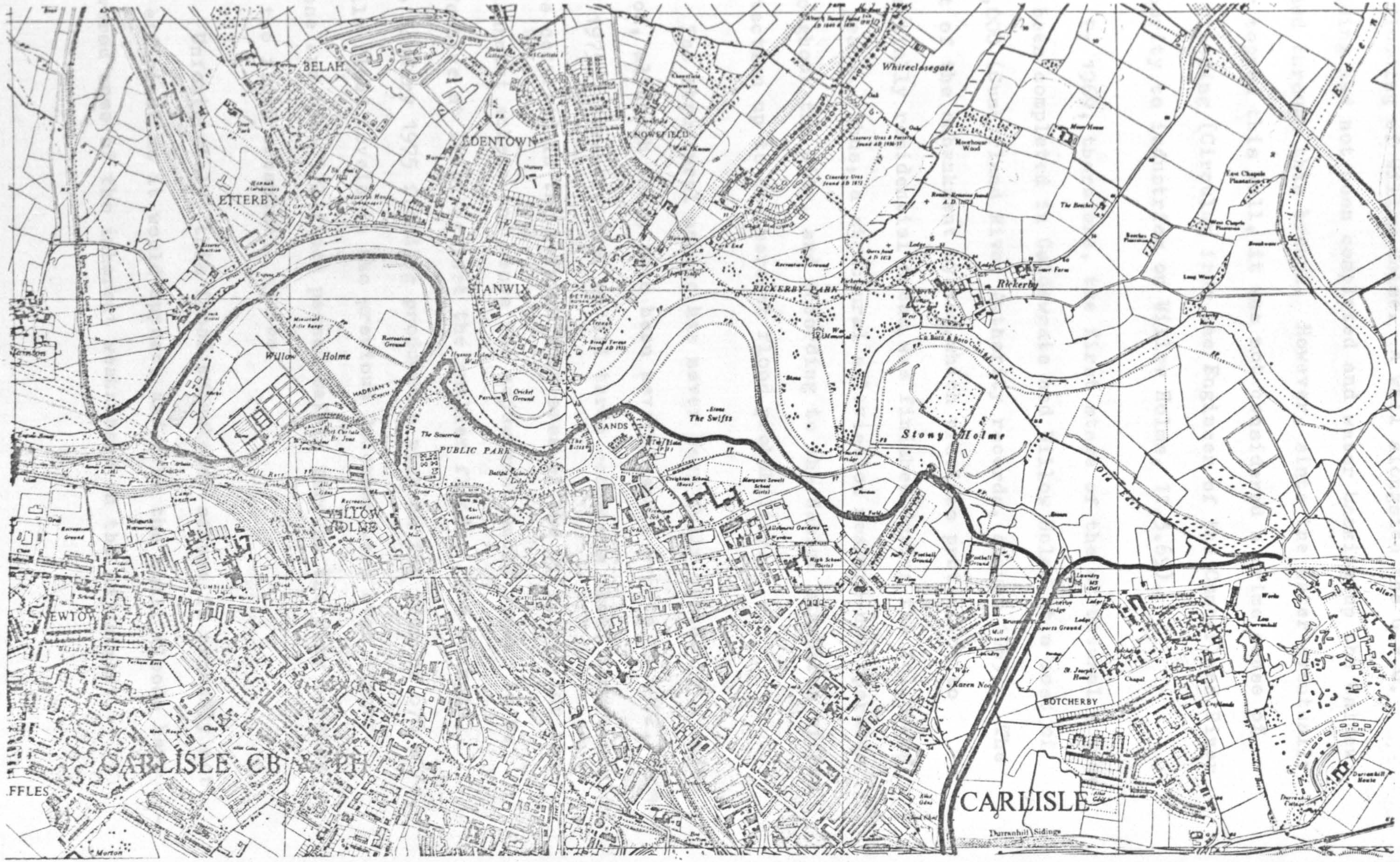
Plate I5. Carlisle: Eden Bridge with the cricket ground to the left.

Plate I6. Carlisle: Part of the flood embankment scheme on the Sauceries.

throughout the City. New banks were built from the railway banking in the west of Willow Holme, round to the railway bridge, then across the Caldew to link up with the old banks on Bitts Park. Plate 16 shows a part of this original system at Bitts Park, on which the new structures were modelled. Other banks were created in the extreme east of the City, extending from Low Durranhill, along the backs of the housing in Warwick Road, across the northern side of Brunton Park football ground, round the end of St. Aidan's Road, to meet the old system at the Swifts. The complete extent of the embankments in Carlisle is shown on map 6-2. The system was designed to withstand flooding up to a magnitude of the one in one hundred year event, which required the tops of the embankments to be constructed approximately 14.34 m above sea level. This would allow 30 cm freeboard for a flood the size of the 1968 event (Cumberland River Authority records, August 1969). However, following the reassessment of the return periods and magnitude of flooding in Carlisle (Field, 1974) the level of protection offered by the banks may be considerably lower than was anticipated at first.

Further structural refinements included the culverting and redirecting of the Little Caldew back to its former course through Willow Holme. The river banks were also strengthened, and a non-return valve was placed on the outlet of the Little Caldew to prevent water backing-up and flooding Willow Holme. In 1968 the Industrial Estate had been inundated due to several factors which these refinements were designed to prevent. For instance, the Little Caldew, which had been directed into the Caldew broke through a sluice which had been damaged since 1963 and added to

Map. 6-2. Carlisle: the flood embankment system.



the flooding of Willow Holme. A wall alongside the G.P.O. building had not been completed and water backing-up the Caldew rushed through this breach. However, since the water eventually over topped this wall, it was not considered a prime cause of the flooding (Circular from the Engineer of the Cumberland River Authority to industries on Willow Holme, 11.3.69).

By 1969, therefore, the first stage of the structural scheme had been completed in Caldewgate and Willow Holme at a cost of £10,000 (Cumberland River Authority records, August 1969). The rest of the embankment system, which provides protection to essentially residential areas, was finished during the following two years. Thus, a structural alleviation measure now operates throughout the City, and according to the design standards offers protection up to one percent flood probability.

The structural scheme has never been fully tested by a major flood, although there have been several small events in 1972, 1974 and 1975. Nevertheless, on all three occasions flood damage would have occurred in the Warwick Road area of the City, but for the embankment scheme and hence the adjustment would appear to be effective at least against the smaller floods. For example, the January 1975 flooding produced a peak on the Eden of 670 m^3/s, while flood levels in the previous December were even higher. These and the 1972 flood passed safely through the City because of the flood embankment system.

Unfortunately, this flood embankment scheme is probably not as efficient as it would appear, and even the small floods have uncovered some of the inherent weaknesses in the adjustment.

Firstly, it was discovered in 1972 that the pressure of water outside the embankments could create localised flooding inside the 'safe areas' by the backing up of water through the sewer system. During the 1972 flood, heavy rocks had to be placed on several man-hole covers, two in Warwick Road by Petteril Bridge and two in Catholic Lonning, which were being lifted by internal water pressure. It is feasible that a larger flood would create greater pressures and hence cause serious flooding in these areas. A further problem resulting from differential water pressure may occur with the small streams flowing through the embankment system. Again in 1972, Durranhill Beck in Botcherby inundated a field on the safe side of the flood embankment. While this stream, or other small streams are unlikely to cause any major flooding, damage could result in particular localities if the main rivers remained high for any length of time. This would involve the sluices in the main embankments remaining closed and thus could cause localised flooding by the backing up of water.

A second weakness in the flood embnakment scheme was found in the Willow Holme area, at the sewerage works. The design standards of the project in this area were reported by the independent surveyors, Waterhouse and Partners, to offer protection from floods up to forty-five centimetres above the 1968 levels. (Cumberland River Authority records, August 1969). It was further added that flooding of the Industrial Estate could only occur by internal rainfall. However, the weakness of the embankment system could endanger the whole of Willow Holme and probably Caldewgate. In the event of a flood warning, the sewerage works are obliged to block the roadway entrance to the site through the embankment with sandbags, since this represents a gap in the structural system, through which Willow Holme Industrial Estate could be flooded. Essentially, this means that the sewerage works will be allowed to flood to save the commercial property on Willow Holme. Although this would only occur during a larger flood event, which would already have inundated the electricity station and possibly backed up through the sewerage works, there is a danger that the sandbags would be insufficient protection against very high flood flows. In fact, during a recent flood alert, there were no sandbags available at the sewerage works for this purpose. In 1975 this situation had still not been rectified, which clearly indicates a major insecurity in the scheme (personal communication with the manager of the sewerage works, 1975 - also see chapter nine).

A third apparent weakness of the embankment scheme was the calculated design standards of the structure. These estimates were made immediately following the 1968 flooding and the safety factor proposed was the one in one hundred year flood. However, the recent calculations by Field (1974) would suggest that the 1968 flood true recurrence interval is only one in forty years, which would imply a lower safety margin of the embankment system. These design standards also require the banks to be periodically maintained, to preserve the level of safety. In 1969, the Surveyors, Waterhouse and Partners, reported that banks on the Willow Holme area had settled twenty centimetres (Cumberland River Authority records, August 1969). The Local Authority corrected this shortly afterwards.

Another weakness of the scheme is the problem of returning water to the channel system once the embankments have been breached or overtopped. Any flooding which occurred in this situation would result in longer duration floods, because water could not be returned quickly to the river system (personal communication, Field 1973).

A final weakness in the structural scheme is one of complacency leading to a general feeling that the flood problem has been eliminated. If this attitude is allowed to develop then no attention will be given to such problems as the pressure on the sewerage system, the backing-up of water on the small streams and the sewerage works, nor of maintaining the embankments. Also, further development may take place on the flood plain putting more property at risk. In the previous chapter, it was shown that Carlisle Corporation has already proposed a new residential estate next to the River Petteril. As a result the City, which will surely flood sometime in the future, will again suffer considerable damage. The flood embankment system, therefore, clearly needs some further refining before it is efficient up to the design standards, although this should not be allowed to obscure the problem of flooding. The flood problem in the City should be reviewed regularly for any changes in the situation.

(b) The non-structural scheme:

In response to the serious flooding in 1968, the Cumberland River Authority implemented a flood forecasting and warning scheme to help reduce flood losses in Carlisle. In 1968, several parts of the county experienced extensive flooding which culminated in the 'Elephant and Castle Conference' of River Authority Engineers to discuss flood forecasting and warning schemes (Cranfield Conference, 1968). This conference undoubtedly influenced the Cumberland River Authority into considering such a scheme. Further technological advances in the instrumentation also made this measure a feasible proposition for Carlisle.

Following several meetings with the Civic Authorities and the local police force, the Cumberland River Authority decided to proceed with a flood forecasting and warning scheme. However, at this time there was very little hydrological or meteorological data available on which to base such a scheme, and hence the first priority was to collect this basic information. Field (1974) pointed out that there was;

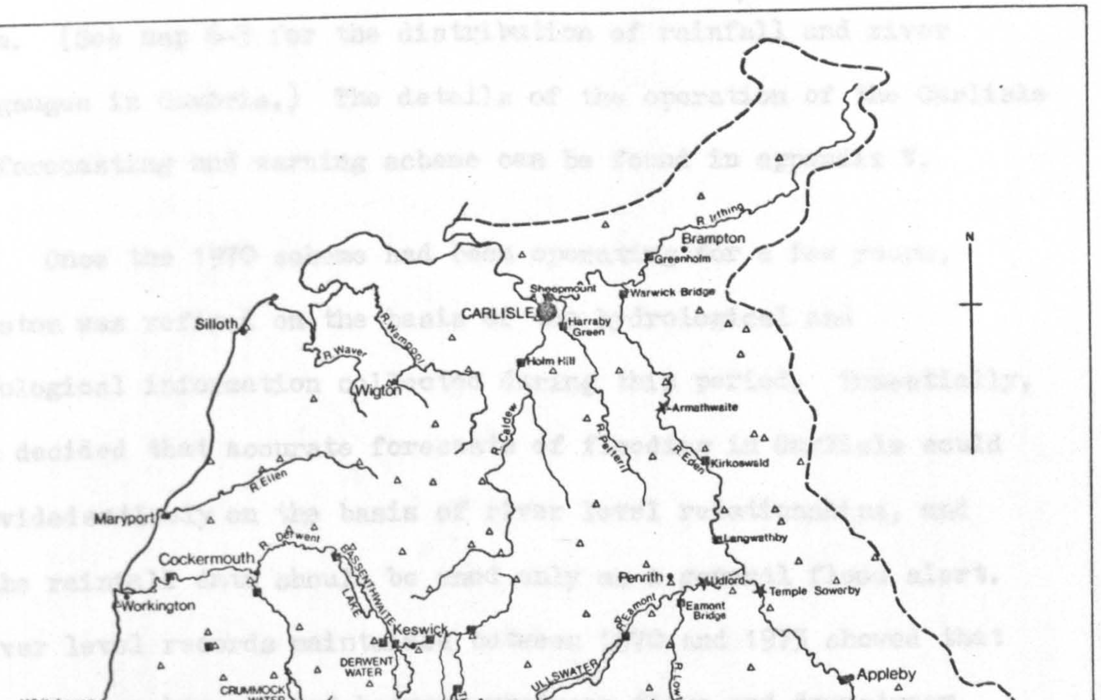
(1) virtually no rainfall data available for the Upper Eden.

(2) no river flow data available for the upper Eden, and

(3) only limited data available for the middle Eden and most of this was unreliable.

The operation of a flood forecasting scheme, therefore, required the River Authority to establish several rainfall and river level sites. The initial scheme was implemented in 1970, at a cost of £9,500, 50% of which was paid by the Central Government (Field 1974).

The scheme, implemented in 1970, operated on the basis of interrogable rainfall and river level gauges which also incorporated



Map. 6-3. Cumbria: distribution of rainfall and river level gauges.

alarm facilities for alerting the Cumberland River Authority headquarters. Map 5-6 shows the distribution of these gauging stations in the Eden catchment. Other gauges outside this area are used not only to provide further hydrological and meteorological data, but are also employed in tracing the route of storms across Cumbria. (See map 6-3 for the distribution of rainfall and river level gauges in Cumbria.) The details of the operation of the Carlisle flood forecasting and warning scheme can be found in appendix V.

Once the 1970 scheme had been operating for a few years, the system was refined on the basis of the hydrological and meteorological information collected during this period. Essentially, it was decided that accurate forecasts of flooding in Carlisle could be providedentirely on the basis of river level relationships, and that the rainfall data should be used only as a general flood alert. The river level records maintained between 1970 and 1973 showed that a good relationship existed between upstream flows and downstream flood levels. Figures 6-3, 6-4 and 6-5 show the relationships of peak flows between gauging stations at Appleby and Temple Sowerby, Appleby and Armathwaite, and the Eden-Eamont confluence to Warwick Bridge. These figures illustrate quite clearly that the relationship between flows at the Eden-Eamont confluence and the flow at Warwick Bridge is very good, and hence, for Carlisle it is possible to operate an efficient flood warning system based on these relationships. While river levels can provide a reasonable indication of flood levels at Carlisle, a check on flows at Warwick Bridge can provide between six and seven hours warning for the town. The flows of the other rivers, the Irthing, Caldew and Petteril are also gauged (see map 5-6) and the time of arrival of peak flows at Carlisle estimated.

Fig. 6-3.

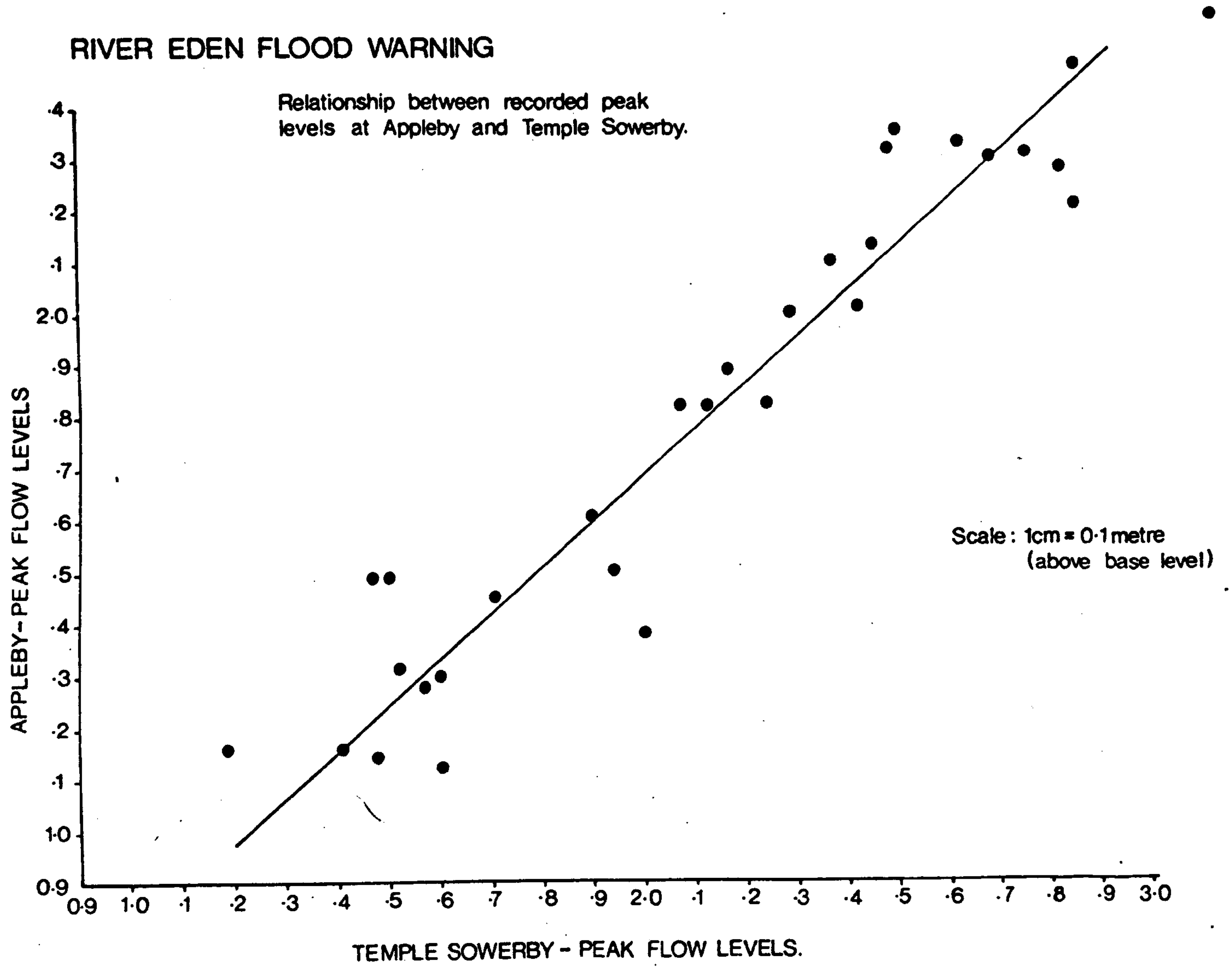

RIVER EDEN FLOOD WARNING
Relationship between recorded peak levels at Appleby and Temple Sowerby.
Scale: 1cm = 0·1 metre (above base level)
APPLEBY - PEAK FLOW LEVELS
TEMPLE SOWERBY - PEAK FLOW LEVELS.
0·9
1·0
·1
·2
·3
·4
·5
·6
·7
·8
·9
2·0
3·0

Fig. 6-4.

RIVER EDEN FLOOD WARNING

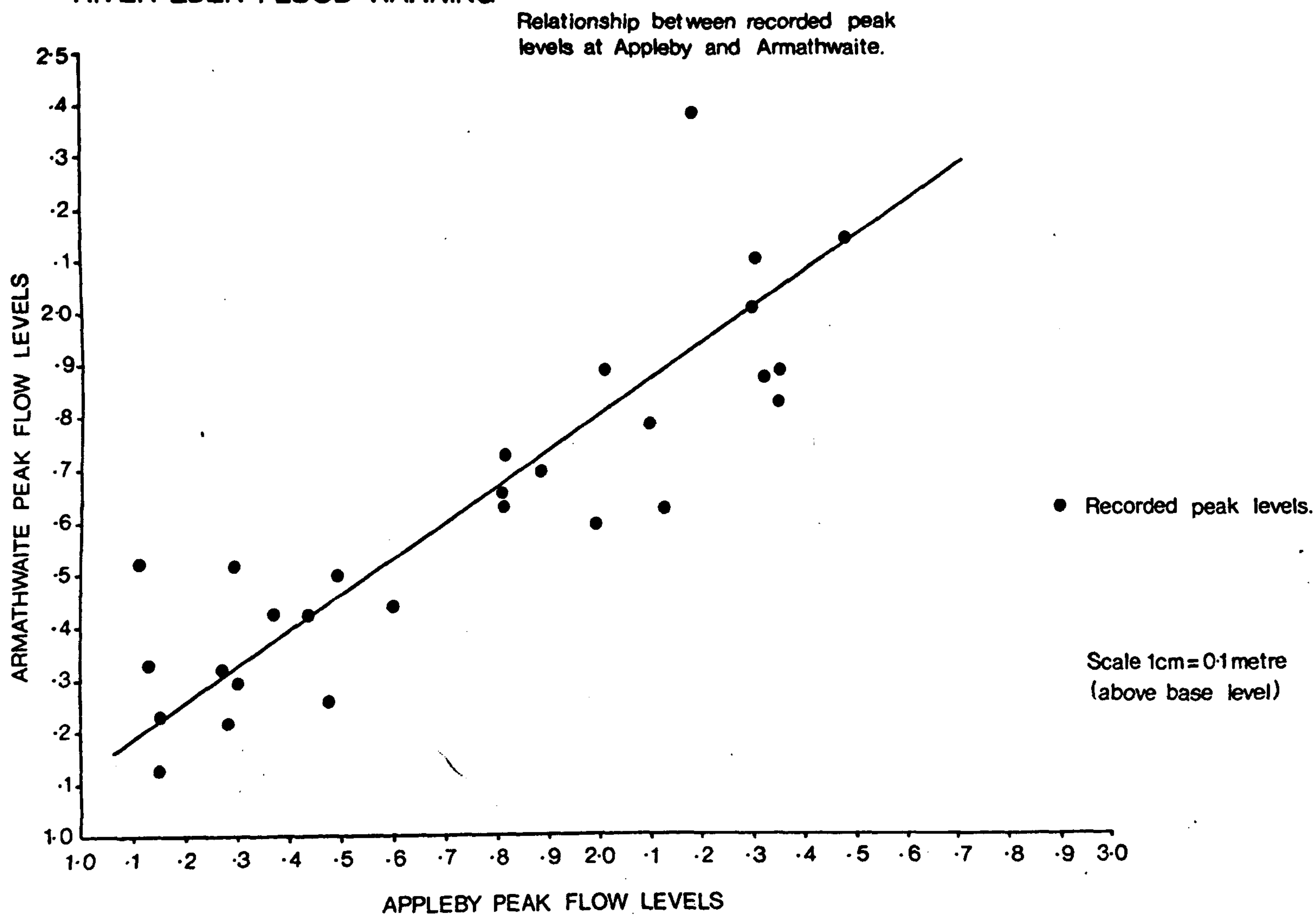
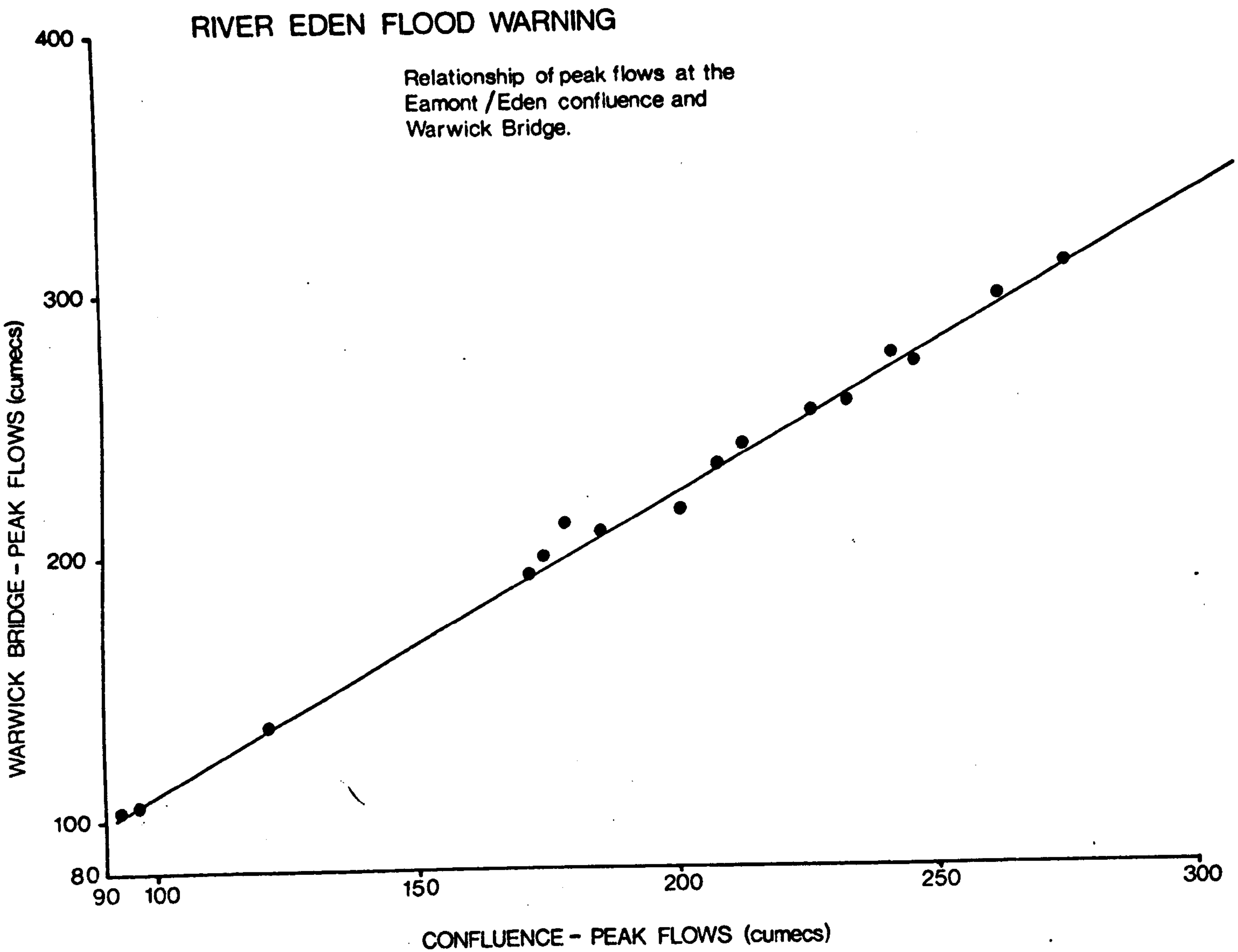


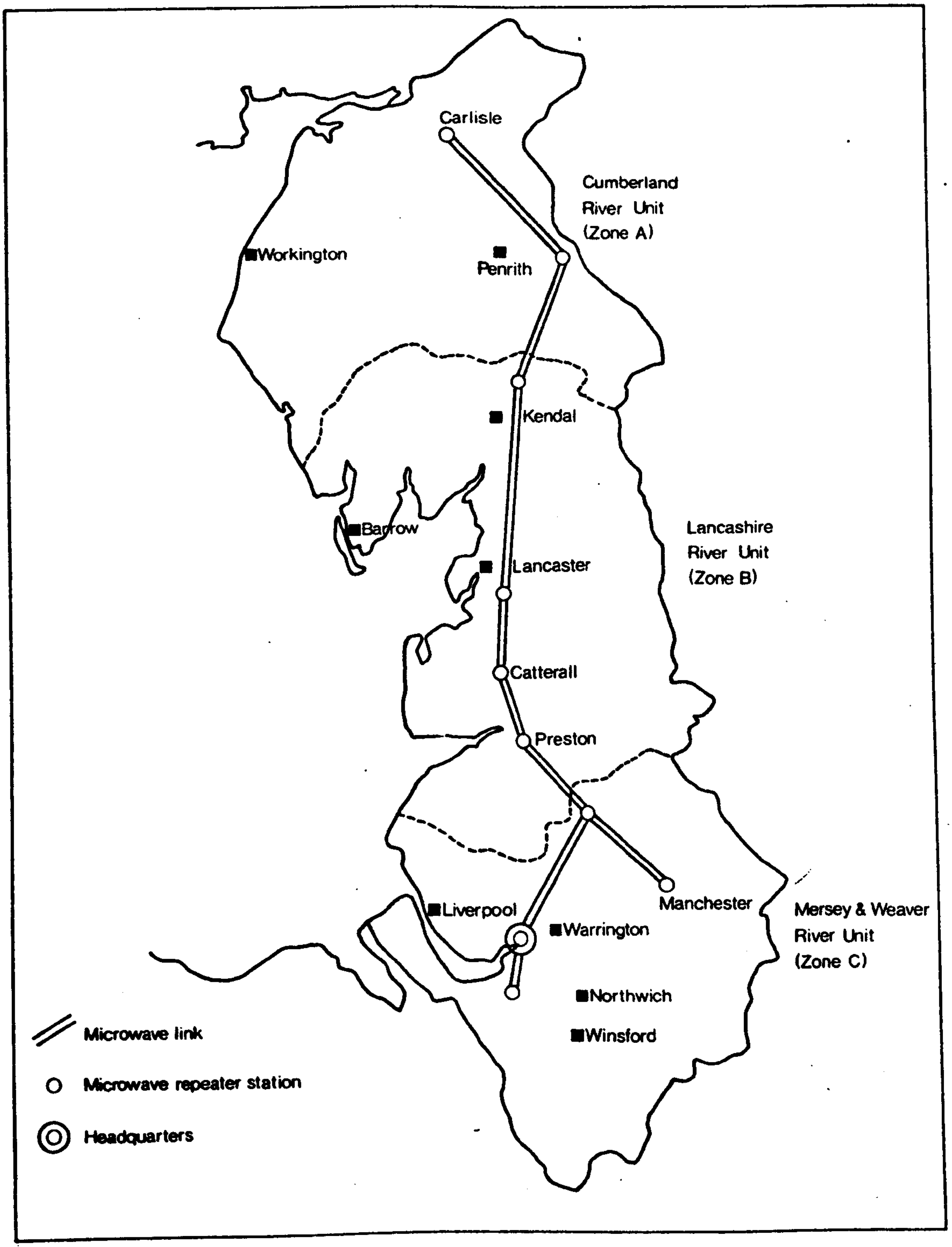
Fig. 6-5.


RIVER EDEN FLOOD WARNING
Relationship of peak flows at the Eamont /Eden confluence and Warwick Bridge.
WARWICK BRIDGE - PEAK FLOWS (cumecs)
400
300
200
100
80
90
100
150
200
250
300
CONFLUENCE - PEAK FLOWS (cumecs)

However, as with the original systems, heavy rainfall or high river flows will also activate alarms in the headquarters of the River Authority. The basic operation of the scheme remains unchanged.

This sytem will probably be further revised in future years following the incorporation of the Cumberland River Authority into the North West Water Authority. New proposals have already been outlined to improve the present flood forecasting and warning system (Lindsay, 1975). The new scheme proposes to undertake flood warning for the whole of the area controlled by the Regional Water Authority by using two computers (one as a standby) to interrogate and interpret data collected by rainfall and river level gauges. The computer will be programmed to evaluate this information in terms of the probability of flooding and, if necessary, issue the appropriate warnings to the headquarters of the Division where flooding is likely. As with the present system, it is not envisaged issuing the initial warning to the general public, but instead allowing individual engineers to make the final assessments on the flood probability. The new system will also be equipped with a verbal or automatic feedback mechanism to ensure that the relevant engineers have been alerted. Map 6-4 shows how this proposed system will operate based on computers in the Regional Headquarters at Warrington.

Further refinements to the present system include the use of radio links between gauging stations and the computer, which are more reliable than G.P.O. lines during bad weather conditions. Also, the Water Authority plans to provide visual display units at the divisional headquarters which will show rainfall histograms, river hydrographs and diagrams of the river system to assist the



Map. 6-4. North West Water Authority: proposed computer links for a flood forecasting and warning system.

engineers in assessing the probability of flooding. Further in the future, it is hoped to include other measurements in the system besides rainfall and river levels, such as estimates of soil moisture content, air temperatures and snow depths.

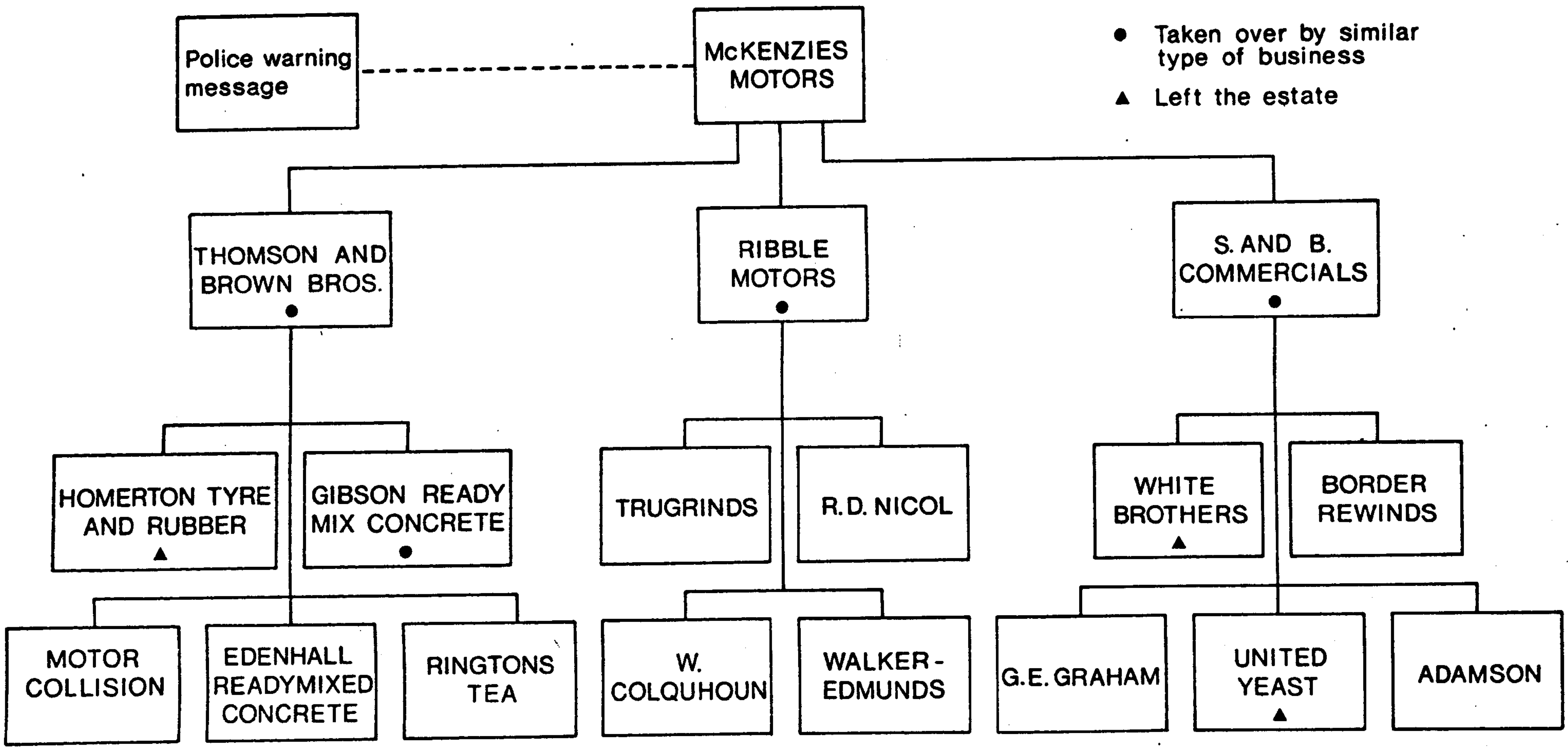
The flood forecasting and warning scheme for Carlisle, therefore, is a highly sophisticated system, which with the technological improvements is becoming increasingly more accurate, as well as providing greater warning times. Unfortunately, this represents only the first stage of flood forecasting and warning systems - the collection and interpretation of data, and the formation of the warning message. The other two stages, dissemination of the warning message, and response to the warning have not been developed to the same extent as the first stage. The three parts of flood forecasting and warning systems were discussed in detail in chapter one and to a certain extent in chapter three. With reference to the Carlisle scheme, dissemination of the warning message is examined below, while response is analysed in chapters seven, eight and nine.

In Carlisle, the responsibility for the second stage of the flood forecasting and warning scheme lies with the local police force, who undertake to notify all those in flood prone areas of any impending floods. The original scheme, which was proposed by the police and Local Authorities, was based on a 'pyramid system' of flood warning. In this system, the warning message would be related by the police to certain prepared 'receivers' who would be responsible for informing several neighbours of the likelihood of flooding. The message would be passed on in this way until the whole flood plain population was alerted to the probability of flooding. The official 'receivers' were volunteers from the public in Brunton Park and Botcherby, who were willing to act as an integral part in the dissemination of the warning message. The remaining residents were prewarned of this system by leaflets distributed by the Local Authority in 1970.

This pyramid system of warning dissemination would be most efficient if kept up to date by regularly reminding the residential population of its important role in the scheme. Unfortunately, this has never been done in Carlisle and hence this could significantly alter the overall efficiency of the warning scheme. For example, there has been a forty-four percent turnover in house occupancy on the flood plain since the last flood, which means there are now many people in flood prone areas quite unaware of these warning procedures (see questionnaire results - chapter seven).

A similar 'pyramid system' was suggested for the industries in the Willow Holme Industrial Estate. A strict procedure was laid down for action by the police and various businesses in the event of a flood warning. The City police were to telephone the managing director of McKenzies Motors, who in turn would telephone the owners or managers of three other named businesses on the estate. These three would then be responsible for notifying four or five other industrialists, while the police were to contact two other businesses direct, Chickpak Ltd. and the Michelin Tyre Company Ltd. Figure 6-6 illustrates the formal operation of the industrial systems. A back-up facility was incorporated into the system by the provision of several alternative phone numbers for each business concern. The system, therefore, was organised to cover all industries in the minimum of time.

Fig. 6-6. Willow Holme Industrial Estate: the pyramid flood warning system.



However, just as the residential warning dissemination procedure has not been updated, so similar problems have arisen with the industrial system. For instance, since the scheme was organised in 1969, many businesses have moved away from Willow Holme altogether, such as Homerton Tyre and Rubber Company, White Brothers Iron Founders, and the United Yeast Company. Other businesses have been taken over by similar companies, Thomson and Brown Brothers by Brown Brothers, Ribble Motors by the National Bus Company, and S and B Commercials by Purvis Petrol. Some Companies are new to the estate and therefore were not included in the original warning procedure; these included Vibroplant, Cartwright Electronics and Geoff Bell Haulage Contractors. The efficient operation of the pyramid system of warning is now very suspect as a result of the turn over in industrial sites. It is to be hoped that the police will contact all the industries directly, both those in Willow Holme and Caldewgate, which were omitted from the original plans, in the event of a flood warning. Alternatively, the pyramid system should be revised.

Police awareness of the hazard and attention to the warning scheme must also be questioned. During the research, interviews at the central police station in Carlisle failed to establish who was responsible for flood warning activities, although the desk sergeant assumed that the duty officer would take charge of any emergency. Attempts to follow up this investigation with the chief superintendent produced no further information. It would appear therefore, that even the police have failed to maintain their part of the system. However, in an emergency, the police would probably cope quite adequately, although it is to be hoped that both residents and business-men would receive sufficient warning to undertake remedial action.

It is clear from the way in which the Carlisle flood forecasting and warning scheme has evolved, that considerable attention has been devoted to improving this measure of flood alleviation. The River Authority and later the Water Authority have spent a large amount of time and money developing a system that will provide Carlisle with quick and accurate warnings of flooding. It is unfortunate, therefore, that the procedures of disseminating the warning message have not been kept up-to-date by the police, because this must surely reduce the efficiency of the overall system, and hence bring into question the value of investing expensive equipment in such a scheme. The third stage of flood forecasting and warning schemes, response to the warning message, has received no attention in the past and hence there is no advice to flood plain residents in Carlisle on what to do following a flood warning. To be effective a flood forecasting and warning scheme requires a positive response from the flood plain residents and business-men, but this cannot be guaranteed in Carlisle because of the lack of concern shown by the responsible Authorities. As a result, some Carlisle residents and business-men would undertake highly ineffective measures in the event of a flood warning (see chapters eight and nine).

The structural alleviation scheme in Carlisle has also received considerable attention, and which, with certain modifications, could be very effective in reducing flood losses. The present authoritarian response to the flood hazard in Carlisle, therefore, appears to be an over reaction to the major flooding in 1968. This may also be the product of the complete inactivity of the authorities in the preceding twenty years. Nevertheless, the two schemes complement each other admirably. The structural scheme provides protection from the small more frequent flood events, while the non-structural measure, if efficiently managed, will provide warnings of larger floods. The flood forecasting and warning scheme will also provide a back up system for the flood embankments, which could prove invaluable if the weakness in the scheme result in serious flooding.

Appleby

Appleby has experienced a totally different response to the flood hazard from Carlisle, both by the Cumberland River Authority and the Local Councils. At present, there is no major alleviation scheme in the town, either structural or non-structural, despite a variety of proposals made over a good many years. This is rather surprising when one considers the frequency of damaging floods in Appleby is once every 4.22 years, which compares with once every 11.4 years in Carlisle (figures from chapter five). However, the extent of property affected on each occasion is considerably less in Appleby (see chapter seven).

The Council Authorities have apparently been aware of the flood problem for a long time. In 1907, for example, attention was called to the silting of the river at Eden Bridge, although the opinion then was that no damage could be done to the bridge by the accumulation of silt (Whitehead papers, quote from Appleby Observer, 1929). In the same report, reference was made to the floods in 1928 and 1929. On this occasion, the authorities discussed several alternative schemes to relieve flooding in Appleby. One such proposal was to remove a portion of the bank upstream of Eden Bridge where the river channel was only half the width of the downstream course. This scheme was dismissed because during the major flooding in 1928, water had reached the tops of the arches of the bridge and inundated the whole of the Sands before the water broke through the bowling green at the narrow part of the river. The authorities decided that such work would have little effect on future floods.

Following more flooding in 1930, it was again reported that the authorities were considering an alleviation scheme for Appleby. The Borough Surveyor was looking at plans for a concrete and cement wall to be constructed around the river banks from Eden Bridge to the swings at Bongate at an estimated cost of £250 (Cumberland and Westmorland Herald, 18.3.30). However, nothing came of this proposal and the residents in the lower areas of the town had to continue to accept any losses accruing from flooding. Occasionally, when the damage from flooding was higher than usual, small relief funds would be set up to help recompense the victims. For instance, the Womens'section of the British Legion supplied one hundredweight of coal to each of the ex-service men flooded in 1947 (Whitehead papers, 1947). As a result of further floods in 1954 and 1964, a more permanent scheme was established for flood victims by the authorities, which became known as the 'Mayor's Fund'. This fund represented the first official response to the flood hazard in Appleby, although it still did nothing to alleviate the actual flood problem. Thus, while the relief fund supplied some compensation this was generally inadequate, and the principal response remained one of bearing the loss. No alleviation scheme was implemented in Appleby in the period up to 1968, and although some proposals had been considered, these were usually rejected because of questions over their ability to control the flooding.

The 1968 flood did not instigate drastic changes in authoritarian attitudes towards the flood hazard in Appleby, as occurred in Carlisle. However, several proposals for the town were forthcoming. The Westmorland County Council, for example, arranged a meeting with the Cumberland River Authority to discuss various alleviation schemes for Appleby, and the Appleby Borough Council also requested action from the River Authority following the 1968 flood (Cumberland River Authority records, October 1968).

In 1972, the Cumberland River Authority submitted proposals for a major structural flood alleviation scheme for Appleby to the Local Council. This scheme involved deepening the River Eden from the main bridge downstream to Holme Farm, in a system of graded banks to accommodate different channel discharges. At the Sands and the bowling green, low retaining walls were planned to protect against any flows in excess of the carrying capacity of the new channel. The Chief Engineer of the River Authority, Mr. Marshall, estimated that these adjustments would cost around £87,000. However, there was a certain degree of opposition to this project. A prominent local resident suggested that the increased flows in the new channel system would cause problems of erosion on the banks, and possibly put several properties at the top of Scattergate at risk (private communication 1975 with Mr. Wood, retired local teacher). A preliminary study was proposed to test the safety of the banks but this, combined with the estimated cost of the scheme, persuaded the Local Council to change its mind over the measure. The Borough Surveyor suggested it was the responsibility of the River Authority to prevent flooding and hence dismissed the Council's responsibility in the scheme (Private communication with Mr. Hirst 1975, Local Councillor, now on the new Appleby Council and the Eden District Council).

In 1975, the River Authority amended the Appleby scheme and resubmitted the proposals to the new administrative units, the

Appleby Council and the Eden District Council. The modified scheme entailed excavating the river bed from Eden Bridge to Holme Farm, which would lower the normal level of water by approximately one metre. This would necessitate strengthening the present river banks which would have to be stone faced rather than grass. Also, there were to be a series of low retaining walls starting at the bowling green and running between the river and the buildings to the bridge then on downstream to the garage at the bottom of Bongate. On the other side of the river, banks approximately 0.6 m high would be constructed to protect the Butts (Cumberland and Westmorland Herald 13.9.75).

At a meeting of the District Council there was only luke-warm acceptance of these proposals and the final decision was deferred (Hirst, private communication, 1975). The cost of the amended scheme was estimated to be £120,000, which was to be divided equally between the North West Water Authority and the Eden District Council. A preliminary study was to cost a further £15,000. Again, it was probably the cost of the scheme, which would have put a penny on the rates, which discouraged the acceptance of the measure. The Chairman of the Council did suggest a cost sharing scheme with the County Council to make the scheme feasible. His argument was that since the bypass road for Appleby had been shelved indefinitely, the County Council were obliged to maintain the A66 through the town, and hence might be interested in the flood alleviation scheme (Cumberland and Westmorland Herald, 13.9.75). Mr. Hirst did not believe the scheme would be accepted because of the present economic climate, and because the whole of the Eden District would be financing a small scheme for the benefit of a few people in Appleby.

It is significant that a similar scheme, incorporating some form of dredging of the river and the construction of low retaining walls along the Sands had been suggested in one form or another as a means of alleviating the flood hazard in Appleby for a great many years. Dredging was first proposed in 1907, while the wall system was seriously considered in 1930. Very few alternatives to this have been suggested, although in a report of the Eden District Council, a Councillor was said to have asked about the possibility of cutting off the loop of the river at Appleby (Cumberland and Westmorland Herald 13.9.75). Apparently, a scheme to divert water through a tunnel in the high land beyond Bongate had been considered, but the cost was prohibitive.

The response following the 1968 flooding was little more than reconstruction of damaged properties. For example, the banks, which had been damaged in several places along the Sands, were repaired and the weir upstream by the old mill restored. This latter work was primarily for aesthetic reasons rather than for hydrological improvements. The Jubilee Bridge, which had been destroyed by the flooding, was replaced in 1971. The wall along Chapel Street was also replaced, and redesigned to prevent a recurrence of the problems in 1968. During the flood, the wall had actually increased flood levels and the duration of flooding in property along Chapel Street by retaining water on the Butts. The wall was eventually knocked down to allow the water to escape. Plates 8 and 9 show the damage in Chapel Street the morning following the flood. The new wall was designed to allow water to return freely to the river channel and according to the Surveyors would be sufficient up to a flood of 1968 magnitude (private communication - Binney Chartered Accountants and Surveyors, 1975). Nevertheless, Appleby is still waiting for a comprehensive flood alleviation policy for the lower areas of the town. Meanwhile, the risk of flooding remains as high as ever and the costs of implementing a structural scheme continue to mount.

As far as non-structural flood alleviation schemes are concerned only the 'Mayor's Fund' has ever been implemented as an official policy. Proposals for a flood forecasting and warning system have been put forward, but it would appear that the physical characteristics of the area preclude this form of alleviation. The Cumberland River Authority considered a flood forecasting and warning system for Appleby in 1970 in conjunction with the original scheme for Carlisle, but subsequent studies proved this to be infeasible given the current level of technology. For instance, a warning scheme based purely on river levels was impractical, because above Appleby the Eden is fed by numerous small tributaries, all of which would need monitoring to predict flood levels downstream (map 6-3). Furthermore, in order to predict flooding in Appleby, the timing of all these streams would have to be assessed. In addition, because of the very flashy nature of the river system in this part of the catchment, there would be insufficient time to make all the necessary calculations and issue a flood warning. Studies also showed that high river flows at Kirkby Stephen did not necessarily imply flooding in Appleby. Thus, a flood forecasting and warning scheme for Appleby would have to be based on rainfall data if reasonable warning time was to be given (Field, 1974).

In 1974, the Cumberland River Authority proposed another scheme for Appleby based on the rainfall data received from gauging stations situated at Barras, Castlethwaite and Scalebeck. From this information, the River Authority proposed to issue warnings of the peak flows and the time of arrival of the flooding in Appleby. It had been calculated by the River Authority that the rainfall-runoff relationship for the Eden catchment above Appleby was only 3½ to 4 hours from the peak rainfall to peak river level (Field, 1974). The scheme was to operate on hourly rainfall figures from the three gauges and calculations of excess river flows, and when a peak threshold was reached warnings would be issued of flooding in Appleby. Unfortunately, even with this scheme a warning time of only two to three hours could be guaranteed. (For full details of the operation of this scheme see appendix V).

The rainfall data for the proposed Appleby warning scheme was required on an hourly basis from the beginning of the storm event, and also had to be available at all times. This was not possible with the rainfall gauges at the three sites in 1974, and hence more sophisticated instruments were required, which would collect data on a more accurate basis, be interrogable and include some form of automatic alarm facility. The River Authority considered renting more advanced equipment from the G.P.O. for these gauges, but instead decided to wait until the reorganisation of the water industry had been completed. It was hoped that the new Water Authority would be able to implement a more sophisticated scheme. In fact, if the plans for the computerised flood forecasting and warning scheme is introduced (described above) then the Appleby plans would be relatively easy to include.

In conclusion, Appleby is in a position where a flood warning may or may not be issued. Officially, the River Authority do not give warnings for Appleby, but if a flood appears probable then the local police may be alerted. The role of the police in the scheme is far less complicated than in Carlisle, because there are fewer people to warn. Unfortunately, the police station at Appleby is no longer manned all the time, and so in the event of a flood alert during the night, the River Authority would be obliged to contact the Penrith Headquarters. The time taken to reach Appleby from Penrith could effectively reduce any warning time to less than one hour, which could be insufficient for some residents and business-men to undertake remedial action. To add to the confusion in Appleby, immediately after the 1968 flood it was decided to ring the Fire Station alarm bell in the event of future flooding. However, few flood plain residents were aware of this scheme in 1975, and those with knowledge of the scheme were unsure whether or not it still operated. On the other hand, it was found that many people in Appleby believed falsely that there was an official flood warning scheme operating in the town (see chapter eight for details of residential awareness in Appleby).

Thus, Appleby has seen little response by the authorities to the flood hazard, although there have been a number of proposals forthcoming immediately following different flooding. The structural alleviation measures have never been implemented, because of the inhibiting costs, while the flood forecasting and warning scheme cannot be implented until expensive equipment has been installed and accurate rainfall-runoff relationships established for the catchment. The new proposals by the North West Water Authority may make these non-structural plans more realistic and financially feasible.

As a final analysis, the authoritarian response to the flood hazard has been through several significant changes in attitudes in recent years. Prior to 1968, the authorities responsible for flood alleviation tended to adopt a piecemeal approach to the hazard, 'solving' the problem when and where it arose. This was reflected particularly in the authoritarian response in Carlisle, where attention moved from Rickergate to Caldewgate and eventually to Willow Holme, Brunton Park and Botcherby. For a long time, the River Board and later the River Authority were totally unconcerned about the flood problem, especially during the twenty years leading up to 1968. As a result no alleviation measures of worth were implemented, and both Carlisle and Appleby, as well as many other sites in Cumbria, suffered extensive flooding. The Local Authorities also did very little during the 1950's and 1960's, and at times, in Carlisle, actually aggravated the flood problem by continuing to develop property in known flood prone areas. The siting of the Industrial Estate at Willow Holme was perhaps one of the biggest errors made by the authorities since the rapid expansion of the nineteenth century.

After 1968, as would be expected, both the authorities were more aware of the hazard, and their attitudes towards the flood problems changed quite significantly. At the same time, the fallacy of dealing with flooding on an ad hoc basis was realised, and their approach to flood alleviation altered accordingly. The post 1968 period, therefore, has seen the consideration of more comprehensive schemes which tackle the whole flood plain problem, while the emphasis on flood forecasting and warning schemes shows a further trend towards non-structural measures.

CHAPTER SEVEN

CHARACTERISTICS OF THE FLOOD PLAIN RESIDENTS

IN CARLISLE AND APPLEBY

Introduction

In Chapter 1, it was shown that in recent years the losses from flooding have continued to mount in spite of the massive capital investment in flood alleviation works. Two major hypotheses were put forward pertaining to the cause of this apparent anomaly :

(i) that the poor planning policies, inadequate decision making and the generally ad hoc structural response by the various responsible authorities to the flood problem had failed to ameliorate the flood situation.

(ii) that the omission of human studies from any consideration of flood plain planning policies, particularly the parts played by residents and business-men in the flood prone areas, had also led to ineffective schemes.

The preceding chapters have already looked at the merits of the authoritarian response to the flood hazard, particularly the heavy dependence on structural adjustments. Examples of the authoritarian response were shown at all levels of government, while the more detailed studies at Carlisle and Appleby stressed the changing attitudes of the local authorities through time. The full significance of the authoritarian response in these settlements is outlined in the general conclusions below.

The second hypothesis is tested and analysed in chapters seven, eight and nine, based on the questionnaire data obtained from residents and business-men in Carlisle and Appleby. The change in emphasis of the authoritarian response to the flood hazard, basically from structural to non-structural measures, now means that the flood plain population is required to undertake positive remedial action if flood losses are to be reduced. Initially, this aspect of flood alleviation was ignored, on the assumption that residents and business men in flood prone areas would act in a rational manner to minimise flood losses. However, since even this new policy incorporating non-structural measures has proved relatively ineffective, serious consideration is now being given to the somewhat critical factor of human attitudes and behaviour, especially with respect to non-structural flood alleviation works.

Chapter seven examines the results of the questionnaire surveys of the flood plain residents, and compares the results from the two contrasting flood environments, Carlisle and Appleby. Four groups of questions were incorporated in the questionnaire to provide information on various aspects of social behaviour on the flood plain.

The four groups were:

(i) Social characteristics - to determine the population features of the flood plain residents.

(ii) Flood statistics - to provide detailed information on previous flooding, especially the 1968 event, and the degree of flood experience of the flood plain population.

(iii) General environmental perceptions - to assess flooding in comparison with other problems.

(iv) Behavioural aspects - to provide further details on the flood plain inhabitants, particularly their perception of the flood hazard and personal perceived response to future events.

(Further details on the construction and preparation of the questionnaire can be found in chapter four in the section on methodology; on the actual questions themselves in Appendix II while the results are reviewed in this and the following chapters).

This chapter is essentially concerned with the socio-economic charateristics of flood plain populations, and the degree of flood experience of the residents. These residential traits were then incorporated into the following chapter, in the examination of attitudes and behaviour in a flood hazard area.

Chapter eight, therefore, examines the latter two aspects of the questionnaire survey, on the perception and behaviour of the flood plain population, dealing in detail with the causes or reasons for such attitudes. Based on this data, the hypothetical model of residential behaviour is reviewed and some improvements and amendments suggested. A final revised model to predict flood plain behaviour is proposed according to the results and analyses made in these two chapters.

Analyses of the questionnaire data involved several types of statistical tests so that more accurate assessments could be made of the relationships between different variables, and variations in the response from the two research centres. The principal technique employed was the chi squared test, which was used to compare data in the form of frequency distributions. Where the data was statistically stronger, covariance (Spearman rank correlation coefficient) or a linear regression formula were often employed.

The Questionnaire Surveys

Period of Survey:

The questionnaire surveys of the flood plain residents in Carlisle and Appleby were undertaken between autumn 1974 and spring 1975. This period was kept to a minimum to reduce the possibility of differential responses occurring due to changing environmental conditions. The nature of the study and the planned intention to compare two contrasting areas precluded a lengthy survey period. The business questionnaire did not involve detailed behavioural studies and hence did not have the same restrictions as the residential survey. This survey was conducted during the summer of 1975.

Size of Survey : Residential

In Carlisle, a full population survey of the flood plain residents was not feasible because of the large number of dwellings situated in flood prone areas within the city. The limited time and resources available were insufficient for such an extensive study, so instead, a random sample of the residents was taken to reduce the numbers for interview, and hence overcome these difficulties. While sampling automatically introduces a degree of error into the study, it was hoped that the proportional stratified random sample technique employed in Carlisle would effectively minimise any such inherent errors involved in sampling.

The size of the sample survey in Carlisle was determined from the response rate generated by the pilot study, using the formula proposed by Moser and Kalton (1971, 147). The basic requirements of the formula are a proportion (π) of the survey, the finite population (N) and an estimate of the standard error (S.E.(p)), while n represents the proposed sample population, and n^1 the finite

$$n = \frac{\pi(1 - \pi)}{(S.E.(p))^2}$$

$$n^1 = \frac{n}{1 + (n/N)}$$

population correction. In Carlisle, the proportion of the survey was represented by the positive response to the pilot questionnaire, which was 69%, the total number of flood plain dwellings was 573 while the standard error was set at 2%.

$$n = \frac{0.69\ (1 - 0.69)}{(0.02)^2} = 534.75$$

$$n^1 = \frac{534.75}{1 + \frac{534.75}{573}} = 276.6$$

According to data collected from the pilot survey a sample of 277 dwellings (48%) was required to maintain a standard error of only 2% in Carlisle.

In Appleby, the questionnaire survey did not require the sophisticated sampling procedures necessary in Carlisle, due to the limited number of dwellings now situated in flood prone areas. The extent of the 1968 flood was used to delimit the areas subject to quite large scale flooding, and this showed that forty-nine residences are now at risk. A full population survey, therefore, was undertaken in Appleby.

Response to the Surveys:

The response rate generated by the Carlisle residential survey was quite high at 79% and compared favourably with other long questionnaire type surveys according to Grebenik and Moser (1970). In all, 218 interviews were successfully completed, which represents 38% of the total dwellings on the flood plain. The remaining 10% (59 dwellings) were not surveyed for a variety of reasons. 45, or approximately 8% of the total either refused to co-operate in the survey or were unable to answer due to illness, while a further two questionnaires were destroyed by the interviewer, because of apparently flippant responses. The remaining 12 (2%) were not interviewed due to the failure to make contact with any adult at the randomly selected address, despite repeated calls.

The accuracy of the final survey was tested based on the response rate to the questionnaire using the formula described by Moser and Kalton (1971, 147) to calculate the standard error of the proportion. In the formula, n represents the sample population, N

$$S.E.(p) = \sqrt{(1 - \frac{n}{N}\quad \frac{\pi(1 - \pi)}{n}}$$

the finite population and π the proportion of the survey, in this case the positive response rate to the questionnaire (79%). Thus:

$$S.E.(p) = \sqrt{(1 - \frac{277}{573})\quad \frac{0.79\ (1 - 0.79)}{277}}$$

$$= 0.0176$$

Hence the standard error of the final sample size based on the response/non-response rate is approximately 1.8%.

In Appleby, the response rate towards the residential questionnaire was even higher than that in Carlisle. Of the 49 total flood plain dwellings at risk to flooding, interviews were obtained from 44 or 90%. Of the 5 non-respondents, two refused to answer the questions, and the other three were unavailable for comment due to illness or lack of contact. Despite the low figures, the Appleby survey was still statistically valid because the total flood plain population had been surveyed and was not dependent on a limited sample.

The proportion of the flood plain population surveyed in both Carlisle and Appleby, and the response rates generated by the surveys, compared favourably with other similar types of studies. For instance, Harding and Parker (1972) planned a 100% study of flood plain residents in Shrewsbury, and successfully interviewed 69%. In the Tewkesbury area, Penning-Rowsell (1972) undertook a larger survey, interviewing 690 residents by either personal contact or mail questionnaire, which amounted to approximately 7% of the total population. In the U.S.A. James et al (1971) carried out an interview survey of nearly ten percent of the flood plain residents in North Atlanta and obtained a positive response rate of sixty-six percent. A later study, also under the leadership of James (James et al 1974), was based on a twenty percent sample using a mail questionnaire, which, with several follow up letters, produced a response rate of thirty-eight percent. However, in this latter study there was a significantly greater response from flood plain residents (41%) than from others (32%). Clearly, the Carlisle and Appleby studies were apparently successful in this respect, especially in comparison with the other major British survey in Shrewsbury.

Commercial Survey:

The commercial survey involved a similar type of questionnaire as the residential one, only with less emphasis on the perception aspect of the flood hazard, since the research was aimed at business-types, rather than business managers. Secondly, since there were only 73 commercial properties at risk in Carlisle and 35 in Appleby, it was decided to undertake a 100 percent survey of these. This eliminated the problems associated with sampling techniques, which would have been more difficult than with the residential survey because of the great variety in business types, particularly in Carlisle. This survey also proved highly successful since response rates of 76.7 percent in Carlisle and 94.3 percent in Appleby were obtained (Full details of the commercial survey may be found in chapter nine).

Chapter seven, therefore, examines the factual information gathered by the residential questionnaire surveys in Carlisle and Appleby. Two distinct groups of questions were included in the section:

(1) Social characteristics.

(2) Extent of flood experience.

(1) Social Characteristics

In determining the social characteristics of the flood plain population the questionnaire survey was utilized to distinguish two important factors : (1) Structural factors, including such details as the area in which the respondent lived and the type of building inhabited ; (2) Personal factors, such as sex, age, length of residence in the area and occupation. These variables were important to the flood studies, to discover the type of people affected by flooding in the two communities, and particularly for the later studies of perception and behaviour.

Structural factors:

The fundamental structural characteristics within the flood plain were assessed by incorporating into the questionnaire, questions and notes on both the street and area in which the dwellings were situated; the type and characteristics of the building in which the respondent lived, and the proximity of the dwelling to the source of the hazard. However, this latter factor was eventually omitted because of the low variation within each flood plain and the problems of obtaining accurate and meaningful data. Nevertheless, since Appleby residents live in closer proximity to the hazard than Carlisle residents, a comparison of responses between the two settlements would automatically incorporate this aspect.

The individual streets were used in Carlisle as the framework, or strata, for the proportional random sampling technique employed in the city. In all twenty-one streets were surveyed ranging in size from Warwick Road with over two hundred dwellings, to Bridge Lane and John Street in Caldewgate with four and five respectively. The positive response rate also varied between one hundred percent and fifty percent, although the more extreme values were obtained from the small streets, where one dwelling could represent up to twenty percent of the proposed interviews.

In Appleby, the residential questionnaire covered six streets which ranged in size from only one occupied dwelling in both Doomgate and The Butts to twenty-four dwellings along Chapel Street. In no street in Appleby did the response rate fall below eighty-five percent.

In Carlisle, three areas were defined as subject to flooding based on air photograph evidence of the 1968 flood (see plates 17, 18 and 19) and river authority data. Map 5-14 distinguishes the three zones Brunton Park, Botcherby and Caldewgate. Brunton Park, which extends along both sides of Warwick Road from St. Aidans Church to the Petteril Bridge, is by far the most closely inhabited of the three with over 400 dwellings (72% of the total flood plain dwellings). Interviews were carried out at 151 of these, while a further 49 represented non-respondents, which produced a response rate for the area of 76%. (table 7-1)

In Botcherby, to the east of Petteril Bridge, there were 120 dwellings subject to flooding, 52 of which were interviewed with a further 6 rejections. The positive response rate in this area was the highest of all at approximately 90%.

Plate 17. Carlisle: Part of Brunton Park during the 1968 flood, showing Warwick Road and St. Aidan's Road (taken after the peak discharge).

Plate I8. Carlisle: View looking up the Eden Valley, showing Brunton Park in the foreground and Botcherby during the I968 flood (taken after the peak discharge).

Plate I9. Carlisle: Caldewgate and Willow Holme Industrial Estate during the I968 flood (taken after the peak discharge).

Caldewgate, located in the industrial sector of the city was for a long time the most densely inhabited area in Carlisle (see chapter five). However, industrial expansion has gradually taken over this area and houses have been allowed to run-down, so that today there are only forty occupied houses in the flood prone area. Fifteen of these were surveyed with a further four non-respondents, which produced a positive response rate of seventy-nine percent.

In Appleby, flooding is less extensive spatially than in Carlisle (again these differences were brought out in chapter five) and now threatens only forty-nine occupied dwellings in three separate residential areas in the town : The Butts, The Holme, and The Sands (Map 5-15). The Butts represents the area immediately inside the meander of the River Eden encompassing such buildings as the Church, vicarage, and swimming pool, and most of the dwellings in Chapel Street. In this area there were twenty-five occupied residences of which twenty-one were surveyed, producing a response rate of eighty-four percent (table 7-2).

The Holme area, which is composed of several small streets, including both High and Low Wiends, Doomgate, part of Chapel Street and Holme Street can be found in the west of the town, also within the river meander. Of the sixteen dwellings in the area, fifteen were successfully surveyed, a response rate of ninety-four percent.

The third area, The Sands, is situated outside the meander, to the east of the town centre and along the main A66 trunk road (plates 20 & 21). Only eight residences are subject to flooding

TABLE 7-1

Residents : Response Rates per Area - Carlisle

	BRUNTON PARK	BOTCHERBY	CALDEWGATE	TOTAL
Number of dwellings	413	120	40	573
% of total	72.1	20.9	7.0	100
Number of selected dwellings	200	58	19	277
% of area dwellings	48.43	48.3	47.5	48.3
% of total dwellings	34.9	10.1	3.3	48.3
Number of interviews	151	52	15	218
% of interviews	69.3	23.9	6.9	101
% of area dwellings	36.6	43.3	37.5	38
% of total dwellings	26.4	9.1	2.6	38.1
Number of rejections	38	6	3	47
Number not available	11	0	1	12
Total non-respondents	49	6	4	59
Non-response rate per area	24.5	10.34	21.1	21.3
Response rate per area	75.5	89.66	78.9	78.7

TABLE 7-2

Residents : Response rates per Area - APPLEBY

	THE BUTTS	THE HOLME	THE SANDS	TOTAL
Number of dwellings	25	16	8	49
% of total dwellings	51	32.7	16.3	100
Number of selected dwellings	25	16	8	49
% of area dwellings	100	100	100	100
% of total dwellings	51	32.7	16.3	100
Number of interviews	21	15	8	44
% of interviews	47.7	34.1	18.2	100
% of area dwellings	84	93.8	100	89.8
% of total dwellings	42.9	30.6	16.3	89.8
Number of rejections	2	0	0	2
Number not available	2	1	0	3
Total non-respondents	4	1	0	5
Non-response rate per area	16	6.3	0	10.2
Response rate per area	84	93.7	100	89.8

Plate 20. Appleby: The Sands and St. Lawrence Bridge during the 1964 flood.

in the Sands and all were successfully surveyed. A fourth area extending from the river at Bridge Street to the Low Cross/ Cloisters area did not support any residential property and hence was excluded from this particular questionnaire survey.

The final structural factor was building type, details of which are given in tables 7-3 and 7-4. Terraced housing was most predominant in Appleby, where eighty-four percent of dwellings were of this type compared to only fifty-four percent in Carlisle. The remaining dwellings were either detached or semi-detached houses, except for nineteen flats and bungalows in Carlisle. The proportion of house types in each area was significantly different at the 0.999 level of probability according to the chi squared test. Similarly the proportion of residences with cellars also differed significantly between the two communities.

House-type was believed to be of particular importance in determining effective remedial actions in the event of a flood. For example, the large proportion of residents occupying terraced housing would find flood proofing measures relatively ineffective, unless the whole terrace undertook similar precautions to prevent flooding through any communal foundations. Similarly, those residents living in flats and bungalows would be somewhat restricted in removing valuables to a higher level.

The type of building in which the resident lived was also an important indicator of various social characteristics including, the location of the residence, the age of the respondent, the number of persons at risk in each dwelling, the tenure of the property and the length of residence in the

TABLE 7-3

Residents - Type of building

	Carlisle		Appleby		Total	
Terrace	118	54%	37	84%	155	59%
Semi/Detached	81	37	7	16	88	34
Flat/Bungalow	19	9	0		19	7
Total	218	100	44	100	262	100

TABLE 7-4

Residents : Cellar in building

	Carlisle		Appleby		Total	
Yes	44	20%	2	5%	46	18%
No	174	80	42	95	216	82
Total	218	100	44	100	262	100

TABLE 7-5

Residents : Sex of Respondents

	Carlisle		Appleby		Total	
Male	67	31%	18	41%	85	32%
Female	151	69	26	59	177	68
Total	218	100	44	100	262	100

building. In Carlisle, all these variables produced significantly different responses from the three different building types. (Unfortunately these responses could not be compared with Appleby, because the chi squared test was invalid due to the lack of variation in house type). For example, sixty-six percent of the housing in Brunton Park was terraced compared to only nineteen percent in Botcherby and forty percent in Caldewgate. Figure 7-1 shows the high proportion of semi-detached and detached residences in Botcherby and flats in Caldewgate. The other figures, 7-2 and 7-3, show the large proportion of flats rented and the length of residence relative to each house type. Other significant differences were found with the age of the respondent and the number of persons per dwelling.

In conclusion, building type may be an accurate guide to the characteristics of the flood plain population. For instance, there is a high probability that a terraced house resident will live in the Brunton Park area, own his own house, have lived in the area for a long time, or be a newcomer to the area, and if the latter then he will be young and have several children. On the other hand, a flat dweller is most likely to be a tenant resident, older and living on his own and have only lived in the building for a relatively short time.

Personal factors:

The initial research hypotheses, described in chapter four, suggested that certain social characteristics could significantly influence individual perception and behaviour patterns. For this reason, several personal questions were

Fig. 7-1. Proportion of house types in each area of Carlisle.

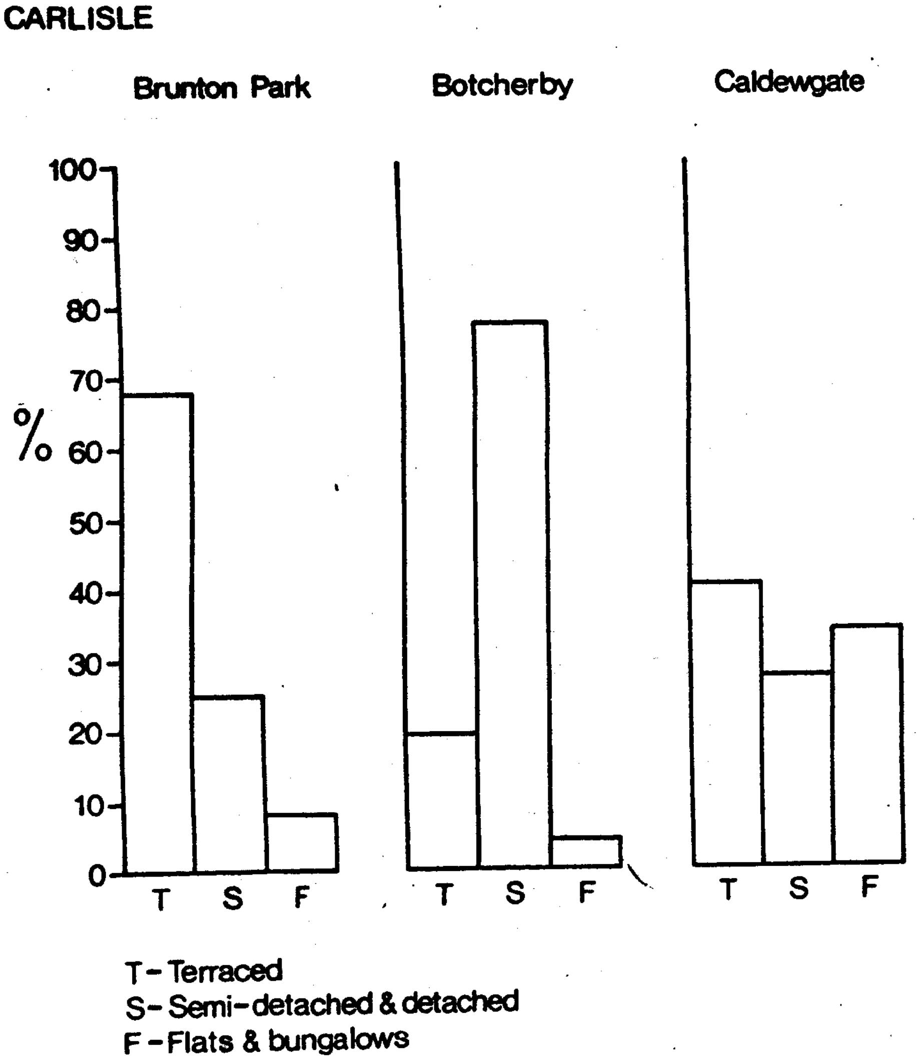


Fig. 7-2. Proportion of rented accommodation by house type in Carlisle.

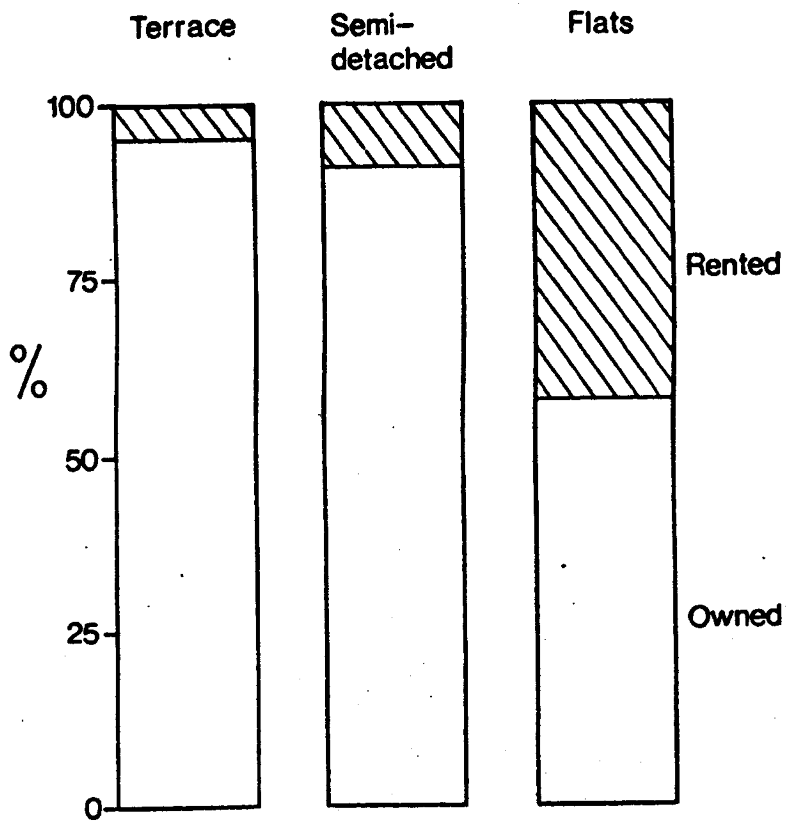
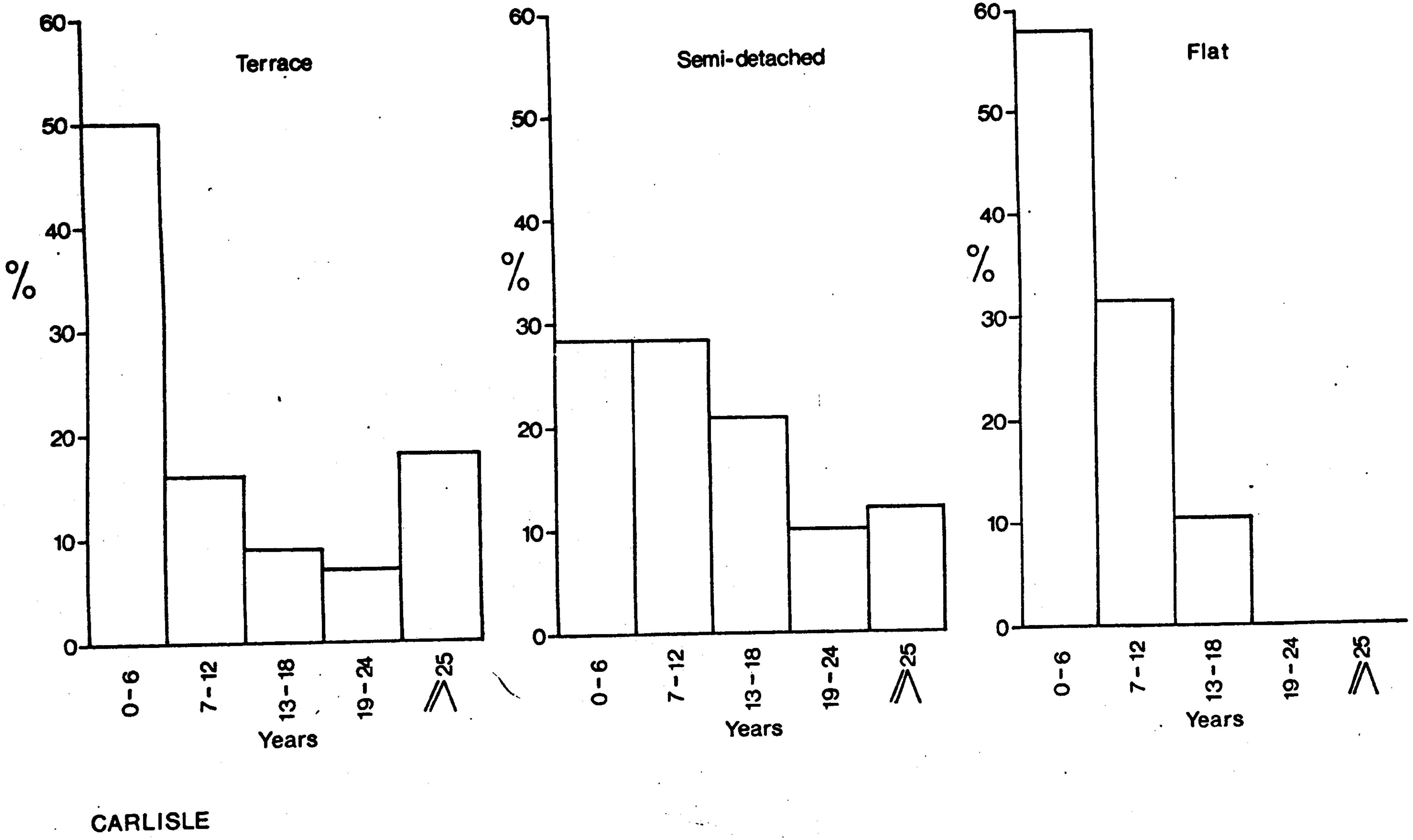


Fig. 7-3. Relationship between length of residence in Carlisle and house type.



included in the questionnaire, which were later used for further analyses. The responses to these questions also provided an indication of the general social characteristics of the whole flood plain populations.

Sex

In Carlisle, sixty-nine percent of the interviews were conducted with female adults and only thirty-one percent with males, while in Appleby the proportions were fifty-nine percent females and forty-one percent males (table 7-5).

Age Structure

Age structures of the respondents in the two communities were quite similar since both had a bias towards the older age groups. A chi squared test showed that any difference between the two distributions was not significant at the ninety-five percent level of confidence. Table 7-6 shows the frequencies of respondents in each age category. Both centres revealed peaks in the thirty-five to forty-four and the sixty-five years and over age groups, although there was a slightly older age distribution in Appleby, where forty-nine percent of residents were over fifty-five years compared to forty-two percent in Carlisle. Figure 7-4 shows the two age distributions in histogram form.

Family structure

The number of people living in each dwelling ranged from one to eight in Carlisle, and one to six in Appleby (table 7-7).

TABLE 7-6

Residents : Age of Respondent

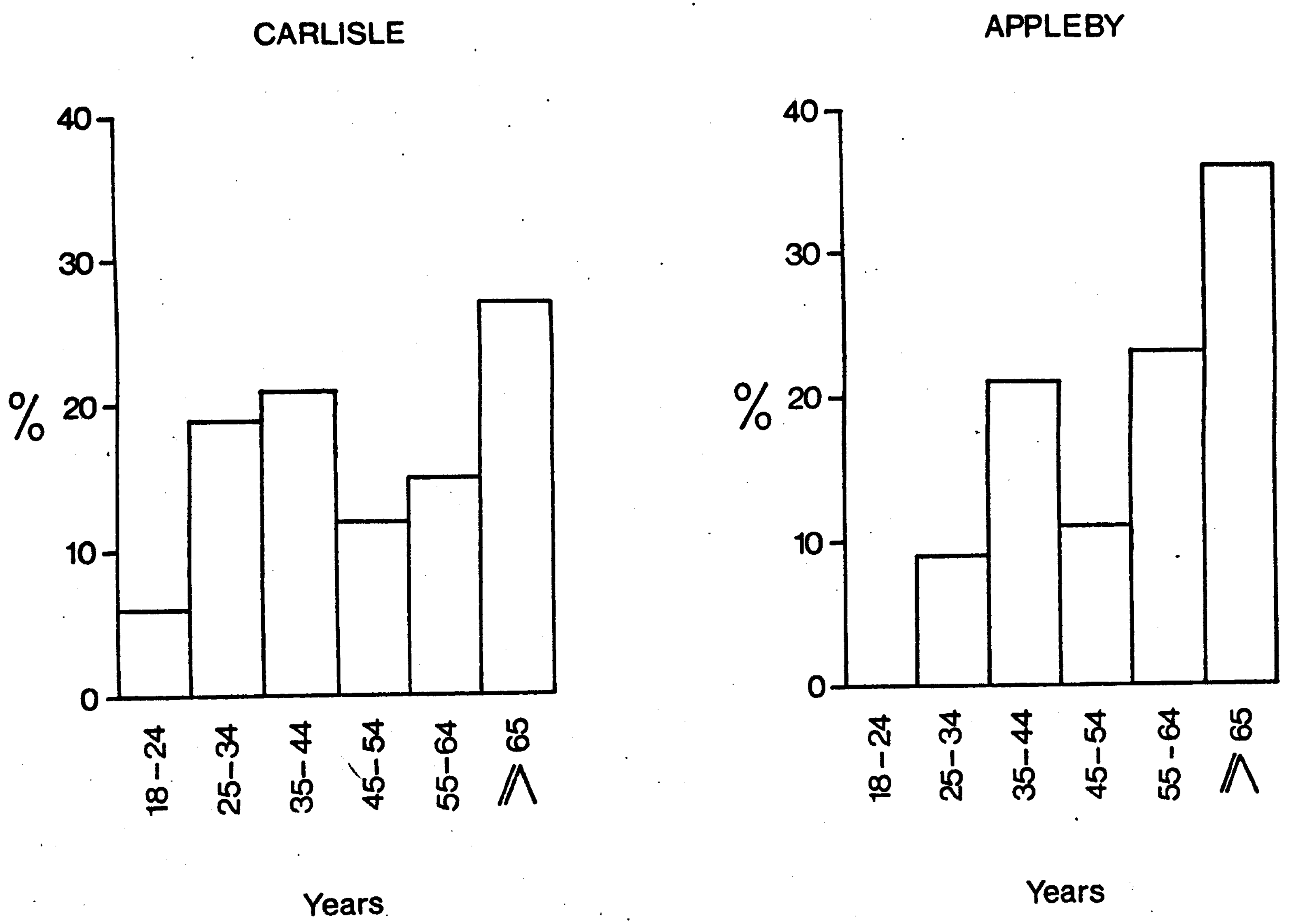
	Carlisle		Appleby		Total	
18 to 24 years	13	6%	0	-%	13	5%
25 to 34 years	42	19	4	9	46	18
35 to 44 years	45	21	9	21	54	21
45 to 54 years	27	12	5	11	32	12
55 to 64 years	32	15	10	23	42	16
65 years and over	59	27	16	36	75	29
Total	218	100	44	100	262	101

TABLE 7-7

Residents : Number of people per dwelling

Total per dwelling	Carlisle		Appleby		Total	
One	37	18	9	21%	46	18%
Two	56	26	20	46	76	29
Three	44	20	7	16	51	19
Four	53	24	2	5	55	21
Five	12	6	4	9	16	6
Six	8	4	2	5	10	4
Seven	6	3			6	2
Eight	2	1			2	1
Total	218	102	44	102	262	101

Fig. 7-4. Age distribution of respondents in Carlisle and Appleby.

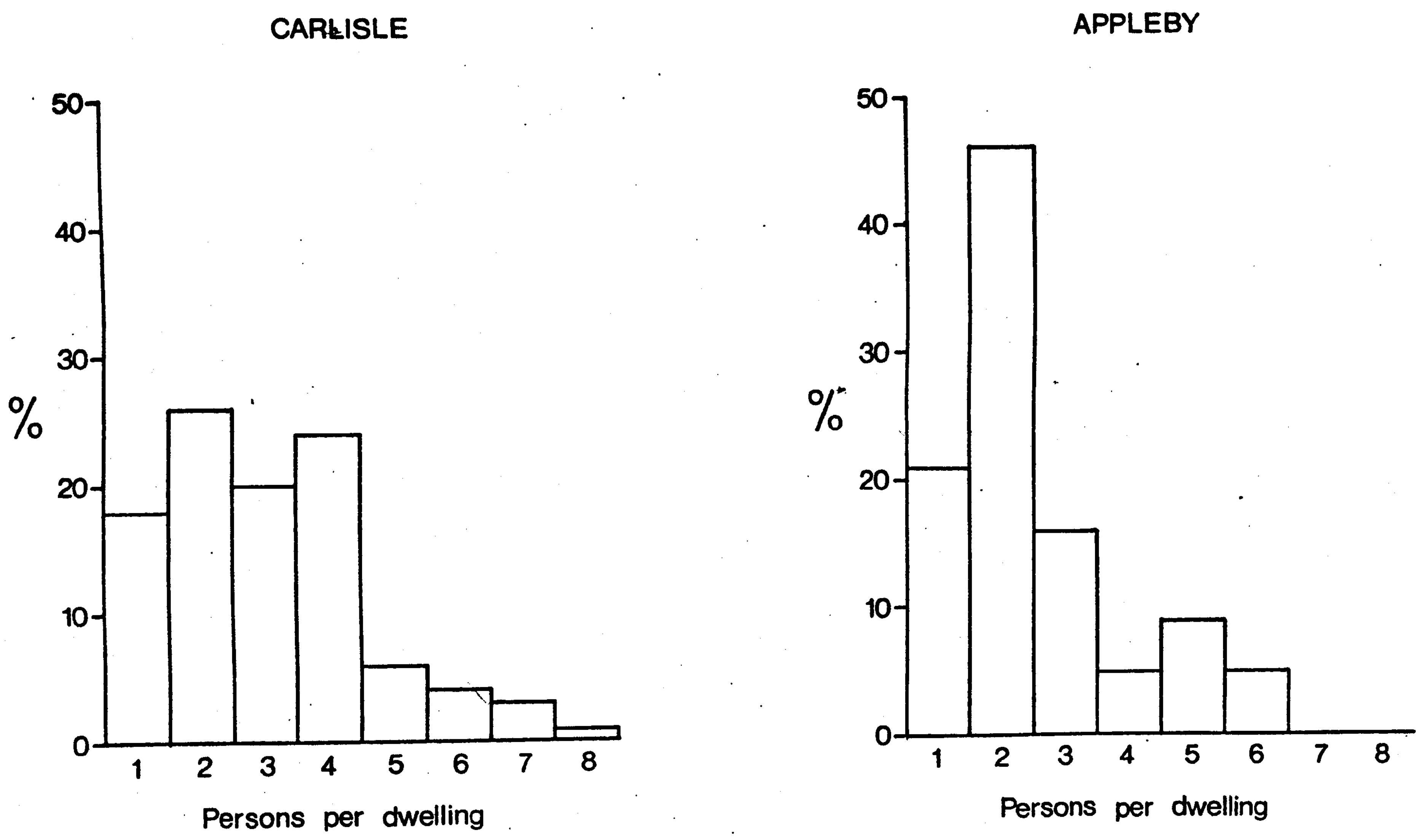


The majority of households contained four or less persons, and both distributions showed a peak at two (figure 7-5). The mean number of persons per dwelling in Carlisle was 3.0 compared to 2.5 in Appleby. If these figures are representative of the whole flood plain, between 1711 and 1773 people are at risk from flooding in Carlisle (allowing for the standard error) and approximately 123 in Appleby. The difference in the two distributions was significant at the 0.0158 level, well within the 95% confidence limits.

However, it was noticeable that the total number of persons per dwelling was inversely related to the age of the respondent. A chi squared test on the Carlisle data, indicated, at a very high level of probability, that the two variables were significantly different, which was further confirmed by a correlation coefficient of -0.5667 significant at the 0.001 level. Thus, younger persons tend to live in large households, while older residents frequently live alone. This is most important to any consideration of flood response, since older residents are often less capable of remedial action in the event of a flood than younger residents. In Appleby, precisely the same relationships were found, with a correlation coefficient of -0.6645 (significant at 0.001).

These family structures were further subdivided into number of adults and children within each household. Table 7-8 shows that the majority of dwellings contained two adults, sixty-three percent in Carlisle and sixty-eight percent in Appleby. Again, if these figures are extended to the complete flood plain, approximately 1200 adults in Carlisle and 98 in Appleby would be living in flood prone areas. However, a chi

Fig. 7-5. Number of persons per household in Carlisle and Appleby.



squared test did not show any significant difference between the two responses. The proportion of families with children, on the other hand, did produce significantly different results. A chi squared test of families with, and those without children between Carlisle and Appleby produced a significance level of 0.0135; enough to suggest the two were different at the 95% level of confidence. Fifty-four percent of households in Carlisle did not contain children, compared to seventy-five percent in Appleby (table 7-9).

The only other aspect of family structure incorporated in the questionnaire survey was the number of family groups living in each residence. However, since only five percent of the household in Carlisle and none in Appleby contained more than one family, this variable was excluded from any further analyses (table 7-10).

Length of residence in the area

The length of residence of respondents both in Carlisle and Appleby varied quite considerably, as shown in table 7-11. For example, fourteen percent of Carlisle respondents had lived in the same house for over twenty-five years, compared to the forty-three percent who have moved onto the flood plain in the six years since the last flood. In Appleby, thirty percent of residents had lived in the same dwelling for more than twenty-five years and forty-one percent were newcomers. Although the mean length of residence varied between the two communities, 17.82 years in Appleby and 12.86 years in Carlisle, this difference was not significant according to a chi squared test on the two

TABLE 7-8

Residents : Number of adults per household

Total per dwelling	Carlisle		Appleby		Total	
One	39	18%	9	21%	48	18%
Two	137	63	30	68	167	64
Three	29	13	4	9	33	13
Four	11	5	0		11	4
Five	2	1	1	2	3	1
Total	218	100	44	100	262	100

TABLE 7-9

Residents : Number of children per dwelling

Total per dwelling	Carlisle		Appleby		Total	
None	117	54%	33	75%	150	57%
One	35	16	4	9	39	15
Two	42	19	2	5	44	17
Three	12	6	3	7	15	6
Four	10	5	2	5	12	5
Five	2	1			2	1
Total	218	101	44	101	262	101

TABLE 7-10

Residents : Family groups per dwelling

	Carlisle		Appleby		Total	
One	208	95%	44	100%	252	96%
Two	10	5	0		10	4
Total	218	100	44	100	262	100

TABLE 7-11

Residents : Length of residence in dwelling

	Carlisle		Appleby		Total	
Up to 6 years	93	43%	18	41%	109	42%
7 to 12 years	48	22	2	5	52	20
13 to 18 years	30	14	7	16	37	14
19 to 24 years	16	7	4	9	20	8
25 years and over	31	14	13	30	44	17
Total	218	100	44	100	262	101

distributions.

The correlation between length of residence in the area and the age of the respondent, (0.5365 significant at the 0.001 level) was not sufficiently high to account completely for the total length of residence, and hence both variables were maintained in the analyses. In Appleby there was no significant correlation between the two variables which further supported the evidence to maintain both variables in the analyses.

Other social variables included in the questionnaire survey were occupation type and level of education of the head of household, and finally the tenure of the household. Research hypotheses again suggested that these variables could be important determinants of residential behaviour on the flood plain.

Occupation of the head of household

Table 7-12 shows the proportion of head of households in each occupation category for Carlisle and Appleby. Both communities indicate a peak of skilled manual workers and similar levels of semi skilled, clerical and professional workers. (A chi squared test showed no significant difference between the two). In this respect, therefore, the two populations were remarkably similar.

TABLE 7-12

Residents : Occupation of head of household

	Carlisle		Appleby		Total	
Self employed	12	6%	4	9%	16	6%
Semi-skilled	22	10	5	11	27	10
Skilled manual	64	29	14	32	78	30
Commercial Traveller	9	4	0		9	3
Clerical worker	25	12	5	11	30	11
Manager	29	13	3	7	32	12
Professional	31	14	6	14	37	14
Other	26	12	7	16	33	13
Total	218	100	44	100	262	99

TABLE 7-13

Residents : Age at which Head of Household finished fulltime education

	Carlisle		Appleby		Total	
15 years and under	127	58%	34	77%	161	61%
16 years	40	18	8	18	48	18
18 years	25	11	0		25	10
21-22 years	15	7	2	5	17	6
Other	8	4	0		8	3
Did not know	3	1	0		3	1
Total	218	99	44	100	262	99

Education level of head of household

Differences in the level of full time education reached by the head of household were significant at the ninety-five percent level of confidence. For instance, only five percent in Appleby had been educated beyond the age of sixteen years, which compared to twenty-three percent of respondents in Carlisle (table 7-13). Seventy-seven percent and fifty-eight percent of residents in Appleby and Carlisle respectively, completed their full time education by the time they were fifteen years old.

Tenure of household

Tenure of household was included because it was purported that home owners would be more inclined to undertake protective measures to prevent structural damage to their property, than tenants. The survey found that only ten percent of Carlisle residences were rented, which compared to a majority of dwellings in Appleby, where fifty-five percent were rented. This difference between the tenure of residences in the two centres was significant at the 0.999 level of probability. The rented accommodation in Appleby was essentially a combination of the Local Authority housing and the Castle estates.

In conclusion, the social characteristics of the flood plain populations in Carlisle and Appleby differed quite significantly in several aspects, particularly those variables relating to the proportion of house types in each settlement, the elements of family structures, and the level of education attained by the head of household. However, the latter two factors essentially reflects the more elderly nature of those residents in Appleby, compared to Carlisle.

The social characteristics found in both Carlisle and Appleby were similar in many respects to those found in other areas, in similar types of survey. For instance, the negatively skewed age distributions, apparent in both communities, has also been found amongst the flood plain population at Shrewsbury where sixty-two percent of respondents were over fifty years old. (Harding and Parker 1972), in North Gloucestershire where forty-nine percent were over forty-five, (Penning-Rowsell 1972) and in Atlanta, Georgia where forty-eight percent of respondents were over forty-five years old (James et al 1971). One possible explanation of this common feature is that flood plain residences frequently represent the older areas of cities, a relic of the vast urban expansion during the industrial revolution, and hence do not attract the younger families as much as the newer housing estates. The difference between the smaller centres and the larger cities also reflects the general movement of younger persons away from the small settlements towards the large towns.

Length of residence on the flood plain also showed a degree of similarity with other studies, particularly that undertaken in Shrewsbury by Harding and Parker, where sixty-two percent of respondents had lived in the same dwelling for over five years. In the Atlanta studies, however (James et al 1971, 1974) found residents less willing to remain in the same property for such long periods, which was probably a reflection of the greater frequency of flooding in these areas compared to the British studies. This argument is supported by further evidence from different zones within Atlanta, for on the flood plain only forty-one percent of respondents had lived in the same house for more than seven years, which compared to fifty and fifty-three percent in the other two areas.

These characteristics of the flood plain residents, collected by the questionnaire surveys in Carlisle and Appleby, were used to test the research hypotheses on the perception and behaviour of flood plain residents to the flood hazard as well as adjustments to the problem. Details are given in chapter eight.

(2) Extent of flood experience

Two types of questions were asked of the flood plain residents in the collection of statistics on flooding. Questions seven to nine and sixteen provided information of the degree of flood experience amongst the respondents, while questions ten to fifteen and seventeen to twenty-three extracted more specific data on residential behaviour during and after the 1968 flood event.

Experience

The questionnaire survey showed that only fifty-seven percent of respondents in Carlisle and fifty-nine percent in Appleby had actually lived in the area during a flood, and that fifty-five percent and fifty-nine percent respectively had personal experience of flooding (tables 7-14 and 7-15). This left a substantial minority in each community (forty-five percent in Carlisle and forty-one percent in Appleby) who were living in a flood prone area, but had yet to experience personally inundation of their property. The evidence suggests that a large number of families, therefore, have moved away from the flood plain since the last flood in 1968, although whether this was a result of the flooding, or a culmination of other factors is not clear. However, there was a difference between the proportion of non-experienced residents in the two research centres, and hence it would appear that flood frequency is not an important factor in this case. (A chi squared test of the data for question eight on flood experience indicated no significance difference between the two responses).

TABLE 7-14

Residents : Personal experience of flooding in the neighbourhood

	Carlisle		Appleby		Total	
Yes	125	57%	26	59%	151	58%
No	93	43	18	41	111	42
Total	218	100	44	100	262	100

TABLE 7-15

Residents : Personal experience of flooding in building

	Carlisle		Appleby		Total	
Yes	120	55%	26	59%	146	56%
No	98	45	18	41	116	44
Total	218	100	44	100	262	100

TABLE 7-16

Residents : Knowledge of the flood problem by those not flooded

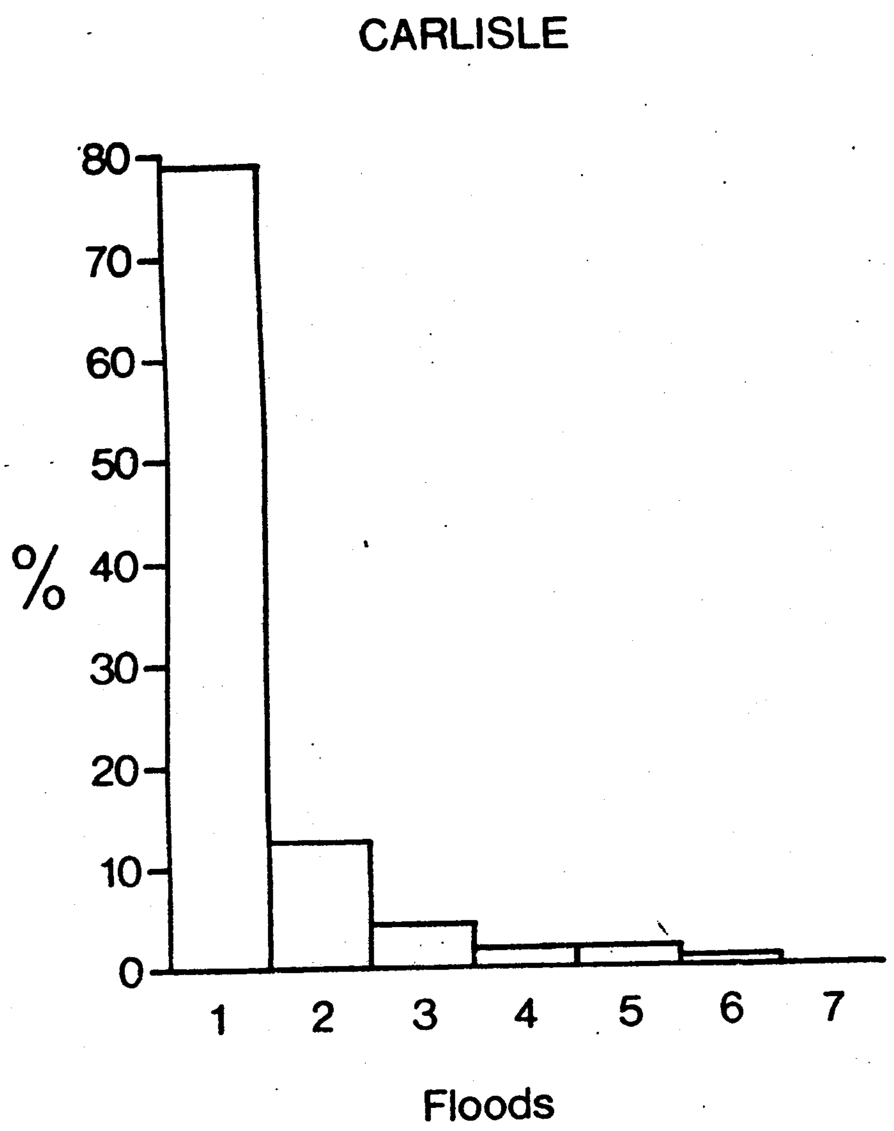
	Carlisle		Appleby		Total	
Knew of problem	86	92%	18	100%	104	94%
Did not know of problem	7	8	0		8	7
Total	93	100	18	100	111	101

For many people in Carlisle, one flood would appear to represent too great a risk and hence they promptly move away from the hazard area.

A further question was asked of those residents without personal experience of flooding, to assess the degree of knowledge of the flood hazard. The response, shown in table 7-16, indicates that the majority of the populations of both communities were aware that the area had flooded in the past. Nevertheless, eight percent of the respondents in Carlisle were totally ignorant of the potential hazard. This proportion of uninformed residents on the flood plain is likely to increase gradually, at least until another flood alters the whole perception of the flood plain population.

Table 7-17 shows the degree of flood experience of respondents in Carlisle and Appleby, while figure 7-6 compares the frequency of flooding experienced at each centre. Clearly, there is a marked difference between the flood experiences of the two communities. While both centres have a similar proportion of residents without personal experience of flooding, the number of floods experienced by the rest of the respondents contrasts quite significantly. In Carlisle for instance, seventy-nine percent of those flooded in the past have experienced just one flood, while only eight percent have experienced three or more. In Appleby, the degree of experience was almost reversed, with twelve percent experiencing one flood and eighty percent three or more. As a result, the mean number of floods experienced by the flood plain residents varied between 0.75 in Carlisle and 2.5 in Appleby. A chi squared test on these reponses showed that the two were

Fig. 7-6. Number of floods experienced by respondents in Carlisle and Appleby.



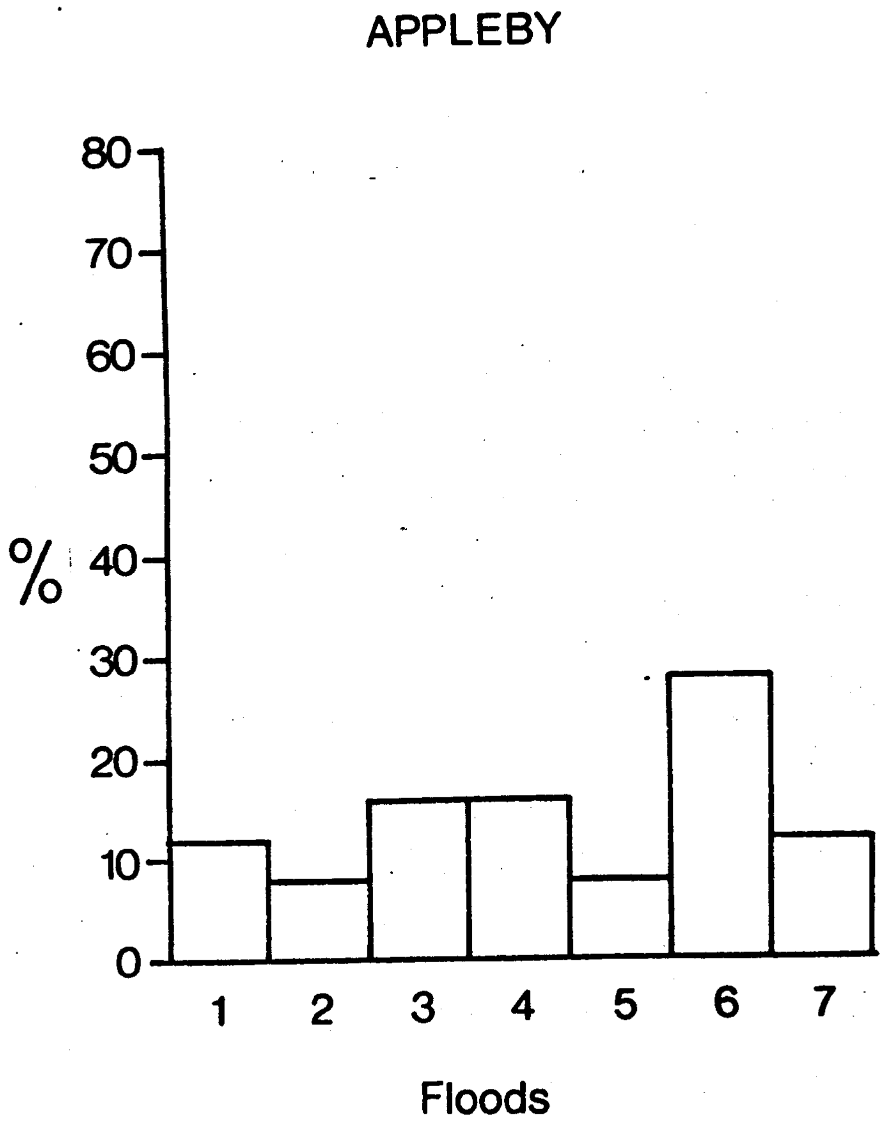


TABLE 7-17

Residents : Frequency of flooding experience

	Carlisle		Appleby		Total	
None	98	45%	18	42%	116	44%
One	95	44	3	7	98	38
Two	15	7	2	5	17	7
Three	5	2	4	9	9	3
More than three	5	2	16	37	21	8
Total	218	100	43	100	261	100
Did not know			(1)			

TABLE 7-18

Residents : Depth of flood water (1968)

	Carlisle		Appleby		Total	
Outer walls	41	34%	3	12%	44	30%
Floor boards	24	20	2	8	26	18
1 to 15 cm	26	22	2	8	28	19
16 to 30 cm	18	15	2	8	20	14
31 to 75 cm	6	5	4	15	10	7
Over 75 cm	5	4	13	50	18	12
Total	120	100	26	101	146	100

significantly different at the 0.999 level of probability.

The number of floods experienced was essentially a product of two variables, the length of residence on the flood plain and the frequency of flooding in that area. Unfortunately, in Carlisle and Appleby the areas defined by the questionnaire survey were not specific enough to distinguish between zones of different flood probability. However, all three areas in Carlisle were flooded extensively in 1968, as shown in plates 17, 18 and 19. (Unfortunately these photographs were taken after the peak flood levels). Plates 6 and 7 show the flooding along the Sands in Appleby, although these pictures were also taken after the peak had passed.

Length of residence on the flood plain proved more significant than different areas within the flood plain, in providing an indication of the number of floods experienced. For example, the correlation between length of residence and number of floods experienced was 0.4528 in Carlisle and 0.4593 in Appleby using the Spearman rank correlation coefficient. Both these were significant at the above the 95% level of confidence. Figures 7-7 and 7-8 illustrate this strong positive correlation between the two variables more clearly. Therefore, flood frequency and length of residence do appear to explain the different extent of flood experience between the flood plain residents, and in particular between the two research centres. The greater flood experience in Appleby was apparently the product of the greater length of residence and the higher flood frequency in the town. Nevertheless, it should also be noted that the difference between the length of

Fig. 7-7. The correlation between the number of floods experienced and the length of residence in Appleby.

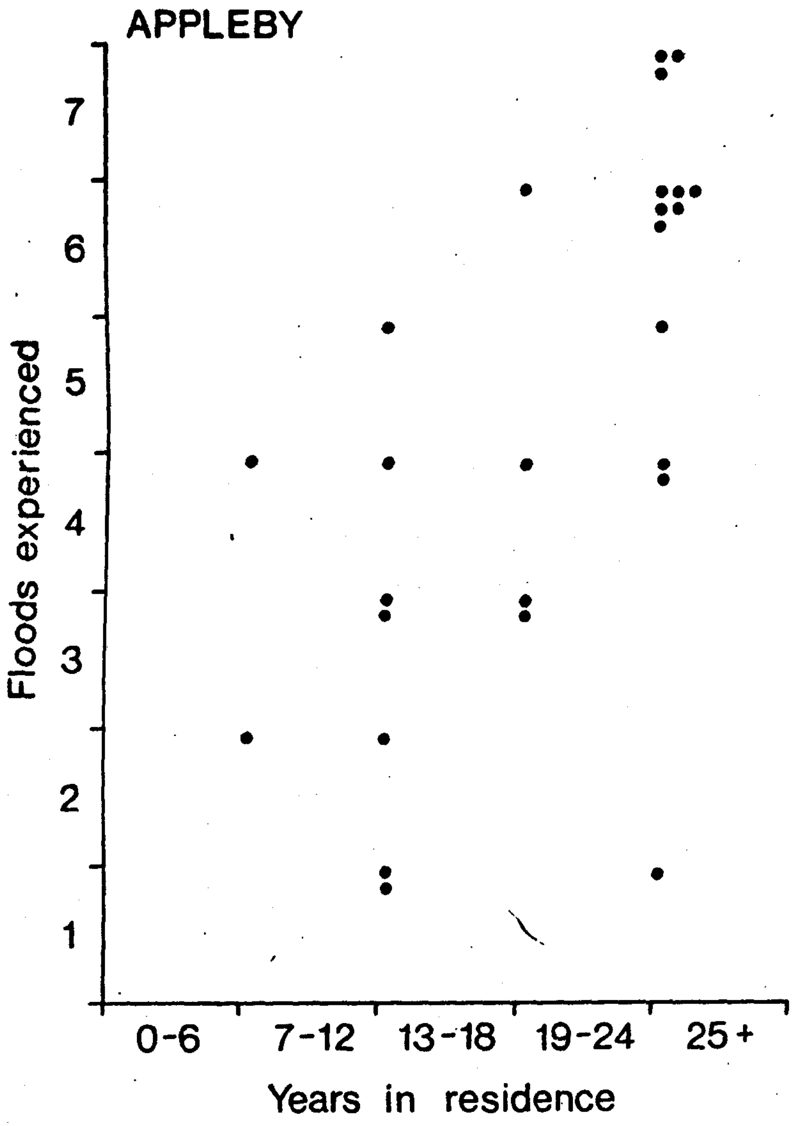
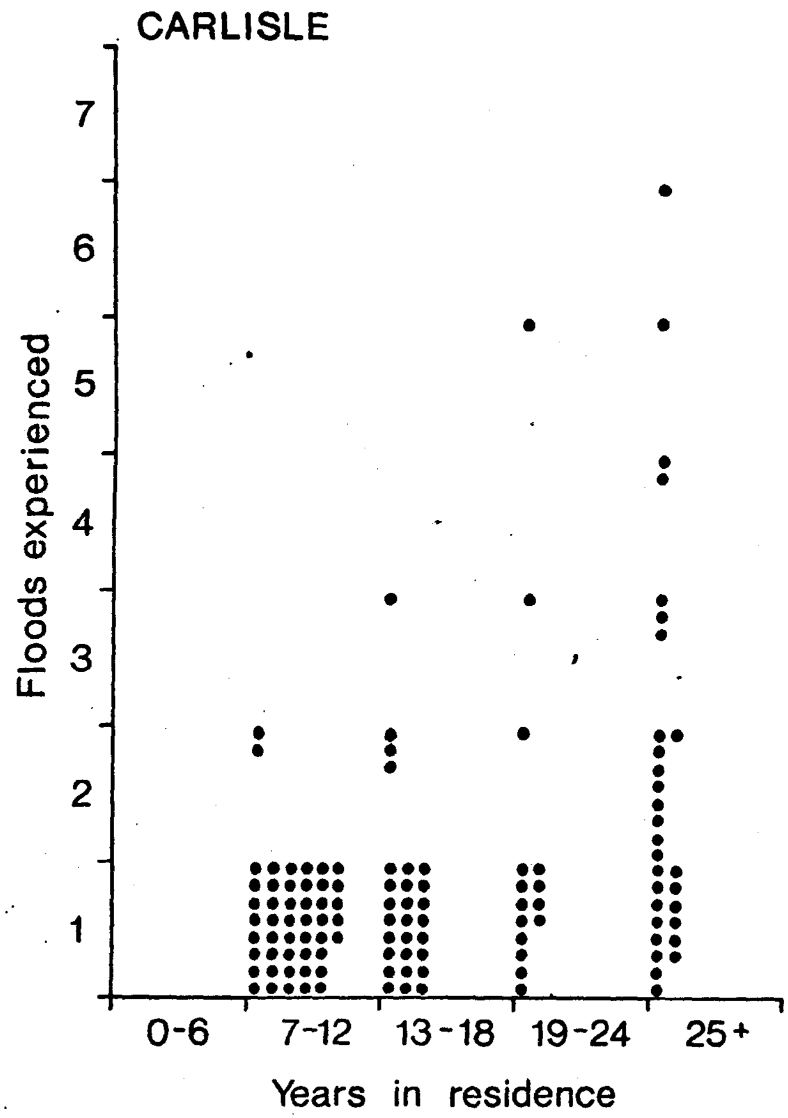


Fig. 7-8. The correlation between the number of floods experienced and the length of residence in Carlisle.



residence in each community was not statistically significant, and hence the different degree of flood experience may be primarily attributed to the variation in flood frequency.

Several other questions on flood characteristics were incorporated into the questionnaire to obtain further details on the 1968 flood. Data were collected on such variables as depth, duration and damage caused by the 1968 event, and again comparisons were made between the extent of flooding in the two communities.

Depth of flooding

The depth of flood experienced in 1968 varied in extent, from water merely surrounding the exterior walls of buildings to the internal inundation of property by over one metre of water. In Carlisle a large number of families and homes were affected in 1968, although only sixty-six percent of these respondents suffered water inside their property. However, if this proportion was extrapolated to the whole flood plain, there would have been between 368 and 388 dwellings (allowing for the 1.8% standard error) with flood water inside, in 1968. Nevertheless, twenty-four percent of respondents reported flood depths in excess of fifteen centimetres (table 7-18) which would represent between 128 and 148 dwellings.

The depth of flooding experienced in Appleby was generally greater than that in Carlisle, due in part to the closer proximity of dwellings to the river channel,and again a chi squared test suggested the two experiences were significantly different at the 0.999 level of probability. For example, in

Appleby fifty percent of respondents reported flood depths of greater than seventy-five centimetres compared to only four percent in Carlisle.

Duration of flooding

The statistics collected on the duration of the flood in 1968 did not show the differences between the two communities anticipated from the earlier theoretical studies. It was suggested that repondents would be less likely to remember the precise timing of a flood event after a lapse of six years, whereas in contrast, flood depths are more easily recalled, and in the survey were frequently described by the respondent in great detail almost with an element of pride. The duration variable, therefore, now probably represents the perceived, rather than actual duration of the 1968 flood. Table 7-19 shows the similarity between the responses of the two communities. While the mean flood duration reported was greater in Carlisle than Appleby, 12.86 hours to 10.27 hours, the chi squared test suggested there was no significant different between the two.

The relationship between flood duration and flood depth, which has been described in studies by White (1964), Penning-Rowsell (1972), Chambers (1973) and Parker (1976) (see chapter three) was also tested in Carlisle and Appleby, based on the questionnaire data. In Carlisle, the two variables produced a Spearman rank correlation coefficient of only 0.1006 which had a level of significance of 0.298. Clearly, this was insufficient to suggest any significant relationship between flood depth

TABLE 7-19

Residents : Duration of flood (1968)

	Carlisle		Appleby		Total	
1 to 6 hours	37	34%	5	23%	42	32%
7 to 12 hours	57	52	13	59	70	53
13 to 24 hours	6	6	4	18	10	8
Over 24 hours	9	8			9	7
Total	109	100	22	100	131	100
Did not know	(11)		(4)			

TABLE 7-20

Residents : Losses incurred in 1968 by Respondents

	Carlisle		Appleby		Total	
None	60	51%	2	8%	62	44%
Less than £100	36	31	12	50	48	34
Between £100,£250	14	12	7	29	21	15
Between £250,£500	7	6	3	13	10	7
Total	117	100	24	100	141	100
Did not know	(3)		(2)			

and duration in Carlisle. Although previous studies had found a positive correlation between the two, the absence of a relationship in this case does not challenge the theories, particularly as a result of the problems of collecting statistics on flood duration. In Appleby, the data conformed to these previous studies, for a positive correlation was found between depth and duration of 0.7767, which was significant at the 0.001 level. Therefore in Appleby, at least, it would appear that increasing flood depths are related to floods of longer duration. It may be that Appleby residents more accurately recall the flood characteristics, because of their generally greater experience of the problem.

Flood damage

Table 7-20 shows the financial losses suffered as a result of the 1968 flood, by residents in Carlisle and Appleby. (The monetary statistics are based upon 1968 values). In Carlisle, just over 50% of respondents reported no significant monetary losses and only 6% estimated losses between £250 and £500. The mean loss per household was approximately £79, which in terms of the whole flood plain would mean residential losses in 1968 somewhere in the region of £45,000. (This may have been larger given that some houses in the Caldewgate area, occupied during the flood, are now derelict, and hence were not included in the questionnaire survey). By comparison, the mean flood loss per household in Appleby was considerably higher at £163. Only 8% of those flooded reported no financial loss, while 13% put their losses in excess of £250. The total residential losses from Appleby, therefore, would probably have been around £8,000 in 1968.

The estimated losses from flooding in the two communities was significantly different, according to a chi squared test, at the 0.995 level of probability. The reason for the proportionally greater losses in Appleby is partially explained by the differences in the types of flooding experienced at the two centres. For instance, there was a high positive correlation between flood losses and flood depth at both Carlisle and Appleby (see figures 7-9 and 7-10), which were both significant at the 0.001 level. Data from both centres, therefore, confirmed the findings of previous studies, that increasing flood depths are directly related to greater flood losses. Furthermore, since Appleby residents generally experienced greater flood depths than Carlisle, it follows that they would also suffer proportionally larger flood losses (given a certain degree of similarity between the social characteristics of the two communities - see above).

A positive correlation was also found between flood duration and flood losses, significant at the 0.001 level, in Appleby but not in Carlisle data. Figure 7-11 shows the full relationships found between the three variables of flood depth, flood duration and flood losses. The obvious anomaly between the two sets of data is the lack of a significant correlation in Carlisle of flood duration, with either depth or loss. While this may be a true reflection of the Carlisle situation, whereby flood depth is the sole determinant of flood losses, it is highly unlikely given the results from both Appleby and from previous studies.

Fig. 7-9. The correlation between flood depth and reported flood damage in 1968.

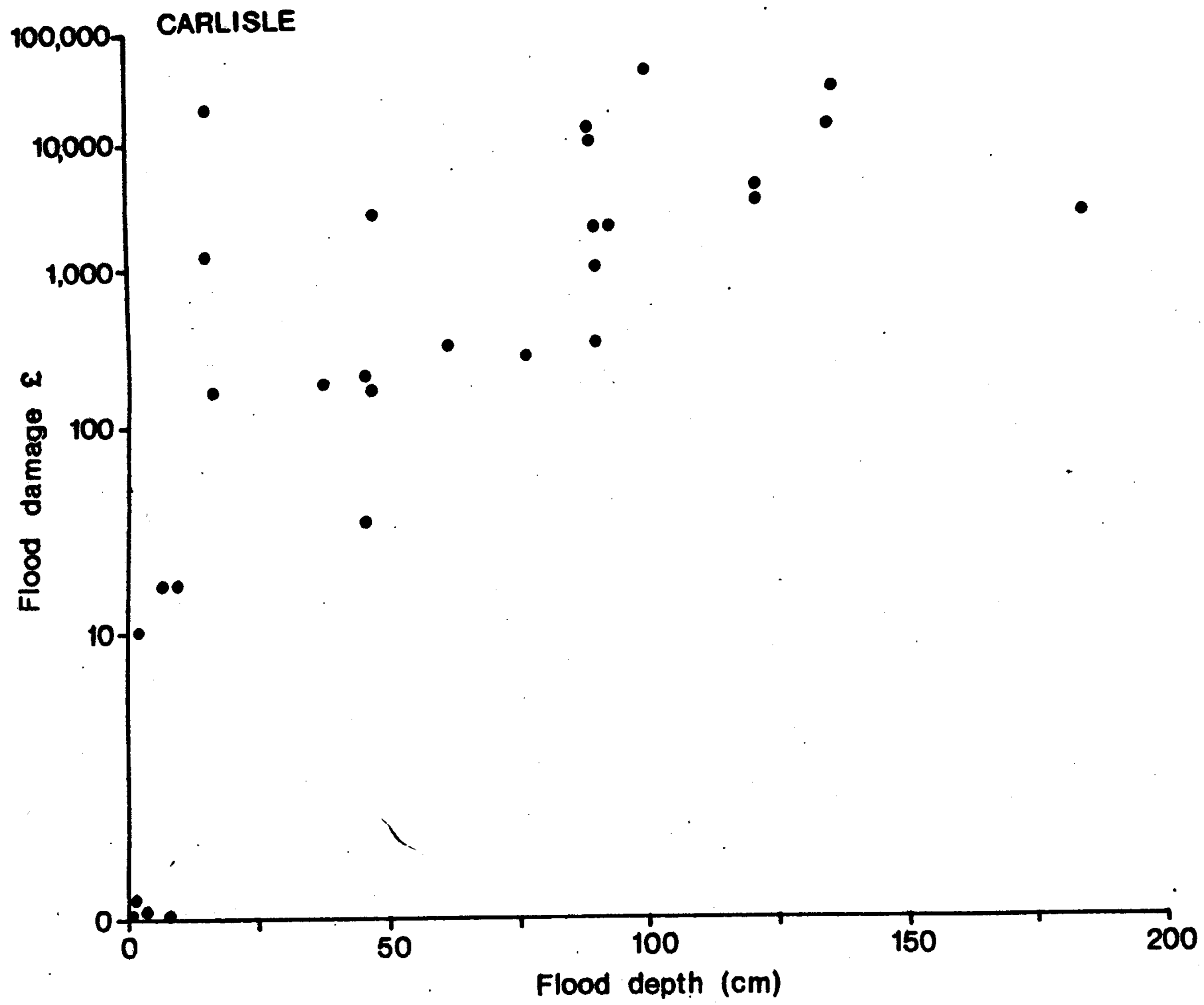
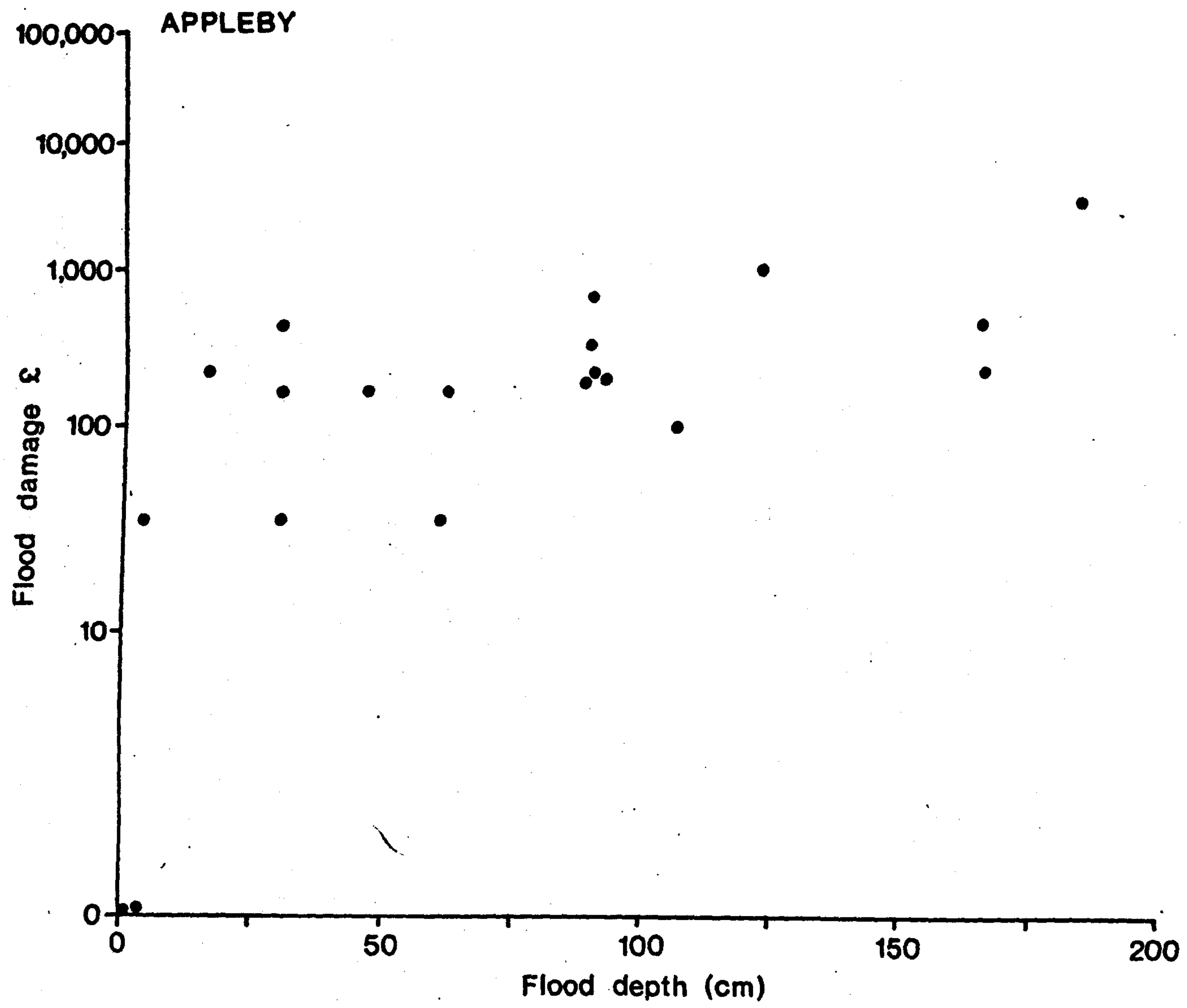


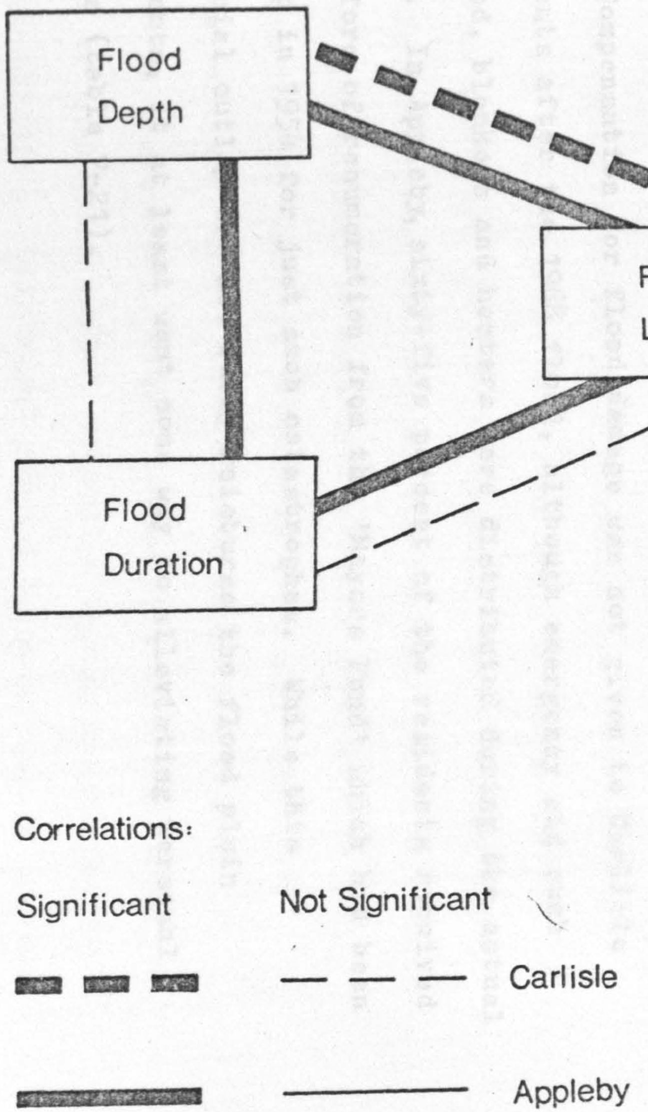
Fig. 7-10. The correlation between flood depth and flood damage in 1968.



More serious flood damage was prevented by the implementation of certain remedial actions by the flood plain residents, prior to, and during the flooding. These schemes, described in greater detail below, included such measures as the employment of sandbags to prevent water entering property, and the removal of valuable possessions to higher levels. The chi squared test suggested that there was a significant difference between those residents who employed these measures and found them useful, and those who found them of no value, the former, as expected, generally suffering less extensive damage than the latter. In Carlisle, such significant differences were found in the responses from those residents employing temporary measures, using the flood warning, and removing valuables, while in Appleby only temporary measures and removing valuables produced significantly different results. The lack of time for a flood warning precluded this measure in Appleby.

Several other social variables were also believed to influence the extent of flood damage only by indirect means. For example, increasing age was purported to decrease the potential efficiency of undertaking remedial measures, particularly heavy activities, in the event of a flood. While the other social characteristics were believed to be an indication of social class, and hence indicate the potential value of property at risk to flooding. However, in both Carlisle and Appleby the chi squared tests found no significant differences to suggest this was the case, except in Appleby where increasing age corresponded to greater flood losses.

Fig. 7-11. The full relationship between flood depth, flood duration and flood damage in Carlisle and Appleby during the 1968 flood.



CARLISLE

R / S	Depth	Duration	Losses
Depth		0·1006 (0·298)	0·7636 (0·001)
Duration	0·7767 (0·001)		0·0881 (0·367)
Losses	0·7207 (0·001)	0·7712 (0·001)	

APPLEBY

R= Spearman rank correlation coefficient

S= Significance

Other aspects of the 1968 flood were also believed to play a part in influencing residential attitudes and behaviour. For instance, initial hypotheses suggested that help during a flood event from various organisations may have a detrimental effect on individual activities during future flooding, particularly if a resident presumed that such aid would be forthcoming. Similarly, experience in the use of various remedial measures prior to a flood was believed to be a significant factor in future behaviour patterns. It was postulated that a resident would repeat successful remedial measures, and hence have less fear of future flooding than a resident who in the past had unsuccessfully protected his property from flooding. Both these groups of variables were included in the questionnaire to see the extent of help and remedial action in 1968, while further analysis of the significance of these factors is described in chapter eight.

Compensation

Compensation for flood damage was not given to Carlisle residents after the 1968 flood, although emergency aid such as food, blankets and heaters were distributed during the actual event. In Appleby, sixty-five percent of the residents received some form of renumeration from the 'Mayors Fund' which had been set up in 1954 for just such catastrophes. While this financial outlay did not fully reimburse the flood plain residents, it at least went some way to alleviating personal losses (table 7-21).

Help from various organisations

The proportion of respondents receiving help from various organisations, such as the police, the Salvation Army, and the Womens' Royal Voluntary Service during the 1968 flood is recorded in tables 7-22 to 7-27. For example, fifty-eight percent of Carlisle respondents and sixty-two percent in Appleby did not receive any help from the police, whereas thirty-seven percent and thirty-nine percent respectively found the police helpful to some extent. This would indicate only a low level of involvement by the police in the private affairs of the flood plain resident, except in the case of emergencies, such as old people living alone. Nevertheless, only a small proportion of residents in Carlisle were dissatisfied with the activities of the police force, and none in Appleby.

The Womens' Royal Voluntary Service only successfully helped six percent of the Carlisle flood victims and twenty percent of those in Appleby. The Salvation Army, on the other hand, was quite active in Carlisle, with over fifty percent of the respondents reporting help to some degree. No one in Appleby was helped by the Salvation Army, although several residents mentioned the British Legion. Help from the local councils also varied between the two communities, with fifty percent of residents in Appleby receiving some form of aid, compared to only thirteen percent in Carlisle. The fire brigade were more active in Carlisle, where thirty-three percent of respondents, either had water pumped from their homes, or industrial heaters installed by the firemen to dry out the building. Only eight percent of residents in Appleby

TABLE 7-21

Residents : Compensation received for losses

	Carlisle		Appleby		Total	
Yes	0	-%	17	65%	17	12%
No	120	100	9	35	129	88
Total	120	100	26	100	146	100

TABLE 7-22

Residents : Police action 1968

	Carlisle		Appleby		Total	
Helpful	28	23%	3	12%	31	21%
Partly helpful	17	14	7	27	24	16
Not helpful	6	5	0		6	4
No help received	69	58	16	62	85	58
Total	120	100	26	101	146	99

TABLE 7-23

Residents : Womens Royal Voluntary Service action 1968

	Carlisle		Appleby		Total	
Helpful	2	2%	2	8%	4	3%
Partly helpful	5	4	3	12	8	5
Not helpful	0		0		0	
No help received	113	94	21	81	134	92
Total	120	100	26	101	146	100

TABLE 7-24

Residents : Salvation Army action 1968

	Carlisle		Appleby		Total	
Helpful	46	38%	0	-%	46	32%
Partly helpful	14	12	0		14	10
Not helpful	2	2	0		2	1
No help received	58	48	26	100	84	58
Total	120	100	26	100	146	101

TABLE 7-25

Residents : Council action 1968

	Carlisle		Appleby		Total	
Helpful	5	4%	2	8%	7	5%
Partly helpful	11	9	11	42	22	15
Not helpful	4	3	0		4	3
No help received	100	83	13	50	113	77
Total	120	99	26	100	146	100

TABLE 7-26

Residents : Neighbours action 1968

	Carlisle		Appleby		Total	
Helpful	24	20%	5	19%	29	20%
Partly helpful	62	52	13	50	75	51
Not helpful	1	1	0		1	1
No help received	33	28	8	31	41	28
Total	120	101	26	100	146	100

TABLE 7-27

Residents : Fire Brigades actions 1968

	Carlisle		Appleby		Total	
Helpful	25	21%	2	8%	27	18%
Partly helpful	14	12	0		14	10
Not helpful	3	3	0		3	2
No help received	78	65	24	92	102	70
Total	120	101	26	100	146	100

were helped in this way, which is not surprising since the fire station itself was inundated. Finally, both communities reported a similar degree of help from their neighbours - approximately seventy percent. Thus, apart from the police and neighbours, the most significant help in Carlisle in 1968 came from the Salvation Army and the fire brigade, while in Appleby the local council and the Womens' Royal Voluntary Service were most active.

Remedial measures

The use of various remedial measures in the event of a flood and the relative success or failure of such actions is recorded in tables 7-28 to 7-32. Temporary measures, such as sand bagging doors and openings, to prevent the inundation of property by flood water, was a technique employed by forty-six percent of the flood victims in Carlisle. However, of these only four percent thought the measure was very helpful, whilst twenty-nine percent suggested the technique was of no value whatsoever. In Appleby, a similar trend was apparent with forty-three percent of those flooded employing the measure, and only four percent stating they found the measure very helpful. This quite high failure rate reflects the general lack of knowledge of effective flood proofing measures, which according to Sheaffer (1967) can significantly reduce flood losses.

One further significant aspect of the employment and relative effectiveness of temporary measures in 1968 was the strong correlation with flood depth. Both in Carlisle, and in Appleby, the chi squared test suggested that there was a significant difference between those respondents flooded to great depths and those flooded only to lower levels, and the reported effectiveness of temporary measures such as sand bagging. This response indicates that while such remedial measures may be highly inefficient in the centre of a flood where flood depths tend to be greater, on the periphery such schemes may be employed quite effectively.

In 1968 only twenty-nine percent of respondents in Carlisle and fifteen percent in Appleby received an official flood warning. Probably the main reason for this relatively small proportion getting prior warning was the timing of the event. In Appleby, there is little time for warning at normal times (see chapter six) but in 1968 the flood reached it peak early on a Sunday morning, which reduced the chances of a warning being raised. In Carlisle, the flood similarly took many people by surprise, and there were numerous stories of residents waking up to find their houses flooded. As the flood spread over wider areas so the alarm was raised, but not before considerable damage had already been done.

The most popular and effective remedial measure in 1968 was the removal of valuables to a higher level. This was undertaken by forty-nine percent of flooded respondents in Carlisle, while all those flooded in Appleby employed this measure to some extent. In this way, Appleby respondents appeared to be more adjusted to the hazard since they all undertook some form of effective action to reduce their flood losses, whereas a large proportion of Carlisle respondents did

TABLE 7-28

Residents : Personal action 1968 - Sandbagging

	Carlisle		Appleby		Total	
Very helpful	5	4%	1	4%	6	4%
Helpful	15	13	3	12	18	12
Not helpful	35	29	7	27	42	29
Did not use	65	54	15	58	80	55
Total	120	100	26	101	146	100

TABLE 7-29

Residents : Received 'official' flood warning

	Carlisle		Appleby		Total	
Very helpful	9	8%	4	15%	13	9%
Helpful	18	15	0		18	12
Not helpful	7	6	0		7	5
Did not receive	86	72	22	85	108	74
Total	120	101	26	100	146	100

TABLE 7-30

Residents : Removed valuables to higher level

	Carlisle		Appleby		Total	
Very helpful	36	30%	19	73%	55	38%
Helpful	23	19	7	27	30	21
Not helpful	0		0		0	
Did not use	61	51	0		61	42
Total	120	100	26	100	146	101

TABLE 7-31

Residents : Evacuated premises

	Carlisle		Appleby		Total	
Very helpful	16	13%	1	4%9	17	12%
Helpful	1	1	0		1	1
Not helpful	0		0		0	
Did not use	103	86	25	96	128	88
Total	120	100	26	100	146	101

TABLE 7-32

Residents : Other actions

	Carlisle		Appleby		Total	
Very helpful	15	13%	0	-%	15	10%
Helpful	1	1	0		1	1
Not helpful	0		0		0	
Did not use	104	87	26	100	130	89
Total	120	101	26	100	146	100

TABLE 7-33

Residents : Proportion of Respondents insured against flooding

	Carlisle		Appleby		Total	
Insured	150	69%	39	89%	189	72%
Not insured	36	17	4	9	40	15
Did not know	32	15	1	2	33	13
Total	218	101	44	100	262	100

nothing throughout the flood.

However, common to both communities was the significant difference between responses when controlled by flood depth. That is, those residents flooded to the greatest depths found this measure most helpful and also a larger proportion of such residents employed this technique. Other measures, such as evacuation of the premises were only employed by a small minority of the population.

As a final consideration of the extent of the individual response to the flood hazard in Carlisle and Appleby, respondents were asked whether they had taken out any flood insurance policies, or undertaken any permanent alterations to their property to prevent inundation by flood waters. The results of the questionnaire surveys indicated that sixty-nine percent of households in Carlisle, and eighty-nine percent in Appleby had some form of insurance. Seventeen percent and nine percent respectively were not covered by insurance, while residents in the remaining households were uncertain whether they were insured or not (table 7-33). The responses from the two communities were significantly different at the 0.975 level of probability according to a chi squared test. From the results therefore, it would appear that the greater frequency of flooding in Appleby had stimulated a more positive response to flood insurance than in Carlisle. In Builth Wells and Shrewsbury, Parker (1976) found that only thirty-five percent and twenty-seven percent respectively had taken out flood insurance. These figures correspond to estimations by Relph (1968) of a maximum fifty percent cover.

Residents with flood insurance were also asked when they had taken out the policy, before or after the last flood, to test the effect of the flood as a stimulous to individual response. In Carlisle, fifty-one percent of those residents with flood insurance had taken out the policy prior to the 1968 event compared to forty-six percent in Appleby. Only ten percent in Carlisle and eighteen percent in Appleby reported taking out insurance since the last flood, although a further thirty-nine percent and thirty-six percent respectively could not remember when the policy had been taken out (table 7-34).

The second individual response, flood proofing, was believed to be implemented only where flooding was perceived as a major hazard, and where there had been only limited authoritarian response to the problem. To a certain extent, this was confirmed by the response to a question on flood proofing, as shown in table 7-35. Only three houses in Carlisle had been protected from flooding in this way, and even this had been restricted to minor adjustments such as the blocking of air vents, and the building of low retaining walls. In Appleby, where the flooding is a more frequent problem, and where there has been no authoritarian response, the individual response has been greater. Eighteen percent of Appleby respondents had implemented some form of individual adjustment to the hazard. Several residents, for instance, had designed doorways so that boards could be slotted into place and act as temporary retaining structures in the event of a flood. One resident had even gone so far as cementing a board approximately forty centimetres high, across the doorway of the house to prevent

TABLE 7-34

Residents : Proportion of Respondents with insurance who started the policy before 1968.

	Carlisle		Appleby		Total	
Before 1968 flood	76	51%	18	46%	94	50%
After 1968 flood	15	10	7	18	22	12
Did not know	59	39	14	36	73	39
Total	150	100	39	100	189	101

TABLE 7-35

Residents : Proportion of dwellings floodproofed

	Carlisle		Appleby		Total	
Floodproofed	3	1%	8	18%	19	7%
Not floodproofed	215	99	36	82	243	93
Total	218	100	44	100	262	100

Plate 2I. Appleby: The Sands during normal river flow.

Plate 22. Appleby: The permanent flood proofing measure employed by an Appleby resident. This board has been cemented into place to prevent flood water entering the property.

flood waters inundating the property. (See plate 22). The difference in the response from the two centres was again significant at the 0.995 level of probability, indicating a greater individual response to the flood hazard in Appleby than Carlisle.

In conclusion, a large amount of data has been generated both on the historical aspects of flooding in Carlisle and Appleby, and on the 1968 event in particular, while the latter two variables have looked at the individual response before and after the event. While the straight forward analyses of the responses to these questions has described the residential behaviour during a flood, many of the variables were believed to influence significantly future decision making through the medium of experience. (Further analyses of these results can be found in chapter eight). However, probably the most important factor to emerge at this point is the greater individual response in Appleby, where there has been less authoritarian action in the past, and also a greater frequency of flooding. The difference in social characteristics between the two centres was less noticeable, being confined to house types and the elements of the family structure. Both communities exhibited similar types of residents in terms of age and length of residence in flood prone areas.

CHAPTER EIGHT

PERCEPTION AND BEHAVIOUR OF FLOOD PLAIN RESIDENTS IN CARLISLE AND APPLEBY

Introduction

Whereas the preceding chapter was concerned with the past adjustments to the flood hazard, and the characteristics of the flood plain population, this chapter examines the attitudes and behaviour of flood plain residents and business-men towards perceived future flood problems. Data for this further analysis were collected by the same questionnaire surveys (Appendix II) and similar statistical techniques were employed in testing the relationships between the different variables. The principal aim of this aspect of the study was to improve the understanding of individual decision making and response to the flood hazard, that is to determine which particular factors are most influential in governing flood plain behaviour. The final conclusion examines these findings with respect to the theoretical model (figure 4-1) proposed in the research hypotheses on flood plain decision-making.

Essentially this chapter attempts to explain flood plain behaviour of residents. It was purported in the research hypotheses that certain independent factors would interact in various ways to influence a respondent's conception of the flood problem. To test these basic hypotheses, the relationships between the independent factors and those variables associated with perception and behaviour were analysed for significant trends or filiation. The objective of this analysis was to produce a predictive model of flood plain decision making by classifying residents and business-men into given 'types' according to established relationships between dependent and independent variables.

To study residential perception and behaviour patterns, three groups of questions were incorporated in the questionnaire

(1) Perception of the flood hazard

(2) Awareness of the Authoritarian response to the flood hazard.

(3) Perceived response to the flood hazard by the individual.

1. Perception of the flood hazard

The research hypotheses purported that perception of the flood hazard was considerably more important than the actual flood hazard because the individual would respond according to his beliefs, no matter to what extent these beliefs were at variance with the real situation. In a study of flood plain behaviour patterns, therefore, perception of the hazard is of utmost importance, and for this reason, much attention is devoted to this aspect of the research.

Three groups of questions pertaining to the perception studies were included in the questionnaire:

(i) general environmental perception.

(ii) Perceived future flood problems.

(iii) Degree of fear of the flood hazard.

(i) General Environmental Questions

The first two questions in the survey were included both to"warm-up" the respondent, and to put the flood problem into perspective as far as other environmental hazards in the area were concerned. Respondents were requested to state both the perceived advantages and disadvantages of living in the particular area. While the question on advantages had little direct value to the survey, the disadvantages cited by the respondents provided an early indication of the extent of the flood problem, as perceived by the individual resident. In Carlisle, the largest single disadvantage was traffic, mentioned by twenty-five percent of respondents, followed by trouble at the football ground (sixteen percent), and with only three percent perceiving flooding to be a disadvantage. Thirty-eight percent of respondents reported no disadvantages with the area at all. However, this sort of response distribution had been anticipated, since the day to day events, such as traffic problems are more likely to be reported as a disadvantage than other events, such as flooding, which occur less frequently. Hence, the degree of annoyance of a problem is related directly to the frequency of the event.

In Appleby, twenty-seven percent reported that flooding was a problem, twenty-one percent complained about the lack of public transport to larger centres, and thirty-nine percent of the flood plain residents stated that there were no disadvantages. This response differed quite significantly from that in Carlisle due to the contrasting problems and environmental conditions at the two centres. The large proportion mentioning flooding clearly reflects these differences, both of the greater frequency of the event, and the closer affinity of Appleby residents to the River Eden, than Carlisle residents.

Residents of both communities were also requested to evaluate the general living conditions of the area (question three) which provided an opportunity for the respondent to weigh up the advantages against disadvantages of living in the area. In Carlisle, fifty two percent stated that the area was very good, forty-five percent that the area was fairly good and only three percent said it was poor. A slightly different response was returned by the Appleby survey, where sixty-six percent of flood plain residents reported that the area was a very good place to live, with the remaining thirty-four percent answering fairly good. (table 8-1)

The perception of the flood hazard was further tested by questions four and five, in which a direct comparison was made between flooding and other named environmental problems and natural hazards in the area. Tables 8-2 to 8-7 show the response to these particular questions. In Carlisle, traffic was considered the most serious environmental problem in the area, which again reflects the greater frequency of the event compared to other problems. However, eighteen percent of the respondents saw flooding as the most serious environmental problem, which was considerably more than the proportion reporting flooding in the previous questions. In Appleby, flooding was mentioned by more respondents than any other problem, which also reflects the greater significance of flooding to this community.

The most frightening natural hazard in both communities was flooding, reported by thirty-two percent of respondents in Carlisle and thirty-four percent in Appleby. This response was somewhat anomalous to previous trends for it placed flooding above other hazards of greater frequencies. However, the other natural hazards are less likely to cause damage to personal property than flooding, and thus, this may be reflected in the response to the most frightening hazard.

In conclusion, the general environmental questions served to place the flood hazard in context with other problems in the area, as perceived by the flood plain residents. The importance

TABLE 8-1

Residents : Living conditions

	Carlisle		Appleby		Total	
Very good	113	52%	29	66%	142	54%
Good	99	45	15	34	114	44
Poor	6	3	0		6	2
Very poor	0		0		0	
Total	218	100	44	100	262	100

TABLE 8-2

Residents : Most serious perceived environmental problem

	Carlisle		Appleby		Total	
Crime	14	6%		-%	14	5%
Noise	22	10	11	25	33	13
Flooding	39	18	16	36	55	21
Pollution	8	4			8	3
Traffic	109	50	12	27	121	46
Others	4	2			4	2
None	22	10	5	11	27	10
Total	218	100	44	99	262	100

TABLE 8-3

Residents : Second most serious perceived environmental problem

	Carlisle		Appleby		Total	
Crime	10	5%		-%	10	4%
Noise	38	17	3	7	45	17
Flooding	38	17	8	18	46	18
Pollution	17	8			17	6
Traffic	30	14	8	18	38	15
Others	5	2			5	2
None	80	37	25	57	105	40
Total	218	100	44	100	262	102

TABLE 8-4

Residents : Perceived environmental problems - combined

	Carlisle		Appleby		Total	
Crime	24	11%		-%	24	9%
Noise	60	28	14	32	74	28
Flooding	77	35	24	55	101	39
Pollution	25	11			25	10
Traffic	139	64	20	45	159	61
Others	9	4			9	3
Total	(334)	153	(58)	132	(392)	150

(% of Respondents 218 & 44 & 262)

TABLE 8-5

Residents : Most frightening natural hazard

	Carlisle		Appleby		Total	
Gales and wind	46	21%	3	7%	49	19%
Fog	15	7	1	2	16	6
Thunderstorms	25	12	6	14	31	12
Flooding	70	32	15	34	85	32
Snow and ice	6	3	4	9	10	4
Other	4	2			4	2
None	52	24	15	34	67	26
Total	218	101	44	100	262	101

TABLE 8-6

Residents : Second most frightening natural hazard

	Carlisle		Appleby		Total	
Gales and winds	26	12%	2	5%	28	11%
Fog	16	7			16	6
Thunderstorms	11	5	4	9	15	6
Flooding	35	16	7	16	42	16
Snow and ice	19	9	3	7	22	8
Other	3	1			3	1
None	108	50	28	64	136	52
Total	218	100	44	101	262	100

TABLE 8-7

Residents : Most frightening natural hazard - combined

	Carlisle		Appleby		Total	
Gales and winds	72	33%	5	11%	77	29%
Fog	31	14	1	2	32	12
Thunderstorms	36	17	10	23	46	18
Flooding	105	48	22	50	127	48
Snow and ice	25	11	7	16	32	12
Other	7	3			7	3
Total	(276)	126	(45)	102	(321)	122

(% of Respondents 218, 44 and 262)

TABLE 8-8

Residents : Source of knowledge of flood problem

	Carlisle		Appleby		Total	
Estate Agents	0	-%	0	-%	0	-%
Neighbours	41	19	11	25	52	20
Personal inspection	2	1	1	2	3	1
Experience	136	62	14	32	150	57
News media	26	12	0		26	10
Surveyors report	6	3	0		6	2
Others	7	3	18	41	25	10
Total	218	100	44	100	262	100

of flooding to these residents in Carlisle was minimal, until compared directly with other environmental problems and natural hazards, when flooding assumed greater significance. Initially, it was found that the degree of annoyance of a problem was proportional to the frequency of its occurrence. In Appleby, where the frequency of flooding is greater, and the authority response to the hazard minimal, flooding was reported as a problem by a large proportion of the flood plain population. Similar studies have produced identical results, with flooding rarely regarded as a problem, or disadvantage, unless mentioned by name, by the interviewer. (Harding and Parker 1972, Penning-Rowsell 1972).

The responses to the general perception questions were significantly related to certain characteristics of the flood plain residents. For example, a chi squared test on the most serious environmental problem perceived in Carlisle as a function of area in which the respondent lived, proved different at the 0.005 level of significance. (To satisfy the requirements of the test, 'crime' and 'pollution' were combined in the 'other' category). Of the three areas in the city, sixty-four percent of respondents in Brunton Park stated that traffic was the most serious problem, compared to thirty-seven percent in Botcherby and thirty-six percent in Caldewgate. The proportion of those residents in each area perceiving flooding as the major problem were thirteen percent, thirty-three percent and thirty-six percent respectively.

These results to some extent confirm the earlier findings that awareness and frequency of a hazard are directly related.

For instance, the Brunton Park area is situated either side of the main road, which now forms the shortest route from Carlisle City centre to the M6 motorway. Taking this into consideration, therefore, it is not surprising that residents of this area perceived traffic to be the major environmental problem.

In Appleby, an analysis of the same two variables produced similar results to Carlisle. For example, the major problem in The Butts was noise, sixty percent of respondents, which was probably a reaction against the swimming pool and youth club located in this area. Similarly, the Sands, where seventy-five percent of respondents mentioned traffic, a result of the main A66 trunk road dissecting this area.

Areal location, therefore, appeared to produce significantly different responses to the question on the perceived environmental problems in both Carlisle and Appleby. However, in reality this association masked the true causal relationship between frequency of occurrence of the hazard and awareness. Areal location bore little relationship with the most frightening natural hazard in the area, nor with the earlier questions on general advantages and disadvantages of the flood plain location.

The perceived major environmental problems were also, to some extent, explained by the degree and extent of flood experience of the respondent. In Carlisle, there was a significant difference between those respondents with and those without flood experience, within the ninety-five percent level of confidence, to the question on the perceived most serious environmental problem in the area. For example, twenty-four percent of residents with flood experience, compared to only fourteen percent of those without, believed flooding to be the most serious environmental problem in the area. In general, those residents without personal flood experience tended to propose more wide ranging problems. In Appleby, although the overall awareness of the hazard was significantly greater than in Carlisle, the same trend was apparent, with fifty-two percent of the experienced residents compared to twenty-one percent of the non-experienced stating flooding to be the most serious environmental problem.

Characteristics of the flooding did not appear to produce any further explanation of environmental awareness. However, because of the poor distribution of data, some of the Carlisle responses were unsatisfactory for more detailed statistical analyses, and hence many causal relationships could have been overlooked. The responses from residents with experience of different numbers of floods were virtually the same in both Carlisle and Appleby, which would indicate that actual experience is the prime causal factor rather than frequency of the experience. The other flood characteristics of depth, duration and damage produced fairly similar results of environmental awareness. However, although the relationship could not be tested statistically, it was noticeable that those respondents flooded to the greatest depths and for the longest duration perceived flooding to be the most serious problem. The proportions, forty percent and thirty-three percent respectively, were considerably higher than for respondents less severely flooded.

Social factors did not appear to explain the response to the general perception questions. Sex, length of residence, occupation, education, and family structure all produced remarkably similar responses in both Carlisle and Appleby, particularly sex which produced virtually identical results. Age of respondent and the perceived most serious environmental problem did produce significantly different results (0.02 to 0.05), but this was probably a response to other problems than flooding, since there was little difference between the proportions mentioning flooding. Perception of flooding as a problem, therefore, does not vary with age, as it would first appear from the statistical evidence. Tenure also showed no association with the general perception responses, although because of the low proportion of rented accommodation in Carlisle, this could not be tested statistically with any degree of accuracy.

In conclusion, the major factor which appears to explain the response to the initial question on perception of the flood hazard is personal flood experience, while other social characteristics have little association. Areal location would probably be important, given the results to these questions if a distinction could be made between areas of varying flood frequencies. This is illustrated to a certain extent by the contrasting levels of awareness between Carlisle and Appleby.

Perception of the flood hazard was also measured by question eighteen, which required respondents to state how they had discovered that the area in which they lived was prone to flooding. In Carlisle, sixty-two percent of respondents reported that they had found out through personal experience of flooding and nineteen percent from their neighbours. (table 8-8).

In Appleby, only thirty-two percent mentioned flood experience and twenty-five percent neighbours, although a further forty-one percent of residents said they had always lived in the town, and hence could not recall the precise source of this knowledge. In general, surveyors and estate agents were very poor in advertising the flood hazard in either community.

It is clear from these results that knowledge of the flood hazard is least likely to be perpetuated by those persons who deal in the buying and selling of property, and most likely to be the product of actual flooding. While such a policy is undoubtedly advantageous to the estate agents and surveyors, they must be held responsible, to a certain extent, for knowingly locating people in a hazardous area. In personal communications with six estate agents in Carlisle, not one admitted to the flood problem in the city, and even when confronted by evidence to this effect (viz aerial photographs such as shown in plates 17 and 18) promptly assured the researcher that such problems had now been eliminated. For example, Telford and Scott Limited stated that district house values had remained high after 1968, while Tiffen said that there had been no change in prices following the flood, statements which seem all the more remarkable considering the extent of damage caused by the 1968 flood. The other four estate agents, Carlisle and Border, Gibbing and Johnston, Smiths and Gore, and Balderstone reported that, while records for this period were not available, there was definitely no sudden exodus from the flood plain following the flood, because to quote a typical comment, 'the council had dealt with the problem.' Thus, full awareness will only be achieved when flood plain residents and persons moving into floodprone areas, are more readily informed of the hazard.

General perception of environmental problems and hazards is essentially a product of the frequency of the occurrence of the event itself. However, when mentioned by name, and in comparison with other problems, flooding assumed greater importance, especially in Appleby with the greater risk involved. Perception of the flood hazard as a problem was also greatest, as would be expected, amongst those respondents with personal flood experience. The other independent factors however, did not appear to influence perception of the hazard, to any great extent.

(ii) Perception of future flooding

Perception of future flooding was measured by questions twenty-four and twenty-five (part i) which concerned both the perceived future risk, as well as the perceived change in flood risk. Responses to these questions were compared with statistics of actual flood frequencies, obtained from the theoretical calculations and the historical surveys.

Table 8-9 shows the residential response to the question 'Do you think this building will be flooded again in the next twenty-five years?' Only eighteen percent of respondents in Carlisle expected flooding in this period, although a further fourteen percent were undecided. The majority of residents, sixty-eight percent foresaw no flooding in the next twenty-five years. Since the return period for damaging floods in the town, according to the historical data (chapter five) is approximately 11.4 years, this proportion seems remarkably low.

However, if the alleviation schemes implemented in the town are effective up to their design standard of fifty years, then the converse is true, and the proportion expecting future floods appears fairly high. Nevertheless, in reality the flood alleviation scheme has never been fully tested, and since there appears to be some inherent weaknesses in the project, the true level of protection may be considerably lower (Chapter six). The proportion expecting future flooding therefore, either have little faith in the ability of the authorities to overcome such problems, or are unaware of the authoritarian adjustment to the hazard. Both these points are discussed in detail in section 2(i) of this chapter.

In Appleby, where there has been no positive response to the problem by the authorities, and where the recurrence interval for damaging floods is approximately 4.22 years, the expectation of future flooding is quite high. Seventy-three percent of residents thought the area would flood again in the next twenty-five years, a further eighteen percent were undecided, and only nine percent did not anticipate further flooding. This high response rate at Appleby was significantly different from that at Carlisle at the 0.001 level.

While the Carlisle response was complicated by the authoritarian adjustments to alleviate the problem, and hence made comparisons with other areas difficult, the Appleby response could more readily be compared with similar flood environments. For example, Parker (1976) at Builth Wells, which has a similar record of flood frequencies as Appleby, found that only thirty-five percent of respondents expected future flooding, with a further eighteen percent who did not know.

TABLE 8-9

Residents : Respondents expecting floods in the next 25 years (Perception of future flooding)

	Carlisle		Appleby		Total	
Expect floods	39	18%	32	73%	71	27%
Do not expect floods	148	68	4	9	152	58
Did not know	31	14	8	18	39	15
Total	218	100	44	100	262	100

TABLE 8-10

Residents : Perception of future flooding as a function of flood depth experienced in 1968

CARLISLE

Depth	Perceived flooding		Did not perceive Flooding		Did not Know	
Outer walls	2	5%	32	78%	7	17%
Floor boards	2	8	21	88	1	4
1 - 15 cm	5	19	17	65	4	15
16 - 30 cm	6	33	10	56	2	11
31 - 75 cm	2	33	3	50	1	17
Over 75 cm	2	40	3	60	0	0
Total	19	16	86	72	15	13

James _etal_ (1971) in Atlanta where the flood return period is about 3.5 years, found that eighty-six percent of the respondents expected flooding at some future date. However, this area had suffered five damaging floods in the nine years prior to the survey, which meant the problem was still relatively fresh in peoples' minds.

The association between the perception of the future flood hazard and various independent variables was tested by chi squared analyses, to see if any significant relationships existed to explain the response to this question. In Carlisle, there was no significant relationship between the perception variable and personal flood experience, although there was a slight trend to suggest that respondents with flood experience were _less_ likely to perceive future flooding then those without. (Sixteen percent compared to twenty percent). In Appleby, the response was the reverse, for eighty-six percent of those residents with personal flood experience, compared to only fifty percent of the others perceived future flooding. A revised hypothesis for Carlisle, suggested that this somewhat anomalous response could be explained by awareness of the flood alleviation schemes. It was purported that flood experienced respondents would be more aware of schemes implemented to alleviate the problem. Some differences in responses were observed between flood experience and awareness of authoritarian actions, particularly with the flood forecasting scheme, which suggested this was the case. (Details of perception and awareness are discussed in part 2).

Experience of different numbers of floods also did not appear to effect the perceived future flooding, for there was only a slight trend to suggest that those flooded most frequently perceived future flooding. In Appleby however, this trend was more pronounced with seventy-six percent of residents flooded once, and ninety percent of those flooded on three or more occasions, stating that the town would flood in the next twenty-five years.

Other significant relationships were obtained between the perception of future flooding, and the more extreme the flood experienced in 1968. For instance, there was a distinct trend in the responses of residents inundated to different depths. Only five percent of Carlisle respondents who were flooded to the outside walls of their premises and eight percent to the floor boards, believed the area would flood again in the next twenty-five years. These figures compared with nineteen percent of those flooded to a depth of fifteen centimetres, thirty-three percent to thirty centimetres, thirty-three percent to seventy-five centimetres, and forty percent of those respondents whose dwellings suffered even more extensive flooding (table 8-10). Unfortunately, these figures were statistically invalid for a chi squared test, and hence no relationship could be proved. However, the response in Appleby to some extent confirmed these findings, since the proportion of residents perceiving future flooding, for the same flood depth categories, were sixty-eight, seventy-five, fifty, one hundred, and one hundred percent respectively.

The duration of flood experienced in 1968 was similarly related to the perception of future flooding. That is, those respondents who experienced the longest duration flood were more likely to perceive future floods, than residents only inundated for short periods. This association was significant at the 0.97 level of probability, although the flood duration categories had to be amalgamated to three to satisfy the requirements of the chi squared test. Only sixteen percent of those respondents flooded for the shortest periods, compared to forty-four percent in the longest duration category, perceived future flooding. In Appleby, despite the greater perception, the same trend was apparent with eighty percent of those flooded for up to six hours, compared to all those flooded for longer durations.

Thus, in both Carlisle and Appleby the more extensive the flood experienced in 1968, the greater the perception of future flooding in the area. This particularly applies to flood depth and duration, although only a small trend was found with flood losses. Actual flood experience, and number of floods experienced were less important in this respect.

As well as flood experiences, the perception of future flooding was also related to certain social characteristics of the flood plain resident. Age of the respondent, for instance, was inversely related to perception of future flooding at the 99.9% confidence level. Only thirteen percent of all respondents in Carlisle perceived future flooding, while seventeen percent of the middle-aged group, and forty-five percent of the youngest residents perceived flooding. This relationship was again probably a function of awareness of the authoritarian adjustment to the flood hazard in the city, since other residents tended to be more aware of such schemes than younger residents (section 2(i). In Appleby, there was a small trend to suggest that, where there had been no authoritarian response to alleviate the problem, the perception of future flooding increases with increasing age.

Of the other social variables only tenure of household produced significantly different responses to the perception of future flooding (0.01). Only sixteen percent of house owners foresaw future flooding compared to thirty-three percent of tenants, while the proportion who completely dismissed the idea of future floods was seventy-one percent of owners and thirty-eight percent of tenants. Several hypotheses were put forward to explain this response. Firstly, it was postulated that because house owners have more at risk than tenants, they may be more aware of the schemes implemented to alleviate the problem. There is also a strong association between flood experience length of residence, and home ownership, which may add to the greater awareness. Secondly, house owners may, because of the greater risk, subconsciously deny the existence of the flood hazard as suggested by Burton etal (1968). Third, it was suggested that the response may be reflecting the influence of other independent variables. Since the response in Appleby showed no such trends, this may indicate other factors at work in Carlisle. In general therefore, social characteristics do not appear to determine the perception of future flooding, except for age of respondent and tenure of household. Other social traits, such as sex, education, occupation, length of residence, and family structure showed no such significant relationships.

The perceived change in the flood risk in both Carlisle and Appleby is shown in table 8-11. Eighty-one percent of respondents in Carlisle perceived a decrease in the hazard in the city, four percent an increase, and nine percent saw no changes in the risk. In contrast, of the total Appleby residents, forty-six percent perceived a decrease, two percent an increase and forty-three percent saw no change. These two responses were significantly different at the 99.9 percent level of confidence according to the chi squared test. While this response had been anticipated in Carlisle, where the local authority had implemented a large-scale flood alleviation scheme throughout the city, and hence hopefully reduced the flood risk, in Appleby no such adjustment to the hazard had been made, and so the high proportion perceiving a decrease was somewhat surprising. (The reasons given by respondents for the perceived decreased in the hazard are analysed in the following section of this chapter).

The response to the perceived change in the flood hazard precluded any statistical tests on the data from Carlisle, because of the vast majority perceiving a decrease in the risk. However, even by visual observation of the figures, no apparent trends emerged from these responses to suggest that either flood experiences or social characteristics were the main determinants of this response. Greater understanding is gained from the analyses of the reasons given for the perceived decrease in the hazard.

Perception of the flood hazard, therefore, was significantly related to several independent variables, notably the degree of flood experience in 1968. In general, the more extreme the flooding, the greater the perceived probability of future flooding. Actual flood experience was less important, although residents with personal experience were less likely to perceive future flooding than those without. This apparently inverted relationship is explained by the greater awareness of the flood

TABLE 8-11

Residents : Perceived change in flood risk

	Carlisle		Appleby		Total	
Increasing risk	8	4%	1	2%	9	3%
Decreasing risk	176	81	20	46	196	75
No change in risk	19	9	19	43	38	15
Did not know	15	7	4	9	19	7
Total	218	101	44	100	262	100

TABLE 8-12

Residents : Respondents fear of flooding

	Carlisle		Appleby		Total	
A lot	8	4%	5	11%	13	5%
Some	17	8	12	27	29	11
A little	36	17	15	34	51	20
Not at all	154	72	12	27	166	64
Total	215	101	44	99	259	100
Did not know	(3)					

alleviation project implemented in Carlisle. Social factors, particularly, age and length of residence produced similar results to flood experience and hence probably reflected the same trends. However, the perceived change in the flood risk was apparently not related to any of these independent variables.

(iii) Degree of fear of the flood hazard:

Fear of the flood hazard was assessed, both directly and indirectly by the response to questions nineteen to twenty-two. In reply to the direct question on the degree of fear of flooding (number nineteen) seventy-two percent of respondents in Carlisle expressed no fear what so ever, and, at the opposite extreme, only four percent worried excessively. In Appleby, only twenty-seven percent of residents did not worry about flooding and eleven percent worried a lot, while a further sixty-one percent worried about the problem to some degree (table 8-12). The responses from the two communities were significantly different at the 0.999 level of probability, with considerably greater fear expressed by those respondents in Appleby. This difference essentially confirms an earlier hypothesis, that the degree of fear of the hazard is directly related to the frequency of the event. In Appleby, where the actual flood frequency is greater than in Carlisle, and where the flood plain inhabitants live in closer proximity to the hazard source, the degree of fear expressed by the residents is correspondingly higher.

The degree of fear of the flood hazard could be partially explained by the inherent characteristics of the flood plain population (described in the previous chapter). For instance, a significant association was found within the ninety-five percent confidence limits between personal flood experience and the expressed fear of flooding. Thirty-two percent of respondents with personal flood experience, expressed some degree of fear of the hazard, whereas only twenty-four percent of those who had never been flooded worried about the problem. In Appleby the same trend was apparent, despite the greater fear of flooding, eighty-eight percent of the experienced residents, compared to fifty percent of the non-experienced expressing some fear of flooding.

Flood frequency illustrated a more complex relationship with the degree of fear of the flood hazard, although in Carlisle the data were not statistically valid for a chi squared test. However, analysis showed that thirty-one percent of respondents flooded only once, forty-seven percent of those flooded twice and only twenty percent of those flooded on three or more occasions expressed some fear of the flood hazard. (table 8-13) While this response was probably the product of the limited data in the final category, it could also demonstrate a break point between two and three floods. It was postulated, therefore, that fear of floods would increase until two floods (one may produce a low response, if the respondent believes it to be a once in a life time event, while two could probably increase the anxiety) when either the respondent would leave the area or become more adjusted to the floodplain environment. A similar trend emerged in Appleby, where everyone flooded in the past worried to some extent about the problem, except for fourteen percent of those flooded three times or more. Nevertheless, this does not confirm the hypothesis one way or the other.

TABLE 8-13

Residents : Degree of fear of flooding as a function of the number of floods experienced

CARLISLE

Number of floods experienced	Worried about flooding		Did not worry about flooding	
None	23	24%	73	76%
One	29	31	66	69
Two	7	47	8	53
Three or more	2	20	8	80
Total	61	28	155	72

TABLE 8-14

Residents : Proportion of residents considering the flood problem before moving into the area

	Carlisle		Appleby		Total	
Considered problem	54	25%	10	23%	64	24%
Did not consider problem	158	73	28	64	186	71
Did not know	6	3	6	14	12	6
Total	218	101	44	101	262	101

Other flood characteristics showed a variable relationship with the degree of fear. For instance, in Carlisle the fear of flooding was significantly different (0.019) between residents inundated to various depths in 1968, although it should be noted, this did not constitute a linear relationship. The results indicated that residents with flood water inside their premises and up to a depth of seventy-five centimetres were more worried about flooding than residents flooded only to the floor boards, or above seventy-five centimetres. This latter category could represent an anomaly in the data or genuinely reflect a greater tolerance of flooding by persons flooded to more extreme depths. However, the Appleby response did not substantiate this hypothesis.

The duration of the flood in 1968 and the losses incurred from the inundation made no significant difference to the degree of fear of the hazard. Nevertheless, there was a slight trend towards a positive correlation between fear and losses. For example, only twenty-three percent of those suffering no financial losses worried about flooding, compared to forty percent of those with losses up to one hundred pounds, and forty-three percent of those with even greater losses. The response in Appleby again showed no significant trends with either of these variables.

Further hypotheses suggested that the remedial action undertaken in 1968 could also affect the degree of fear of the flood hazard. For example, it was postulated that the successful utilisation of individual adjustments to the hazard would produce less fear than unsuccessful measures. The Carlisle response regarding the employment of temporary measures, to some extent, confirmed this. Of those residents using temporary measures, thirty percent of those who were successful, compared to forty-six percent who were unsuccessful, worried about flooding. The Appleby data again failed to confirm the Carlisle findings.

In conclusion, the fear of flooding appeared to be related to the actual flood event rather than the other flood characteristics. However, because the data on certain flood characteristics was limited, further research is essential to confirm or reject these particular hypotheses.

The third group of independent factors which appeared to influence the degree of fear of the flood hazard were social characteristics. The difference between the sexes in the expressed fear of flooding was most significant in both Carlisle and Appleby (within 95% confidence limits). In Carlisle, sixteen percent of males and thirty-three percent of females worried about flooding, while in Appleby the two percentages were fifty-six and eighty-six for males and females respectively. Two propositions were put forward to explain this difference : (i) Males were generally less concerned about the flood problem than females; (ii) Males were more reluctant to admit to any fears than females. Whatever the actual reason, there is clearly a significant difference between the expressed fear of the two sexes.

Age of the respondent showed only a slight association with the degree of fear of the flood hazard. For example, in Carlisle twenty-seven percent of the youngest, twenty-seven percent of the middle-aged and thirty percent of the eldest worried about flooding to some extent. However, the proportion of residents who worried more than just a little were eight, eight and seventeen percent for the three age categories. The same trend was found in Appleby, where older residents expressed a more intensive fear of flooding. Naturally, older residents are less mobile, frequently live alone, and incidentally often have greater experience of flooding, and are more likely to fear flooding than a young newcomer to the area.

The other social characteristics such as family structure, length of residence, education and occupation showed no significant trends as far as the fear of flooding was concerned. One noticeable aspect was that in Carlisle semi-skilled workers (32%) and professional workers (42%) expressed the greatest fear, which also corresponds to the groups suffering the greatest losses in 1968. In general however, these social factors did not appear to influence the extent of fear of the flood hazard.

Fear of flooding was directly related to those variables measuring the perception of the flood hazard, as illustrated in figure 4-1. For example, residents perceiving future flooding in the area also had greater fear of the hazard. In Carlisle, forty-nine percent of the respondents who foresaw future flooding also worried about the flood problem, whereas by comparison, only nineteen percent of those who perceived no future flooding, expressed any degree of fear. These responses were significantly different within the ninety-nine percent confidence limits. In Appleby, the same relationship was apparent despite only a small proportion of respondents perceiving no flooding.

Perceived change in the flood risk was also related to the degree of fear. In Appleby, forty-seven percent of residents who perceived no change in the hazard were worried about the problem, compared to only twenty percent of those who perceived a decrease. Naturally, fear diminishes with a perceived decrease in the risk. The Carlisle results showed only a small trend because such a large majority perceived a decrease in the hazard, twenty-six percent compared to thirty-nine percent worried.

In Carlisle, those residents who perceived that enough had been done to alleviate the problem worried significantly less than those who believed that insufficient measures had been taken and those who did not know. The proportion of respondents worried about flooding in each case were twenty-two percent, fifty-one percent, and thirty-three percent respectively. The Appleby response, although not strictly comparable because of the altered question structure, did not produce significant results.

The faith placed in government and individual actions was purported to influence the fear of flooding. However, in Carlisle these two variables made no appreciable difference to the expressed degree of fear, although in Appleby, residents with faith in either the government or individual adjustments were less likely to worry about the flood hazard, than those with little or no faith. For example, fifty percent of those who believed the individual could overcome the flood problem did not worry about flooding, while conversely seventy-eight percent of those residents without such faith worried about the problem to some degree. Similarly, for government action, thirty-two percent compared to fifty-four percent worried more than a little about flooding. Hence other perceived aspects of the flood hazard are inextricably linked with fear of flooding.

A further assessment of the degree of fear of the flood hazard was made by examining the responses to questions twenty, twenty-one and twenty-two. Question twenty asked which residents had considered the flood problem before locating in their present residence, since those who had were more likely to value a flood-free site highly in their reasons for choosing such a location. The response to this question is shown in table 8-14, twenty-five percent of respondents in Carlisle and twenty-three percent in Appleby had considered the problem. There was no statistically significant difference between the two, although seventy-eight percent of those residents in Carlisle (fifty percent in Appleby) who had considered the flood problem, had moved into the flood prone area since the last flood. The proportion who had considered the problem was fairly low in comparison with the first Atlanta study (James et al 1971) where forty-three percent of residents had considered the flood problem before locating on the floodplain, although, in Britain, in a similar study the figure was only thirty percent (Penning-Rowsell 1972). The current studies, therefore, would indicate a distinct difference between the two countries in this respect.

To some extent, the degree of fear was also measured by a relocation factor, although this could also be termed the tolerance level of the respondent. Interviewees were requested to state, if given the same choice they would relocate in the same building. Table 8-15 shows the similarity between the responses from Carlisle and Appleby, with eighty-six and eighty-nine percent respectively, replying positively to the question. These figures, therefore, suggest that flooding is not regarded as a major problem by the majority of residents. However, those residents who have moved away from the flood areas, since the last flood, may have had an entirely different perception of the hazard.

To further test the tolerance levels and degree of fear of flooding, respondents were asked the hypothetical question, 'would you leave this building forever if you were flooded each year for the next three years?' In Carlisle, sixty-eight percent of respondents said they would definitely leave and only twenty-four percent stay. This contrasted significantly with the Appleby response (0.001) since only thirty percent would leave and fifty-nine percent remain (table 8-16). Thus, it would appear that while Appleby residents are living under considerably greater stress with respect to the greater flood risk, they are at the same time more attached to their home environment. For instance, Appleby residents worry about flooding to a greater extent than residents in Carlisle, and yet fewer Appleby residents would leave if the flooding became more serious. However, given the present conditions the majority of both communities are content to remain in the same building.

As expected, there was a close association between these latter variables and the degree of fear. That is, those residents in Carlisle who would not relocate in the same building, and those who considered the flood problem before locating

TABLE 8-15

Residents : Proportion of respondents who given the same choice would relocate in the same area

	Carlisle		Appleby		Total	
Would relocate	188	86%	39	89%	227	87%
Would not relocate	22	10	4	9	26	10
Did not know	8	4	1	2	9	3
Total	218	100	44	100	262	100

TABLE 8-16

Residents : Proportion of respondents who would leave the area if flooded three years in succession

	Carlisle		Appleby		Total	
Leave	148	68%	13	30%	161	61%
Stay	53	24	26	59	79	30
Did not know	17	8	5	11	22	8
Total	218	100	44	100	262	99

expressed greater fear than others. Nevertheless, only the relocation factor was significant in Carlisle and no associations were apparent in Appleby.

The relationship between the independent factors of structure, social and flood characteristics with the dependent variables of general perception, perception of the flood hazard and the degree of fear of flooding, confirmed many of the hypotheses set up during the formative stages of the research. The complete relationship , significant at the 0.05 level, between these variables is shown diagramatically in figures 8-1, 8-2 and 8-3/i.(The key to the variable numbers can be found in appendix II). These figures, based on the data from Carlisle, clearly illustrate the relative importance of the various independent factors in determining residential perception and fear. The general perception variables, for example, show the greatest association with social characteristics and structural features, rather than a relationship with any degree of flood experience. This trend in fact confirmed the results of earlier studies, that the perception of a problem is related to the frequency of the event. The different conditions in the three flood zones of Carlisle produced significantly different results in this respect. In contrast to this, perception of the flood hazard in relation to other named hazards and problems, showed a greater association with the degree of personal flood experience. Again the research hypothesis purported that experienced residents would be more likely to perceive a flood problem in the area than non-experienced residents. However, where social characteristics and flood features were fully expected to influence significantly residential perception, that was concerning the perception of future flooding and the perceived change in the flood risk, very little association was apparent. Only age and tenure of household bore any relation to these perception variables.

The degree of fear expressed by the respondents, also confirmed certain reasearch hypotheses, when analysed in conjunction with the independent variables. For example, it was hypothesised that personal flood experience would lead to greater worry about the problem unless the respondent had been flooded so frequently, that he was now fully adjusted to the environment. Flood experience data, and statistics on the number of floods experienced in particular showed this trend. Similarly, there was a significant association with flood depth, which showed that those residents flooded to the lowest and those to the greatest depths worried least about flooding. The association of other independent variables with the expressed degree of fear of flooding was less clear. Age, family structure and length of residence were all significantly related to different aspects of fear measure, although they all essentially showed that younger respondents, those resident in the area for shortest time and those with smaller families would be more likely to leave the area if the flood problem became worse. Structural factors were found to have no relation with the degree of fear whatsoever. It had been suggested that residents in flats and bungalows might express greater fear because of the problems of removing valuables to higher levels, but this was not found to be the case.

In conclusion, perception of the flood hazard and the degree of fear of flooding is probably influenced to the greatest extent by personal experience of flooding and to lesser extent by social characteristics. However, since social characteristics are more readily available from census data, these could prove invaluable in predicting residential perception and fear of the flood hazard. Further studies, therefore, are necessary to confirm these findings.

Variables relevant to figures 8-1 to 8-7.

INDEPENDENT FACTORS

(A) Structural factors

(B) Physical factors

- (i) Characteristics of flood experience.
- (ii) Help received during the 1968 flood.
- (iii) Actions undertaken during the 1968 flood.

(C) Social factors

DEPENDENT FACTORS

(D) Perception of the hazard

- (i) Perceived future flood hazard.
- (ii) Environmental problems and natural hazards.
- (iii) General perception variables.

(E) Degree of fear of flooding

(F) Perception and awareness of individual remedial measures

- (i) Perceived response to a flood warning.
- (ii) Perceived effectiveness of individual measures.
- (iii) Other responses.

(G) Perception and awareness of authoritarian alleviation schemes.

- (i) Awareness of authoritarian schemes.
- (ii) Awareness of the flood forecasting and warning scheme.
- (iii) Perceived faith in authoritarian measures.

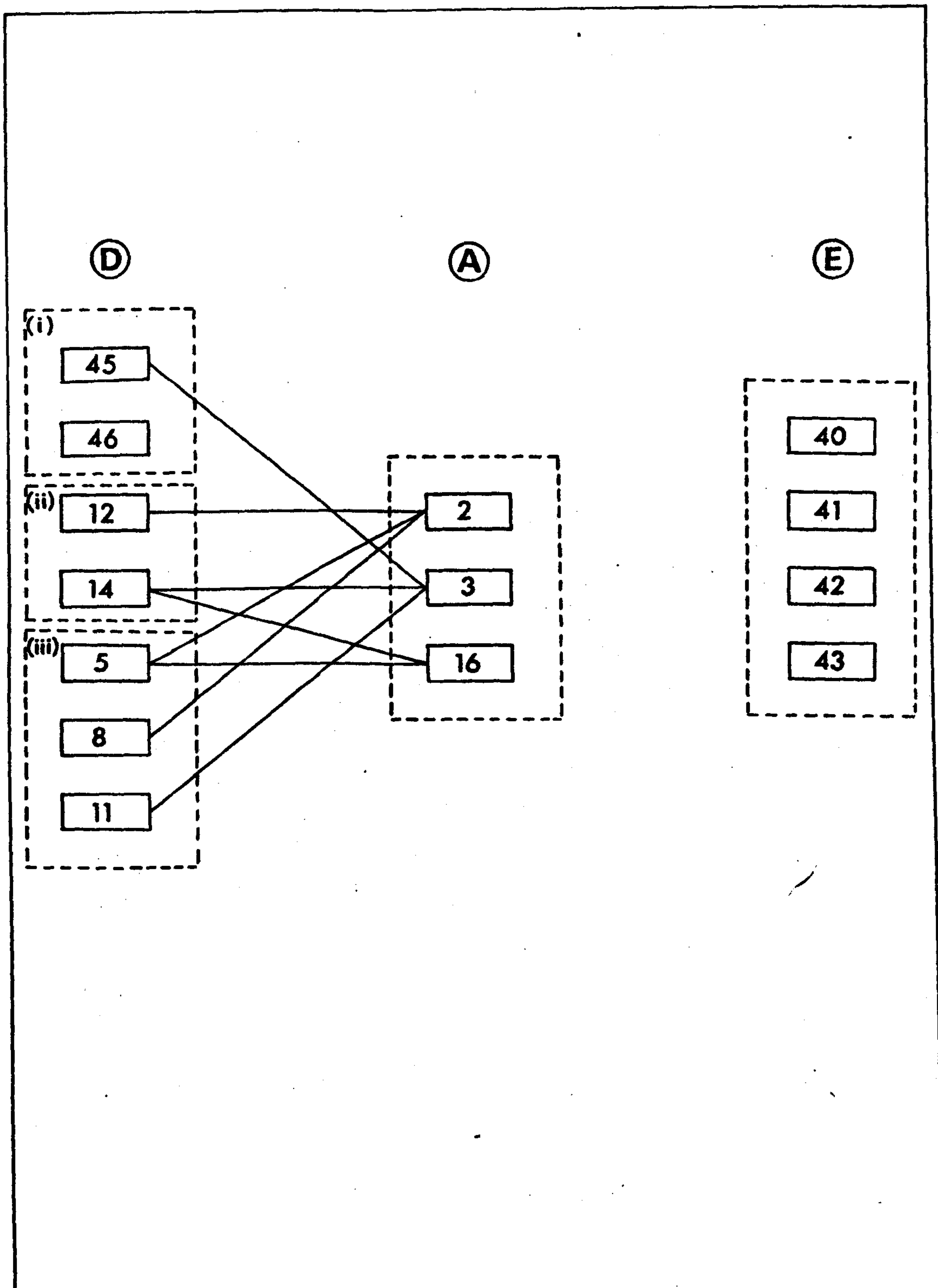


Fig. 8-1. Carlisle residents: significant relationships between structural factors (A) and variables of perception of the flood hazard (D) and the degree of fear of flooding (E) using the chi squared test (see appendix II for list of variables).

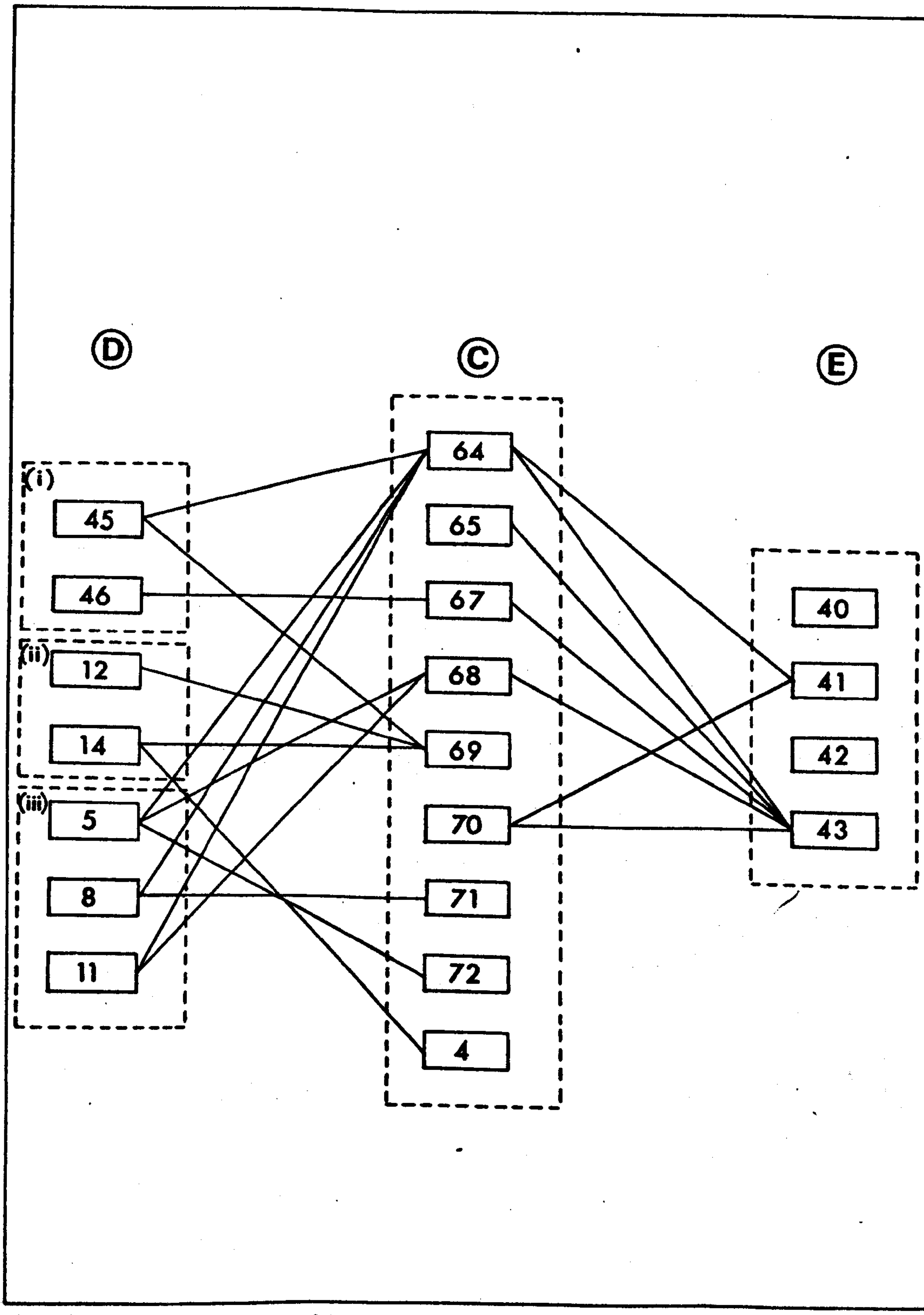


Fig. 8-2. Carlisle residents: significant relationships between social factors (C) and variables of perception of the flood hazard (D) and the degree of fear of flooding (E) using the chi squared test (see appendix II for list of variables).

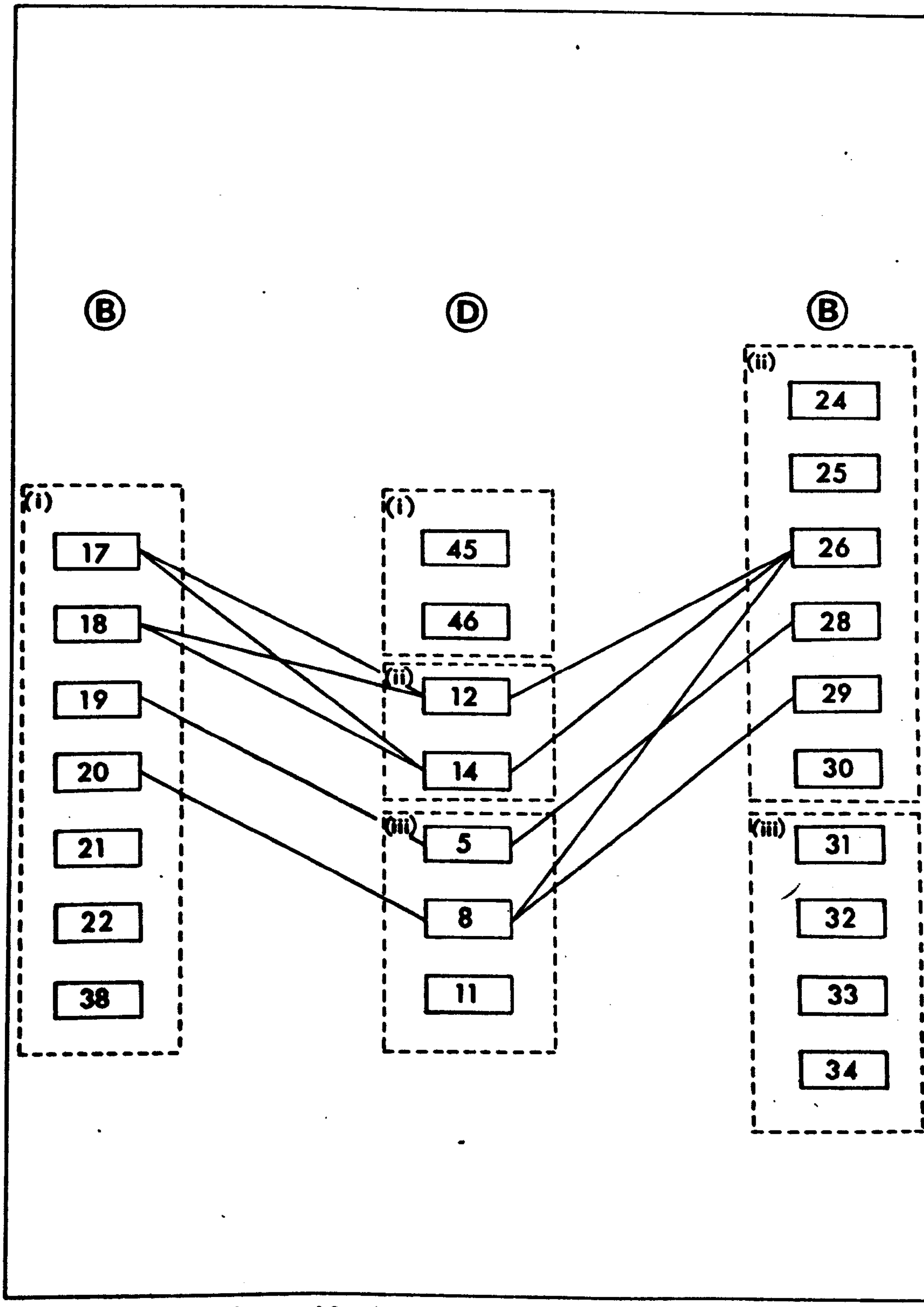


Fig. 8-3. Carlisle residents: significant relationships between physical factors (B) and variables of perception of the flood hazard (D) using the chi squared test (see appendix II for list of variables).

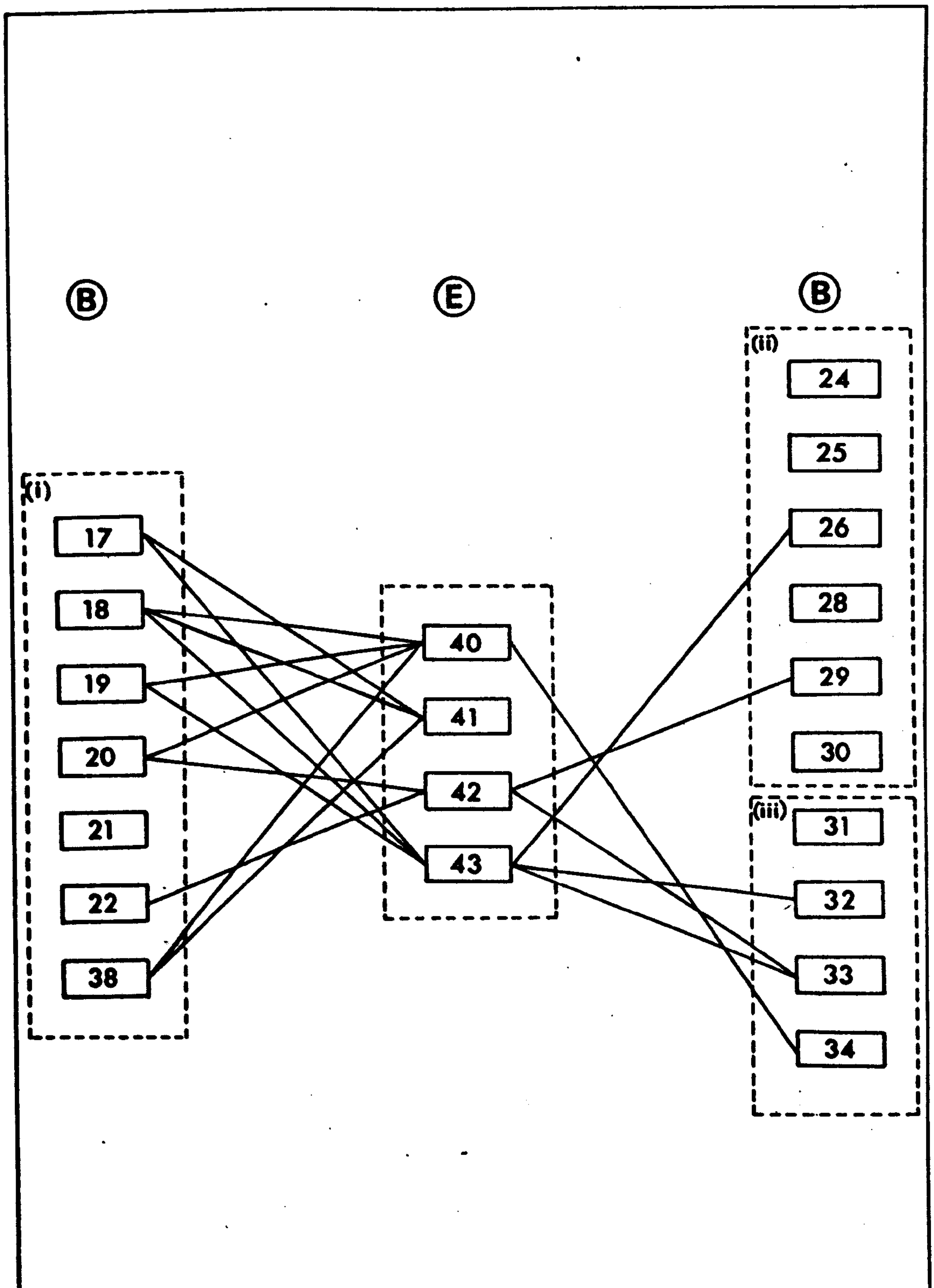


Fig. 8-3(i). Carlisle residents: significant relationships between physical factors (B) and the degree of fear of flooding (E) using the chi squared test (see appendix II for list of variables).

2. Awareness of the authoritarian response to the flood hazard

The early research hypotheses purported that awareness of the authoritarian response to the flood hazard, along with a perceived faith in the ability of such schemes would significantly alter flood plain residents' attitudes and behaviour patterns. Thus, it was suggested that the perceived effectiveness of flood alleviation schemes is actually more important than the 'real' design standards of the project in any consideration of flood plain decision-making. Three aspects of awareness of flood alleviation schemes, therefore, were incorporated into the questionnaire:

(i) General awareness of authoritarian adjustments

(ii) Awareness of the flood forecasting scheme.

(iii) Opinions on different alleviation project strategies.

(i) General awareness of authoritarian adjustments

The second part of question twenty-five was designed to assess the awareness of any schemes, implemented in either of the communities, to reduce the flood hazard. Respondents who perceived a decrease in the first part of the question were then asked what reasons they had for perceiving such a change in the flood risk. Table 8-17 shows the proportion of respondents perceiving a decrease in the hazard and the reasons given for this belief. In Carlisle, eighty-six percent of these respondents attributed the decrease to the construction of flood embankments and walls, while twenty-three percent specified river course alterations , and twelve percent cleaning rivers. This response showed a generally high awareness of the authoritarian response to the flood hazard, for all these measures have been employed at different times, in various parts of the city. However, the most important and recent authoritarian adjustment was the embankment system, which not surprisingly was mentioned by the majority of respondents.

The response in Appleby produced quite different results. Sixty percent of respondents who perceived a decrease in the flood risk, attributed the cause to the cleaning of the River Eden, while fifty-five percent mentioned river course alterations, and a further ten percent river banks and walls. However, none of these measures had been carried out in the town, at least in recent years, for the express purpose of flood alleviation. A certain amount of work had been undertaken on the River Eden a few miles downstream of the town of Bolton, but, according to the Water Authority, this was not expected to cause any significant difference to the frequency of flooding in Appleby. (Personal communication, 1974). Similarly, the river banks in Appleby had been repaired, but this was for aesthetic reasons, and not for flood alleviation purposes.

A further six percent of respondents in Carlisle and twenty percent in Appleby intimated that climatic factors had been the cause of the (perceived) decrease in flood risk. While this would be extremely difficult to assess with any degree of accuracy for such a short period, floods have occurred less frequently, particularly in Appleby since the 1968 event. It is also true that rainfall during the first four years of the 1970's,

TABLE 8-17.

Residents : Reasons given for the perceived decrease in flood risk

	Carlisle		Appleby		Total	
Climatic changes	11	6%	4	20%	15	8%
Motorway construction	5	3	0	0	5	3
Town building	0	0	0	0	0	0
Cleaning rivers	21	12	12	60	33	17
Building river banks	151	86	2	10	153	78
Reservoir management	2	1	0	0	2	1
Other	40	23	11	55	51	26
Total	(176)	131	(20)	145	(196)	133

(% of those suggesting the flood risk had decreased)

TABLE 8-18

Residents : Proportion of respondents who believe enough has been done in Carlisle to prevent future flooding

	Carlisle	Residents
Enough done	131	60%
Not enough done	33	15
Did not know	54	25
Total	218	100

especially 1971 to 1973, was below the average for Cumbria, based on the 1915 to 1950 data. (Monthly Weather Reports 1970 - 1973). In considering the short-term hydrometeorological characteristics of the area, therefore, some reference to climatic factors was to be expected.

The factors influencing this perception did not emerge very clearly from the analyses with the independent variables. In Carlisle, the reasons given for the perceived decrease did vary according to spatial location of the respondent in the town, and results confirmed the hypothesis that residents were more aware of adjustments in their own locality than throughout the city. For example, the largest proportion of respondents mentioning the embankment system lived in Brunton Park, while cleaning rivers, and other course alterations were favoured by residents in Botcherby and Caldewgate. In Appleby, there was no clear variation between the areas.

The degree of flood experience produced no significant relationships in Carlisle to explain this perception, although in Appleby several trends were observed. The cleaning of rivers, for instance, was suggested as a reason for the perceived decrease in the hazard by seventy-one percent of residents with personal flood experience compared to only twenty-nine percent without. Alternatively, other course alterations were favoured by the non-experienced group (eighty-six percent) compared to the experienced residents (thirty-six percent). In general however, flood charateristics did not appear significantly to influence the perceived change in the flood hazard.

The response to the causes of the perceived decrease in the flood hazard to some extent confirmed the research hypotheses, when analysed as a function of social characteristics. For instance, in Carlisle age of the respondents indicated several variations in perception of these causes, particularly the correlation between increasing age and the older adjustments to the hazard. The older residents were more likely to suggest other course alterations as a reason (correlation of -0.2472 at the 0.001 level of significance) frequently referring to the work on the Eden and Caldew in Caldewgate, and the Petteril in Brunton Park/Botcherby. (for details see chapter six). The more recent scheme (flood embankments) was more generally known throughout the different age categories.

Other social factors, such as, sex, length of residence, education, and occupation did not produce significant associations with any of the reasons for the perceived decrease in the flood hazard. Also in Appleby, no trends were apparent, although here the situation was complicated because the authorities had not implemented any flood alleviation programme, despite the beliefs of the flood plain residents to the contrary. For the most part, therefore, social factors played only a minimal role in the perceived change in the flood hazard. In the final analysis, Appleby residents were probably more aware of the hazard than residents in Carlisle, although the Appleby residents were more likely to assume a high degree of optimism regarding the flood hazard, since many respondents perceived a decrease in the problem. Carlisle respondents on the other hand maintained a high level of faith in the ability of the authorities to eradicate the problem.

Awareness of the Authoritarian response to the flood hazard was further tested by question twenty-six, which differed slightly for the two communities. In Carlisle, where there had been considerable authoritarian adjustment, respondents were asked whether enough had been done in the city to overcome the flood problem; whereas in Appleby, where there had been no positive response by the authorities, residents were asked if anything had been done to alleviate the flood problem.

In Carlisle, sixty percent of respondents believed that enough had been done to prevent future flooding, and only fifteen percent thought that insufficient action had been undertaken. (table 8-18). Thus, only six years after a major flood, the majority of residents believed the problem had been eliminated. A frequent response to this question was to the effect that 'they had stopped all that (flooding)'.

An analysis of these results in Carlisle illustrated some significant relationships, although these beliefs were not explained by any independent factors. For example, ninety-one percent of respondents who believed enough had been done in the city, perceived a decrease in the flood risk, although seventy-two percent of those who did not believe enough had been done also perceived a decrease in the risk. However, these responses were significantly different above the ninety-five percent level of confidence. Similarly, there was also a significant relationship (within the ninety-nine percent confidence limit) between perceived future flooding, and the belief that the authority have stopped the flood problem. Eighty percent of respondents who believed enough had been done, perceived no future flooding, while thirty-three percent who believed that insufficient action had been taken foresaw future flooding.

Appleby residents responded to the amended question slightly differently. Fifty-two percent of residents specified that something had been done to alleviate the flood problem in the town, and only thirty-six percent were aware that nothing had been done. (table 8-19) This response was quite exceptional considering no alleviation scheme had been implemented in the town. However, informal discussions with the local residents gave some indication as to the causes of these false perceptions. For instance, work had been carried out on the river in recent years, but unfortunately this has been construction work for a new sewer pipe, and the improvement of the river banks for a tourist attraction, and definitely not flood alleviation work.

While this response could not be explained in terms of the environmental or social factors, certain relationships similar to those in Carlisle were established with other perception variables. Seventy-one percent of those residents who perceived some authoritarian action also perceived a decrease in the flood hazard while only twenty-nine percent believed there had been no change. This compared with nineteen percent and seventy-five percent respectively who did not perceive any authoritarian response to prevent flooding.

(ii) Awareness of the flood forecasting system

To test for more detailed knowledge of authoritarian response, a specific question was included in the survey concerning flood forecasting and warning schemes; the response

TABLE 8-19

Residents : Proportion of respondents who believe something has been done in Appleby to prevent future flooding

	Appleby	Residents
Action	23	52%
No action	16	36
Did not know	5	11
Total	44	99

TABLE 8-20

Residents : Respondents knowledge of flood warning scheme for this area. (Carlisle had a public flood warning scheme although there is no such scheme for Appleby).

	Carlisle		Appleby	
Warning system	92	42%	32	73%
No warning system	78	36	10	23
Did not know	48	22	2	5
Total	218	100	44	101

TABLE 8-21

Residents : Respondents belief in the reliability of the flood warning scheme

	Carlisle		Appleby	
Reliable	36	39%	29	91%
Unreliable	0		0	
Did not know	56	61	3	9
Total	92	100	32	100

to which is shown in table 8-20. However, again a strict comparison between the two communities was not possible with this question, because of the different characteristics prevailing at each centre at the time of the survey. For instance, a flood forecasting and warning scheme had been in operation since at least 1970 in Carlisle, whereas no such scheme existed in Appleby, because of the technical difficulties of providing an accurate forecast combined with an adequate warning period (see chapter six for details).

Despite the sophisticated flood warning scheme employed in Carlisle, the current level of awareness of the scheme is very low, since only forty-two percent knew about the scheme, and the rest either were not sure or said there was no such scheme. Considering that the scheme had been operational for several years at the time of the survey, and that the procedure for disseminating the warning message involved all the flood plain residents at different levels within a pyramidal system, very few respondents were apparently aware of the scheme. The question remains, therefore, how would these people respond in the event of an unexpected flood warning, and would the warning message be successfully transmitted throughout the flood prone areas? It is doubtful if either of these would be very efficient given a real flood warning.

The Appleby response was perhaps more remarkable, because seventy-three percent of residents believed that a flood forecasting and warning scheme operated in the town, when in fact no such scheme existed. This high level of awareness was probably due to confusion over the purpose of the river level recording station located at Appleby. In effect this had little value for the town of Appleby, for it is essentially a part of the back-up mechanism and check station for the Carlisle warning system. Thus, the responses from the two communities were the reverse of the actual situation regarding flood warning schemes. Naturally, this wrong belief could create dangers in both Carlisle and Appleby in the event of a flood warning.

Those respondents who were aware of the flood warning scheme were also requested to give an appraisal of the reliability of the scheme. (table 8-21). Thirty-nine percent of respondents aware of the Carlisle system found the scheme reliable, while the rest did not know, because it had yet to be tested. Ninety-one percent of Appleby respondents found the scheme reliable despite the absence of such a scheme.

The awareness of the flood forecasting and warning scheme varied significantly with certain independent factors, which would suggest that some residential types were more likely to be aware of the scheme than others. For example, in Carlisle significantly different levels of awareness were obtained from the three areas of the city. Forty percent of respondents in Brunton Park, fifty-four percent in Botcherby and only twenty percent in Caldewgate were aware of the warning system. In Caldewgate the proportion was undoubtedly low, because the scheme was never fully extended to this area, however the others had been in position to receive warnings for several years. The relatively low level of awareness in these other cases may be explained by the proportion of residents with personal flood experience. Fifty-six percent of the respondents with flood experience were aware of the flood warning system compared to only twenty-eight percent of the non-experienced. This difference was significant at the 0.999 level of probability. Further trends in the data suggested that the more extensive the flood experience in 1968, the greater the probability of awareness. For example, only fifty-four percent of respondents flooded once were aware of the scheme, while sixty percent of those flooded twice, and seventy percent of those flooded on three or more occasions were aware of the scheme.

An analysis of the response in Appleby brought about a refinement to the above theory. Evidence suggested that the more extreme the experience of flooding the greater the probability that perception and reality will be equated. For instance, fewer residents with personal flood experience (65%) compared to non-experienced (83%) perceived (falsely) the existence of a flood warning scheme. Different characteristics of the flood hazard also showed this trend. None of those residents flooded three or more times, seventy percent of those flooded twice and all those flooded only once believed there was a flood warning scheme in Appleby. Similarly, those residents suffering the greatest monetary losses in 1968 were less likely to perceive a warning scheme, while flood duration and depth produced much the same trends only to a lesser degree. Clearly, in both communities the perception of authoritarian measures was greatly enhanced by personal experience, while more accurate perception was found amongst residents flooded to the greatest extremes.

Of the social factors only age, length of residence and tenure of the household were significantly related to awareness of the flood warning scheme in Carlisle. Older residents were more aware of the scheme than younger residents (0.005 level of significance). Fifty percent of the older residents compared to thirty-seven percent of the middle aged and only thirteen percent of the youngest were aware of the warning scheme. A similar trend was observed in the length of residence data, which also produced a very high level of significance. However, since the major difference was between newcomers to the area, and others, this probably reflects flood experience, rather than purely length of residence in the area. Tenure of the household also produced significantly different results, the responses suggesting that home owners were more aware than tenants of measures taken to alleviate the flood problem. Thus older residents, those who have lived in the area for longer periods and house owners are the most likely to be aware of the flood forecasting and warning schemes.

In conclusion, the awareness of the flood forecasting scheme in Carlisle, and the belief of one in Appleby was more likely to be accurately perceived by some residents than others. Results suggested quite significantly, that those residents with personal flood experience were generally more aware of the actual situation, than non-experienced residents, and that the greater the extent of flood experience in 1968, the more accurate the perception. In terms of social factors, older residents, respondents resident in the area for a long time, and home owners were also more likely to be aware whether a forecasting scheme operated in the town or not, compared to young newcomers in rented accommodation.

(iii) Opinions on different alleviation project strategies:

Respondents were also requested to submit opinions on various aspects of the flood hazard and flood alleviation works. These questions were designed to provide further information on the residential perception, of the effectiveness of different organisations, and of different proposed programmes to overcome the flood problem. For example, table 8-22 shows the response to the question 'what is the most reliable source of information on the flood hazard?' In Carlisle, the police were considered the most reliable organisation by forty-four percent of the respondents, while other sources of information, such as local radio, the river authority, and own judgement were mentioned by fifteen to twenty percent of respondents each. Where Carlisle respondents would depend very heavily on the police, the Appleby residents were considerably more independent, since forty-eight percent would rely on their own judgement. This independent trend was further confirmed by the response to other questions on perceived individual behaviour as shown in section three of this chapter.

The contrast between the two communities reflects the general trend for greater independence by residents of small settlements compared to those of large cities. It may also help that Appleby residents can see the river more easily, and hence are more likely to rely on their own judgement. Penning-Rowsell (1971) found similar responses to that in Appleby in the small settlements in the North Gloucestershire region, where thirty-five percent suggested they would rely on their own judgement.

TABLE 8-22

Residents : Most reliable source of information on flood risk in the area

	Carlisle		Appleby		Total	
Council	8	4%	3	7%	11	4%
Police	96	44	16	36	112	43
Local radio	33	15	0		33	13
River authority	41	19	3	7	44	17
Own judgement	34	16	21	48	55	21
Others	6	3	1	2	7	3
Total	218	101	44	100	262	101

TABLE 8-23

Residents : Opinions on upstream surface reservoirs as a means of alleviating the flooding

	Carlisle		Appleby		Total	
Strongly favour	52	24%	8	18%	60	23%
Favour somewhat	81	37	10	23	91	35
Oppose somewhat	50	23	5	11	55	21
Strongly oppose	13	6	12	27	25	10
Did not know	22	10	9	20	31	12
Total	218	100	44	99	262	101

Question thirty-six, subdivided into eight parts, provided further information on the opinions of flood plain residents towards various strategies in flood plain alleviation. To make these relevant to the interviewee, the schemes and proposals were suggested for the two communities by name.

Upstream surface reservoirs, as a means of alleviating the flooding downstream, were favoured by sixty-one percent of respondents in Carlisle, but by only forty-one percent in Appleby. Twenty-seven percent of Appleby residents were strongly opposed to such a measure compared to only six percent in Carlisle (table 8-23). This difference between respondents for and against the scheme was significant at the ninety-five percent level of confidence. The probable reason for this difference was a perceived degree of risk in the proposed structure. Appleby residents in response to this question frequently expressed fear at the thought of living so close to a major reservoir, and hence strongly objected to the scheme. This kind of attitude was never found in Carlisle, presumably because any reservoir would be well away from the residential areas of the city.

The support for flood embankments as a means of alleviating flood losses was similar for the two communities, although several trends were observed in the more extreme attitudes (table 8-24). Forty-eight percent in Carlisle, and only twenty-seven percent in Appleby were strongly in favour of such a measure, while four percent and sixteen percent respectively, were strongly opposed. The response in Carlisle confirmed the support for the present embankment scheme, and further developments to the system were seen as adding to the safety margin. In

TABLE 8-24

Residents : Opinions on the construction of flood embankments as a means of alleviating the flooding

	Carlisle		Appleby		Total	
Strongly favour	105	48%	12	27%	117	45%
Favour somewhat	51	23	16	36	67	26
Oppose somewhat	51	23	7	16	58	22
Strongly oppose	8	4	7	16	15	6
Did not know	3	1	2	5	5	2
Total	218	99	44	100	262	101

TABLE 8-25

Residents : Opinions on deepening and widening the rivers, as a means of alleviating flooding

	Carlisle		Appleby		Total	
Strongly favour	70	32%	25	57%	95	36%
Favour somewhat	68	31	9	20	77	29
Oppose somewhat	65	30	3	7	68	26
Strongly oppose	7	3	6	14	13	5
Did not know	8	4	1	2	9	3
Total	218	100	44	100	262	99

Appleby, strong opposition to the scheme came from residents concerned about the effect of such measures on the aesthetic appearance of the town.

The final structural alleviation scheme considered was the deepening and widening of rivers. The response in Carlisle indicated that sixty-three percent of residents were generally favourable to the scheme, and that half of these were strongly in favour (table 8-25). Even greater support was generated in Appleby, where fifty-seven percent of the residents were strongly in favour, out of a total of seventy-seven percent advocating some degree of support. Only three percent in Carlisle, and fourteen percent in Appleby were in strong opposition to the measure. These results suggest that residents in both communities saw this adjustment as effective in alleviating the flood problem, and as less disruptive to the local environment than other schemes.

Respondents were also given the opportunity to express their opinion on preserving the flood plain environment. Table 8-26 shows that forty-five percent of respondents in Carlisle were in favour of preserving the status quo, which compared to only twenty-seven percent in Appleby. This difference between the two research centres, which was significant within the ninety-five percent confidence limits, would suggest that Appleby residents are more dissatisfied with the present situation than Carlisle residents. This is understandable, since no adjustment has been made to alleviate the flood problem in Appleby.

TABLE 8-26

Residents : Opinions on preserving the status quo in the area

	Carlisle		Appleby		Total	
Strongly favour	74	34%	11	25%	85	32%
Favour somewhat	23	11	1	2	24	9
Oppose somewhat	55	25	11	25	66	25
Strongly oppose	62	28	19	43	81	31
Did not know	4	1	2	5	6	2
Total	218	99	44	100	262	99

TABLE 8-27

Residents : Opinions on payment for flood protection - everyone should pay through rates and taxation

	Carlisle		Appleby		Total	
Strongly favour	162	74%	30	68%	192	73%
Favour somewhat	22	10	5	11	27	10
Oppose somewhat	20	9	4	9	24	9
Strongly oppose	13	6	3	7	16	6
Did not know	1		2	5	3	1
Total	218	99	44	100	262	99

Opinions on the finance sources for flood alleviation schemes were consistent between the two communities, as illustrated in tables 8-27 and 8-28. Seventy-four percent of respondents in Carlisle, and sixty-eight in Appleby, were strongly in favour of everyone paying for flood protection through rates and general taxation, while similar proportions were strongly opposed to the suggestion that only those persons at risk from flooding should pay for the protection. This response was to be expected from residents living in flood prone areas, and a more relevant comparison would have been with residents living in safe areas of the city, who would receive no direct benefits from flood alleviation works.

The most controversial 'opinion' questions were those concerning direct government involvement in flood alleviation programmes. Table 8-29 shows the opinions of floodplain residents to the suggestion that persons living in flood hazard areas should receive a government grant to help protect personal property from flood damage. Neither community produced a clear majority either for or against the proposal, for fifty-two percent in Carlisle supported the idea, and forty-two opposed, and in Appleby opinions were equally divided for and against the scheme. Similar opinions were expressed towards the suggestion that flood plain residents should be rehoused to safer areas by the government. Fifty percent of Carlisle respondents were in favour of this measure and forty-four percent opposed, while in Appleby the proportion for and against was thirty-six percent and fifty-five percent (table 8-30). The larger proportion opposed to such a rehousing policy in Appleby reflects the greater affinity for the home environment,

TABLE 8-28

Residents : Opinions on payment for flood protection - only those at risk to flooding should pay

	Carlisle		Appleby		Total	
Strongly favour	15	7%	3	7%	18	7%
Favour somewhat	17	8	4	9	21	8
Oppose somewhat	23	11	5	11	28	11
Strongly oppose	162	74	30	68	192	73
Did not know	1		2	5	3	1
Total	218	100	44	100	262	100

TABLE 8-29

Residents : Opinions on a government grant for those in flood areas to protect themselves

	Carlisle		Appleby		Total	
Strongly favour	56	26%	9	20%	65	25%
Favour somewhat	56	26	13	30	69	26
Oppose somewhat	57	26	11	25	68	26
Strongly oppose	35	16	11	25	46	18
Did not know	14	6			14	5
Total	218	100	44	100	262	100

TABLE 8-30

Residents : Opinions on government rehousing of those in high flood risk areas

	Carlisle		Appleby		Total	
Strongly favour	47	22%	5	11%	52	20%
Favour somewhat	60	28	11	25	71	27
Oppose somewhat	25	11	6	14	31	12
Strongly oppose	73	33	18	41	91	35
Did not know	13	6	3	7	16	6
Total	218	100	44	98	262	100

TABLE 8-31

Residents : Proportion of respondents who believe individual action can overcome the problem of flooding

	Carlisle		Appleby		Total	
Overcome problem	29	13%	8	18%	37	14%
Not overcome problem	188	86	36	82	224	86
Did not know	1				1	
Total	218	99	44	100	262	100

and the reluctance of residents to leave the area, in spite of the considerable stress from flooding.

Significantly different responses were obtained for several of these opinion questions from various environmental, social and structural factors. For example, in Carlisle the views on government grants and rehousing varied significantly between the three areas. Eighty percent of respondents in Caldewgate were in favour of the schemes compared to fifty-five percent in Brunton Park and only thirty-six percent in Botcherby. Similar trends were apparent for the proposed structural schemes, although it should be noted that areal location is not the causal factor, but it merely reflects other social and environmental characteristics inherent in each area. In Appleby, structural factors did not produce any significant different responses, although in general the residents of Holme area were less favourable towards flood alleviation schemes than the other two areas.

Personal flood experience was again an important characteristic. More non-experienced respondents (eighty percent) than flood experienced (sixty-six percent) favoured larger embankments in Carlisle as a further flood precaution measure. (These results were different at the 0.0354 level of significance) while the reverse relationship tended to favour upstream reservoirs. Experienced residents, therefore, appeared to be contented with the present embankment system, but would still favour 'remote' measures, whereas non-experienced residents were more concerned with additional safety in the town. The same trends were apparent in Appleby, though these were not as extreme as Carlisle. For example, eighty-five percent of the flood experienced residents compared to seventy-one percent of the non-experienced favoured the deepening and widening of rivers. It is feasible that the flood experienced residents are more aware of the value or necessity of different schemes than those with no personal experience.

Certain social factors were also associated with the opinions expressed in question thirty-six. There was, for example, a significant difference between the responses from the different age groups at the ninety-nine percent level of confidence, which indicated an inverse relationship between increasing age, and support for a flood embankment scheme. A similar trend was observed for age response and support for the deepening and widening of rivers, significant at the ninety-five percent level. Length of residence of the respondent also produced significantly different support for the flood embankment scheme (0.0126). Clearly, in Carlisle older residents were more conservative in their attitudes towards flood alleviation measures and were generally more satisfied with the current situation.

In Appleby a different trend emerged from the age and length of residence data. In this case, there was a tendency for older residents, and those of longest residence in the town to favour structural schemes, particularly flood embankments and other river course alterations. However, the overall proportions in favour were still less than in Carlisle, except for deepening the river. These differences may be explained by the different environmental conditions found at each research centre. For example, it was postulated that residents perceiving flooding in the next twenty-five years would be most likely to favour structural flood alleviation schemes. Analyses of the responses to these questions indicated that this hypothesis was probably correct. In Carlisle, eighty-nine percent of respondents who foresaw future flooding, also favoured upland reservoirs, and ninety percent favoured the flood embankment scheme. By contrast, only sixty-three percent and sixty-six percent respectively of those who did not perceive future flooding, supported the two schemes. Both these responses were significantly different at the ninety-nine percent level. Further confirmation of this association was afforded from those respondents favouring the preservation of the current situation. In this case only twenty-four percent of those perceiving future flooding supported the proposal, compared to fifty-five percent of those who thought the area now safe. The Appleby data did not confirm these findings, but instead produced the converse relationships. However, this anomaly may be explained by the extremely low proportion of respondents who did not foresee future flooding.

One trend not explained by the above analyses is the reason for the consistently lower proportion of respondents in Appleby in favour of the proposed allevation schemes, compared to Carlisle, particularly since other evidence would indicate the opposite response. For instance;

(a) there is greater frequency of flooding in Appleby

(b) Appleby residents have a greater faith in the ability of the authorities to control flooding.

(c) Appleby residents have a greater belief that something should be done to alleviate the problem.

Other factors, therefore, must be operating in Appleby to reduce the level of support for alleviation schemes. It was found both from the questionnnaire data and council records (chapter six) that Appleby residents have a stronger feeling for their local environment and would be less willing to disturb the aesthetic appearance of the town, even to reduce the psychological stress of flooding, than Carlisle residents. Hence, the only scheme well supported in Appleby was deepening the river, which would interfer with the environment to a lesser extent than alternative schemes.

Opinions on government rehousing proposals differed significantly between house owners and tenants. Fifty percent of owners and seventy-six percent of tenants in Carlisle supported the measure, although the majority of the residents gave the proviso 'if the flooding became serious'. The difference between the tenants and owners, however, confirmed the hypothesis that owners would be less willing to vacate their property than tenants. Also, owners had lived in the area for a significantly longer period than tenants, and hence would be less willing to move. In Appleby, there was no association between tenure and opinions on the proposed schemes, but since there was also no relationship between owners and greater length of residence either, it would appear that length of residence may be the critical variable in Carlisle.

In conclusion, the influence of social variables and environmental factors on the opinions of residents towards a variety of alleviation schemes was quite diverse. Age of the respondents, length of residence and tenure of the household appeared to significantly influence residential attitudes both in Carlisle and Appleby, while personal flood experience had an even greater effect on most opinions.

One significant point to emerge from this aspect of the study was the effect of different social characteristics of the flood plain population, on the awareness of authoritarian measures. The general relationship between the perceived authoritarian actions and the independent variables in Carlisle are shown diagramatically in figures 8-4, 8-5 and 8-6. For instance, older residents were generally more aware of various flood alleviation schemes, other than the flood embankment system, which had been implemented in Carlisle on earlier occasions. Similarly, older residents showed greater awareness of the flood warning schemes; a trend also common to residents of longest duration in the area. It was also noticeable that areal location played a significant role in awareness, with respondents principally stating those alleviation measures implemented in their particular area. The environmental factors were less important than personal traits, except in that flood experienced respondents were more aware of the flood warning scheme than non-experienced residents. However, this could be a function of length of residence since the scheme was initiated after the last flood.

Thus, awareness of authoritarian action to alleviate the flood problem is essentially a product of the social and structural characteristics of the flood plain resident. This result corresponds to the findings of Roder (1961) on the Topeka flood plain, where awareness was found to relate to certain social features. However, the Cumbrian study would also suggest that proximity of any scheme is also an important factor determining awareness. The Appleby data confirmed this by the false awareness of the flood forecasting and warning scheme.

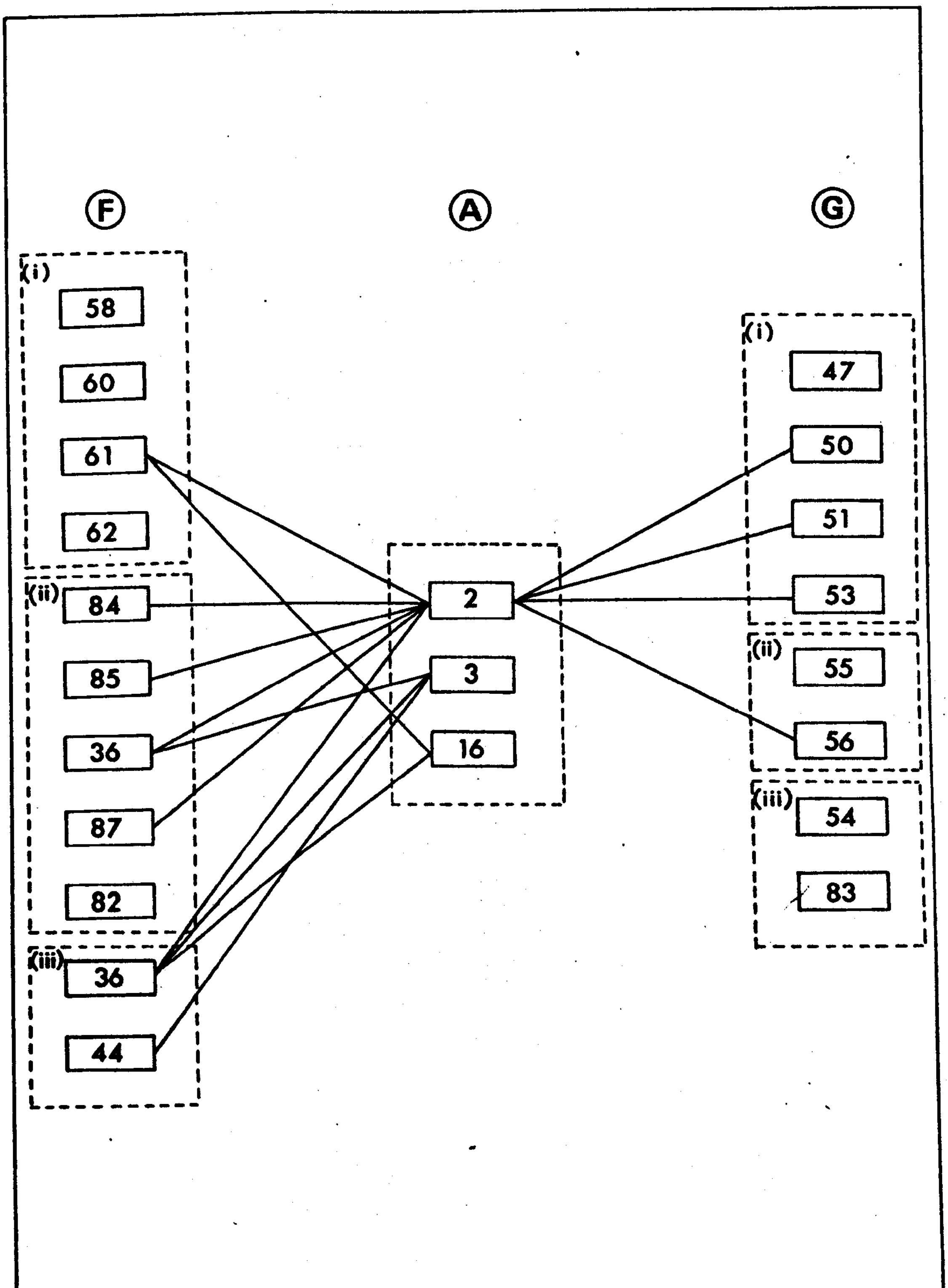


Fig. 8-4. Carlisle residents: significant relationships between structural factors (A) and variables of perception and awareness of individual remedial measures (F) and authoritarian alleviation schemes (G) using the chi squared test (see appendix II for list of variables).

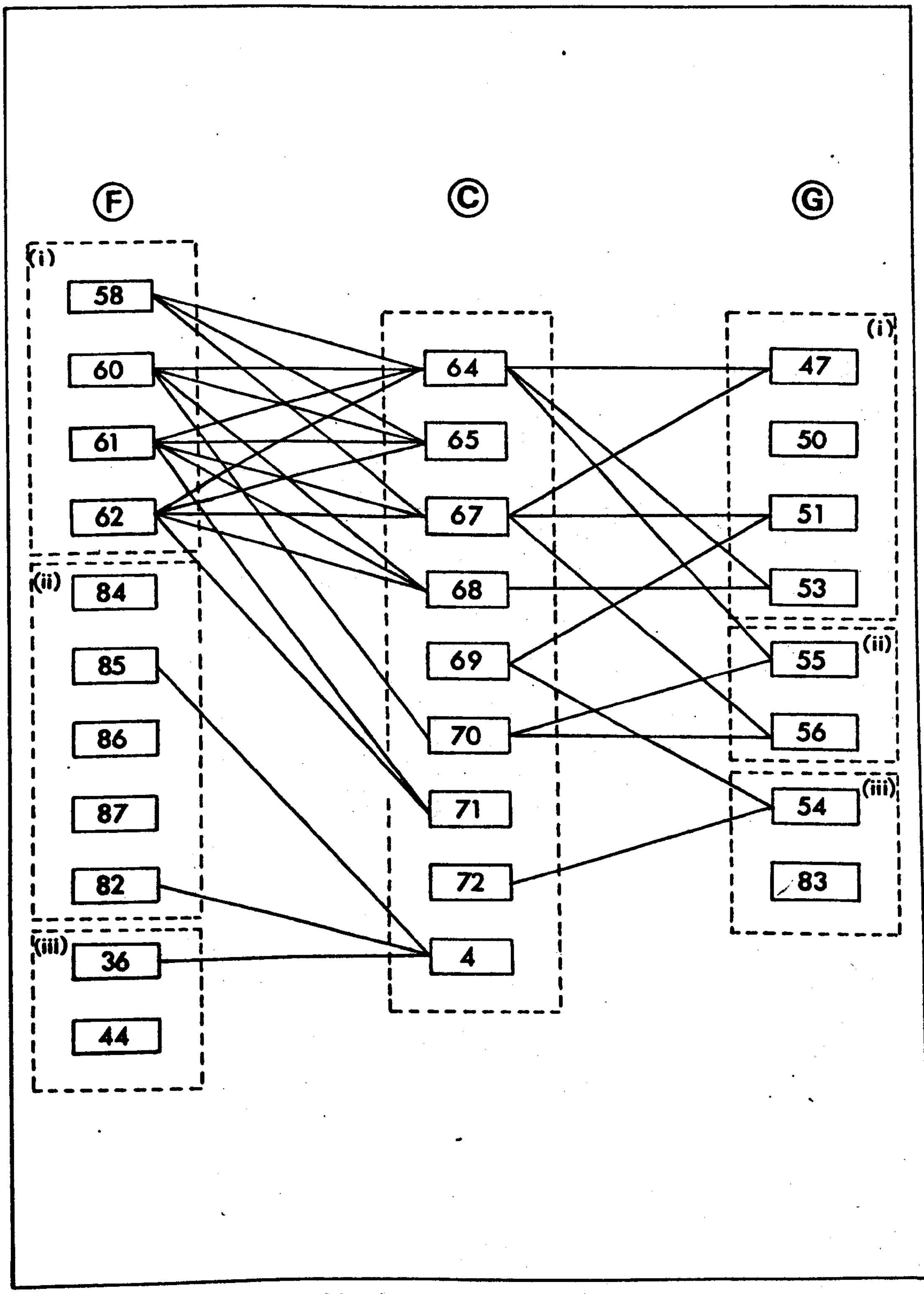


Fig. 8-5. Carlisle residents: significant relationships between social factors (C) and variables of perception and awareness of individual remedial measures (F) and authoritarian alleviation schemes (G) using the chi squared test (see appendix II for list of variables).

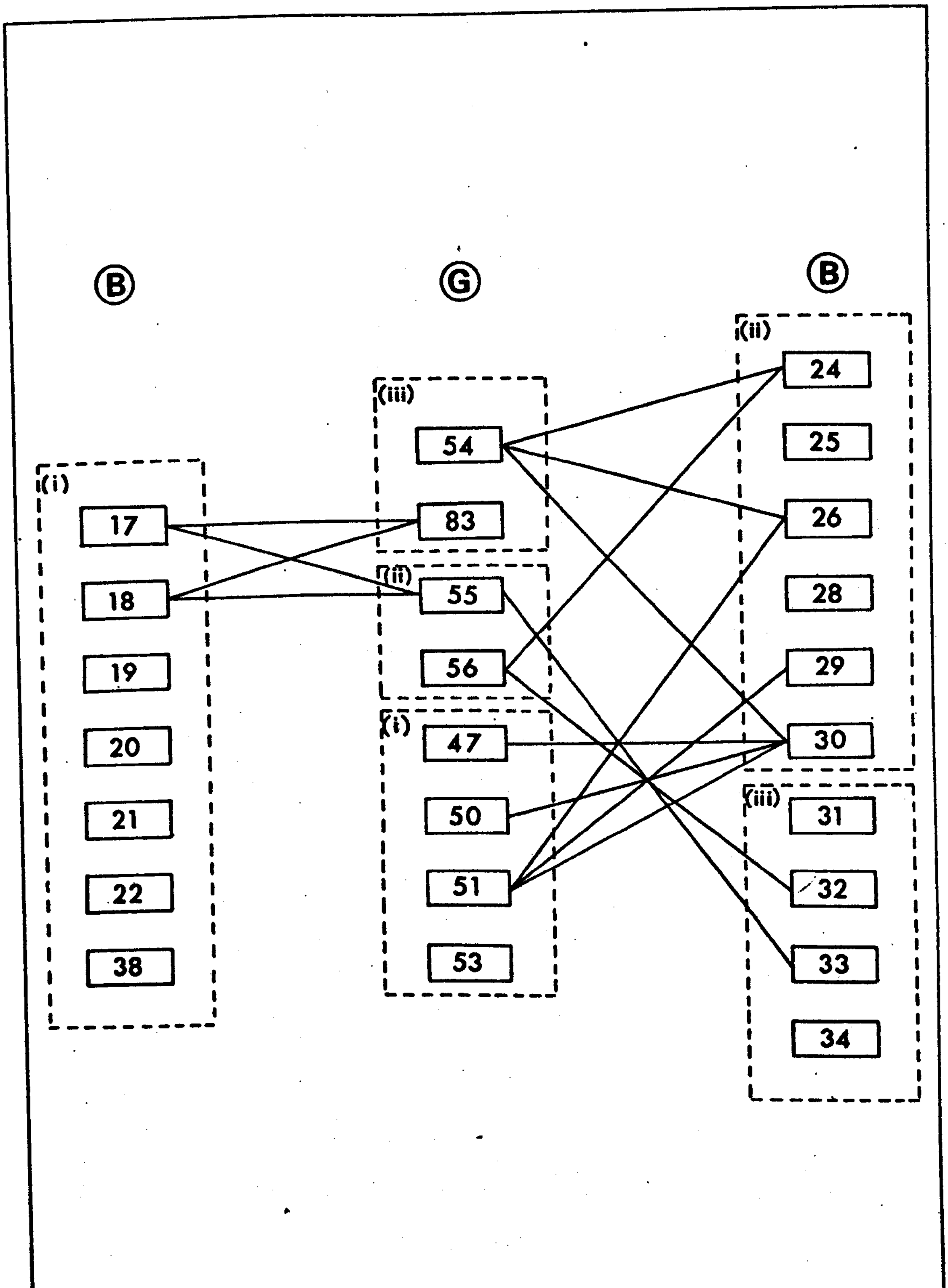


Fig. 8-6. Carlisle residents: significant relationships between physical factors (B) and variables of perception and awareness of authoritarian alleviation schemes (G) using the chi squared test (see appendix II for list of variables).

3. Individual perceived response to the flood hazard

Several questions were incorporated into the questionnaire to assess the perceived behaviour, and the perceived effectiveness of such behaviour by the flood plain resident in the event of future flooding. The basic premise of this aspect of the research was the assumption that the individual resident in responding to a flood would seek to minimise his losses in the most efficient (perceived) way. The research hypothesis, developed from this assumption, postulated that the perception would be the product of a series of independent forces and stimuli , acting on the flood plain resident in a complex interaction of environmental, social and structural factors. Three groups of questions were analysed:

(i) General residential attitudes.

(ii) Perceived response to a flood warning.

(iii) Personal evaluation of response to a flood warning.

(i) General residential attitudes

General residential attitudes were essentially examined through an analysis of the response to question thirty-seven, and in conjunction with this, question thirty-eight. Respondents were requested to state whether they thought either individual, or authoritarian action, could overcome the problem of flooding. The response to these questions for the two communities were quite similar, a low faith expressed in the ability of individual measures, and a generally high degree of faith in the ability of authoritarian measures to overcome the flood problem. For example, only thirteen percent of residents in Carlisle, and eighteen percent in Appleby believed in individual measures, while fifty-four and seventy-one percent respectively, believed that the authorities could eliminate the flood problem. (tables 8-31 and 8-32). A common response by those residents with faith in neither individual nor government measures was to believe that flooding was uncontrollable, and hence an 'Act of God', that is they transfer the hazard to some higher power. Similarly, those residents with complete faith in authoritarian action are, to a certain extent, transferring all responsibility from themselves. These results compared favourably with those for the North Gloucestershire region (Penning-Rowsell 1971). Nine percent of residents expressed faith in individual actions and thirty-two percent in authoritarian measures to alleviate the flood problem.

The responses to these two questions were explained to some extent by the degree of flood experience of the respondent. For instance, the faith in the ability of the authorities to overcome the flood problem was higher for respondents without personal experience of flooding (sixty-three percent) than for those with (forty-eight percent) at the 0.455 level of significance. In Appleby, seventy-eight percent and sixty-five percent respectively, expressed faith in government measures. Identical trends were apparent for the expressed faith in individual actions, in both Carlisle and Appleby. These results suggested, therefore, that residents without personal flood experience probably do not appreciate the numerous problems involved in flood control, neither at the small-scale individual level, nor at the large-scale authoritarian level.

TABLE 8-32

Residents : Proportion of respondents who believe government action can overcome the problem of flooding

	Carlisle		Appleby		Total	
Overcome problem	118	54%	31	71%	149	57%
Not overcome problem	97	46	13	30	110	42
Did not know	3	1			3	1
Total	218	101	44	101	262	100

TABLE 8-33

Residents : Faith in government ability to overcome the flood problem as a function of respondent's age

CARLISLE

Age (years)	Faith in Gov.		No faith in Gov.	
18-34	42	76%	13	34%
35-54	39	56	31	44
55 and over	37	41	53	59
Total	118	55	97	45

Also, the correspondingly lower faith expressed by Carlisle respondents may reflect the perceived failure of older authoritarian adjustments to control the flooding.

The research hypotheses also stated that faith in individual actions would decrease the greater the experience of flooding, because residents would perceive fewer ways of preventing inundations by flood water. While the number of floods experienced appeared to have no effect on the perceived effectiveness of individual actions, the characteristics of the 1968 flood did, to some extent, confirm the hypothesis. In Carlisle for instance, there was an inverse relationship between flood depth and faith in individual actions (not statistically significant). A similar but significant relationship, was found between faith and flood losses in 1968. Those respondents suffering no financial loss during the flood, expressed greater faith than those who had lost valuables and belongings. The same inverse relationship with the characteristics of the 1968 flood were observed with faith in the ability of authorities to overcome the flood problem.

The successful utilization of remedial measures during the 1968 flood also had an effect on the perceived effectiveness of individual actions. Evidence from both Carlisle and Appleby suggested that the past successes in controlling the flooding led to greater confidence in future actions. For example, in Carlisle twenty percent of respondents who successfully used sand bagging in 1968 had faith in the ability of individuals to overcome the flood hazard, while only eleven percent of those who used the measure, but found it of little value, had similar faith. Similarly, only three percent of those who received a flood warning, perceived effective individual action, compared to fifteen of those who did not. Hence, this particular variable would appear to be related to the relative perceived success or failure of past experiences.

Social factors also played a part in determining the degree of faith in individual and authoritarian actions. It would appear that females have generally less faith in either alternative to overcome the flood problem. In Carlisle, forty-eight percent of males and twenty-eight percent of females had faith in individual actions, and sixty-five percent males and fifty-one percent in authoritarian measures. These two responses were significant at the ninety-five percent and ninety percent levels respectively. In Appleby, twenty-eight percent of males, and twelve percent of females, put forward the same views on individual measures, and ninety-four percent and fifty-four percent on authoritarian measures.

Apart from sex, age also produced significantly different responses to these questions. Table 8-33 shows the inverse relationships between faith in the authoritarian ability to overcome the flood problem and increasing age, significant well within the ninety-nine percent confidence limits, while table 8-34 shows a similar association between age and faith in individual measures, significant at the ninety-five percent level. Most faith in individual actions to overcome the problem of flooding was expressed by the younger respondents. Again, this reflected either (i) the greater mobility and agility of this group and hence the perceived greater effectiveness of remedial measures in preventing the inundation of property; or

TABLE 8-34

Residents : Faith in individual ability to overcome the flood problem as a function of respondent's age

Age (Years)	Faith in individual		No faith in individual	
18-34	11	21%	42	79%
35-54	12	17	60	83
55 and over	6	7	85	93
Total	29	13	188	87

TABLE 8-35

Residents : Response to an official six hour warning of an impending flood

	Carlisle		Appleby		Total	
Do nothing	6	3%	1	2%	7	3%
Keep watch	23	11	19	43	42	16
Consult others	10	5	3	7	13	5
Use temporary measures	78	36	10	23	88	34
Move valuables	161	75	20	45	181	70
Evacuate premises	21	10	1	2	22	8
Total	299(139)		(54)(123)		(353)136	
Did not know	(3)					
	(% of 215		44		259)	

(ii) the lack of experience of this group, and hence the inability to appreciate some of the problems of flood prevention.

Other social variables showed a variety of trends with this data, but none were significant within the 0.05 level set by the research design. Clearly, the most important social factors affecting the faith in authoritarian and individual capabilities are sex and age, while the environmental factors of personal flood experience, extent of past flooding and the perceived effectiveness of remedial measures in the past are also vital in determining the attitudes of flood plain residents to these questions.

(ii) Perceived response to a flood warning

This aspect of the research was included to investigate the response of the flood plain resident to a public flood warning. This incorporated two main objectives:

(a) To assess the effectiveness of the residential response to the warning, and hence examine the perceived efficiency of the whole scheme.

(b) To develop the predictive aspect of the research by analysing the causes and stimuli governing the perceived response to the flood warning. This also incorporated a review of residential awareness of various individual flood alleviation measures.

Unfortunately, at least as far as the research was concerned, an official flood warning had never been issued in Carlisle since the inception of the scheme, and hence there was no evidence of residential response during such an emergency. As a result, it was decided to test the resident's perceived response to such a warning, under the artificial conditions of a questionnaire survey. (In the future it may be possible to compare the respondent's perceived behaviour, with actual behaviour following a real flood alert).

The perceived response to a six hour flood warning by the individual flood plain resident is shown in table 8-35. In Appleby residents were more likely to rely on their own judgement than undertake immediate remedial action as in Carlisle. For example, while relatively few respondents in either community would do nothing or consult others following a warning, forty-three percent of residents in Appleby would keep watch on the river, which compared with only eleven percent in Carlisle. Since Appleby residents live in closer proximity to the river, this high proportion is perhaps to be expected. On the other hand, thirty-six percent of respondents in Carlisle, but only twenty-three percent in Appleby, would employ temporary measures to prevent flood waters entering their property. Seventy-five percent of respondents in Carlisle would remove valuables to a higher level, whereas only forty-five percent in Appleby intimated that they would do this. It would appear that Appleby residents would use their own judgement before undertaking any major remedial measures in the event of a flood warning.

Certain characteristics of the flood plain residents appeared to influence significantly the perceived response to the flood hazard, and hence advance knowledge of these characteristics could be useful in predicting residential response to a flood warning in the future. For example, in Carlisle personal flood experience was a critical factor determining response to a warning. Of the respondents with flood experience, only twenty - six percent would employ temporary measures, such as sand bagging, whereas fifty percent of the non-experienced would use this technique. These responses were different at the 0.0006 level of significance. Evacuation of premises during a flood warning also produced significant results with proportionally more non-experienced than experienced residents perceiving this response. The non-experienced residents, therefore, tend to opt for the more extreme measures, either expressing great faith in temporary adjustments or perceiving evacuation of the property as the only response.

Further explanation of these trends was derived from an analysis of actions undertaken in 1968. Seventy-eight percent of those residents, who utilized some form of temporary measure to control flooding, stated that they would not do so again, and neither would seventy percent of those who did not employ such techniques. To a certain extent, this was due to the high failure rate of such schemes in 1968, and to the perceived problems of preventing the inundation of property by temporary measures.

The other flood characteristics were less important than actual experience, in determining the perceived response to the flood warning. Flood depth and the employment of temporary measures varied significantly (table 8-36) but this probably reflected the decreasing success of such measures with increasing flood depth. The opposite trend was apparent for the removal of valuables to higher levels, the proportion increasing with the experience of greater flood depth in 1968 (table 8-37).

In Appleby, similar trends were found, which confirmed the Carlisle findings, between environmental factors and the perceived response to a flood warning. For instance, only four percent of flood experienced residents would employ temporary measures, compared to fifty percent of the non-experienced group. Only one resident who used such measures in 1968 perceived similar schemes in the future. A further association observed in Appleby, but not Carlisle, was found between environmental factors and those respondents who would keep watch on the river in the event of a flood warning. The evidence suggested that flood experience, experience of more than one flood, and residents flooded for the longest duration in 1968, were most likely to perceive this response. These results suggest that the greater the experience of flooding the greater the dependence on own judgement in future events. Also, the closer proximity of Appleby dwellings to the river than Carlisle dwellings may have encouraged this response, on the assumption that residents need to see the river in order to keep watch on it.

Social characteristics were also important in determining the perceived response to a flood warning. The proportion of

TABLE 8-36

Residents : Perceived employment of temporary measures following a flood warning, as a function of flood depth experienced in 1968

CARLISLE

Depth	Employ measure		Not employ measure	
Outer walls	16	39%	25	61%
Floor boards	6	25	18	75
Internal flooding	9	16	46	84
Total	31	26	89	74

TABLE 8-37

Residents : Perceived removal of valuables to higher levels following a flood warning, as a function of flood depth experienced in 1968

CARLISLE

Depth	Employ measure		Not employ measure	
Outer wall	27	66%	14	34%
Floor boards	18	75	6	25
Internal flooding	46	84	9	16
Total	91	76	29	24

respondents employing temporary measures for example, decreased with increasing age (table 8-38) which was significant at the 0.001 level according to the chi squared test. However, two explanations were proposed to explain this response; first older residents would probably be less capable of intensive, and perhaps heavy work in the event of a flood warning; second, older residents were also the more experienced group, and hence may perceive little value in trying to prevent flood water entering buildings. However, since the same trend was found between age and removal of valuables to a higher level (table 8-39) significant at the ninety-nine percent level, it would appear that the former explanation is more valid.

The response in Appleby tended to confirm the Carlisle statistics, with the proportion employing temporary measures declining from fifty to eleven percent from youngest to oldest, and for the removal of valuables from seventy-five percent to forty-five percent. Thus, age apparently plays a major role in determining future flood plain behaviour, which also corresponds with the greater faith expressed in individual actions by the younger respondents.

The number of persons per household also played a significant role in the perceived response to a flood warning, although to a certain extent this response could be a function of age and experience. Only a very small proportion (14%) of one person households perceived the use of temporary measures, but since this group corresponded to the older residents, this response was to be expected. Two and three person households were generally the residents, more capable of undertaking such

TABLE 8-38

Residents : Perceived employment of temporary measures following a flood warning, as a function of respondent's age

CARLISLE

Age (years)	Employ measure		Not employ measure	
18-34	29	54%	25	46%
35-54	28	39	43	61
55 and over	21	23	69	77
Total	78	36	137	64

TABLE 8-39

Residents : Perceived removal of valuables to higher levels following a flood warning, as a function of respondent's age

CARLISLE

Age (Years)	Employ measure		Not employ measure	
18-34	47	87%	7	13%
35-54	62	87	9	13
55 and over	52	58	38	42
Total	161	75	54	25

schemes, but probably less effective because of their lack of experience. Finally, there was a tendency for large families, who incidentally have lived in the area longer, and hence have greater flood experience, to be less interested in temporary measures. These reponses were different at the 0.0071 level of significance. Corresponding to this was the response to the removal of valuables to a higher level (0.0002) with the proportion increasing with increasing family size. Not only does this reflect the greater experience of flooding, but also the greater availability of labour for undertaking such a response. The Appleby data did not confirm these findings because of the lack of variation in household size in the town.

Length of residence in the Carlisle area illustrated a more complex relationship with the perceived response to a warning. The first category, up to six years residence, corresponded to the non-experienced group, and hence, as shown above, a large proportion favoured temporary measures. Similarly, a large proportion of respondents, resident in the area for the longest period, also perceived this response, which probably reflects their greater experience, and successful application of such measures in the past. Apart from this, length of residence showed no particular relationships with any other perceived response in either Carlisle or Appleby.

The responses based on tenure, education and occupation did not produce significantly different results concerning the perceived response of residents to the flood warning. However, skilled manual workers, and professional workers were the most confident in preventing inundation by temporary measures of the various occupation types. In general, flood plain behaviour did not appear to be affected by these three variables.

In conclusion, the perceived response to a six hour flood warning is to a certain extent determined by the social characteristics, and the degree of flood experience of the flood plain resident. Age, length of residence and population structure all play differing roles in influencing the flood plain resident, while personal flood experience and experience of similar remedial measures in real flood situations significantly effect the perceived response. Probably the most noteworthy trend, with respect to the perceived response to a flood warning, was that expressed by the non-experienced residents. A relatively high proportion of this group perceived the utilisation of temporary measures to prevent flood waters entering their property. It is reasonable to suggest, on the evidence of the 1968 flood, that the majority of these measures would be ineffective in a real flood, because of problems similar to those expressed in the previous chapter. In such a situation as this, therefore, the flood warning scheme would be of little value, since many respondents would waste valuable time undertaking unproductive remedial measures. This research, therefore, would indicate that flood plain residents require expert advice on effective action in the event of a flood, especially on flood proofing measures, and particularly in those areas which rely purely on flood forecasting and warning schemes for flood alleviation.

(iii) Personal evaluation of response to a flood warning

The final question in the questionnaire requested the respondents to estimate the damage that would occur from two types of flooding, first without any warning whatsoever, and second with six hours flood warning. This question provided not only a crude estimation of future flood losses for each flood plain, but, probably of more value to the research, the perceived effectiveness of remedial action in the event of a flood. The residential attitude, response and behaviour, following a flood warning, could then be assessed, and hence the effectiveness of such a scheme for Carlisle and Appleby evaluated. The two hypothetical floods considered in this respect differed in respect of depth: 15 cm (6 inches) and 120 cm (4 feet).

The fifteen centimetre flood produced significantly different responses between residents in Carlisle and those in Appleby for flood loss estimates, both with and without six hours warning. Table 8-40 shows the estimated losses from the flood with no warning, for Carlisle and Appleby. In Carlisle, 47% of respondents perceived losses to be less than £500, 31% between £500 and £1000, and 23% more than this, while in Appleby the proportion of residents estimating similar losses were 80%, 15% and 5%. The mean losses for each community, based on the actual perceived losses were £858 in Carlisle and £453 in Appleby. A chi squared test on the data suggested the difference between the responses was significant at the 0.995 level of probability.

TABLE 8-40

Residents : Estimated losses from 15 cm (6") flood without warning

	Carlisle		Appleby		Total	
Nothing	0	0%	0	0%	0	0%
1 to 500 pounds	92	47	32	80	124	52
501 to 1000 pounds	61	31	6	15	67	28
1001 to 3000 pounds	39	20	2	5	41	17
Over 3000 pounds	5	3	0		5	2
Total	197	101	40	100	237	101
(Did not know)	21		4			

TABLE 8-41

Residents : Estimated losses from 15 cm (6") flood with 6 hours warning

	Carlisle		Appleby		Total	
Nothing	24	12%	3	8%	27	11%
1 to 500 pounds	133	68	37	93	170	72
501 to 1000 pounds	26	13	0		26	11
1001 to 3000 pounds	11	6	0		11	5
Over 3000 pounds	2	1	0		2	1
Total	196	100	40	101	101	100
(Did not know)	22		4			

Table 8-41 shows the perceived losses from a flood of similar depth, but this time following six hours warning. Again the two responses were significantly different at the 0.99 probability level according to the chi squared test. The Carlisle response, 12% suggested there would be no losses and only 20% put their losses in excess of £500, which compared with the Appleby response where 8% reported no losses and the rest put their losses less than £500. The mean perceived losses with six hours warning fell to £471 in Carlisle and £150 in Appleby. Clearly, the estimated losses, both with and without flood warning, are significantly higher in Carlisle than Appleby. Throughout the four aspects of this particular question the estimated flood losses from Carlisle respondents was significantly higher than those for Appleby, which contradicts the actual experiences of 1968 when considerably greater losses were reported by Appleby households. However, on this occasion Appleby suffered generally greater flood depths than Carlisle, which has been shown to be positively correlated with flood losses. With hypothetically equal flood depths this trend was reversed, which would indicate a fundamental difference in the socio-economic characteristics of the two settlements. Evidence from the social characteristics of the questionnaire survey supports this hypothesis, since significant differences were found between such factors as house type, family structure, number of adults, number of children and tenure of household in the two communities. Each of these variables suggested that Carlisle residents would generally have more property and valuables at risk to flooding than Appleby residents.

The percentage savings perceived from a flood with a six hour warning, produced an entirely different picture than the actual figures. For instance, individual perceived savings ranged from nought to one hundred percent, and, of even greater significance, the percentage savings were considerably higher in Appleby than Carlisle (table 8-42). The mean perceived savings in Carlisle amounted to 45.08%, whereas in Appleby the mean was 66.85%. Again, the chi squared test suggested these two responses were significantly different within the 99% confidence limits.

The total perceived losses from a fifteen centimetre flood, both with and without warning are shown in table 8-43 and these figures are further extended to the whole flood plain. The total losses in Carlisle would amount to £492,000 (plus or minus £10,000 allowing for the error due to sampling) and to £22,000 in Appleby from such a flood without warning, while given a six hour warning these losses would be reduced to £270,000 (+/- £5,400) in Carlisle and £7,250 in Appleby. The perceived savings as a result of implementing a flood warning scheme would be approximately £220,000 (+/- £4,400) and £15,000 for Carlisle and Appleby respectively. Nevertheless, these figures are based on the individual <u>perceived</u> losses and hence may not accurately reflect the <u>actual</u> losses accruing from such a flood situation.

Similar results were obtained for estimates of losses from a flood with a depth of 120 cm, both with and without warning. Without a flood warning perceived losses were quite high, with only 10% of Carlisle respondents estimating their losses to be less than £500, and 55% at over £1000 (table 8-44) In Appleby,

TABLE 8-42

Residents : Perceived savings - 15 cm flood with 6 hours warning

	Carlisle		Appleby		Total	
0 - 25 percent	33	17%	3	8%	36	%
26 -50 percent	54	27	5	13	59	
51 - 75 percent	39	20	10	25	49	
76 - 100 percent	71	36	22	55	93	
Total	197	100	40	101	237	

TABLE 8-43

Residents : Total perceived losses and savings - 15 cm flood

	Carlisle	Appleby	Total	
Total perceived losses	£169,100	£18,100	£187,200	No Warning
Mean losses	£ 858.4	£ 425.5	£ 789.9	
Total flood plain losses	£491,863	£22,173	£514,036	
Total perceived losses	£ 92,400	£ 6,000	£ 98,400	6 hours warning
Mean losses	£ 471.43	£ 150	£ 416.9	
Total flood plain losses	£270,129	£ 7,350	£276,729	
Perceived savings	45.08%	66.85%	46.22%	
Total flood plain savings	£221,734	£14,823	£236,557	

35% estimated losses to be less than £500 and 23% in excess of £1000, which indicated a significant difference between the two communities at the 0.999 level of probability, according to the chi squared test. The mean perceived losses were much higher than with the previous flood, £2161 in Carlisle and £958 in Appleby, which again shows up the generally higher perceived losses in the larger settlement.

Losses from a 120 cm flood were significantly reduced given a six hour warning. Table 8-45 shows that 5% of Carlisle respondents would expect no losses, 43% less than £500, and only 26% over £1000. The similar proportions for Appleby were 3% and 88%, and none put their losses over £1000. These differences were again significant at the 0.999 level of probability. The mean losses with warning for Carlisle and Appleby respectively were £1122 and £278.

The perception of individual savings with six hours warning also differed between the two communities, as shown in tables 8-46 and 8-47. The mean percentage savings in Appleby at 71.83% were considerably higher than at Carlisle 48.1% (although both represented greater savings than with the previous smaller flood). In Appleby, eighty-three percent of the residents estimated savings in excess of fifty percent, which compared to only forty-five percent in Carlisle.

The total perceived losses from the 120 cm flood without warning, when extrapolated to the whole flood plain, amounted to £1,238,000 (+/- £24,360) in Carlisle and £48,000 in Appleby. With six hours warning these losses would be reduced to £643,000 (+/- £12,860) and £13,600, which represents savings of £600,000

TABLE 8-44

Residents : Estimated losses from 120 cm (4') flood without warning

	Carlisle		Appleby		Total	
Nothing	0	-%	0	-%	0	-%
1 to 500 pounds	18	10	14	35	32	14
501 to 1000 pounds	66	35	17	43	83	36
1001 to 3000 pounds	72	38	8	20	80	35
Over 3000 pounds	33	17	1	3	34	15
Total	189	100	40	101	229	100
Did not know	29		4			

TABLE 8-45

Residents : Estimated losses from 120 cm (4') flood with 6 hours warning

	Carlisle		Appleby		Total	
Nothing	10	5%	1	3%	11	5%
1 to 500 pounds	80	43	35	88	115	51
501 to 1000 pounds	48	26	4	10	52	23
1001 to 3000 pounds	34	18	0		34	15
Over 3000 pounds	14	8	0		14	6
Total	186	100	40	101	226	100
Did not know	32		4			

TABLE 8-46

Residents : Perceived savings - 120 cm flood with 6 hours warning

	Carlisle		Appleby		Total	
0 - 25 percent	59	31%	4	10%	63	%
26 - 50 percent	45	24	3	8	48	
51 - 75 percent	38	20	13	33	51	
76 - 100 percent	47	25	20	50	67	
Total	189	100	40	101	229	

TABLE 8-47

Residents : Total perceived losses and savings - 120 cm flood

	Carlisle	Appleby	Total	
Total perceived losses	£408,450	£39,400	£447,850	No warning
Mean losses	2161.11	£ 985	£ 1955.68	
Total flood plain losses	£1,238,316	£48,265	£1,286,581	
Total perceived losses	£208,600	£11,100	£219,700	with warning
Mean losses	£1,121.51	£ 277.5	£972.12	
Total flood plain losses	£642,625	£13,598	£604,659	
Perceived savings	48.1%	71.83%	53.0%	
Total flood plain savings	£595,691	£34,667	£681,922	

(+/- £12,000) and £35,000 for Carlisle and Appleby. As with the previous flood, these data are based on perceived losses, rather than actual figures, and hence may not reflect the real situation but rather the perceived. Similarly, both flood levels reflect the same patterns of response, with the actual losses estimated by the Carlisle residents far in excess of those by Appleby, although the percentage savings are greatest in Appleby. Also, while the larger flood increases the perceived losses quite significantly, the perceived savings are also raised.

Further analyses of both the perceived losses and the perceived percentage savings from six hours warning of a flood showed several significant relationships with the independent variables. In Carlisle, the estimated losses for both flood events, with and without warning, varied significantly within the ninety-five percent confidence levels, with the areal location of the respondent. The trend was the same in all four cases, with highest estimates from Brunton Park residents, followed by Botcherby and finally Caldewgate. There would appear to be a fundamental difference in the economic characteristics of these three cases, a characteristic which was confirmed by personal observation during the questionnaire survey. In Appleby, there was no such significant difference between different areas.

General flood characteristics were not very significant with respect to the estimated flood losses, or with perceived savings from a six hour warning in either Carlisle or Appleby. The only trend to emerge from the statistical testing, which was observed in both communities, was the tendency for non-experienced residents to estimate greater flood losses than experienced residents. For example, in Carlisle twenty-eight percent of respondents without personal flood experience, and only eighteen percent of those with, put losses from a 15 cm flood in excess of £1000. However, with six hours warning the responses were almost identical. A similar, though not significant trend, was found for the larger flood, which would suggest that non-experienced residents possibly overestimate their losses, given that the other residents are more likely to be correct, because of their personal experience. In Appleby, these differences were less pronounced, although a more noticeable trend was observed with perceived savings with a flood warning. Experienced residents generally perceived smaller percentage savings than the non-experienced residents, fifty-two to fifty-nine percent for the fifteen centimetre flood, and forty-three and fifty-nine percent for larger event. In this case, it would appear that non-experienced residents have overestimated the effectiveness of their remedial action prior to a flood, again given the assumption that experienced residents are more likely to be correct.

Several social factors also appeared to affect the perceived losses from the two floods, as well as the perceived savings following six hours flood warning. In Carlisle, age of the respondent was significantly related to the perceived losses accruing from the fifteen centimetre flood, both with and without warning. The youngest residents estimated losses significantly higher than the other residents, while with six hours warning the trend was completely reversed with the oldest expecting the greatest losses, and the youngest the least.

As a result, the percentage savings made due to a flood warning was also significantly different between the three age groups, with the greatest savings perceived by the youngest residents. The larger flood exhibited the same association between age and estimated losses, although it was only the perceived percentage savings, which proved statistically significant, within the ninety-five percent level of confidence. Further support for this association came from the Appleby data, which showed exactly the same tendencies as Carlisle. One hypothesis put forward to explain this relationship, concerned a combination of age and personal flood experience, which themselves were related (chapter seven). It was postulated that younger residents, who for the most part had little personal experience of flooding, would tend to over estimate flood losses, and have a greater faith in the ability to prevent the inundation of property by flood waters. Alternatively, older residents, with experience, would probably more accurately estimate flood losses, but would be less capable of remedial action prior to a flood, and hence perceive less savings. It may also be that older residents are more aware of the difficulties of preventing flooding and hence have less faith in their own ability. Both these aspects were discussed in more detail in part 3(i) of this chapter.

Population per household also had a significant effect on the response to this question. The estimate of losses from the first flood showed a positive correlation with numbers per household, whilst with warning this trend was inverted. This relationship indicates the greater property at risk in a large household, but since more persons are available for remedial action given a flood warning, the perceived losses are greatly reduced in the larger families by such a warning. As a result, the highest perceived savings correspond to the larger families. This relationship was further confirmed by the response to the larger flood event, while similar trends were apparent with the number of adults and number of children per household. (Significantly different results were restricted to the perceived savings for these latter two variables).

Tenure of the household confirmed the research hypotheses, that home owners would perceive greater losses from flooding than tenants, because of the greater value of property at risk. However, significantly different results were only obtained in the larger flood, although the smaller event exhibited the same trends. In Carlisle, 58% of home owners and only 29% of tenants estimated losses in excess of £1000 for the large flood without warning, and 28% and 6% respectively with warning. This trend, however, was not apparent in Appleby. Also, tenure, as anticipated, had no effect on the perceived effectiveness of remedial action following a flood warning.

Occupation did not significantly affect the perceived losses from flooding, although in Carlisle the same two groups, in assessing losses for the two floods, were consistently higher than others - the self employed and managerial workers. Similarly with education, there was a small trend to suggest that longer education was related to larger perceived losses. These two variables in fact probably reflected the differences in the value of possessions at risk in properties.

In conclusion, it was found that structural and social variables had the greatest effect on the estimated losses from the two floods, since these were probably the best indications of social class. However, the perceived percentage savings were determined by previous flood experience, and to a certain extent by social characteristics such as age.

The overall relationship between the independent variables and the perception of individual actions is shown diagrammatically in figures 8-4, 8-5 and 8-7. Clearly, these indicate the great importance of social factors in determining this aspect of residential attitudes and behaviour. For instance, the perceived response to a flood warning differed significantly according to age of the respondent, family structure and in some cases by length of residence and occupation of the head of household. Younger residents invariably envisaged the greatest and widest forms of response to a flood warning, although as was shown above these may not always prove effective, while, at the same time, this group foresaw the greatest losses from flooding without warning. House owners and larger families also put their perceived flood losses higher than other groups. However, younger residents also perceived the largest savings following remedial action prior to a flood, a trend which was further confirmed by the very high faith expressed in both individual and government ability to overcome the flood problem. These results may be explained by environmental factors, since younger residents in general have less personal experience of flooding than older residents. Quite frequently, therefore, the young inexperienced resident perceived actions, which have been proved ineffective to the older experienced resident, as well as perceiving unrealistic savings from such remedial actions. However this immediately puts in doubt the value of the flood warning scheme, given that a large proportion of flood plain residents may well undertake inefficient action. This proportion of inexperienced residents on the flood plain is likely to increase in time, until another flood.

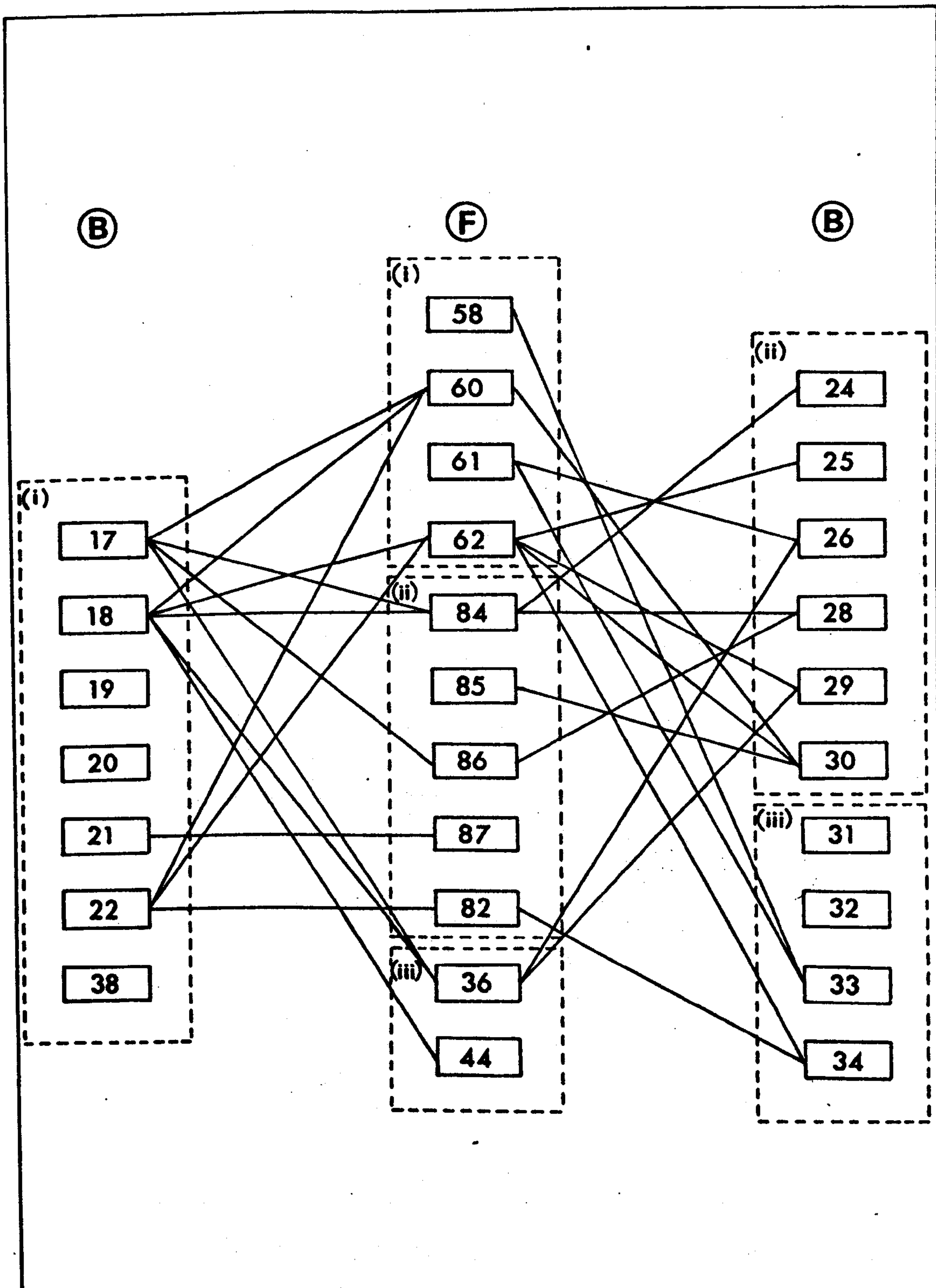


Fig. 8-7. Carlisle residents: significant relationships between physical factors (B) and variables of perception and awareness of individual remedial measures (F) using the chi squared test (see appendix II for list of variables).

CONCLUSIONS:

The analyses of the questionnaire data indicated a more complex interrelationship between the perception and behaviour of flood plain residents, than was presupposed by the initial research hypotheses. While the basic associations between the variables, illustrated in figure 4-1, were observed in the survey data, further, more detailed, relationships were also found. Using the criteria of structural factors of the household, personality traits, family features, and extent of flood experience, certain types of resident were seen to behave in a set way, compared to other residential types. On a more general level however, the thought processes remained essentially the same for each group. Thus, two major conclusions emerged from the questionnaire studies -

(i) The behaviour and attitudes related to residential types.

(ii) A revised model of residential response to the flood hazard.

Together, these two aspects provide the insight for a predictive model of flood plain behaviour.

(i) Behaviour and attitudes related to residential type.

Throughout the questionnaire survey, it became apparent that some factors played a considerably greater role in determining flood plain behaviour than others. For example, the structural factor of areal location was particularly important concerning general perception, and the perceived losses from various hypothetical floods. In this latter case, in Carlisle certain socio-economic features were reflected in responses, which classified Caldewgate, Botcherby and Brunton Park into their relative social divisions. Brunton Park residents for instance, perceived much greater losses than Caldewgate.

Social factors of particular significance were age of respondent, length of residence in the area and tenure of household. Older residents, residents of longest duration and home owners (a degree of correlation existed between these three - chapter seven) showed the greatest awareness of the flood hazard, of the authoritarian response to the hazard, and were generally more adjusted to the flood plain environment. Evidence from both Carlisle and Appleby indicated that the perception and awareness expressed by these groups was probably nearer reality, than young newcomers to the area. For example, perception of future flooding was inversely related to increasing age in Carlisle, despite the greater experience of older residents, whilst in Appleby, perceived future flooding generally increased with age. This apparent discrepancy between the results is essentially explained by the greater knowledge of the older residents. In Carlisle, older residents showed more awareness of authoritarian schemes to alleviate flooding, and hence perceived a greater decrease in the flood hazard, whereas in Appleby the older residents were less likely falsely to perceive a flood alleviation scheme, and hence more likely to perceive future flooding in the town. Similarly, younger residents tended to over estimate perceived losses from flooding, but at the same time, have considerably greater faith in individual measures to prevent flood losses. However, the perceived actions were frequently techniques which had failed in 1968, and thus fewer savings would be made by this group than presently perceived. This response, therefore, casts some doubt on the validity of the flood forecasting and warning schemes, because studies usually assume that individuals will take effective remedial action to minimise flood losses. This does not appear to be the case with the greater proportion of younger residents. Length of residence and house ownership showed similar such relationships as age, all three of which are illustrated in figures 8-8, 8-9 and 8-10.

Probably the most significant of all the independent variables in determining behavioural attitudes was personal flood experience. This variable was significantly associated with both awareness of the hazard and of schemes implemented to control the hazard. Experience of flooding in the past would appear to produce more factually accurate perceptions of future flood risk. As well as flood experience, the extent and degree of flooding, such as total number of floods experienced, and the depth, duration and damage caused by flooding in 1968, also have a profound effect on the perception and behaviour of flood plain residents. For example, persons employing temporary measures in 1968, such as sand bagging, and finding them unsuccessful were unlikely to perceive such adjustments again. It is perhaps significant that all those residents who found such measures effective in 1968 were only flooded to low depths (chapter seven). One suggestion to emerge from these surveys, therefore, would be for sand bags to be issued to householders

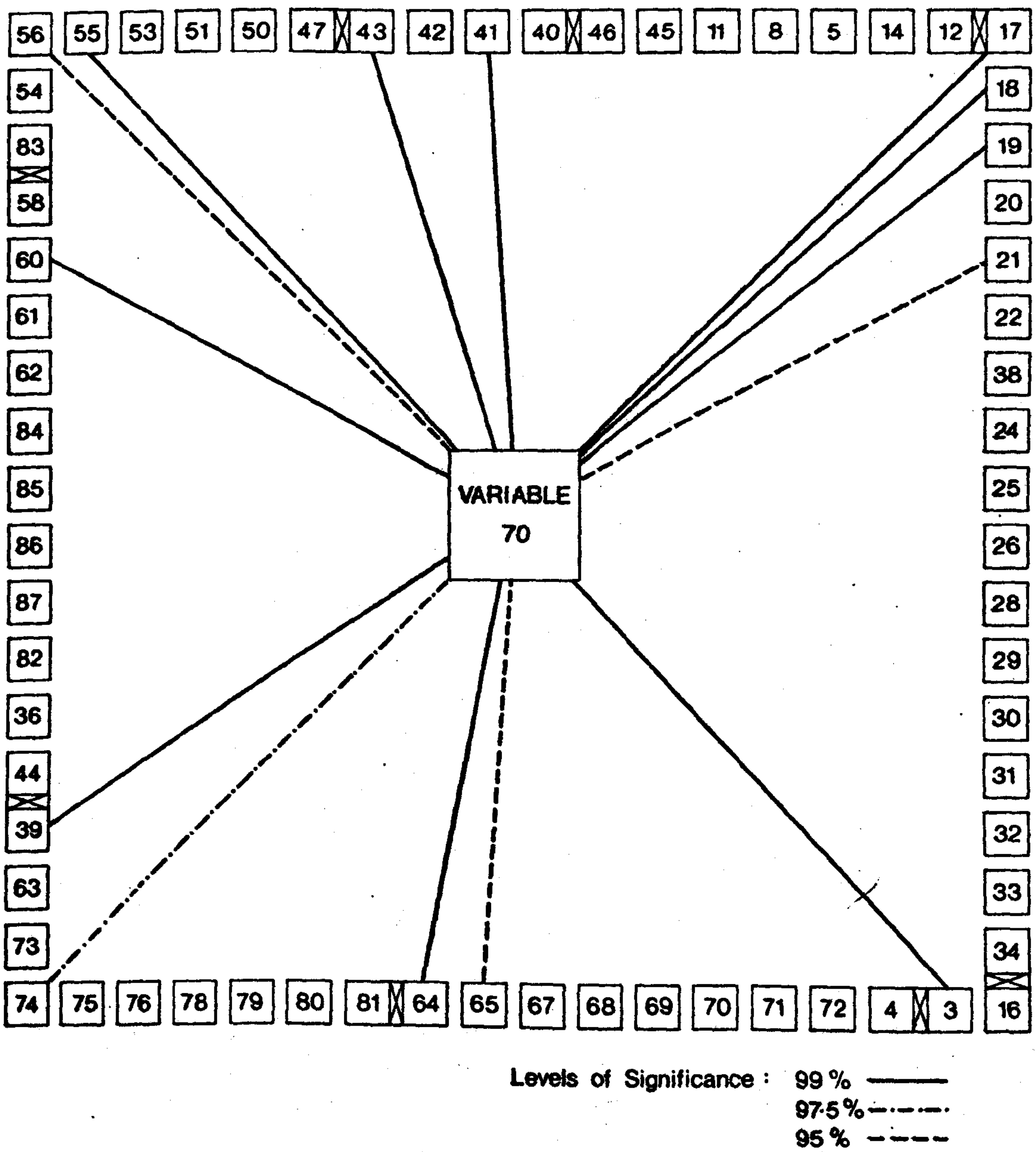


Fig. 8-8. Carlisle residents: the significant relationships between length of residence in the area and all other variables using the chi squared test (see appendix II for list of variables).

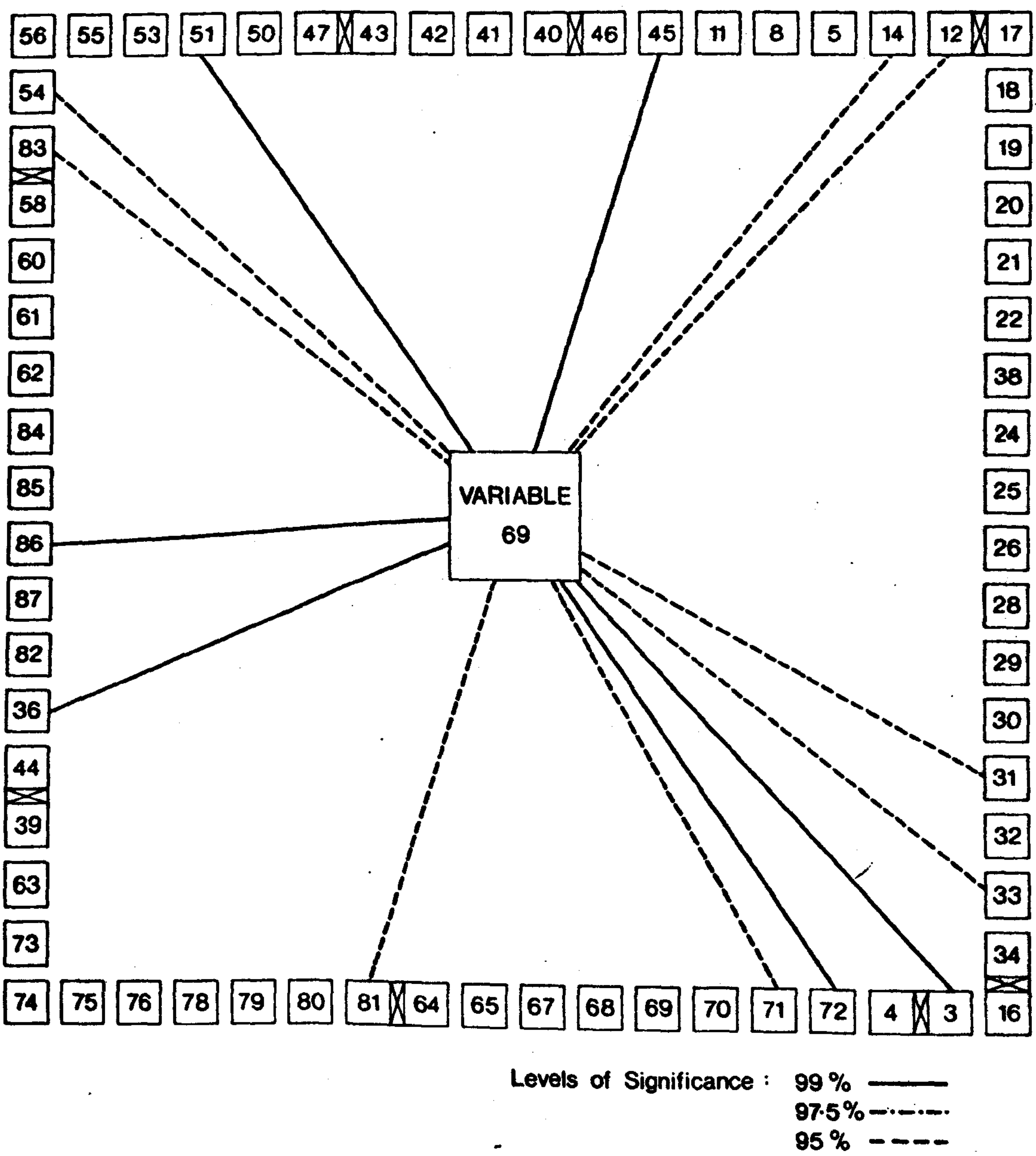


Fig. 8-9. Carlisle residents: the significant relationships between house ownership and all other variables using the chi squared test (see appendix II for list of variables).

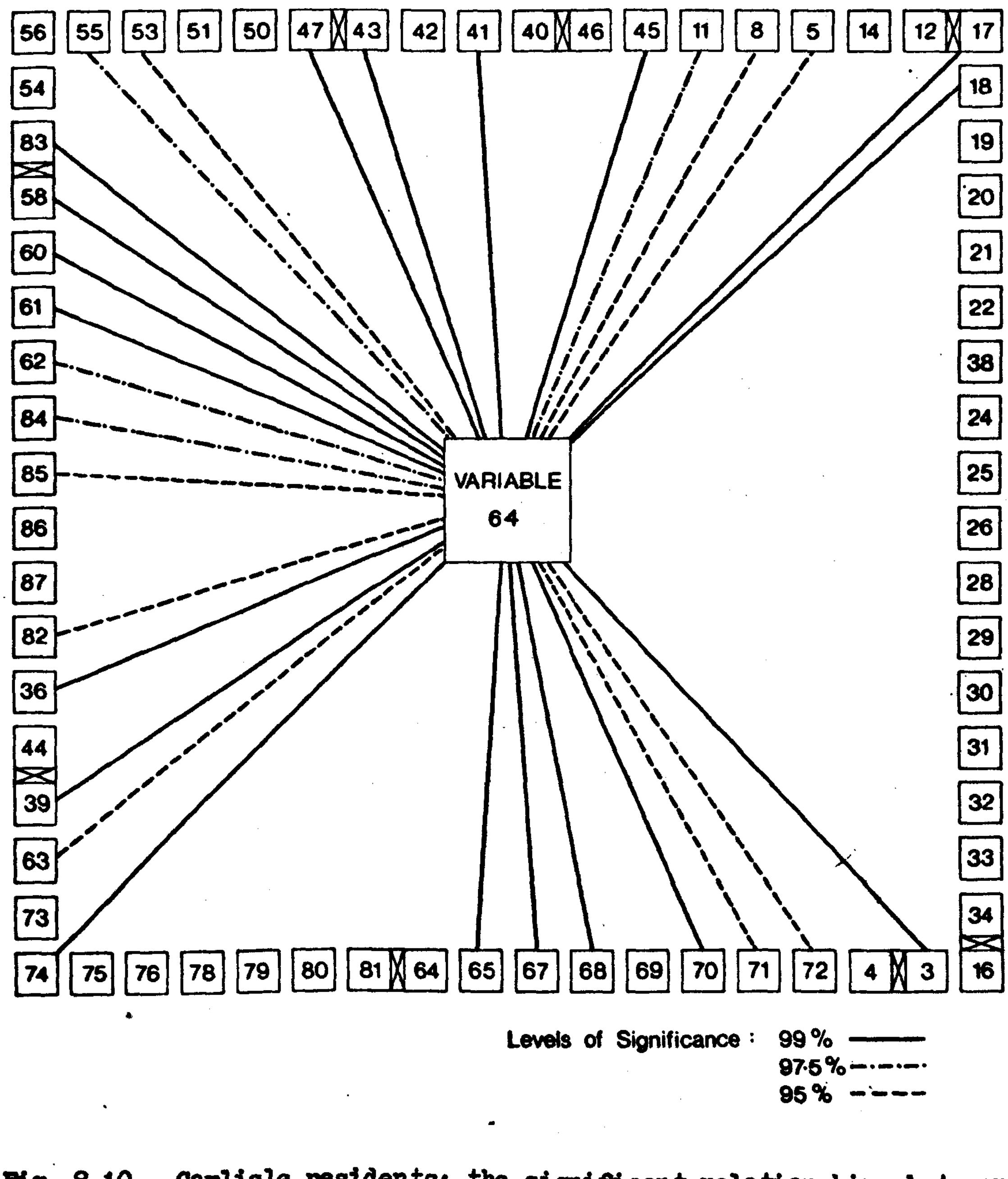


Fig. 8-10. Carlisle residents: the significant relationships between age and all other variables using the chi squared test (see appendix II for list of variables).

on the peripheries of the flood, where they would be most effective. In areas where flooding would be deeper, energy and time could be more effectively employed removing valuables to higher levels. Of course, ideally, permanent flood proofing measures should be implemented before an emergency arose.

For the most part experience of flooding proved a highly significant variable, particularly regarding the greater awareness and perception expressed by this group. The full significant relationships are shown in figure 8-11.

(ii) Revised model of residential response to the flood hazard.

From the above analyses a revised model of residential response to the flood hazard was established (figure 8-12). The model is essentially subdivided into two sub-systems, the independent factors of structure, social characteristics and flood experience, and the dependent factors of perception, awareness and response. The evidence above indicated that these independent factors were significantly associated with several aspects of the dependent sub-system; for example, older residents were more aware of authoritarian flood alleviation schemes, non-experienced residents expressed greatest faith in individual measures, while females expressed more fear of the hazard than males. However, only the one relationship is retained in the simplified model, because this association is paramount to all other relationships with fear and response. For instance, a resident needs to be aware of the flood hazard before any personal fear or response can be generated, where as the ignorant resident would show no such signs of living under

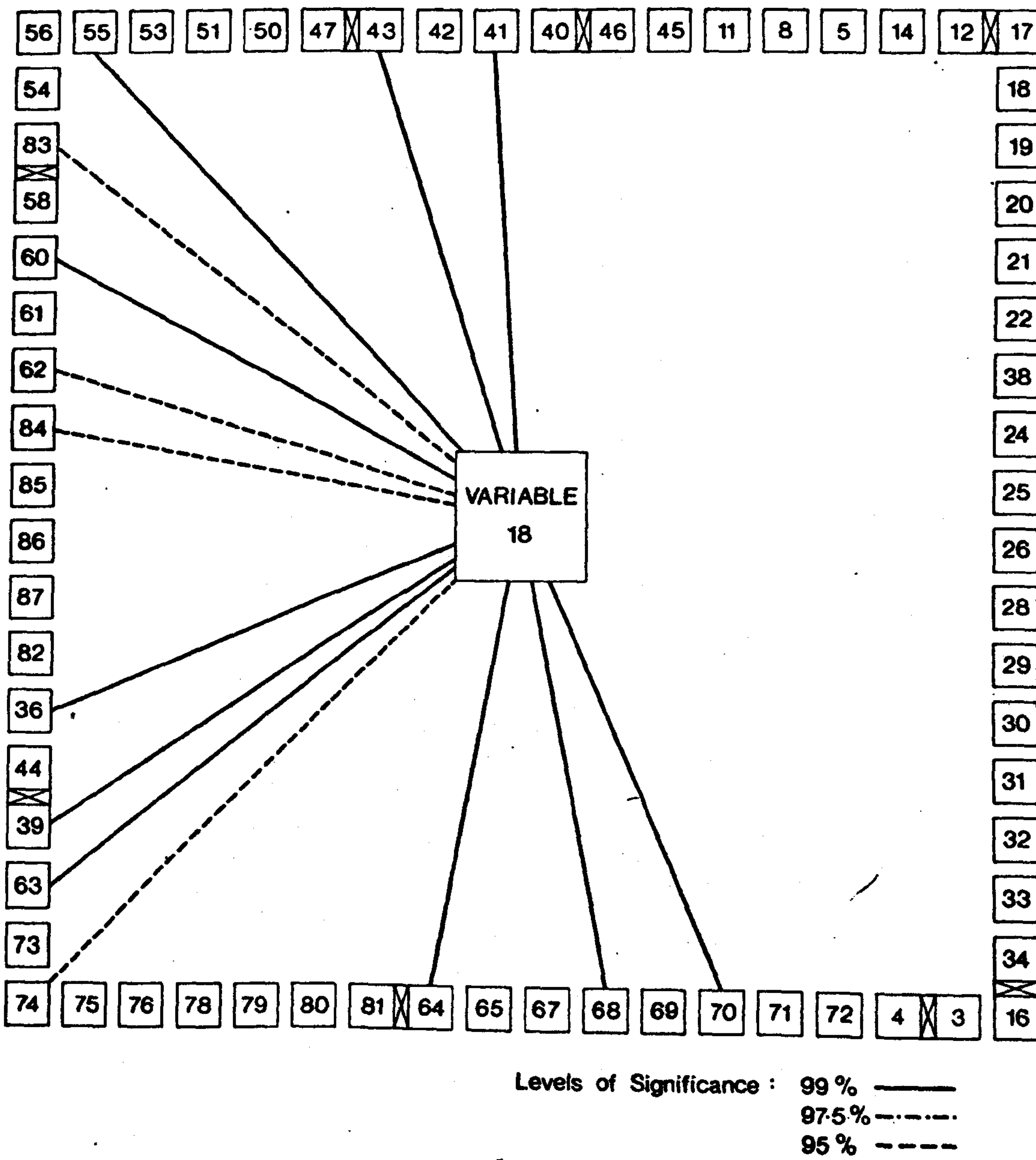


Fig. 8-11. Carlisle residents: the significant relationships between flood experience and all other variables using the chi squared test (see appendix II for list of variables).

stress.

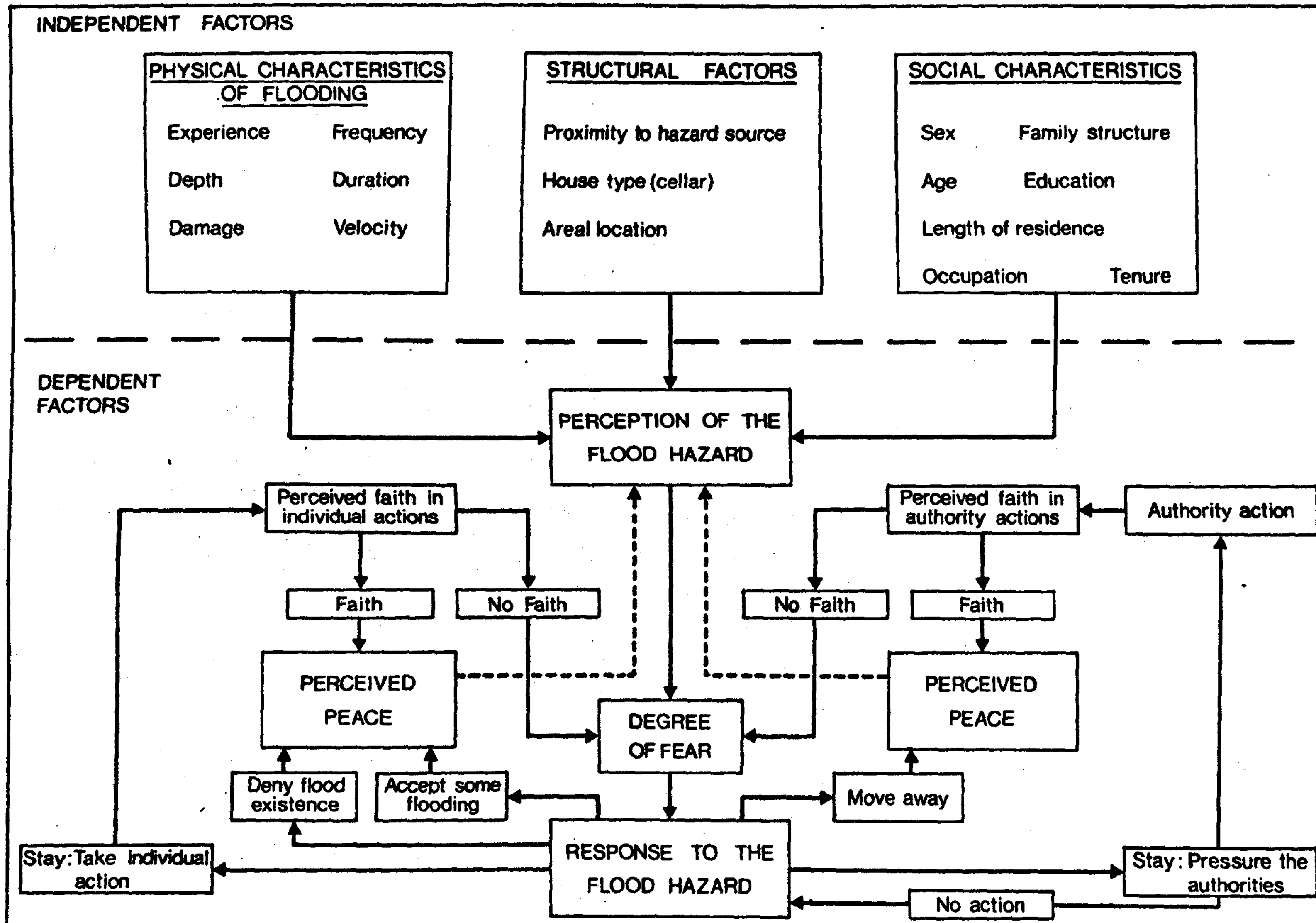
Once aware of the flood hazard, the resident may show some degree of fear (significant relationships were found between the degree of fear and perception) which in turn may be modified by awareness of flood alleviation schemes and a corresponding faith in their effectiveness. Awareness of authoritarian schemes, for instance, coupled with a perceived faith in the ability of this scheme to prevent future flooding may result in a perceived peaceful environmental location. Similarly, perceived faith in the ability of individual measures, either permanent flood proofing techniques or temporary adjustments prior to a flood, would lead to a reduction in the psychological stress associated with such a flood plain location.

The extent of fear of the hazard may generate different types of response, which tend to lead towards a perceived peaceful environment. For instance, stress is frequently eliminated by denying the existence of flooding. A common response to this effect in Carlisle was 'It will never happen again'. Other residents apparently accept periodic inundation as inevitable, or as an 'Act of God'. However, the process of blaming the authorities for such events was not found in Cumbria. Another more positive response is to leave the flood plain altogether, although evidence of this response is not readily forthcoming. (Future studies may well incorporate some research into why residents leave the flood plain, particularly following a series of floods.) Finally, the resident may either take personal remedial action if made aware of the schemes available, or pressure the authorities to take some form of action. Clearly, action in either case would lead to a reduction in fear, and hence a perceived safer environment. Failure to undertake one or the other may add to the psychological stress.

The research hypotheses purported that the degree of fear of the flood hazard was directly related to the response, that is those most worried by the hazard would leave the area and those least worried would do nothing, and continue to live in the same area. Those in between would probably carry out various actions depending on the perceived effectiveness of such responses. However, in contrast to all these is the resident who actually enjoys flooding, particularly the associated excitement and break in day-to-day routines, and hence these people derive direct benefit from the flooding. In Carlisle, many people now talk with pleasure about the 'time of the flood' and of the 'boats going down the road'.

The revised model, therefore, appears to explain some of the thought processes of the flood plain resident in responding to the flood hazard. However, there are some drawbacks to this model, especially those associated with classification and categorisation of behaviour and attitudes into the individual boxes. In reality, this is hardly the case as frequently one respondent could follow several lines through the system at the same time. Also, variations within individual categories may also mask true behaviour. For example, the perceived peace, classified at the end of the system, will quite clearly vary tremendously between different residents. Some residents

Fig. 8-12. A general model of hazard perception and response by individual flood plain residents.



may tolerate some flooding in return for an unspoilt local environment, whereas for others 'perceived peace' may constitute the complete elimination of flooding. Both these responses were found in the Cumbrian studies. For example, Appleby residents were very much against any scheme, which would disrupt the aesthetic appearance of the town, while in Carlisle, residents were in favour of increased structural flood alleviation projects, despite the lower flood frequency. Similarly, variation in the level of awareness was apparent, particularly regarding authoritarian response to the hazard in Carlisle.

The questionnaire data also showed that many respondents live under the delusion of safety, in that their perceived peace is very much the opposite. This group were notably those completely ignorant of the hazard, or those who tended to deny its existence. These groups would undoubtedly suffer severe psychological stress in the event of a future flood. Hence, the model is very much one for the individual rather than for flood plain populations as a whole, although it is useful in determining the important aspects of decision-making on the flood plain.

Finally, a further drawback of the model is its apparent static nature, since little has been incorporated in the system for change. While this would probably make the model more realistic, the essential relationships would then become confused by the complex interaction between variables. Naturally, perception of the hazard will change given changes in attitudes and awareness, and, to a certain extent, this has been allowed for by the dotted line from 'perceived peace' to perception of the hazard.

In conclusion, the model has two principal drawbacks, the problems of classification and the static nature of the model. However, as a simplified explanation of the processes involved in residential decision-making, the model reflects reality fairly closely. More detailed explanations are required (as above) to discover fully the true association between all variables. From this, the predictive aspect of the research may be established, since certain independent factors were found to influence perceived future behaviour. However, because of the inconclusive results in some aspects of the research further studies are required before a full predictive model can be set up.

CHAPTER NINE

THE COMMERCIAL SURVEY

Introduction

This chapter examines the data collected by a questionnaire survey of the flood plain industrialists and business-men in the two research centres, Carlisle and Appleby. The commercial questionnaire was similar in design to the residential one, in that both considered the characteristics and degree of flood experience of a particular group, along with further studies of behaviour and attitudes towards the flood hazard. However, the commercial survey laid greater stress on the actual business rather than the individual respondent, and correspondingly less emphasis on general environmental and perception questions. The attitudes and perceived behaviour of the business-men are discussed in the second part of this chapter, while the commercial characteristics of the two flood plains, and the extent of flood experience of individual businesses are examined below.

PART A

(1) Commercial characteristics of the flood plains

Several questions were incorporated into the questionnaire to establish the characteristics of the commercial enterprises situated in the flood hazard areas of Carlisle and Appleby. These questions included such factors as the type of business, the size of the company and the number of years the firm had been located in the area, and in this respect were similar to the social variables in the residential survey.

Type of business

The commercial properties situated on the two flood plains were initially classified into four distinct types using the criteria employed by the Central Statistical Office in the 'Standard Industrial Classification' (revised in 1968). This division, shown in table 9-1, clearly reflects the differing functions of Carlisle and Appleby. The two distributions were different at the 0.0051 level of significance. For instance, 19.2% of commercial property in Carlisle was concerned with manufacturing and construction, which compared to only 5.7% in Appleby. Alternatively, 94.3% of commerce in Appleby involved either the sevice industry or retail outlets, whereas in Carlisle the proportion was only 68.5%. Naturally, the larger centre would have both a greater number and variety of commercial functions than the smaller settlement, and this difference has emerged even from the restricted flood plain areas. The difference between the two communities has undoubtedly been further enhanced by the siting of the industrial estate at Willow Holme. This relatively new estate has brought many new industries into a known flood hazard area. (See map 5-16 and plate 19 for details).

A similar variation between Carlisle and Appleby was found on a smaller scale within the City of Carlisle, where different areas were devoted to one or another of the industry types. Table 9-2 shows the proportion of specialisation within each of the four areas of the City. For example, 92.9% of the manufacturing and construction industry was located in Willow Holme and Caldewgate, while all the retail properties were found

TABLE 9-1

Commercial : Business types (including rejections and non-contacts)

	Carlisle		Appleby		Total	
Manufacturing and Construction	14	19.2%	2	5.7%	16	14.8%
Wholesale	9	12.3	0		9	8.3
Retail	19	26.0	17	48.6	36	33.3
Services	31	42.5	15	45.7	47	43.5
Total	73	100	35	100	108	99.9

TABLE 9-2

Commercial : Business type by area - Carlisle

	Man & Con		Wholesale		Retail		Service		Total	
Willow Holme	6	42.9%	4	44.4%	0		11	35.5%	21	28.8%
Caldewgate	7	50.0	5	55.6	11	57.9	14	45.2	37	50.7
Brunton Park	0		0		8	42.1	5	16.1	13	17.8
Botcherby	1	7.1	0		0		1	3.2	2	2.7
Total	14	100	9	100	19	100	31	100	73	100

in the predominantly residential parts of Brunton Park and Caldewgate. Any differences, therefore, in the behaviour of business-men, attributable to industrial type would also be reflected spatially in Carlisle.

It should be noted that the above tables include all the commercial properties on the flood plain at the time of the survey, whereas the following studies only include fifty-six businesses in Carlisle and thirty-three in Appleby, because of the failure to interview several flood plain business-men. Rejections were received from thirteen service industries and four retail outlets in Carlisle, and one of each of manufacturing and service in Appleby. Spatially in Carlisle, these involved ten from Caldewgate and a further five from Brunton Park, which proportionally represented a higher non-response rate for the latter area.

Years in business at present site

In Carlisle, the average number of years in business at the time of the survey was 25.04 compared to the significantly longer period in Appleby of 57.64 years. However, both these sets of figures were to some extent distorted by a few concerns with over one hundred years of business. For example, Carrs of Carlisle have been making biscuits for 130 years, while in Appleby the three retail outlets of Whiteheads, Salkeld and Graham have been in business for a total of 440 years. The brewery in Carlisle and the public houses in both communities have been licensed premises for considerably longer. These figures show some of the differences between the years of production for various industrial types. For example, in Carlisle manufacturing and construction averaged 39 years compared to only 13.71 years in the wholesale business, while retail outlets and services were about the same, 23.31 and 20.71 years respectively. In Appleby the difference between retail and services was also comparatively small, 61.65 years to 53.33 years.

Years employed at present site

To complement the previous question and to assess the extent of personal knowledge of the flood hazard, each respondent was also requested to state how long he/she had worked for the particular company at the present location. In Appleby, the average number of years employment was 16.61 which was again much longer than the 12.96 years in Carlisle. These figures, in conjunction with the response to the previous question, would suggest both a greater degree of flood experience and a greater awareness of the future problem by business-men in Appleby than those in Carlisle.

Position of respondent within the firm

The research hypothesis also stated that the position of a respondent within a business could conceivably affect the attitudes and perceived behaviour towards the flood hazard. It was suggested, for instance, that an owner or partner in a company could well respond to a flood in a different manner to a works manager, because one would be more personally involved than the other. (Table 9-3 shows the position of the respondents within the businesses in Carlisle and Appleby). Most noticeable of this,

TABLE 9-3

Commercial : Position of Respondent in the business

	Carlisle		Appleby		Total	
Director	7	13%	3	9%	10	11%
General Manager	2	4	0		2	2
Area Manager	2	4	0		2	2
Works Manager	16	29	7	21	23	26
Personnel Manager	3	5	0		3	3
Assistant Manager	4	7	0		4	4
Owner/Partner	22	39	23	70	45	51
Total	56	101	33	100	89	99

TABLE 9-4

Commercial - Number of employees

	CARLISLE		APPLEBY	
	Total	Mean	Total	Mean
Man & Construction	1620	116	10	10
Wholesale	256	28		
Retail	25	2	68	4
Services	359	20	55	4
Total	2260	40	133	4

was the large percentage of businesses owned by the respondents in Appleby (seventy percent) compared to Carlisle (thirty-nine percent). However, commercial ownership was also closely related to business type; this was a feature common to both communities since seventy-six percent of retail outlets in Appleby were owned by the respondent, and eighty percent in Carlisle.

Number of employees

Table 9-4 shows the number of employees at each type of business. There was considerable variation in business sizes, particularly between the small retail outlets, which frequently employed fewer than three workers, usually from within the family unit, and the larger commercial establishments such as Carrs which employ over one thousand workers. The mean figure for each business type, shown in table 9-4, reflect these differences, although even without 'Carrs', manufacturing and construction in Carlisle would still employ proportionally more workers. In general, Carlisle businesses were larger than those in Appleby, despite the opposite trend for retail establishments.

Branches

Further hypotheses purported that firms with branches elsewhere would be less likely to suffer serious losses in production during a flood than businesses located at the one site, because business could be transferred to the other site. Forty-eight percent of companies in Carlisle were in this position, but only twenty-one percent in Appleby had alternative centres of production.

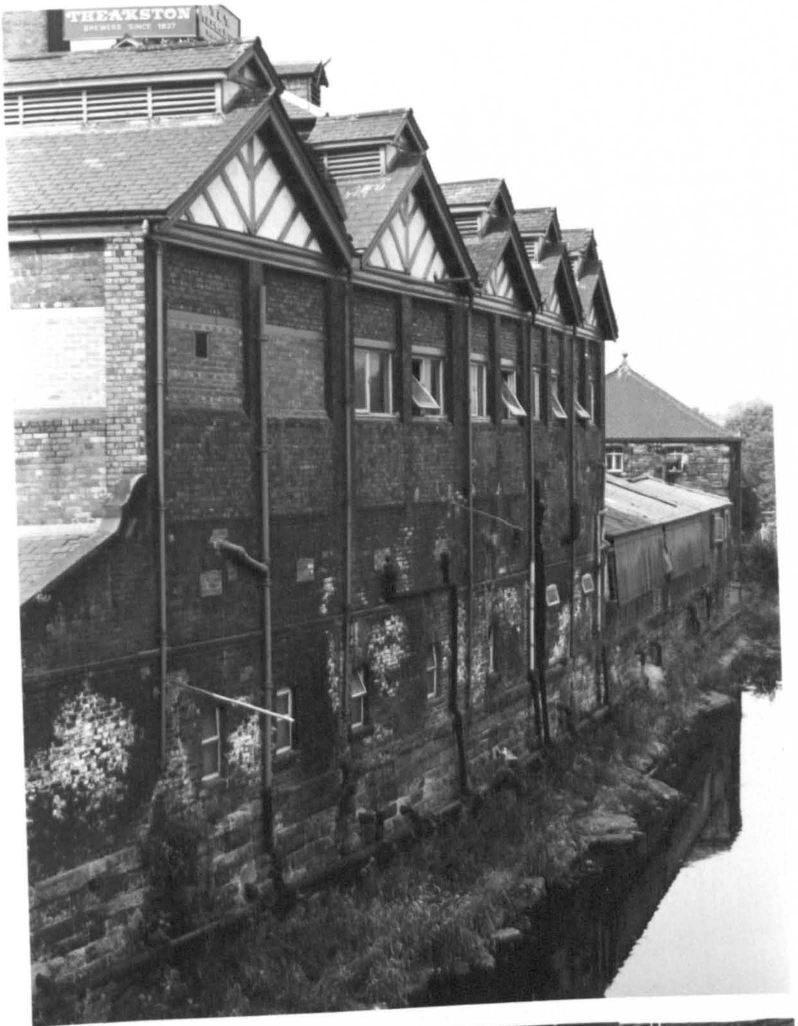
Thus, the characteristics of the commercial sector of the two communities varied in several respects, including the nature of the business, the period of production and the size of the company. Even different manager 'types' had been interviewed in the survey. The effect of these independent factors on behaviour is described in part B, while the extent of flooding experience is examined below.

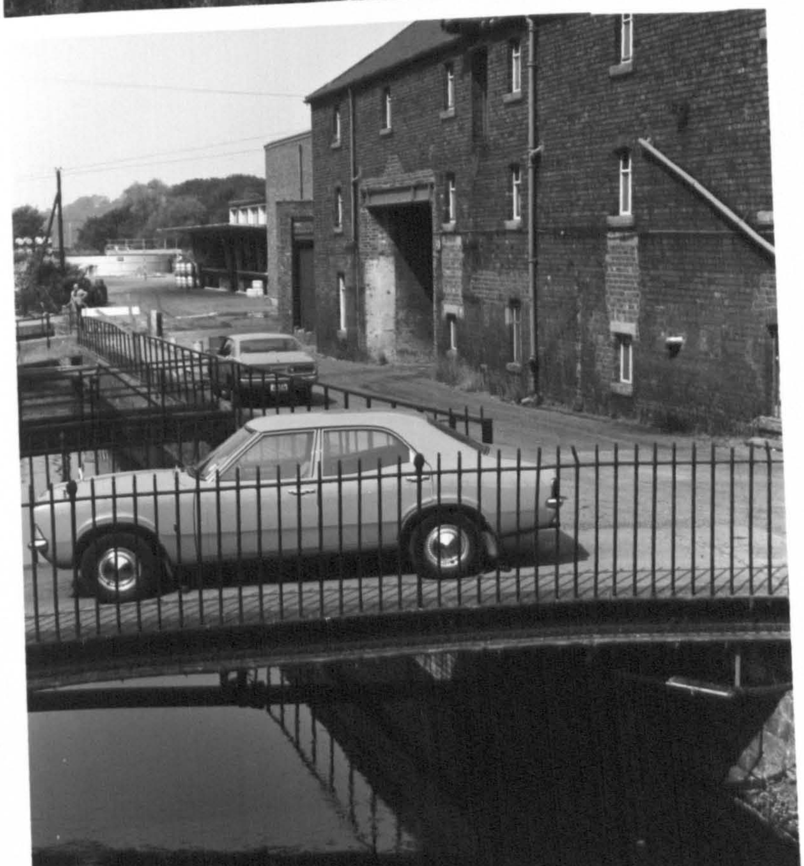
(2) Extent of flood experience

The second group of respondent variables, the extent of flood experience, was assessed in much the same way as the previous study, only the data related to particular industries rather than individual residences. Respondents were questioned on both the degree of flood experience and the characteristics of the 1968 event.

Experience of flooding

In Carlisle, sixty-four percent of business-men reported flooding of their property, and sixteen percent flooding on more than one occasion, while in Appleby the proportions were seventy-six and thirty-nine percent respectively (Table 9-5). These figures were considerably higher than the residential survey. However, unlike the previous survey, there was no strong correlation between years of production and number of floods experienced, probably due to the lack of knowledge of the individual flood plain managers. For instance, without records the present managers would be unlikely to know the precise frequency of flooding in such long established firms as Carrs, or the Brewery in Carlisle. Carlisle brewery, now part of the Theakstons group is located between the River Caldew and a mill race (see plates 23 and 24) and according to the manager has been flooded quite frequently, often two or three times a year. Evidence from the newspaper survey showed that in both Carlisle and Appleby managers were generally unaware of the true frequency of flooding of their properties. Similarly, there was no significant correlation between length of employment and flood





Plates 23 and 24.
Carlisle: The Carlisle Brewery (now Theakston's) showing the River Caldew and the Old Mill Race.

frequency, because some managers were aware of previous flood events and others were not. Nevertheless, flood plain businessmen were more aware of the flood problem than the residents.

Characteristics of the 1968 Flood

Table 9-6 shows the depth of water experienced by industries in 1968. The results were comparable for both communities with thirty-nine percent of businesses in Carlisle flooded to depths in excess of sixty centimetres, and forty-three percent in Appleby. Several businesses were inundated to quite considerable depths, especially those located in the north-western part of Willow Holme. Plates 25 and 26 show the flood waters at McKenzies Motors in this part of Carlisle, a while after the peak has passed. The wet areas on the building to the left and hut centre would indicate a maximum depth probably thirty centimetres higher than when the photograph was taken.

The reported duration of flooding in the two communities differed significantly at the 0.999 level of probability, with the inundation lasting considerably longer at Carlisle than Appleby. For instance, thirty-six percent of businesses in Carlisle were flooded for over twenty-four hours compared to only twelve percent in Appleby (table 9-7). However, unlike the residential data there was no apparent relationship between flood depth and flood duration in either community.

The damage resulting from the 1968 flood also differed between the two communities. In Carlisle, the mean losses from all businesses was £6,760 compared to £524 in Appleby, although

TABLE 9-5

Commercial : Frequency of flooding experience

	Carlisle		Appleby		Total	
None	20	36%	8	24%	28	31%
Once	27	48	12	36	39	44
Twice	6	11	7	21	13	15
Three times or more	3	5	6	18	9	10
Total	56	100	33	99	89	100

TABLE 9-6

Commercial : Depth of flood water in 1968

	Carlisle		Appleby		Total	
Up to 30 cm	13	36%	10	43%	23	39%
31 to 60 cm	9	25	3	13	12	20
61 to 90 cm	8	22	7	30	15	25
Over 90 cm	6	17	3	13	9	15
Total	36	100	23	99	59	99

Dk 2

TABLE 9-7

Commercial : Duration of flood in 1968

	Carlisle		Appleby		Total	
Up to 12 hours	13	36%	11	44%	24	39%
13 to 24 hours	6	17	7	28	13	21
25 to 36 hours	7	19	3	12	10	16
37 to 48 hours	6	17	0		6	10
Did not know	4	11	4	16	8	13
Total	36	100	25	100	61	99

Plates 25 and 26. Carlisle: The flood damage at McKenzies Motors (Willow Holme Industrial Estate) several hours after the peak discharge.

there was considerable variation between different types of businesses. The breakdown of these figures into business types is shown in table 9-8. Clearly, in Carlisle manufacturing and construction suffered the greatest losses with the retail outlets generally suffering only minimal losses. On the other hand, in Appleby retail losses were much higher and services more than twice as much again. If these mean losses are extended to the whole flood plain of both research centres, to include all the industrial properties, then a total of approximately £418,500 worth of damage was caused to businesses in Carlisle in 1968, and £16,400 in Appleby (1968 figures).

The losses suffered by businesses in 1968 varied to a much greater extent than residential losses, with several industries experiencing considerable losses, while others, apparently less susceptible to flooding, found the event little more than an inconvenience. Border Engineers Contractors and Tiffen motor cycle repair shop in Carlisle reported no losses. Alternatively, three businesses, Adamson electrical company, Carrs biscuit factory, and Edmund Walker dealers in motor components, accounted for thirty-one percent of the estimated total industrial losses. Carrs damages alone accounted for fourteen percent, while Adamson believed they also lost one months production and Tilcon cement one week. Other businesses could not fully estimate the overall damages from the 1968 flood. McKenzies Motors, for instance, suffered extensive damage with everything under 1.7 metres written off by the insurance company. This included many new cars, which were subsequently auctioned off to recoup some losses, and several private cars in for repairs. In Appleby, the greatest losses were suffered by Jocelyn's garage,

TABLE 9-8

Commercial : Flood losses - 1968

CARLISLE

	Total losses	Mean	(All Inds) Total for flood plain
Man & Construction	145,180	10,370	145,180
Wholesale	34,425	3,825	34,425
Retail	240	16	304
Service	138,546	7,697	238,607
Total	318,391	6,760	418,516

APPLEBY

	Total losses	Mean	(All Inds) Total for flood plain
Man & Construction	300	300	600
Wholesale			
Retail	5,195	306	5,195
Service	9,937	663	10,600
Total	15,433	468	16,395

which includes a car show room and which accounted for thirty percent of industrial losses in the town. However, even this has not prevented the owner purchasing and developing further flood plain property on the opposite side of the road.

On a purely economic basis, therefore, the most important conclusions to emerge from this aspect of the study was the great proportion of losses suffered by a minority of the businesses. With this in mind, the flood proofing of just three businesses in Carlisle and one in Appleby could reduce flood losses by up to one third. However, the protection of only selected industries would have other political implications. One further aspect regarding flood damage to emerge from the study, which was particularly relevant to the Sands area in Appleby, was the additional damage caused by lorries and cars driving through the flood waters. Several complaints were received from business men and residents that the wash created by lorries driven along the A66 caused valuables in 'safe' areas to be inundated, while the pressure built up by the movement of water caused some structural damage. Jocelyns garage reported that the glass doors and windows to the show room were eventually destroyed by this action. Thus, some losses could be prevented by more effective measures to prevent vehicles entering flood areas.

The correlation between different flood parameters in 1968 were less pronounced than the relationships found in the residential data. However, there were some significant associations. For example, the correlation between flood depth and flood losses in Carlisle using the product moment correlation coefficient, produced a value of 0.6904, which using the 't' distribution was significant at the 0.9999 level of probability. Figure 9-2 shows the correlation between the two variables. The Appleby data confirmed the trend that increased flood depth corresponds with greater flood losses. The correlation between the two was 0.6718 significant at the 0.9988 level of probability (see figure 9-3). The only other significant relationship between flood parameters was found in the Carlisle data between reported flood duration and flood losses. The correlation of 0.6344 was significant at the 0.9995 level of probability. Thus, while the data from the commercial survey confirmed the relationships between depth and damage, and to a certain extent between duration and damage, no other associations were apparent.

Activities undertaken by business-men during the 1968 flood were limited in both variety and extent, probably because of insufficient warning of the hazard. In Carlisle, sixty-four percent did nothing and only seventeen percent reported removing stock to higher levels, which perhaps is not surprising considering that only one business received prior warning of the flood (tables 9-9 and 9-10). In Appleby, fifty-six percent of business men received some form of flood warning, and hence considerably more action was undertaken, prior to, and during the flood. For instance, sixty percent removed valuables to safe areas and twenty percent used temporary flood proofing measures. Only thirty-two percent reported doing nothing.

Two other aspects of the response to flooding were included in this section, flood insurance and flood proofing. Flood insurance, it was found had been taken out by sixty-four percent

Fig. 9-1. The correlation between flood depth and reported flood damage by industries in Appleby (1968).

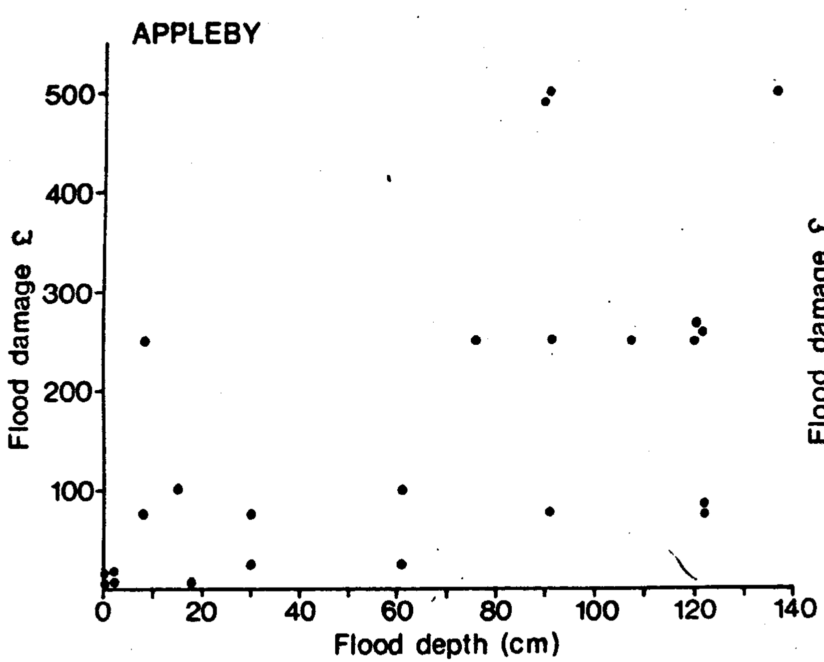


Fig. 9-2. The correlation between flood depth and reported flood damage by industries in Carlisle (1968).

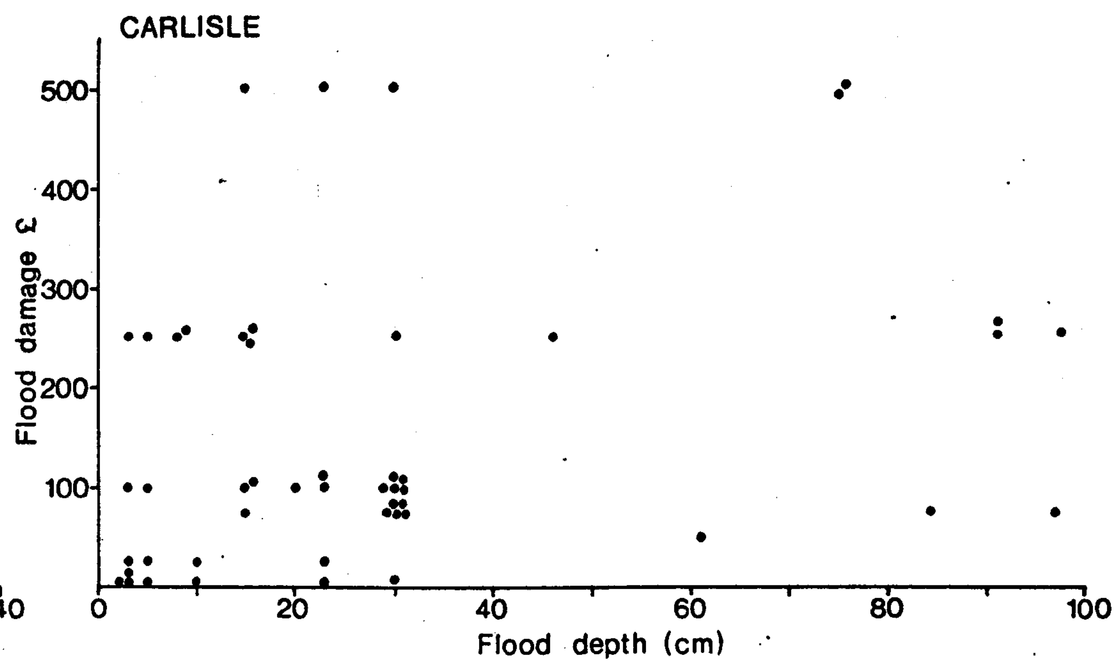


TABLE 9-9

Commercial : Actions undertaken in 1968

	Carlisle		Appleby		Total	
Nothing	23	64%	8	32%	31	51%
Switched off electricity	1	3	1	4	2	3
Sandbagged exits	4	11	5	20	9	15
Moved machines/stock	6	17	15	60	21	34
Closed works	1	3			1	2
Hired pumps/driers	1	3	1	4	2	3
Did not know	1	3			1	2
Total	(37)	104	(30)	120	67	110

% of those flooded

TABLE 9-10

Commercial : Proportion of industries receiving an official flood warning in 1968.

	Carlisle		Appleby		Total	
Received warning	1	3%	14	56%	15	25%
Did not receive warning	35	97	11	44	46	75
Total	36	100	25	100	61	100

of the businesses in Carlisle and fifty-two percent in Appleby. Of these, seventy-two percent in Carlisle and seventy-six percent in Appleby had started the policy before 1968 (tables 9-11 and 9-12). Several Appleby firms have since suggested that flood insurance is no longer avaliable for the town because of the relatively high risk. In Carlisle, Alexandra Saw Mills found similar problems when trying to obtain insurance, whereas other businesses were insured through different agencies, such as the Government or the head company. P.O. Telephones, Drew Wine Company and the Carlisle Brewery all come into this category. Other businesses must stand large losses before the insurance company will pay, for Carrs biscuits factory this amounts to £90,000, although the policy also covers the company for lost production.

Flood proofing of property was only slightly greater than that carried out by residents, and was similar for Carlisle and Appleby (table 9-13). For instance, in Carlisle, the sewerage works had installed non-return valves to prevent water backing up from the river, and, somewhat in reverse of proofing were required in the event of a flood warning to block the railway arch with sandbags. This action would probably save the rest of Willow Holme from extensive damage, although leave the sewerage works open to flooding, unfortunately during a minor alert in 1975 no sandbags were to be found. P.O. Telephones had completed a 1.5 metre wall between the industrial site and the River Caldew, which would probably protect certain areas from smaller floods. The 1968 flood was, according to many Willow Holme industrialists, caused by the incompletion of this wall. In the same areas, Carlisle brewery have fitted flap valves to

TABLE 9-11

Commercial : Proportion of business premises insured against flooding

	Carlisle		Appleby		Total	
Insured	36	64%	17	52%	53	60%
Not insured	13	23	13	39	26	29
Did not know	7	13	3	9	10	11
Total	56	100	33	100	89	100

TABLE 9-12

Commercial : Proportion of those with insurance who took out the policy before the 1968 flooding

	Carlisle		Appleby		Total	
Before 1968	16	72%	13	76%	29	55%
After 1968	10	28	2	12	22	42
Did not know			2	12	2	4
Total	36		17	100	53	101

TABLE 9-13

Commercial : Proportion of business with flood proofing measures

	Carlisle		Appleby		Total	
Flood proofed	9	16%	5	15%	14	16%
Not flood proofed	47	84	28	85	75	84
Total	56	100	33	100	89	100

certain water outlets to prevent the backing up of flood water. Carrs have stopped using various lower areas of their factory, and now ensure that all food stuffs are well out of reach of any flood waters. Trugrinds have raised the floor of the workshop and both the Building Repairs Company and the British Fermentation Products have improved their internal drainage. Finally, the Electricity Station maintains a supply of sandbags and pumps ready to protect machinery from flood waters.

In Appleby, flood proofing measures were even more limited. The two warehouses in Chapel Street tended to store more vunerable goods in the upper rooms; Pennine Shoes had raised the steps to the shop, and Potts the building contractors had raised the yard. In conclusion, no industries in either Carlisle or Appleby have been protected by any comprehensive and permanent flood proofing schemes, and those measures which have been implemented were frequently of dubious effectiveness. The high flood frequency in Appleby and the long established businesses should have developed a more efficient way of dealing with the problem.

PART B

Behavioural Aspects

The second part of chapter nine examines the attitudes and behaviour of flood plain business-men towards perceived future flood problems. As with the residential survey, the object of the study was to improve the understanding of flood plain decision-making, and combined, the two surveys would provide a comprehensive review of the perceived response to the flood hazard. The behavioural aspects of the commercial sector were studied under three broad headings, and each section analysed according to the independent factors discussed in part A of the chapter.

1. Perception of the flood hazard

2. Awareness of the Authoritarian response to the flood hazard.

3. Perceived response to the flood hazard.

However, it should be noted that the commercial study was considerably less involved than the residential survey, because of the problems involved in collecting accurate perception data from a company which may have several persons with responsibility for taking decisions. Ideally, for a full perception study of industries, a cross section of each work force would need to be interviewed, then an assessment made of the general perceived behaviour based on the relative levels of responsibility of each respondent. However, the perception studies undertaken here were useful in determining likely behaviour, since invariably either the owner, partner, or manager of the business was consulted, and it is reasonable to assume that in a flood emergency, these people would take any major decisions. Only further research following a flood would show to what extent these assumptions were true.

(1) <u>Perception of the flood hazard</u>

This aspect of the commercial survey was similar to the residential survey, since it was purported that business-men, like residents, would behave according to the perceived, rather than the actual danger. Perception studies therefore, maintained an integral part of the commercial survey. Three groups of questions pertaining to perception were involved in the questionnaire:

(i) General environmental questions.

(ii) Perceived future flood problems.

(iii) Degree of fear of the flood hazard.

(i) General environmental questions

In the commercial questionnaire this section was limited to a general discussion of the advantages and disadvantages of the area, and the source of the respondent's knowledge about the flood hazard. Unfortunately, very little meaningful data were obtained from these questions, because in the general discussion flooding had been mentioned by the interviewer to help secure the interview (unlike the residential survey, where flooding was not mentioned until the seventh question). Similarly, data of little statistical value were secured on source of knowledge, since eighty-one percent in Carlisle and seventy-nine percent in Appleby had either 'always known' about the flood problem, or had found out through direct experience (table 9-14).

(ii) Perceived future flooding

Table 9-15 shows the perception of flooding in the next twenty-five years by the flood plain managers. Twenty-one percent

TABLE 9-14

Commercial : Source of knowledge of flood problem

	Carlisle		Appleby		Total	
Estate Agent	0	0%	0	-%	0	-%
Neighbouring firms	3	5	6	18	9	10
Personal inspection	2	4	1	3	3	3
Experience	24	43	5	15	29	33
Local media	0		0		0	
Surveyors	3	5	0		3	3
Other (always known)	21	38	21	64	42	47
Did not know	3	5	0		3	3
Total	56	100	33	100	89	99

TABLE 9-15

Commercial : Perception of flood hazard for next 25 years

	Carlisle		Appleby		Total	
Will flood	12	21%	21	64%	33	37%
Will not flood	36	64	9	27	45	51
Did not know	8	14	3	9	11	12
Total	56	99	33	100	89	100

of respondents in Carlisle, and sixty-four percent in Appleby expected to experience some flooding during this period, while sixty-four percent and twenty-seven resepctively did not anticipate future flooding. In Carlisle, this represented a slightly higher proportion of business-men than residents perceiving future flooding, but this still failed to reflect the true frequency of flooding as calculated from the historical data. Alternatively, as with the residential study, this apparently low response could be the result of awareness and faith in authoritarian schemes implemented in the City to alleviate the flood problem. In this case, the response may be termed relatively high. In Appleby, the reverse was found with fewer business-men perceiving flooding in the next twenty-five years. No immediate explanation of this was forthcoming.

Flood experience made little difference to this perception of future flooding, although in Carlisle twenty-nine percent of experienced residents and only ten percent of non-experienced foresaw future flooding. In Appleby, the proportions were sixty and seventy-five percent respectively. Similarly, flood depth did not explain the differences in perception. Flood duration experienced in 1968, on the other hand, indicated that perception of future flooding was correlated with greater duration of flooding. Unfortunately, these data were invalid for further statistical analysis.

Characteristics of the businesses did not appear to influence significantly the perception of future flooding. In Carlisle, more manufacturing and construction industries anticipated future flooding, while none of the retail outlets did. In Appleby all perceived future flooding, particularly the retail outlets. In this respect, therefore, the retail business-men hold similar views to the residents.

Respondents were also asked whether there had been a change in the flood risk. The response to this question was similar to the residents, with eighty-four percent of business-men in Carlisle and thirty-six percent in Appleby perceiving a decrease in the hazard. Seven percent and forty-eight percent respectively saw no change in the flood risk (table 9-16). The response to this question precluded any statistical analysis of the data in Carlisle, because of the large majority perceiving a decrease in the risk. However, even by visual observation, there were no apparent trends in the figures, to suggest that either the commercial characteristics or the extent of flood experience influenced the response. Awareness of authoritarian flood alleviation schemes were apparently most significant in Carlisle, while in Appleby there was the belief that something had been done (see below). Also in Appleby, proportionally more retailers, than service industries, were found to perceive a decrease in the hazard (forty-one to twenty-seven percent) and similarly more flood experienced business-men than non-experienced perceived a decrease (forty-four to thirteen percent). This perception by the experienced group may represent a genuine decreasein the hazard in recent years since, unlike the non-experienced group, they were less likely to believe falsely in the authoritarian alleviation schemes. Details are given in section 2.

TABLE 9-16

Commercial : Perceived change in the flood risk

	Carlisle		Appleby		Total	
Increasing	1	2%	2	6%	3	3%
Decreasing	47	84	12	36	60	67
No change	4	7	16	48	19	21
Did not know	4	7	3	9	7	8
Total	56	100	33	99	89	99

TABLE 9-17

Commercial : Proportion of business men worried by flooding

	Carlisle		Appleby		Total	
A lot	1	2%	4	12%	5	6%
Some	7	13	4	12	11	12
A little	10	18	10	30	25	28
Not at all	38	68	15	45	48	54
Total	56	101	33	99	89	100

(iii) Degree of fear of the flood hazard

Fear of the flood hazard was assessed both directly and indirectly, by a series of questions, which ranged from worrying about the problem, to levels of tolerance to the hazard. In response to a direct question on the degree of fear, sixty-eight percent of business-men in Carlisle stated that they did not worry about flooding at all, and only one reported worrying a lot. By contrast, in Appleby forty-five percent did not worry, forty-three percent worried to some extent and a further twelve percent worried a great deal (table 9-17). The responses from Carlisle and Appleby were significantly different at the 0.9978 level of probability, comparing the numbers who worried and those who did not.

Further analyses of these figures indicated that proportionally more business-men with flood experience worried about the hazard than those without experience. In Carlisle, thirty-six percent of the experienced respondents, compared to only twenty-five percent non-experienced, worried. It was also noticeable that non-experienced respondents worried to a lesser extent than the others (table 9-18). The same trend, though less extreme, was apparent in Appleby, where the proportions were fifty-six percent and fifty percent. No such trends were apparent with the other flood characteristics, such as duration, frequency or damage. Similarly, the characteristics of the businesses showed little further explanation of these responses. Although not significant, it was worth noting that fewer respondents in the retail business worried about flooding than other business-men, where only thirteen percent of retail managers worried about flooding, forty-three percent of those in manufacturing and construction, forty-four percent in wholesale and thirty-three percent in service industries worried about the problem. A similar, though less pronounced trend was found in Appleby. Also, and perhaps somewhat surprisingly, owners of businesses expressed less fear of flooding than business-men in other positions. Forty-eight percent of owners compared to seventy percent of managers in Appleby, and eighteen percent and forty-one percent in Carlisle worried about the flood problem.

Apart from the degree of fear, several other questions were included to test the tolerance of flooding by the flood plain business-men. For example, fifty-two percent of business-men in Carlisle and sixty-one percent in Appleby had prior knowledge of the flood hazard before locating their businesses on the flood plain. Thus, in this respect, the flood hazard does not appear to worry the business-men. An extension to this question asked whether business-men would relocate in the same area, given the same choice, to which only eleven percent in Carlisle replied negatively. Again, this was further confirmation that, as far as industries were concerned, the advantages of a flood plain site outweighed the disadvantages. Even if flooding became a serious hazard, only thirty-eight percent of business-men in Carlisle and six percent in Appleby would contemplate leaving the area. This latter response incorporated a slight trend to suggest that those respondents with flood experience would be more likely to leave the area than those without, while proportionally more wholesale managers suggested they would also leave. Details of the responses to these questions are indicated in tables 9-19 to 9-21.

TABLE 9-18

Commercial : Fear of flooding as a function of flood experience

Degree of fear	CARLISLE				APPLEBY			
	Experienced		Non experienced		Experienced		Non experienced	
A lot	1	3%		%	3	12%	1	13%
Some	7	19			3	12	1	13
A little	5	14	5	25	8	32	2	25
None	23	64	15	75	11	44	4	50
Total	36	100	20	100	25	100	8	101

TABLE 9-19

Commercial : Proportion of business men with knowledge of the flood risk before locating the area

	Carlisle		Appleby		Total	
Prior knowledge	29	52%	20	61%	49	55%
No prior knowledge	18	32	6	18	24	27
Did not know	9	16	7	21	16	18
Total	56	100	33	100	89	100

TABLE 9 - 20

Commercial : Given the same choice proportion of business men who would relocate in this area

	Carlisle		Appleby		Total	
Would relocate	46	82%	33	100%	79	89%
Would not relocate	2	4	0		2	2
Did not know	8	14	0		8	9
Total	56	100	33	100	89	100

TABLE 9-21

Commercial : Proportion of business men who would leave the area if the flooding became a serious problem

	Carlisle		Appleby		Total	
Would leave	21	38%	2	6%	23	26%
Would not leave	24	43	29	88	53	60
Did not know	11	20	2	6	13	15
Total	56	101	33	100	89	101

(2) Awareness of the authoritarian response to the flood hazard

Awareness of the authoritarian adjustments to control the flood hazard was believed to play an important part in determining the attitudes and behaviour of flood plain business-men. In this respect, it was the perceived effectiveness of such measures which were important, rather than the actual design standards of the projects. As with the residential survey, three aspects of awareness were considered:

(i) General awareness of authoritarian adjustments

(ii) Awareness of the flood forecasting and warning scheme.

(iii) Opinions on different proposed alleviation schemes.

(i) General awareness of authoritarian adjustments

The second part of question nineteen was designed to assess the general awareness of the authoritarian schemes in Carlisle and Appleby. Those business-men who had previously perceived a decrease in the flood risk were asked to state why they had perceived such a change. The results, shown in table 9-22, indicated that the majority of business-men in Carlisle were aware of the flood embankment scheme, while thirty-eight percent attributed the decrease in flood risk to alterations in the river courses, and nineteen percent to cleaning the rivers, all of which have been carried out in recent years. In Appleby, where only twelve business-men perceived a decrease in the hazard, fifty-eight percent put the cause down to cleaning of the river

TABLE 9-22

Commercial : Reasons for perceived decrease in risk

	Carlisle		Appleby		Total	
Climate change	2	4%	1	8%	3	5%
Motorway construction	0		0		0	
Town building	0		0		0	
River cleaning	9	19	7	58	16	27
Embankments	44	92	4	33	48	80
Reservoirs	0		0		0	
Other (course alterations)	18	38	7	58	25	42
Total	(73)	153	(19)	157	(92)	154

TABLE 9-23

Commercial : Proportion of business men who believe enough has been done to counteract the flood problem in Carlisle

	Carlisle	
Enough done	41	73%
Not enough done	4	7
Did not know	11	20
Total	56	100

and course alterations, and thirty-three percent to embankments, none of which have been carried out in recent years.

Flood experience, to some extent, explained these responses. In Carlisle, those business-men without flood experience only perceived one reason for the decrease in risk, whereas many of the business-men with flood experience were aware of several of the authoritarian schemes. For instance, eighty-nine percent of the experienced respondents were aware of the embankment scheme and thirty-nine percent of the other course alterations, which compared with sixty and twenty percent of the non-experienced group. The other flood characteristics and independent business variables showed no such trend in the responses to explain the reasons for the perceived decrease in the hazard.

Awareness of the authoritarian response to the flood hazard was further tested by question twenty, which was adapted slightly for the different conditions in Carlisle and Appleby. In Carlisle, business-men were asked whether enough had been done to overcome the flood problem, while in Appleby respondents were asked if anything had been done. Table 9-23 shows that seventy-three percent of business-men in Carlisle thought enough had been done, with only seven percent perceiving insufficient action. Of this latter group, all were located either in Caldewgate or Willow Holme and all, except one, had experience of flooding in the past.

In Appleby, where there had been no flood alleviation schemes implemented, forty-two percent of business-men believed that something had been done, and fifty-eight percent observed correctly that no such measures had been implemented (table 9-24).

It would appear that flood experience is important to accurate perception, although as with the residential survey, this may reflect greater residence time in the area, since ninety-three percent of non-experienced business-men compared to only sixty-percent of the experienced believed falsely that something had been done. Evidence from these questions, therefore, indicated that both flood experience and length of stay in an area are of great importance in reducing the discrepancies between perception and reality.

(ii) Awareness of the flood forecasting and warning scheme

As with the residential study, this question was not directly comparable between the two research centres, because while there was a flood warning scheme for Carlisle, no such official measures had been implemented in Appleby. The extent of awareness of the flood warning scheme is shown in table 9-25. In Carlisle, only forty-five percent of business-men were aware of the scheme, and fifty percent stated that no such scheme existed. However, this is still slightly higher than the degree of awareness amongst the residents. By area, it was noticeable that, whereas fifty-three percent of respondents in Willow Holme were aware of the warning system, the proportion fell to forty-four percent in Caldewgate and to only twenty-five percent in Brunton Park. In fact, Willow Holme Industrial Estate has a special pyramidal system for flood warning dissemination, although unfortunately this is now out of date (see chapter six). Business type did not appear to affect the response, although retailers showed less awareness than others. Flood experience, however, was much more important with fifty-six percent of experienced

TABLE 9-24

Commercial : Proportion of businessmen who believe something has been done to counteract the flood problem in Appleby

	Appleby	
Something done	14	42%
Nothing done	19	58
Did not know	0	
Total		100

TABLE 9-25

Commercial : Knowledge of an official flood warning scheme

	Carlisle		Appleby		Total	
Warning system	25	45%	22	67%	47	53%
No warning system	28	50	10	30	38	43
Did not know	3	5	1	3	4	4
Total	56	100	33	100	89	100

TABLE 9-26

Commercial : Perceived reliability of flood warning scheme

	Carlisle		Appleby		Total	
Reliable	9	36	12	55	21	45
Not reliable	2	8	3	14	5	11
Did not know	14	56	7	32	21	45
Total	25	100	22	101	47	101

business-men compared to only twenty-five percent of the non-experienced aware of the warning scheme. A chi squared test on these data (the don't know' category were eliminated for purposes of the test) suggested the responses were significantly different at the 0.9574 level of probability.

In Appleby, sixty-seven percent of business-men thought that a flood warning system operated in the town, with only thirty percent correctly perceiving no such scheme. Proportionally more business-men than residents were aware of the real situation in the town. As in Carlisle, flood experience proved the most significant independent variable. However, in contrast to the residential survey, proportionally more flood experienced respondents than others wrongly perceived a warning system. This response though could be the result of the fairly low figures in Appleby, since it was generally found that greater experience tended to improve the accuracy of perception and awareness of the real situation.

The perceived reliability of the flood warning scheme (table 9-26) shows that the majority of business-men in Carlisle did not know because the scheme had, to date, never been tested. In Appleby, fifty-five percent of those perceiving a flood warning scheme also believed the scheme to be reliable, which reflects the similar trend found amongst the residents of the town.

(iii) <u>Opinions on different alleviation strategies</u>

Business-men were requested to state their opinion on various flood plain strategies similar to those cited in the residential questionnaire, to test the relative support for different measures.

The proportion of business-men both in favour and against the schemes is shown in tables 9-27 to 9-34. For example, in Carlisle forty-three percent of respondents were in favour of upstream reservoirs, sixty-one percent for flood embankments and fifty-nine percent for deepening and widening the river. In Appleby, the proportions of business-men in favour were twenty-one, thirty-nine and seventy-three respectively. It was only with deepening and widening of the rivers did the business-men in both Carlisle and Appleby show as much support as the residents. Nevertheless, the same trends emerged, particularly in Appleby where the greatest support was given to a scheme which would do least to disturb the local environment, and yet prove effective against smaller floods. This consideration was further reflected in the response to preservation of the status quo, since thirty-nine percent of business men in Appleby and thirty-one percent in Carlisle favoured preservation. However, in Carlisle fewer business men than residents favoured this policy towards the flood hazard.

The financial aspects of flood alleviation programmes produced similar responses to those of the residents. Eighty-nine percent of business-men in Carlisle and eighty-five percent in Appleby were in favour of flood alleviation being of general concern, rather than the express responsibility of the flood plain communities. As with the residential survey, it would be interesting to compare these views with those of business men located in 'safe' areas. In Carlisle, forty-three percent were in favour of government grants for protection and fifty-three percent for government relocation, while in Appleby considerably fewer were in favour, twenty-seven and fifteen percent respectively.

TABLE 9-27

Commercial : Opinions on upstream surface reservoirs as a means of alleviating flooding

	Carlisle		Appleby		Total	
Strongly favour	9	16%	5	15%	14	16%
Favour somewhat	15	27	2	6	17	19
Oppose somewhat	11	20	0		11	12
Stongly oppose	15	27	24	73	39	44
Did not know	6	11	2	6	8	9
Total	56	101	33	100	89	100

TABLE 9-28

Commercial : Opinions on the construction of flood embankments as a means of alleviating flooding

	Carlisle		Appleby		Total	
Strongly favour	20	36%	5	15%	25	28%
Favour somewhat	14	25	8	24	22	25
Oppose somewhat	13	23	2	6	15	17
Stongly oppose	8	14	18	55	26	29
Did not know	1	2	0		1	1
Total	56	100	33	100	89	100

TABLE 9-29

Commercial : Opinions on deepening and widening the river as a means of alleviating flooding

	Carlisle		Appleby		Total	
Strongly favour	18	32%	17	52%	35	39%
Favour somewhat	15	27	7	21	22	25
Oppose somewhat	10	18	2	6	12	13
Strongly oppose	10	18	7	21	17	19
Did not know	3	5	0		3	3
Total	56	100	33	100	89	99

TABLE 9-30

Commercial : Opinions on preserving the status quo in the area

	Carlisle		Appleby		Total	
Strongly favour	16	29%	13	39%	29	33%
Favour somewhat	1	2	0		1	1
Oppose somewhat	4	7	9	27	13	15
Strongly oppose	35	63	11	33	46	52
Did not know	0				0	
Total	56	101	33	99	89	101

TABLE 9-31

Commercial : Opinions on payment for flood protection - everyone should pay through rates and taxation

	Carlisle		Appleby		Total	
Strongly favour	46	82%	28	85%	74	83%
Favour somewhat	4	7	0		4	4
Oppose somewhat	5	9	0		5	6
Strongly oppose	1	2	3	9	4	4
Did not know	0		2	6	2	2
Total	56	100	33	100	89	99

TABLE 9-32

Commercial : Opinions on payment for flood protection - only those at risk to flooding should pay

	Carlisle		Appleby		Total	
Strongly favour	2	4%	3	9%	5	6%
Favour somewhat	5	9	0		5	6
Oppose somewhat	3	5	0		3	3
Strongly oppose	46	82	28	85	74	83
Did not know	0		2	6	2	2
Total	56	100	33	100	89	100

TABLE 9-33

Commercial : Opinions on a government grant for those in flood areas to protect themselves

	Carlisle		Appleby		Total	
Strongly favour	14	25%	2	6%	16	18%
Favour somewhat	10	18	7	21	17	19
Oppose somewhat	11	20	2	6	13	15
Strongly oppose	21	38	22	67	43	48
Did not know	0		0		0	
Total	56	101	33	100		100

TABLE 9-34

Commercial : Opinions on government relocating industry in flood hazard areas

	Carlisle		Appleby		Total	
Strongly favour	25	45%	2	6%	27	30%
Favour somewhat	10	18	3	9	13	15
Oppose somewhat	2	4	0		2	2
Strongly oppose	18	32	28	85	46	52
Did not know	1	2			1	1
Total	56	101	33	100	89	100

Flood experience again proved the most significant variable influencing the response of business-men. In Carlisle for instance, government grants and relocation aid were favoured to a greater extent by flood experienced business-men (fifty-three and seventy-five percent) than non-experienced (twenty-five and forty percent). The two responses were significantly different above the 0.95 level of probability. If the significance level was reduced to 0.90 then significantly different responses were also found to reservoirs and preservation. Fifty-three percent of experienced business-men compared to twenty-five percent of non-experienced were in favour of reservoirs, and with a reversed trend, twenty-two percent to forty-five percent in favour of preserving the status quo. The other schemes did not produce significantly different responses, although experienced respondents were consistently more in favour of the structural alleviation schemes than were non-experienced respondents. The responses to the financial proposals, on the other hand, were virtually the same. In Appleby the data was more restricted and hence could not be tested statistically. However, the evidence indicated that the non-experienced respondents showed more support for both upstream reservoirs, sixty-one percent compared to only eight percent, and preserving the environment, fifty percent to thirty-six percent. Flood banks (44% to 25%) and deepening and widening rivers (76% to 61%) were favoured by proportionally more flood experienced business-men than non-experienced. The other proposals produced fairly similar responses.

(3) Perceived Response to the Flood Hazard

As with the residential survey, it was postulated that those business-men with property in flood prone areas would seek to minimise the losses accruing from flooding. It was further suggested that to do this, the business-man would undertake certain activities prior to a flood, given a warning, which he perceived as the most effective remedial measure in the given circumstances. It is these perceived actions, and the causes for such a response, which are examined here, followed by an assessment of the perceived effectiveness of such actions.

(i) Perceived response to a flood warning

The perceived response to a flood warning by the business-men of Carlisle and Appleby is shown in table 9-35. Eighty percent of Carlisle business-men suggested they would remove machinery and stock to safer areas, and thirty-two percent perceived the employment of sandbags to prevent water entering their premises. In Appleby, sixty-seven percent and eighteen percent respectively said they would carry out these measures, while a further twenty-seven percent suggested that they would keep watch on the river. Several trends emerged from these data; for example, in both Carlisle and Appleby business-men in retail were more likely to employ sandbags in the event of a flood warning than others. Of even more significance was the response from those business-men with personal flood experience compared with the non-experienced group. In Carlisle, only twenty-two percent of the experienced, compared to fifty percent of the non-experienced, anticipated the use of sandbags, while in Appleby the proportions were twelve percent

TABLE 9-35

Commercial : Response to official 6 hour warning of flooding

	Carlisle		Appleby		Total	
Do nothing	4	7%	1	3%	5	6%
Keep watch	3	5	9	27	12	13
Consult others	0		0		0	
Sandbagging	18	32	6	18	24	27
Move machines/stock	45	80	22	67	67	75
Other	5	9	1	3	6	7
Total	(75)	133	(39)	118	(114)	128

% of Respondents

and thirty-eight percent. This response would indicate similar findings to the residential survey, with the older business-men less likely to undertake ineffective remedial action.

Business-men were also asked if they had any set procedure to follow in the event of a flood warning or emergency. To this question only four business-men in Carlisle and two in Appleby responded positively. The sewerage works in Carlisle have certain operations to fulfil in the event of a flood warning to protect the rest of Willow Holme Industrial Estate. (These have been described in chapter six). Carrs of Carlisle also implemented a general emergency plan, whereby workers are requested to undertake certain preplanned exercises. The electricity power station in Carlisle has fittings to protect some machinery and some pumps to remove water once the flood has receded, and finally Vibroplant, in the industrial estate maintains a standby team for any general emergencies, which would be mobilised in the event of a flood warning. In Appleby, less formal arrangements have been made. For example, Eggleston's warehouse, where goods are already stored above ground level, is kept under constant surveillance during a flood alert in case further removal of stock is deemed necessary.

Several businesses, therefore, appear to be prepared for flooding, and have tried and tested plans for dealing with such contingencies. Others, however, particularly those which have located on the flood plain since the last flood, tend to have no plans and frequently perceive relatively ineffective actions such as sandbagging. Temporary measures to prevent flood waters entering property are only fully effective if given considerable thought and planning, and only then with floods of low depth. In Carlisle, Carrs biscuit factory and the electricity station showed the greatest adjustment to the flood hazard, and it is probably significant that both businesses had been in the area for many years, and hence had considerable experience of flood problems. In Appleby, the warehouses along Chapel Street were the most adjusted to the flood hazard.

(ii) Perceived effectiveness of remedial actions.

The final question in the survey requested the business-men to evaluate the losses which would accrue from two hypothetical floods, first without any prior warning and secondly with six hours warning. In this way, a crude estimate of the total losses from flooding was obtained, and also the perceived effectiveness of remedial action prior to a flood. The two floods considered were of 15 cm (6 inches) and 120 cm (4 feet) depth. The question produced a wide range of responses from the business-men, with perceived losses from flooding varying between nought and sixty thousand pounds. For this reason, the estimated losses were converted to a logarithmic scale, so that both the high extremes and the generally more common lower values could be incorporated into the same distribution table.

In Carlisle, the total losses perceived by business-men in the event of a 15 cm flood without any warning amounted to £191,670, while given a 6 hour warning, this figure fell to £78,000, an overall saving of 59.35%. In the case of the 120 cm flood, total losses without warning amounted to £570,750, which again fell considerably following a warning to £325,100, a saving on this occasion of 43.04%. The mean losses per business establishment were £3,616 and £1470 for the smaller flood, and £11,200 and £6375 for the larger. The perceived losses for Carlisle businesses, based on the logarithmic scale are shown in table 9-36, while figure 9-3 illustrates how the perceived losses varied between the two floods, both with and without warning.

In Appleby, the perceived losses accruing from flooding were not as high as in Carlisle, although there was still a wide variation in the responses. The distribution of these responses is shown in table 9-37 and further illustrated by figure 9-4. Based on the actual data, rather than the classification groupings used in the diagrams, the total perceived losses from a 15 cm flood amounted to £23,600, and with 6 hour warning, to £5,600. The mean losses per business fell from £736 to £175 for an overall perceived saving of 76.2%. With the 120 cm flood, perceived losses rose to £170,700 without warning and to £28,900 with, and the mean losses rose correspondingly to £5690 and £963 respectively. The perceived savings for this larger flood amounted to 83.07%. Thus, while Carlisle business-men generally perceived the largest flood losses, the greatest savings given a six hour flood warning were anticipated by the business-men in Appleby.

The perceived losses were explained to a certain extent by the type of business to which they referred, which was expected considering some industries are more susceptible to flood damage than others. Tables 9-38 and 9-39 show the total perceived losses accruing from the two flood events for the four types of businesses in Carlisle, while similar data for Appleby are shown in tables

TABLE 9-36

Commercial : Perceived flood losses from 15 cm flood and 120 cm flood

CARLISLE

	15 cm				120 cm			
Log of Damages	No warning		With warning		No warning		with warning	
None	2	4%	17	32%		%	5	10%
1.0 - 1.749	5	9	4	8	1	2	2	4
1.75 - 2.499	18	34	16	30	4	8	7	14
2.5 - 3.249	7	13	8	15	8	16	9	18
3.25 - 3.999	14	26	6	11	17	33	16	31
4.0 - 4.749	7	13	2	4	19	37	12	24
4.75 - 5.499					2	4		
Total	53	99	53	100	51	100	51	100

TABLE 9-37

Commercial : Perceived flood losses from 15 cm flood and 120 cm flood

APPLEBY

	15 cm				120 cm			
Log of damages	No warning		With warning		No warning		With warning	
None	3	9%	13	41%	1	3%	7	23%
1.0 - 1.749	1	3	3	9			2	7
1.75 - 2.499	9	28	9	28	1	3	7	23
2.5 - 3.249	16	50	7	22	9	30	7	23
3.25 - 3.999	3	9			13	43	7	23
4.0 - 4.749					6	20		
4.75 - 5.499								
Total	32	99	32	100	30	99	30	99

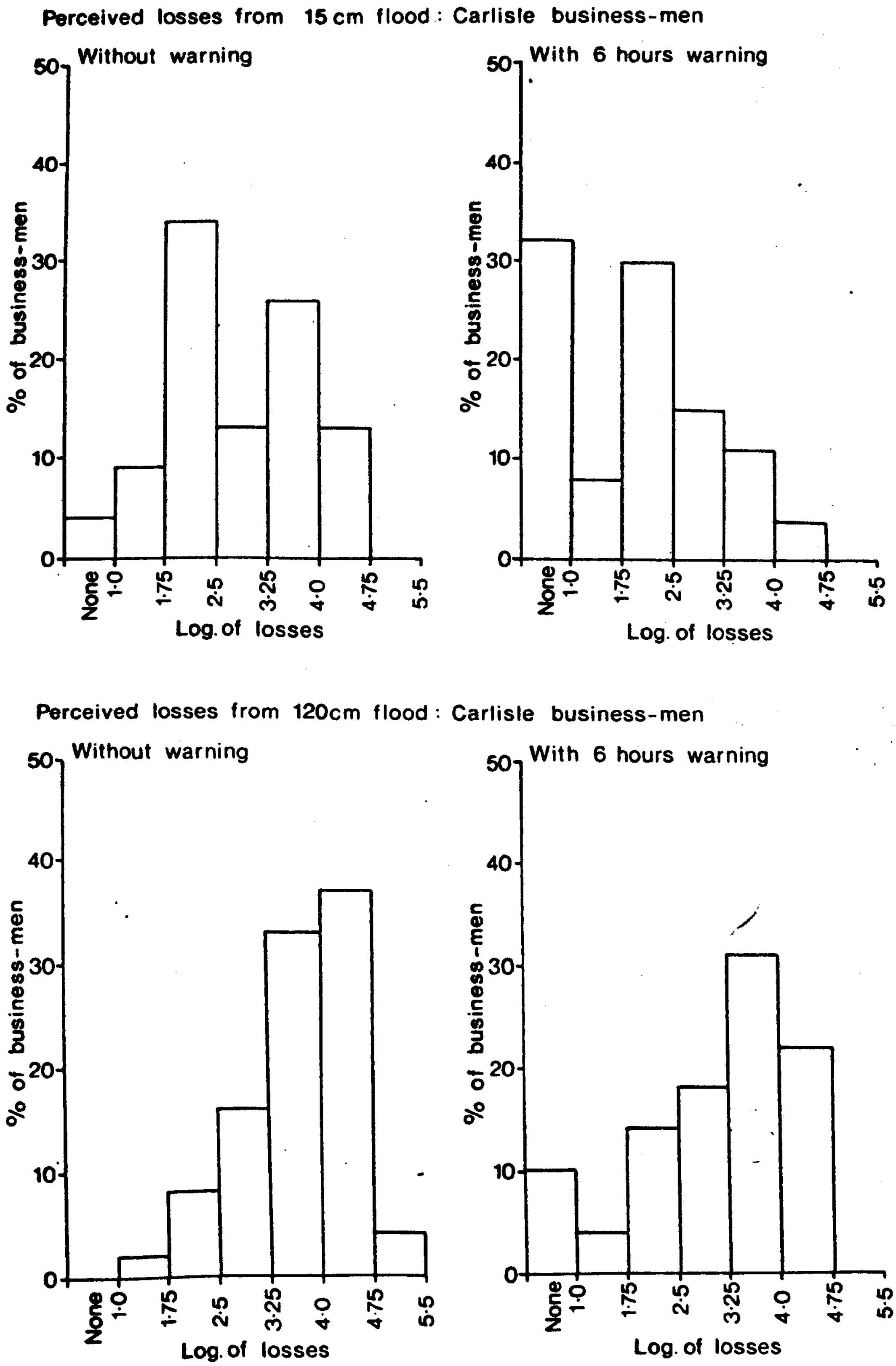


Fig. 9-3. Estimated flood losses both without and with a six hour flood warning in Carlisle.

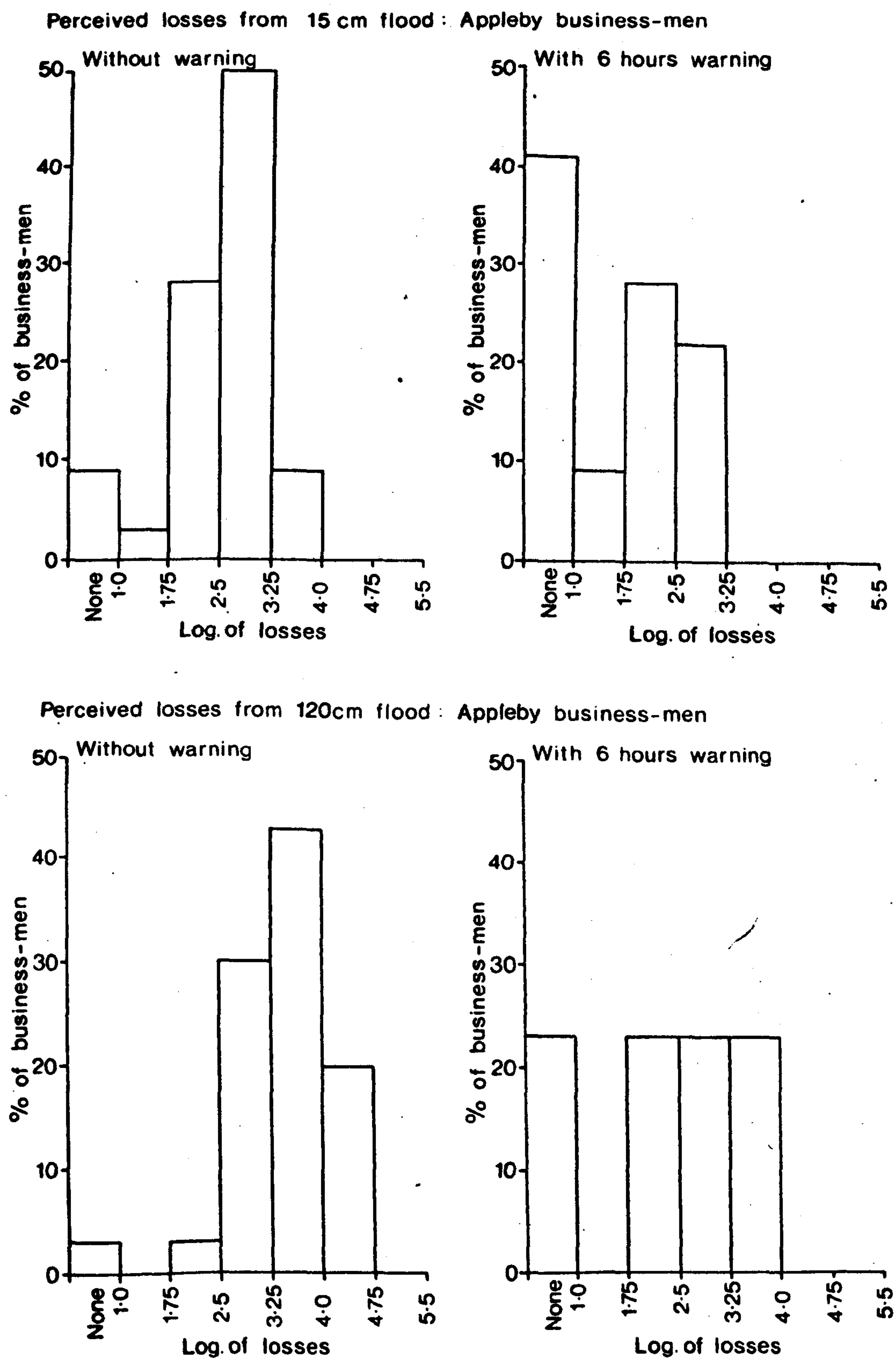


Fig. 9-4. Estimated flood losses both without and with a six hour flood warning in Appleby.

9-40 and 9-41. In Carlisle, the greatest perceived losses were accounted for by the wholesale businesses, which produced average losses twice as high as other businesses, whilst the lowest average losses were recorded by the retail outlets. This response was probably a function of two business characteristics, size and type. For example, retail outlets were generally very small and hence, even if totally inundated would in actual figures suffer less damage than larger concerns would from even minimal flooding. Other businesses, such as the manufacturing and construction industry, because of the nature of their goods and machinery, could well survive certain flood levels with relatively little damage. On the other hand, wholesale business, which in Carlisle principally involved food and electronic concerns, would maintain stock particularly vulnerable to flood damage and at the same time have a greater value of goods at risk than retail outlets. This difference between the different types of industries was even greater following a flood warning, with mean losses for wholesale three times larger than manufacturing and construction perceived losses. The same trend was apparent for the larger flood event, although the differences between the businesses were less pronounced. The depth, therefore, would appear to cause proportionally more damage to other businesses, although wholesale business-men still perceived the largest losses.

The perceived effectiveness of a six hour flood warning also varied between the different business types. In the smaller flood, the manufacturing and construction industry estimated average savings of 69.44% compared to 66.49% in services, 57.69% retail and only 50.72% for the wholesale businesses. In the larger

TABLE 9-38

Commercial : Perceived flood losses from 15 cm flood and estimated total flood plain losses from commercial property - based on actual figures from different business types

CARLISLE

Without warning

	Total perceived losses	Mean perceived losses	Estimated total flood plain losses
Man & Construction	£65,600	£4,685	£65,600
Wholesale	86,100	9,567	86,100
Retail	12,220	940	17,860
Service	27,750	1,632	50,603
Total	191,670	3,616	220,163

With warning

	Total perceived losses	Mean perceived losses	Estimated total flood plain losses	Percentage Saving
Man & Construction	20,050	1,432	20,050	69.44
Wholesale	42,400	4,711	42,400	50.75
Retail	5,170	398	7,556	57.69
Service	9,300	547	16,959	66.49
Total	77,920	1,470	86,965	59.35

TABLE 9-39

Commercial : Perceived flood losses from 120 cm flood and estimated total flood plain losses from commercial property - based on actual figures from different types of business

CARLISLE

Without warning

	Total perceived losses	Mean perceived losses	Estimated total flood plain losses
Man & Construction	199,500	14,250	199,500
Wholesale	144,000	18,000	162,000
Retail	25,650	1,973	37,489
Service	201,600	12,600	390,600
Total	570,750	11,191	789,589

With warning

	Total perceived losses	Mean perceived losses	Estimated total flood plain losses	Percentage Savings
Man & Construction	117,750	8,411	117,750	40.98
Wholesale	112,200	14,025	126,225	22.08
Retail	9,800	754	14,323	61.79
Service	85,350	5,334	165,366	57.66
Total	325,100	6,375	423,668	46.34

flood, there was even greater variation, with the largest savings perceived by retailers 61.79% compared to 57.66% services, 40.98% in manufacturing and construction, and only 22.08% in wholesale. This low perceived saving in the wholesale business, particularly in the 120 cm flood, was caused by large stocks of goods and a lack of safe areas in which to move them, according to several business-men. Nevertheless, the most important aspect to emerge from this question, as far as business type was concerned, was the susceptibility of wholesale establishments to flood damage in general.

In Appleby, the significance of business type on perceived flood losses was less clear, which could be a result of the smaller number of businesses and the general similarity between them. Also, since there were no wholesale concerns, the results did not help to substantiate the findings in Carlisle. The greatest perceived losses in both the 15 cm and 120 cm floods without warning were recorded by services followed by retail outlets. However, following a six hour warning the greatest mean losses for both floods were found in the retail businesses. These figures reflect the greater perceived savings following a flood warning by the respondents in service businesses, particularly in the larger flood, compared to other business types. For example, the estimated savings for services was 79.38% and 91.64% for the small and large floods respectively, whereas the perceived savings for retail outlets were 72.33% and 52.43%. The perceived savings for the one manufacturing and construction establishment in Appleby were 75 and 80%.

Using the data collected on the perceived losses from flooding for the different types of business, the total losses for all industries on the two flood plains were calculated. This included those industries not surveyed in the questionnaire. The results of these calculations are shown in tables 9-38 to 9-41. In Carlisle, the total losses for all flood plain businesses amounted to approximately £220,200 for the small flood without warning and to £86,965 with a warning. For the large flood, the figures were £789,589 and £423,668. However, because of the great variation in perceived losses even between similar businesses, these extended figures could incorporate a degree of inaccuracy given that seventeen businesses were not surveyed.

In Appleby, similar calculations indicated that for the small flood £25,300 worth of damage would be caused, falling to £6000 with a warning. In the large flood, total losses would rise to £195,600, and to £33,000 with warning. Nevertheless, even given the possible source of error, these figures show a very high degree of flood damage even in the smaller flood with a six hour warning.

While the two centres produced comparable responses to this question, the perceived losses from Carlisle business-men were consistently above those from Appleby. This probably reflects the generally larger establishments in Carlisle which would have more goods at risk to flood damage compared to the small family shop in Appleby.

The other major independent variables apparently influencing the response to this question was flood experience. While

TABLE 9-40.

Commercial : Perceived flood losses from 15 cm flood and estimated total flood plain losses from commercial property - based on actual figures from different business types

APPLEBY

Without warning

	Total perceived losses	Mean perceived losses	Estimated total flood plain losses
Man & Construction	200	200	400
Wholesale			
Retail	10,500	656	11,156
Service	12,850	857	13,707
Total	23,550	736	25,263

With warning

	Total perceived losses	Mean perceived losses	Estimated total flood plain losses	Percentage Savings
Man & Construction	50	50	100	75.00
Wholesale				
Retail	2,905	182	3,087	72.33
Service	2,650	177	2,827	79.38
Total	5,605	175	6,014	76.19

TABLE 9-41

Commercial : Perceived flood losses from 120 cm flood and estimated total flood plain losses from commercial property - based on actual figures from different business types

APPLEBY

Without warning

	Total perceived losses	Mean perceived losses	Estimated total flood plain losses
Man & Construction	1,000	1,000	2,000
Wholesale			
Retail	37,000	2,467	41,933
Services	132,700	9,479	151,657
Total	170,700	5,690	195,590

With warning

	Total perceived losses	Mean perceived losses	Estimated total flood plain losses	Percentage Savings
Man & Construction	200	200	400	80.00
Wholesale				
Retail	17,600	1,173	19,947	52.43
Service	11,100	793	12,686	91.64
Total	28,900	963	33,033	83.07

business type tended to reflect the actual property and valuables at risk to flood damage, flood experience was expected to give a clearer indication of actual savings to be made following a flood warning. It was purported that personal experience of the physical processes of flooding would greatly enhance the accuracy of perceived losses accruing from flooding.

Tables 9-42 and 9-43 show the perceived losses from the two floods based on flood experience for the business-men in Carlisle and Appleby respectively. In Carlisle, the mean perceived losses for those business-men with flood experience were invariably higher than the mean perceived losses of non-experienced business-men. This would suggest that non-experienced business-men tended to underestimate losses, given that the flood experience was likely to improve the perception of the other group. The perceived savings from a flood warning also differed between the two groups with the non-experienced estimating savings of 72.77% compared to 54.94% of the experienced respondents, for the smaller flood. The savings for the larger flood were comparable 43.14% and 43.02%. In this case, it would appear that the non-experienced business-men tend to overestimate the potential of remedial action prior to a flood, at least for the smaller event.

In Appleby, the reverse trends were found. Non-experienced business-men perceived greater losses than the experienced in all cases except the large flood without warning, and the experienced perceived the greatest savings, 83.65% and 88.56% compared to 57.46% and 55.32%. However, the data for Appleby may be somewhat unreliable in this case, particularly for the

TABLE 9-42

Commercial : Perceived flood losses based on flood experience

CARLISLE

15 cm flood

	Without warning Total	Without warning Mean	With warning Total	With warning Mean	Percent Savings
Experienced	144,300	4,123	65,020	1,858	54.94
Non experienced	47,370	2,632	12,900	717	72.77
Total	191,670	3,616	77,920	1,470	59.35

120 cm flood

	Without warning Total	Without warning Mean	With warning Total	With warning Mean	Percent Savings
Experienced	461,000	13,171	262,700	7,506	43.02
Non experienced	109,750	6,859	62,400	3,900	43.14
Total	570,750	11,191	325,100	6,375	43.04

TABLE 9-43

Commercial : Perceived flood losses based on flood experience

APPLEBY

15 cm flood

	Without warning		With warning		Percent Saving
	Total	Mean	Total	Mean	
Experienced	16,850	702	2,755	115	83.65
Non experienced	6,700	838	2,850	356	57.46
Total	23,550	736	5,605	175	76.20

120 cm flood

	Without warning		With warning		Percent Saving
	Total	Mean	Total	Mean	
Experienced	142,500	6,196	16,300	709	88.56
Non experienced	28,200	4,029	12,600	1,800	55.32
Total	170,700	5,690	28,900	963	83.07

non-experienced estimates because the figures are based on only eight business responses.

In the final analysis, the commercial survey indicated that flood plain business-men were more aware of the flood problems and the programmes implemented to alleviate them, than the residents. Businesses had a longer length of residence time in the flood prone areas, which had led to greater flood experience, and hence, in some cases, to more effective adjustments to the hazard. The commercial survey also confirmed the correlation between increasing flood depth and greater flood losses, although commercial losses were consistently larger than residential (this was found for both actual reported losses, and perceived future losses). The efficient flood proofing of only a few business premises on each flood plain would reduce the losses accruing from flooding quite significantly, although this would do little to reduce the psychological stresses and anxiety for the rest of the business-men and residents. The commercial data showed that, in general, greater residence in the area corresponds to a more accurate perception and awareness of the local environment. The commercial survey, therefore, showed that despite the two research flood plains being primarily residential (apart from Willow Holme Industrial Estate in Carlisle) business premises still warranted considerable attention in terms of flooding, at least as far as financial losses were concerned.

GENERAL CONCLUSIONS

Introduction

The aim of this research was to improve the understanding of flood plain management with a view to reducing flood losses. Initially, it was shown that flood plain residents would respond to the flood hazard on the basis of their perceptions of the problem, and that this behaviour is often assumed to constitute a rational decision on the part of the individual to minimise flood losses. In practice, however, this perceived action could represent irrational behaviour which could exacerbate flood losses. The main conclusion to emerge from the research, therefore, was that if individual perception and awareness of various aspects of the flood problem was improved, then a more favourable response to the flood hazard would be generated, and hence flood losses could be reduced. The importance of these behavioural studies was shown for all aspects of flood plain management, including structural schemes and non-structural adjustments. Particular attention was given to the social implications of flood forecasting and warning schemes because of the importance of these measures to the present British flood planning policies.

The flood problem

The flood problem exists, not because all rivers flood at some time, but primarily because man has put a high premium on a flood plain location. The reasons for this have varied over the years, from water supply, power generation and modes of communication, to flat land for construction purposes, or more recently for purely aesthetic reasons. Each of these in turn has added to the flood problem by encouraging development on the flood plain, and thus placing increasing property in hazardous areas. The study of the historical development of Carlisle provided a typical example of how the flood problem arose in many British cities (see chapter five for details). This study showed that Carlisle expanded rapidly during the late eighteenth and throughout the nineteenth centuries as a direct result of the industrial revolution. Almost all this development was confined to the flood plain areas around the old medieval core of the City. In Appleby, the flood problem was the relic of earlier settlement patterns and is probably typical of the development of many other upland villages in Britain. This pattern of flood plain encroachment has occurred throughout the world, and in chapter one, it was shown how this behaviour had resulted in large damages in many countries. For example, catastrophic losses in terms of both property and life are reported almost annually from such places as India, Pakistan, Bangladesh, Indo -China and the U.S.A. The flood problem, therefore, is very much the result of the interaction between man and nature, although the problem exists only because of the activities of man.

Adjustment to the hazard

A major conclusion to emerge from parts I and II of this work was the changing emphasis in flood plain management policies since the 1930's. Two principal findings stood out : firstly, there had been a gradual change from structural to non-structural measures, and secondly, alleviation policies had developed from a piecemeal response to the problem to a more comprehensive approach to the whole flood plain. For instance, flood alleviation was originally synonymous with large scale structural schemes, particularly in the

U.S.A. where many large dams and reservoirs were constructed during this early period. Since then, there has been a trend towards smaller adjustments, which are more flexible, as well as the incorporation of some non-structural measures into the overall system. These changes in emphasis, especially with regard to general flood plain management, have increased the need for behavioural studies.

The change in flood plain management arose because of failures in the earlier policies significantly to reduce flood losses, despite ever increasing investments in flood alleviation schemes (see chapter one for details). Kollmorgen (1953, 214) was one of the first to express dissatisfaction with such policies.

> "Under present plans, we will flood hundreds of acres of the finest agricultural land in the state (Kansas) to protect one acre of urban flood plain land which has only limited site value for improvements that could readily be shifted to secure upland locations."

He further suggested that, for many schemes, it would have been cheaper to purchase the upland areas, rather than flood them. Hence, the cost of implementing such schemes in conjunction with the ever rising flood losses, brought about the change in attitude. Many schemes are now implemented, which in the past were considered to have little or no value, such as flood insurance, or to be impractical in many environments, such as flood forecasting and warning schemes. However, the important technological advances since the 1930's have made such adjustments viable means of reducing flood losses.

The importance of behavioural studies

An important conclusion to emerge from the early review of the literature was the significance of behavioural studies to the success of any flood plain management programme. In the past, flood alleviation schemes have been subject to a series of feasibility studies, in particular benefit-cost analyses, to select the most effective measure for a specific area. However, these feasibility tests have failed, since flood losses have continued to rise, and many schemes have been implemented which have been less effective than originally anticipated. The evidence would suggest that these failures have arisen because of the lack of consideration for the social implications of the flood plain management programmes. In general, social factors have been ignored, on the assumption that any scheme implemented to alleviate the flood problem would be acceptable to those persons living and working on the flood plain. This view was clearly not true, even for the earliest schemes, but has become less with the recent trend towards non-structural measures.

(a) Structural measures

One of the fallacies of the early flood plain management policies was the belief that social factors would have no effect on the efficiency of structural alleviation schemes. Unfortunately, such schemes have generated an inefficient response from the flood plain populations, a feature common to most structural measures. This response, subsequently called the 'levee effect', has resulted in increasing investments in flood plain property on the so-called safe sides of the alleviation scheme. Thus, any scheme incorporating structural measures should also incorporate some form of development control to prevent an increase in potential flood losses.

(b) Non-structural measures

The significance of behavioural aspects to non-structural flood alleviation measures is even greater, and the need for such studies has increased with the recent trend in flood plain management. As with structural schemes, so the assumption has been made that flood plain residents (and business-men) would respond favourably to minimise flood losses, with any non-structural scheme. For example, a flood proofing policy or an insurance programme is only effective for those persons who undertake such actions, while a flood forecasting and warning scheme is only effective if the majority of the flood plain population take positive remedial action.

The Behaviour Studies - Major findings

(a) Flood plain characteristics

The initial part of the flood plain surveys established several features common to many flood plains. For instance, the age distribution of the flood plain residents in Carlisle and Appleby was skewed towards the elderly. This feature compared with similar findings of other surveys, such as Penning-Rowsell (1972) in North Gloucestershire and Harding and Parker (1972) in Shrewsbury, and even to the Atlanta flood plain studied by James et al (1971).

Further research is necessary to establish whether this is a common feature of flood plains or purely a chance occurrence. It may be that the flood plains in these larger centres represent the older residential properties, and do not attract the younger families to the same extent as newer housing estates; this was certainly the case in Carlisle. The smaller settlements, such as Appleby may simply reflect the generally aging populations found in communities.

The information collected on previous flooding, particularly the 1968 event, also supported the evidence from other surveys. Most noticeable was the correlation between flood depth and flood duration, with the extent of flood losses in 1968, for both the residential and commercial data. (The relationship in the residential data for both Carlisle and Appleby is shown in figure 7-11). These findings corresponded to the earlier studies of White (1964) and Chambers and Rogers (1973) who produced different stage-damage curves for various flood events (see figures 1-12 (a-h) and 1-13). The Carlisle and Appleby surveys had not been designed to collect information for such detailed economic analyses, although precisely the same trends were present : increasing flood losses corresponding to greater flood depths and longer duration of flooding. In Britain, the study of flood losses, both theoretical and practical has received only cursory attention in the past, particularly in comparison with the American studies. Parker (1976) has recently investigated this aspect of the flood hazard in greater detail, but the current level of research is still insufficient to propose any realistic model of general flood plain losses from different magnitudes of flooding.

A further feature of the 1968 flood losses was the relatively small proportion attributed to residential damage, and the large amount accounted for by the commercial properties. In Carlisle, the response to the questionnaire (adjusted to include all flood plain properties) indicated that approximately £463,500 of damage had been caused, and that of this 90% was from the commercial sector of the community. In Appleby, the total losses amounted to approximately £24,500 of which 67% was attributed to commercial loss. Thus, purely on economic terms, the ideal solution to the flood problem would be to protect only a few of the more flood prone industries subject to particularly high losses. However, this would be unacceptable on social grounds, since nothing would be done either to reduce residential losses, or to reduce the psychological stress associated with such flood plain locations.

Another conclusion to emerge from this initial behavioural study was the importance of effective remedial action prior to a flood. A significant relationship, for instance, was found between those who successfully employed certain measures and those residents with lower flood losses, which supports the concept of a flood warning scheme in the area. It was also found that residents who experienced the least severe floods in terms of depth, were more likely to find temporary measures, such as sandbagging, useful than residents flooded to greater depths. Therefore, it is suggested in future that the most efficient employment of time and resources would be for the Local Authorities to issue sandbags only to those households located on the periphery of the flooding, given that this zone could be determined relatively easily, while other actions, such as the removal of valuables to higher levels, should be actively encouraged in the areas of more extreme flooding.

(b) Studies of perception and awareness

Studies of perception and awareness were incorporated into this research on the basis that flood plain residents would respond to the flood hazard according to their perception of the situation, which may not necessarily represent reality. Thus, behaviour, which on a superficial level would appear illogical, could represent a rational decision-making process on the basis of the perception of the individual. In places, therefore, this work has suggested ways of improving perception and awareness of various aspects of the flood hazard, in the belief that this would improve the residential response to the hazard and thus reduce flood losses. Many conclusions emerged from the mass of questionnaire data on this aspect of behaviour, although only the more pertinent findings are reviewed here. (Further details may be found at the end of each section in chapter eight).

Two variables were found to influence perception and awareness in particular. These were the frequency of the hazard event and personal experience of the problem. First of all, not everyone on the flood plain in Carlisle was aware of the flood problem, and the extent of awareness was clearly related to personal flood experience. Evidence also suggests that residents who are aware of the hazard are more likely to take ineffective action prior to a flood, and will not have undertaken any pre-planned action in the form of flood proofing or flood insurance (see below). Newcomers to the area, therefore, are more likely to suffer greater losses than experienced residents of longer duration. This situation could be improved quite significantly if new occupants of flood prone propertywere made aware of the hazard, either officially by the Local Authority or by estate agents and surveyors who have not advertised the problem in the past. Residents with flood experience, especially those with experience of more extreme events, were also more likely accurately to perceive the flood hazard. With reference to probable future flooding, for instance, those residents with experience perceived the true situation more accurately than the inexperienced residents.

The degree of fear of flooding was related primarily to the frequency of its occurrence, since Appleby residents tended to worry more about the problem than Carlisle residents. This result was confirmed by earlier data on various hazards, which suggested that day to day events caused greater annoyance than seasonal problems. Fear was also related to personal experience, although those flooded more frequently often expressed less fear than others. This suggests that certain residents after several floods become adjusted to the environmental conditions of their location. Again, a policy of informing residents of the flood hazard may eventually reduce the psychological stress, by mentally adjusting residents to the flood problem. Social factors also brought out several differences; for instance, women and older residents expressed greater fear than younger residents and males. This could either represent a genuine difference between the two groups, or a reluctance of the latter group to admit to such fears.

The awareness of the authoritarian response to the flood hazard was also related to social factors and personal experience. For instance, those respondents who had lived in the area for the longest period, the older residents, and those with the greatest personal experience of flooding, were most likely to be aware of any authoritarian response. In Appleby, the same group were more likely to be aware that no action had been undertaken in the town. It was also found that residents not aware of authoritarian schemes were more likely to worry about the flood problem. Thus a programme of education concerning the flood hazard could reduce the psychological stresses of a flood plain location, especially for those residents aware of the probability of flooding, but unaware of any alleviation measures. It was also significant that younger, less experienced, residents expressed greater faith in authoritarian schemes to overcome the flood problem, and hence tended to worry less about the hazard.

(c) Flood forecasting and warning schemes

The flood forecasting and warning scheme which operates in the Eden Valley, and the attitudes of flood plain residents and business-men towards the scheme, illustrate many of the findings associated with flood plain behaviour. Although this survey concerned only one flood warning system, many of these conclusions are relevant to flood forecasting and warning systems elsewhere, as well as to other non-structural measures.

In chapter one, flood forecasting and warning schemes were examined as a system, consisting of three parts each an integral subsystem of the whole. The first subsystem, collection and evaluation of the data, was discussed in theoretical terms in chapter three. This study showed the rapid technological advances made in this form of flood alleviation in the last fifteen years, especially in the field of instrumentation. The Cumbrian schemes were analysed in chapter six, including proposals for future amendments to the scheme following the reorganisation of the water industry. The new plans would greatly enhance an already highly sophisticated system, since further settlements not presently incorporated in a flood warning scheme, such as Appleby, could be more easily included. Improvements in the system would also increase the potential for flood loss reduction by this means in Cumbria.

The second subsystem, dissemination of the warning message, has received very little attention in the past and must represent a major weakness in most flood forecasting and warning schemes. Without an efficient method of broadcasting the warning message to all persons on the flood plain, any great advantage offered by an efficient first subsystem is immediately invalidated. Of all the forecasting schemes discussed in chapter three, only one had promoted any procedure for the dissemination of the warning message. The Severn River Authority reported employing flood wardens for this purpose, and then only in rural areas. The remainder left all responsibility for warning dissemination with the police, who usually resort to touring the flood prone areas with loud hailers to alert the local population. Therefore, to improve the efficiency of flood forecasting and warning systems a more effective method of disseminating the warning message should be devised.

In Carlisle, a more sophisticated scheme for the dissemination of flood warning messages was developed, which at least in theory would cover the whole flood plain population quickly and efficiently. This scheme was based on a pyramid call-out system, whereby the police would alert several volunteer receivers by telephone, who in turn would pass the message on to several of their neighbours, and so on. A similar scheme was developed for the industrial premises at Willow Holme. However, the efficiency of these schemes was shown to be extremely suspect, because of the high turn-over of flood plain occupants, both residential and commercial, and the subsequent failure by the authorities to update the system. A flood warning in Carlisle, therefore, would undoubtedly cause some confusion given the present state of the system. To improve this system, not only should the whole of the flood plain population be informed of the procedures following a flood warning, but also the official receivers should be reminded of their obligations.

A further potential weakness in the Carlisle scheme is the attitudes of the flood plain residents. For instance, the majority of respondents expressed greatest faith in the police and River Authority in the event of flooding, and hence it is questionnable how much response would be generated by the verbal dissemination of a warning between residents as the pyramid system proposes. This attitude supported the hypothesis put forward by Mileti and Krane (1973) who suggested that respondents would react most favourably to a warning that came from an authoritative source. An improvement to the Carlisle scheme, which would have other benefits later, would be to designate certain volunteer residents as official flood wardens, and give them responsibility for small blocks on the flood plain. In this way the present scheme could be maintained, if updated and the new wardens could act as initial receivers of the warning message from the police. It is believed that a warning message received from such a semi-official person would generate a greater response than would the present pyramid system.

The final stage of flood forecasting and warning schemes, reponse to the warning message, has received even less attention than the previous stage. This is a critical factor, since the relative success or failure of the scheme eventually depends on the favourable response of the flood plain residents and businessmen prior to a flood. The scheme, like most others, has always been implemented on the basic assumption that receivers of the warning message would act rationally to minimise losses accruing from flooding. In general, the flood plain resident will probably aim to do this, but the measures undertaken may not in fact be very efficient, although the resident himself may perceive them as most effective. For example, in Carlisle many residents employed very poor schemes in 1968, such as sandbagging, which were frequently found to have little effect in controlling the flooding.

A further factor, which could impair the effectiveness of the warning scheme, was the generally low awareness of the system by Carlisle residents. An official flood warning, therefore, would take many residents by surprise, and even if they believed the warning, they would probably implement ineffective measures. In Appleby, an even worse situation exists with many respondents expressing faith in a non-existent flood warning scheme. This would cause even greater flood damage if residents waited for a warning rather than kept watch on the river themselves. Fortunately, however, this latter response is a common feature of the older Appleby residents, and those who have lived in the town for a long time, and hence flood losses may not be as high as it would first appear. Nevertheless, it would seem essential to advertise the Carlisle flood warning scheme widely over the flood plain, and to clarify the position in Appleby, if flood losses are to be reduced in the future.

One of the major conclusions to emerge from this study of flood forecasting and warning schemes is the absolute necessity for authoritarian help with the third stage of the system. For instance, the perceived response to a flood warning was frequently of little value in reducing flood losses, as had been proved by such actions in 1968. For this reason, those respondents with flood experience, who incidentally had often learnt through their experience, were more likely to perceive efficient remedial action in the future, and hence suffer less serious flood losses than inexperienced residents. Thus, to reduce flood losses in the future by improving pre-flood action some form of official advice should be available, particularly to inexperienced residents, detailing the most efficient action to be taken in the event of a flood warning. Such information would reduce the number of residents who spend valuable time securing openings against flooding, only to find that flood waters have inundated the property by rising up through communal foundations, or even by overtopping the defensive structures. This information could easily be distributed in the form of a leaflet to all flood plain households, and may also encourage certain preparations to be made even before a warning is issued by making more people aware of the flood proofing techniques available.

Further authoritarian help of a physical nature should be available to the old and infirm residents, who may be incapable of undertaking extensive or remedial action prior to a flood. The questionnaire survey showed that many older residents in both Carlisle and Appleby perceived no action in the event of a flood warning. Clearly, a system of such aid would both reduce losses accruing from flooding, and probably just as important, reduce the psychological stress of the hazard to these people. Ironically, it is often this group who have the greatest experience of flooding and who perceive the most effective response to the hazard, but are physically incapable of carrying out any action. This research therefore, suggests that some organised system, possibly on a voluntary basis, should be set up to deal with this problem, and that older flood plain residents should be made aware of the scheme. This scheme could be combined with the flood warden system, whilst the leaflets informing residents of the flood hazard and the flood warning scheme could also provide this additional information. In this way, older residents would have less need to fear flooding, and flood losses would also be reduced.

The rationality of individual behaviour was confirmed by further evidence from the questionnaire surveys. Those inexperienced residents who perceived actions following a flood warning that would in reality be of little value, also perceived the greatest savings from six hours flood warning. Thus, to the residents themselves their perceived response was a logical decision to minimise their flood losses. If this initial perception, however, could be improved by a policy of education in flood proofing techniques, then the response to a flood warning may well improve and so in turn significantly reduce flood losses.

In the case of flood forecasting and warning schemes, therefore, there were essentially two resident types who required help in different forms. (In practice these constituted a graduation between two extremes, but these two groups illustrate the problem most clearly).

(i) Older persons - these were typified principally by the Appleby survey but also parts of Carlisle. This group of respondents tended to live alone, to have experienced flooding and/or to be aware of the hazard, and also to know exactly what action to take in the event of a flood. Unfortunately, the physical limitations of these residents restrict the response of this group. A programme of aid in the form of physical help should be offered to these residents, and they should be informed of this before any flood warning is necessary, to reduce any psychological stress.

(ii) Younger persons - these represented the respondents in other parts of Carlisle. This type tended to live in larger families, and to have lived in the area for a more limited period; their awareness of the hazard is limited and their perceived response to the flood hazard often ineffective. While this group is capable of undertaking quite extensive remedial action, their lack of personal flood experience would reduce the efficiency of their response. Some advice on flood proofing techniques and temporary remedial action would not only make these residents more aware of the hazard, but also stimulate a more effective response to a flood warning. At the same time both groups would benefit in various ways from a flood warden system, since this could be the source of both information and physical aid, as well as helping in the dissemination of the warning message.

From the above classification, it would appear that social factors can be used to classify residents according to the perceived response to a flood warning. However, further research is necessary to test the applicability of these findings to other areas. Nevertheless, the other proposals for the flood forecasting and warning scheme would probably be just as applicable elesewhere.

(d) Decision-making model

The perceived response and attitude towards the flood forecasting and warning scheme illustrated many of the complex relationships important in flood plain behaviour patterns and individual decision-making. Figure 8-12 was constructed on the basis of these and other relationships established from the residential questionnaire surveys in Carlisle and Appleby. The model attempts to explain the processes of individual decision-making on the flood plain as a function of certain independent factors, and through the perception and awareness of different aspects of the flood hazard. The model assumes that all residents would seek a peaceful coexistence with the natural environment, although the scheme was flexible to allow for differences in this perceived peace. For example, the perceived peace for one resident could well represent an intolerable level of flood risk to another. It was anticipated that by establishing these relationships of flood plain decision-making a predictive model could be derived to determine future flood plain behaviour on the basis of easily acquired information on flood plain characteristics. For instance, if behaviour patterns could be determined from certain social traits, such data could be obtained readily from censuses, and hence authoritarian flood plain programmes could be geared towards the perceived behaviour of these persons. In this way, some consideration could be made of the social implications of flood plain management, which would hopefully make any alleviation programme more effective.

In these studies three groups of independent factors were examined : structural factors, physical/environmental characteristics and social traits (see chapter eight for details). Of these, several variables emerged as the most significant in governing flood plain decision-making processes. These were age of the respondent, length of residence in the area and various aspects of personal flood experiences. Unfortunately, the other social characteristics were often inadequate, for further research is required to determine the real significance of these factors to decision-making. Similarly, further studies should be conducted on the structural factors, for while the contrast between Carlisle and Appleby suggests this is important, this comparison is rather tenuous given the other differences between the two communities. Nevertheless, the research did show the significance of behavioural studies to flood plain research, especially the influence of certain social and physical factors on perception andawareness of various aspects of the flood hazard.

The data produced by this research were not sufficient for the construction of a comprehensive model of flood plain behaviour, although several types of respondent did emerge. For example, the older residents were more likely to live alone, to have lived in the area for a long time and to have experienced flooding to some extent. These residents were most aware of the flood hazard, and their perception of the hazard was most accurate, and as a result they were most likely to perceive a favourable response to any future flooding. The other group, young, in larger families and resident in the area for only a relatively short period, generally have little experience of flooding and are possibly unaware of the hazard. Clearly, the proposals for the flood forecasting and warning system would improve this awareness, and thus generate more effective flood plain behaviour. However, further research is required in other parts of the country to confirm these relationships, so that a more effective and detailed model of flood plain behaviour may be produced. It may be that several models are required for different flood plain environments, such as an upland model and a lowland model. Alternatively, perhaps flood problems are unique to specific areas. Nevertheless, this work does illustrate the importance of behavioural studies to flood plain management programmes, and the significance of behaviour to the scale of flood losses.

In conclusion, this work provides an example of the flood problem in one part of Britain. Particular attention has been devoted to flood plain behaviour and individual decision-making, which in the past has not been considered in any great detail. Harding and Parker (1972) looked at certain behaviour aspects of the flood problem in Shrewsbury, while the Middlesex Polytechnic research team (1972) has examined similar problems in the North Gloucestershire region, although neither survey has established any detailed conclusions on flood plain decision-making. The most recent work (Parker, 1976) which has only just become available, has considered behaviour in further detail, especially aspects of perception, although even this research tended to concentrate more on the economic aspects of flood damage. Clearly, more extensive work is required in Britain to establish the true causes of flood plain behaviour, if flood losses are to be significantly reduced in the future.

APPENDIX I

Definition of terms relevant to flooding

Bank full:	The maximum discharge reached by a stream when still within it's banks. At this point small sections of low lying land maybe inundated.
Design Standards:	Level of protection offered by structural flood alleviation schemes. Usually calculated in terms of flood frequency (see below) ie. a structure may offer protection against the 1 in 100 year flood (including all floods up to this level).
Discharge:	Rate of flow at a given point in terms of volume per unit of time, usually expressed in cubic metres per second (m^3/s)
Flood:	Any relatively high streamflow which overtops the natural or artificial banks in any reach of the stream; ie. the stage above bankfull discharge.
Flood damage:	The physical damage caused by flooding.
Flood depth:	The depth of water at a particular point on the flood plain usually measured at the peak flow.
Flood duration:	The period from the onset of flooding until the area is completely free from water.

Flood frequency:	The average number of floods during a given period. (usually calculated over a fairly long time).
Flood loss:	The economic cost of damage by flooding, both direct and indirect losses.
Flood routing:	The process of computing the progressive movement of a flood wave moving downstream.
Flood peak:	The maximum rate of flow attained by a flood at a given point.
Flood plain:	Area prone to flooding either side of the channel.
Flood return period:	The probability of a flood recurring at any one time. A given flood may have an average return period of once in 100 years or the probability of being equalled or exceeded of 0.01 in any one year.
Flood velocity:	Speed of river flow in channel during flood; usually expressed in metres per second.
Lag time:	Time from the beginning of rainfall (or centre) to the peak of runoff (or centre).
Maximum probable flood:	The largest flood for which there is any possibility given the hydrological and meteorological conditions of the area.
m^3/sec:	Cubic metres per second (see discharge).

Reach: Any section of a river channel between two given points.

Sediment yield: The material carried downstream by the flooding and deposited on the flood plain. This can range from large scale debris to smaller dirt particles.

APPENDIX II

QUESTIONNAIRE - RESIDENCES

NOTE

		VARIABLE
(1) Address	Name of Street	1
	Area	2
(2) Type of building -	1. Terrace	3
	2. Semi-detached	
	3. Detached	
	4. Flat	
	5. Bungalow	
(3) Sex of interviewee	1. Male	4
	2. Female	

QUESTION

1. What do you consider the three main advantages of living in this neighbourhood?

1.	5
2.	6
3.	7

2. What do you consider the three main disadvantages of living in this neighbourhood?

1.	8
2.	9
3.	10

3. In general how do you feel about the living conditions in this neighbourhood? Are they- 11

   1. Very good
   2. Fairly good
   3. Poor
   4. Very poor

4. Which do you consider the most serious and which is the second most serious environmental problem in this area? 12 13

1. Crime	4. Pollution
2. Noise	5. Traffic
3. Flooding	6. Other - (specify)

5. Which of the following natural hazards frightens you most and which is second most frightening? 14 15

1. Gales and winds
2. Fog
3. Thunderstorms
4. Flooding
5. Snow and ice
6. Other - (specify)

6. Does this building have a cellar/basement? 16

If yes please include the cellar in the following questions.

The following questions concern flooding. A building is considered flooded when flood water enters it or rises around the outer walls without getting inside.

7. Has there been any flooding in this neighbourhood while you have been living here? 17

8. Has this building been flooded while you have been living here? 18

If 'no' go to question 16.

9. How many times has this building been flooded? 19

10. What was the depth of water during the 1968 flood? 20

11. How long was the building flooded (underwater) during the 1968 flood? 21

12. Approximately how much did the 1968 flood cost you? 22

1. £0
2. £10
3. £25
4. £75
5. £100
6. £250
7. £500
8. £1000
9. £5000
10. Over £5000

13. Did you receive compensation after the 1968 flood? (Note: NOT insurance). 23

was this compensation adequate?

14. Did you receive help from any of the following during the 1968 flood and was this help very useful? 24-30

	Help Yes/No	Was this useful: Very	Partly	No	D.K.
1. Police					
2. W.R.V.S.					
3. Salvation Army					
4. Civil Defence/Army					
5. Council					
6. Neighbours					
7. Fire Brigade					

(Tick or cross boxes)

VARIABLE

15. Did you undertake any of the following actions during the 1968 flood? What was the approximate cost of each and how effective were they? 31-35

	Tried Yes/No	Approx. Cost	Usefulness Very	Partly	No	D.K.
(1) Tried to keep water out with sandbags and other temporary measures.						
(2) Received public flood warnings.						
(3) Moved valuables to higher level.						
(4) Moved to temporary accommodation.						
(5) Others, e.g. moved car.						

16. Are you insured against flooing? 36

If yes, when did you take out this policy? 37

17. Only ask those who answered No to question 8.

Do you know about the flood situation in Appleby/ Carlisle? 38

18. How did you first find out about the flood problem in Carlisle/Appleby? 39

1. Estate Agent
2. Neighbours
3. Personal Inspection
4. Experience
5. Radio, television, newspapers.
6. Surveyors report
7. Other (specify)

19. Does this knowledge of the flood risk worry you? 40

1. A lot
2. Some
3. A little
4. None

20. Did you consider the risk of flooding when moving here? 41

21. Knowing what you know now, given the choice would you move here all over again? 42

VARIABLE

22. Would you leave this building forever if you were flooded each year for the next three years? 43

23. Is this building designed (or modified), or have you made any permanent structural changes to keep out flood-waters? 44

24. How many times do you think this building will be flooded during the next 25 years? 45

25. Do you think the risk of flooding in Appleby/Carlisle is increasing or decreasing? 46

1. Increasing
2. Decreasing
3. No change
4. Do not know

Indicate reasons for perceived decrease: 47-53

1. Changes in climate
2. Motorway construction
3. Town building
4. Cleaning/silting of rivers and ditches
5. Building river banks and walls
6. Reservoir management upstream
7. Other (specify)

26. Do you think enough has been done in Carlisle to prevent flooding? 54

(In Appleby - has anything been done to prevent flooding?)

27. Are public flood warnings given in this neighbourhood? 55

If 'yes' are these warnings reliable? 56

28. If you were given 6 hours warning of floodwaters reaching your property how would you react? 57-62

1. Do nothing
2. Do nothing but keep watch.
3. Consult others for second opinion.
4. Employ temporary measures such as sandbagging.
5. Move valuables to higher level.
6. Move to temporary accommodation.

29. What is the most reliable source of information on the flood risk in Appleby/Carlisle? - 63

1. The Council
2. Police
3. Local radio /television
4. The River Authority
5. Own judgement
6. Other (specify)

Note: There now follow some more personal questions so that comparisons can be made between different family groups and age structures.

		VARIABLE
30. In which category are you?		64
1. 18-24 (years)	4. 45-54	
2. 25-34	5. 55-64	
3. 35-44	6. 65 and over	
31. How many people live in this building?	Total:	65-68
	1. Family groups	
	2. Adults	
	3. Children	
32. Is this building -		
	1. Owned	
	2. Rented (Council ?)	69
33. How long have you lived in this building?		70
34. What is or was the occupation of the Head of Household?		71
1. Self employed	5. Clerical worker	
2. Semi-skilled manual	6. Manager	
3. Skilled manual	7. Professional	
4. Commercial traveller	8. Armed forces	
35. When did you (the Head of Household) finish full time education? At:		72
1. 15 years or under	4. 21-22 years	
2. 16 years	5. Other (specify)	
3. 18 years		

Note: The following questions are of a more general nature for which there are no correct answers- it is your opinion that is required.

36. How would you feel about each of the following possible schemes for Appleby/Carlisle?

Please state - 1. Strongly favour
2. Favour somewhat
3. Oppose somewhat
4. Strongly oppose

(i) Build upstream reservoirs which could be used to retain excess water when flooding threatened. 73

(ii) Construction of more and larger embankments along the rivers in Appleby. 74

(iii) Deepen and widen the rivers through Appleby 75

(iv) Preserve everything as it is and leave the rivers alone. 76

(v) Allow industrial development (more jobs and money) even if this aggravated the flooding situation. (Deleted because of confusion). 77

(vi) To pay for flood protection everybody should pay more in taxes - not just those at risk from flooding. 78

(vii) The people who live in the flood prone areas should pay for their own protection. 79

(viii) The government should provide a grant or loan for people to protect themselves from flooding. 80

(ix) The government should give financial support for the rehousing of flood plain residents to safer areas. 81

37. Do you believe there is anything the individual can do to overcome the problem of flooding? 82

(Specify)

38. Do you believe there is anything the government can do to overcome the problem of flooding? 83

(Specify)

39. Finally, could you estimate the cost of damage of - 84-87

(i) 6 inches of water in this building with no warning.

(ii) 6 inches of water in this building with 6 hours warning.

(iii) 4 feet of water in this building with no warning.

(iv) 4 feet of water in this building with 6 hours warning.

QUESTIONNAIRE - COMMERCIAL PROPERTIES

NOTE		VARIABLE NUMBER
(i) Name of business		1
(ii) Location of business -	Area	2
	Street	2 (i)

QUESTION	VARIABLE NUMBER
1. What do you consider the advantages of this site for your business?	3 4 5
2. What do you consider the disadvantages of this site for your business?	6 7 8
3. Has there been any flooding in this area since you have been located here? (if no go to question 11)	9
4. Have these premises ever been flooded?	10
5. How many times have the premises been flooded?	11
6. What was the depth of water in 1968?	12
7. How long were the premises flooded in 1968?	13
8. Approximately how much did the 1968 flood cost you?	14
9. What action did you undertake during the 1968 flood?	15 16 17
10. Did you receive a warning of the flood in 1968?	18
(if so, how much warning?)	19
11. Are you insured against flooding:	20
When did you take out this insurance	21

12. How did you first find out about flooding in this area? 22

1. Real estate agents
2. Neighbouring firms
3. Personal inspection
4. Did not know until flooded
5. Radio or television
6. Surveyors
7. Other sources

13. Does this knowledge of the flood risk worry you? 23

14. Did the business know of the flood problem when locating here? 24

15. Based on what you know now would the firm still locate here - given the same choice? 25

16. Would the firm leave this area if flooding became more serious? 26

17. Is any part of the premises modified or designed to keep out flood waters? 27

18. Do you think these premises will be flooded in the next twenty-five years? 28

19. Do you think the risk from flooding in Carlisle/ Appleby is: 29

1. Increasing
2. Decreasing
3. No change
4. Do not know

Reasons for a perceived decrease in the risk 30 31

1. Changes in climate
2. Motorway construction
3. Town building
4. Cleaning rivers
5. Building river banks and walls.
6. Reservoir management
7. Other

20. Do you think enough has been done to protect you? 32

(In Appleby has anything been done to protect you?)

21. Are public flood warnings given in this area? 33

If so are these warnings reliable? 34

22. If you were given six hours warning of a flood what would you do? 35 36

1. Do nothing
2. Keep watch on the rivers
3. Consult others for a second opinion
4. Employ temporary measures such as sandbags.
5. Remove valuables to a higher level
6. Other

Do you have any set procedure to follow in the event of an emergency? 37

23. What is the most reliable source of information on flooding in Carlisle/Appleby. 38

1. Council
2. Police
3. Local radio, television
4. River Authority
5. Own judgement
6. Other

---

24. What type of business is this? 39

(Classify into - i) Manufacturing and construction
ii) Wholesale
iii) Retail
iv) Service

25. How long has the business been located here? 40

26. How long have you been employed by the business at this site? 41

27. What is your position with the business? 42

28. How many people does the business employ at this site? 43

29. Does the firm conduct business at any other site? 44

---

30. The following are opinion type questions for which there is no right or wrong answer. Please state whether you:

1. Strongly favour
2. favour somewhat
3. object somewhat
4. Strongly object
5. Do not know

What is your opinion on:

(a) Building upstream surface reservoirs which could be used to retain excess water when flooding threatened? 45

(b) Construction of more and larger embankments along the rivers? 46

(c) Deepen and widen the rivers through Carlisle/ Appleby? 47

(d) Preserve everything as it is and leave the rivers alone? 48

(e) To pay for flood protection everyone should pay more taxes - the Local Authority should be responsible? 49

(f) To pay for flood protection - those at risk should pay? 50

(g) The government should pay a grant or loan to those industries at risk to protect themselves? 51

(h) The government should give financial support for the relocation of industries in flood prone areas? 52

---

31. Finally could you estimate the cost of damage from:

1. 6 inches of water in this building with no warning? 53

2. 6 inches of water in this building with six hours warning? 54

3. 4 feet of water in this building with no warning? 55

4. 4 feet of water in this building with six hours warning? 56

APPENDIX III

Sites of reported flooding in Cumbria since 1809. Most of these have experienced more than one flood, and the majority were flooded in 1968.

(1) The River Eden Catchment Area:

RIVER EDEN:

Rockcliffe	Corby Castle
Kirkandrews	Armathwaite
Grinsdale	Lazonby
Carlisle	Great Salkeld
Rickerby	Langwathby
Linstock	Eden Hall
Park Broom	Temple Sowerby
Crosby	Bolton
Newby East	Appleby
Warwick Holme	Warcop
Eden Holme	Musgrave
Warwick Bridge	Beckfoot
Warwick Hall	Kirkby Stephen
Wetheral	

RIVER IRTHING:

Eden Holme	Gisland
Green Holme	
Rule Holme Bridge	Brampton
Lannercost Priory	Aglionby

RIVER GELT:

Talkin

RAVENSBECK:

Kirkoswald

MILBURN BECK:

Milburn

TROUT BECK:

Kirkby Thore	Long Marton

RIVER CALDEW:

Dalston	Hesket-New-Market
Hawksdale Bridge	Millhouse
Sebergham	Haltcliffe Bridge

CALDBECK:

Caldbeck

RIVER PETTERIL:

Carleton	Laithes
Plumpton Walls	Little Blencow
Plumpton Head	Greystoke
Newton Reigny	Penrith

RIVER EAMONT:

Udford	Pooley Bridge
Carleton	Howtown
Brougham Castle Mill	Waternook
Eamont Bridge	Grisedale Bridge
Kirkbarrow	Patterdale

RIVER LOWTHER:

Bampton

RIVER LYVENNETT:

Moreland | Maulds Meaburn

RIVER LEITH:

Cliburn | Shap

Thrimby Grange

HOFF BECK:

Hoff | Draybeck

SWINDAL BECK:

Church Brough | Spurrig End Farm

Brough

(2) The Wampool Drainage Area:

RIVER WAMPOOL:

Kirkbride | Gamblesby

RIVER WIZA:

Wigton | Red Dial

RIVER WAVER:

Lessonhall | Abbeytown

CROOKHURST BECK:

Allonby

RIVER ELLEN:

Maryport | Blennerhasset

Aspatria | Bothel

Silloth

(3) The Derwent-Cocker Catchment Area:

RIVER DERWENT:

Workington	Grange
Cammerton	Borrowdale
Broughton	Seatoller
Cockermouth	Mountain View
Isel Village	Seathwaite
Portinscale	

DASH BECK:

Bassenthwaite

RIVER GRETA:

Keswick	Briery
Crosthwaite	Threkeld

ST. JOHNS BECK:

Thirlemere

STONETHWAITE BECK:

Rosthwaite	Stonethwaite

RIVER MARRON:

Dearham	Low Lorton

RIVER COCKER:

Scalehill	Loweswater
Kirkhead	Crabtree

NEWLANDS BECK:

Newlands	Powbeck

COLEDALE BECK:

Braithwaite

(4) The Ehen Catchment Area:

RIVER EHEN:

Braystones Cleator

Egremont

RIVER CALDER:

Calderbridge

COASTAL:

Workington

(5) The Duddon Catchment Area:

RIVER IRT:

Holmrook

RIVER ESK:

Beckfoot Boot

(6) The Leven Catchment Area:

RIVER CRAKE:

Lowick Bridge

RIVER LEVEN:

Newby Bridge Windemere

TROUTBECK:

Troutbeck Bridge

RIVER ROTHAY:

Ambleside Grasmere

RIVER BRATHAY:

Clappersgate

Elterwater

Great Langdale farms

RIVER YEWDALE:

Coniston

(7) The Kent Catchment Area:

RIVER KENT:

Kendal

Burneside

Laithwaite

Stavely

Kentmere

APPENDIX IV

Theoretical calculations of the flood problems at Carlisle and Appleby.

This method was proposed by the Flood Studies Report using data from various maps. The technique was applicable primarily to catchments of less than 500 km^2, and to events of less than twice the mean annual flood. Thus, caution should be given to the Carlisle results and the greater return periods calculated at the end of this appendix. Nevertheless, this technique illustrated the value of such computations in ungauged catchments. This method was applied to catchments based on Appleby and Carlisle.

1. Stream frequency (STMFRQ)

The number of natural stream junctions was counted upstream on the 1:25,000 map including the starting point as a junction. Junctions which did not appear on the map, such as those in urban areas and lakes, were also included.

	Appleby	Carlisle
Number of Junctions	843	3665
Area of catchment (km^2)	338.5	2285.25
STMFRQ / Area (junctions/km^2)	2.49	1.6038

These figures compared to estimates of various areas in the Flood Studies Report (Volume 1,302) of between 2 and 4 in the Appleby area and 1 and 2 in Carlisle.

2. Stream Length (L)

This measurement was taken on the main channel (defined as the longest stream) using dividers set at 4 mm (0.1 km).

	Appleby	Carlisle
Number of steps	407	1128
Length of channel (km)	40.7	112.8

3. Slope (SLOPE)

The points 10% and 85% along the main channel were marked off and the height above sea level interpolated. The slope factor was then equal to

$$\frac{\text{difference in height}}{\text{Number of steps in stream length}} \times 4.064$$

(the latter figure represents a conversion factor).

	Appleby	Carlisle
Height 85% (feet)	1020	665
Height 10% (feet)	430	51
Difference (feet)	590	614
SLOPE (m/km)	5.89	2.2121

These figures were also comparable to other estimates (Volume 1,299)

4. Areas draining through lakes and built up areas

Only lakes greater than 1% of the catchment area were included. The areas draining through each lake were summed then divided by the total catchment area. 1:250,000 scale maps were used for this. Urban areas were calculated from the grey areas on the 1:63360 scale maps, and the total divided by the catchment area.

	Appleby	Carlisle
Urban factor	0	0.0079
Lake factor	0	0.0718

5. Soil Index (SOIL)

The flood studies report identified five classes of soil with differing runoff potentials. The areas for each class were determined from the soil map (Volume V, figure 1.4.18) and the 1:625,000 scale map of the catchments. (The areas were obtained by counting the squares on 1/10 th inch graph paper). The areas were multiplied by a constant for the particular soil type, and the total divided by the number of squares to give the soil index.

Appleby

Soil type	Number of squares	constant	total
1	56	0.15	8.4
2	0	0.30	0
3	0	0.40	0
4	17	0.45	7.65
5	54	0.50	27.0
unclassified			
	127		43.05

$$\text{Soil Index} = \frac{43.05}{127} = 0.339$$

Carlisle

Soil type	Number of squares	constant	total
1	286	0.15	42.9
2	2	0.30	0.6
3	28	0.40	11.2
4	224	0.45	100.8
5	369	0.50	184.5
	909		340

$$\text{Soil Index} = \frac{340}{909} = 0.374$$

6. Standard Average Annual Rainfall (SAAR)

The SAAR was obtained by grid sampling the rainfall map (Volume V, figure 11.3.1) and calculating the arithmetic mean.

Appleby	1188 mm
Carlisle	1221.15 mm

7. Rainfall minus the Soil Moisture Deficit (RSMD)

This calculation was based on different rainfall events with a five year return period (M5) and the effective soil moisture deficit. In all cases, catchment average values were taken as in 6.

To calculate RSMD:

(i) Compute ratio 'r' between M5-60 min and M5-2 day rainfall (Volume V, figure 11.3.5)

(ii) Estimate M5-24 hour/M5-2 day ratio in terms of (i) from table 11.3.10 (Volume II, 32).

(iii) Calculate M5-2day rainfall (Volume V, figure 11.3.2).

(iv) Calculate M5-24 hour rainfall by multiplying (ii) and (iii).

(v) Convert M5-24 hour rainfall to M5-1 day by dividing by 1.11 (figure obtained from table 11.3.1., Volume II, 21).

(vi) Obtain the areal reduction factor (ARF) (Volume II, figure 11.5.1).

(vii) Calçulate soil moisture deficit from map (Volume V, figure 1.4.19).

(viii) Multiply M5-1 day by ARF and subtract SMD from the total to obtain RSMD.

$$RSMD = M5\text{-}1 \text{ day} \times ARF - SMD$$

		Appleby	Carlisle
(i)	M5-60 min/M5-2 day	27.14	26.82
(ii)	M5-24 hour/M5-2 day	83%	83%
(iii)	M5-2 day (mm)	70.68	67.49
(iv)	M5-24 hour (mm)	58.66	56.01
(v)	M5-1 day (mm)	52.85	50.46
(vi)	ARF	0.925	0.875
(vii)	SMD (mm)	4.0	3.137
(viii)	RSMD (mm)	44.89	41.02

8. Calculation of the mean annual flood (Q)from catchment characteristics

$$Q = AREA^{0.94}\ STMFRQ^{0.27}\ SOIL^{1.23}\ RSMD^{1.03}\ (LAKE + 1)^{-0.85}$$
$$SLOPE^{0.16}\ (Region\ Constant).$$

This formula was obtained from Beran (1975).

Appleby

	Value	log	Constant	Total
AREA	338.5	2.5296	0.94	2.3778
STMFRQ	2.49	0.3962	0.27	0.1070
SOIL	0.339	-0.4698	1.23	-0.5779
RSMD	44.89	1.6522	1.03	1.7018
LAKE + 1				
SLOPE	5.89	0.7701	0.16	0.1232
Region Constant	0.0213	-1.6716	1.0	-1.6716
				2.0603

Mean annual flood = 114.9 m^3/s

Carlisle

	Value	log	Constant	Total
AREA	2285.25	3.3589	0.94	3.1574
STMFRQ	1.6038	0.2051	0.27	0.0554
SOIL	0.374	-0.4271	1.23	-0.5253
RSMD	41.0185	1.6130	1.03	1.6614
LAKE + 1	1.0718	0.0302	-0.85	-0.0257
SLOPE	2.2121	0.3448	0.16	0.0552
Region Constant	0.0213	-1.6716	1.0	-1.6716
				2.7068

Mean annual flood = 509.1 m^3/sec

9. Return Periods

Further constants were derived to calculate the peak discharge of floods of different return periods (Beran, 1975). However, the error was shown to increase significantly with the less frequent events (Flood Studies Report, 1975, Volume 1 456). This was clear from the Carlisle data where the estimate flows for the 100 year flood were still less than the calculated flows for the 1968 event (chapter five).

Constant for hydrometric area 76	Return Period (years)	Appleby m^3/s	Carlisle m^3/s
0.93	2	106.9	437.5
1.19	5	136.7	605.8
1.38	10	158.6	702.6
1.64	25	188.4	834.9
1.85	50	212.6	941.8
2.08	100	239.0	1058.9

APPENDIX V

CUMBERLAND RIVER AUTHORITY EDEN FLOOD WARNING SCHEME

OPERATIONAL SEQUENCE

1. Warning received from Meteorological Office, Preston of possible heavy rain expected over the Eden catchment area.
2. Warning by telephone received from Automatic Interrogation/ Warning rain gauges situated at (a) Castlethwaite (Kirkby Stephen), (b) Barras old Railway Station, (c) Scalebeck Farm (Great Asby), when a pre-determined quantity has fallen.
3. Rain gauges interrogated at regular intervals to track progress and intensity of storm.
4. River level alarm raising equipment, situated in the gauging station at Kirkby Stephen, will give first and second warnings. These levels have been based on information given by the police and conform to the visual levels at which they have notified Appleby in the past. This equipment telephones automatically to the C.R.A. or, out of office hours, to Police Control at Penrith.
5. River level interrogation and alarm raising facilities have been installed at Appleby which enables continuous monitoring of the river level at Appleby. The alarm facility is a safety measure and will provide advance information of possible downstream flooding.
6. Similar equipment to (5) is installed at Armathwaite to provide additional warning/data for Carlisle. This station records the combined flow from the Eden, Eamont and the major Pennine tributaries, and provides a good indication of the magnitude of flooding to be expected in Carlisle City.

7. River level interrogation only equipment is installed at Warwick Bridge, on the Eden, Greenholme on the Irthing and Holm Hill (Dalston) on the Caldew. This enables monitoring of the flow into Carlisle.

Operation of a proposed flood warning scheme for Appleby

1. Obtain rainfall readings on an hourly basis from the commencement of the event.
2. Calculate the weighted mean hourly total for the catchment using the data from (1).
3. Calculate the 'residual quantity' for each hour and update this figure as each batch of hourly readings is received.
4. When the 'residual quantity' reaches a specified threshold value, it would give a reasonable indication of possible flooding with a warning time of two to three hours.

REFERENCES

AHUJA, P.R. (1960): Flood warning in India. In Transactions of the inter-regional seminar on hydrologic networks and methods held at Bangkok, Thailand, July 1959, Bangkok: World Meteorological Organisation.

AITKEN, A.P. (1973): Assessing systematic errors in rainfall-runoff models. Journal of Hydrology 20, 121-136.

ALBERTSON, M.L., TUCKER, and D.C. TAYLOR, editors (1971): Treatise on urban water systems. Fort Collins : Colorado State University.

AMEY, G. (1974): The collapse of Dale Dyke Dam, 1864. London: Cassel.

APOLLOV, B.A., G.P. KALININ and V.D. KOMAROV (1964): Hydrological forecasting. Israel programme for scientific translations. Jerusalem.

ATKINSON, J. (1967): A handbook for interviewers. Government Social Survey. London: Government Publications M136.

AUSTIN, G.L. and L.B. AUSTIN (1974): The use of radar in urban hydrology. Journal of Hydrology 22, 131-142

BAUMANN, N (1976): Adoption of the Federal flood insurance program in two Texas Communities. In Flood insurance and community planning. Natural Hazard Research working papers, 29. University of Chicago.

BENWELL, G.R.R. (1967): The jet stream at 500 mb as a predictor of heavy rain. The Meteorological Magazine 96, 4-10.

BERAN, M.A. (1975): Flood computations using the Flood Studies Report (1975). Edinburgh: Flood Studies Conference, unpublished.

BERAN, M.A. and J.V. SUTCLIFFE (1972): An index of flood-producing rainfall based on rainfall and soil moisture deficit, Journal of Hydrology 17, 229-236

BERDIE, D.R. and J.F. ANDERSON (1974): Questionnaires, design and use. Metuchen, N.J: The Scarecrow Press Inc.

BISWAS, A.K. (1970): History of hydrology. Amsterdam : North Holland Publishing Company.

BLALOCK, H.M. (1972): Social statistics. New York : McGraw-Hill

BLEASDALE, A. (1973) Meteorological contributions to operational hydrological forecasting in the United Kingdom. Meteorological Magazine 102, 298-308.

BODY, D.N. (1969): The acquisition of data for flood forecasting Proceedings of the W.M.O./U.N.E.S.C.O. symposium on Hydrological Forecasting, 1967. Technical paper 122 : World Meteorological Organisation 228.

BODY, D.N. and A.F. RAINBIRD (1964): Predicting flood flows from rainstorms. Water resources, use and management: proceedings of a symposium, Canberra, 1963. Melbourne University Press

BRITISH RAINFALL (1974): British Rainfall 1968, London : H.M.S.O.

BROOKES, C.E.P. and J. GLASSPOOLE (1928): British floods and droughts. London : Ernest Benn.

BURGESS, L.C.N. (1970): Airphoto interpretation as an aid in flood susceptibility determination. In Nelson, J.G. and M.J. Chambers, editors, Water. London : Methuen.

BURTON, I. (1961): Invasion and escape on the Little Calumet. In White, G.F., editor, Papers on flood problems, University of Chicago, Department of Geography, Research paper number 70. Chicago : University of Chicago Press.

BURTON, I. (1961,a): Some aspects of flood loss reduction in England and Wales. In White, G.F., editor, Papers on flood problems, University of Chicago, Department of Geography, Research Paper number 70. Chicago : University of Chicago Press.

BURTON, I. (1962): Types of agricultural occupance of flood plains in the United States. University of Chicago, Department of Geography, Research paper number 75. Chicago : University of Chicago Press.

BURTON, I. (1970): Flood damage reduction in Canada. In Nelson, J.G. and M.J. Chambers, editors, Water, London : Methuen.

BURTON, I. and R.W. KATES, editors (1960): Readings in resource management and conservation. University of Chicago Press.

BURTON, I. and R.W. KATES (1964): The flood plain and the sea shore. A comparative analysis of hazard-zone occupance. Geographical Review 54, 336-385.

BURTON, I. R.W. KATES and G.F, WHITE (1968): The human ecology of extreme geophysical events. Natural Hazard Research Working Paper 1. University of Chicago.

BUSSELL, R.B. and E.JACKSON (1968): Telemetry for river authorities. Journal of the Institution of Water Engineers 22, 196-201

BUTLER, R.M.J. (1972): Water as an unwanted commodity : some aspects of flood alleviation. Journal of the Institution of Water Engineers 26, 311-321.

BUTLER, R.M.J. (1972a): Runoff from urban development. Paper presented at the Cranfield Conference, 1972. unpublished.

BUTLER, R.M.J. (1972,b): Flood proofing. Paper presented at the Cranfield Conference 1972 : unpublished.

CAMPBELL, A.A. and G. KATONA (1965): The sample survey. A technique for social science research. In Festinger, L. and D. Katz, editors, Research methods in Behavioural Sciences, New York : Holt, Rhinehart and Winston.

CANNELL, C.F. and R.L. KAHN (1965): The collection of data by interview. In Festinger, L. and D. Katz, editors, Research methods in Behavioural Sciences, New York : Holt, Rhinehart and Winston.

CHAMBERS, D.N. (1975): Procedures for determining the design flood in engineering works. Proceedings of the Institute of Civil Engineers 58, 723-726

CHAMBERS, D.N. and K.G. ROGERS (1973): The economics of flood alleviation. Local Government Operational Research Unit, Report C.155, Government publications.

CHANCELLOR, F.B. (1954): Around Eden. An anthology of fact and legend from and around the Eden Valley Appleby : J. Whitehead and Sons.

CHORLEY, R.J. editor, (1969): Water, earth and man. London : Methuen.

CHORLEY, R.J. editor, (1973): Directions in geography. London : Methuen.

CLIFFORD, R.A. (1956): The Rio Grande flood: a comparative study of border communities in disaster. Disaster study 7, National Academy of Sciences - National Research Council, publication 458. Washington.

COCHRAN, W.G., F. MOSTELLER and J.W. TUKEY (1970): Principles of sampling. In Forcese, D.P. and S. Richer, editors, Stages of social research : contemporary perspectives, Englewood Cliffs: Prentice Hall.

CONWAY, F. (1967): Sampling, Minerva series of handbooks, Chapman, B. London : George Allen and Unwin.

COOKE, R.U. and J.C. DOORNKAMP (1974): Geomorphology in environmental management, an introduction, London : Oxford University Press.

CORDERY, I. (1970): Initial loss for flood estimation and forecasting. Proceedings of the American Society of Civil Engineers, Journal of the Division of Hydraulics 96, HY. 12, 2447-2466.

COSSINS, G. (1969): The operation of Somerset Dam - A multi-purpose project. Proceedings of the W.M.O./U.N.E.S.C.O. Symposium on Hydrological Forecasting, 1967. Technical paper 122 W.M.O. 228

COX, R. (1976): Acts of God...and men. Daily Telegraph Magazine 595 (May) 9-31.

CRAWFORD, N.H. (1969): Analysis of watershed changes. In Moore, J.A. and C.W. Morgan, editors, Effects of watershed changes on streamflow, University of Texas Press.

DATAR, S.V. and P. MOHAMMED (1969): Automatic instrumentation for telemetering rain and river-level data remote stations. Proceedings of the W.M.O./U.N.E.S.C.O. Symposium on Hydrological Forecasting, 1967. Technical paper 122, W.M.O. 228

DAVIDSON, P. and R.A. HARGREAVES (1966): River flood warning systems. In Thorn, R.B., River engineering and water conservation works, London Butterworths.

DAY, H.J. G. BUGLIARELLO, P.H.P. HO, and V.T. HOUGHTON (1969): Evaluation of benefits of a flood warning system. Water Resources Research 5, 937-946.

DEE WEATHER RADAR REPORT (1974): The use of a radar network for the measurement and quantitative forecasting of precipitation. Report by the Operations System Group: Water Resources Board, Meteorological Office and Plessey Radar Ltd., Reading : Water Resources Board.

DOUBLET, A.R. (1966): Storm, tempest and flood. Journal of the Chartered Insurance Institute 63, 17-30.

DOUGHERTY, I.N. (1969): Flood warnings - the role of the New South Wales Civil Defence Organisation. Proceedings of the W.M.O./U.N.E.S.C.O. Symposium on Hydrological Forecasting. Technical paper 122, W.M.O. 228.

DWORKIN, J. (1974): Global trends in natural disasters 1947-1973. Natural Hazard Research, Working paper 26. University of Chicago.

ECKSTEIN, O. (1958): Water resource development. The economics of project evaluation. Harvard University Press.

EMMER, R. (1976): The problems and issues of implementing the National Flood Insurance Act in Oregon. In Flood insurance and community planning. Natural Hazard Research, Working paper 29. University of Chicago.

ERICKSEN, N.J. (1967): Changing land use as an alternative measure for reducing flood losses. New Zealand Geographical Society : Record 44, 12-13

ERICKSEN, N.J. (1971): Human adjustments to floods in New Zealand New Zealand Geographer 27, 105-129.

ESPEY, W.H., D.E. WINSLOW and C.W. MORGAN (1969): Urban effects on the unit hydrograph. In Moore, M.A., and C.W. Morgan, editors, Effects of watershed changes on streamflow, University of Texas Press.

ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION (1968): Science and engineering 1965-1967 (U.S. Department of Commerce).

ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION (1970): Science and engineering 1967-1969. (U.S. Department of Commerce).

EZEKIEL, M. and K.A. FOX (1963): Methods of correlation and regression analysis, New York : John Wiley and Sons.

FARHAR, B.C. (1974): The impact of Rapid City flood on public opinion about weather modification, Institute of Behavioural Science, University of Colorado.

FERGUSON, R.S. (1894): History of Westmorland., London : Elliot-Stock.

FESTINGER, L. and D. KATZ, editors (1965): Research methods in the behavioural sciences, New York : Holt, Rinehart and Winston.

FIELD, P.J. (1974): Flood warning instrumentation and operation, Paper presented at a Meeting of the Scottish Hydrological Group, Edinburgh, unpublished.

FISHER, R.A. (1970): Statistical methods for research workers, Edinburgh : Oliver and Boyd.

FLEMING, G. (1973): Flood frequency and the effects of catchment changes. Water and Water Engineering. 77 127-131.

FLOOD STUDIES REPORT (1975): Five volumes, Natural Environment Research Council.

FORCESE, D.P. and S. RICHER, editors, (1970): Stages of social research, contemporary perspectives, Englewood Cliffs : Prentice Hall.

FRITZ, C.E. and J.H, MATTHEWSON (1957): Convergence behaviour in disasters. A problem of social control. Disaster study 9, National Academy of Sciences - National Research Council, publication 476. Washington.

GARRET , W. (1818): An account of the great floods in the Rivers Tyne, Tees, Wear, Eden etc. in 1771 and 1815, Newcastle : Emerson Charnley.

GATELY, J.E. (1973): The idea of a flood. Middlesex Polytechnic Flood Hazard Research Project, special publication 1.

GIBSON, T. (1877): Legends and historical notes on places in the East and West Wards, Westmorland, Manchester : Heywood.

GODDARD, J.E. (1971): Flood plain management must be ecologically and economically sound. Civil Engineering - special issue Environment for man and nature American Society of Civil Engineers, 81-85.

GOODHEW, R.C. (1970): Weather is my business. Weather 25, 33-39.

GORDON, J. (1861): Carlisle sewerage reports 1850-1880

GREBENIK, E. and C.A. MOSER (1970): Statistical surveys. In Forcese, D.P. and S. Richer, editors, Stages of social research, contemporary persepctives, Englewood Cliffs : Prentice Hall.

HAAS, J.E. (1970): Response to planned weather modification : implications for urban resource management Paper presented at Western Resources Conference, University of Denver, July 1970.

HAMMERTON, M (1975): Statistics for the human sciences, New York : Longman

HANKE, S.H. (1972): Flood losses will they ever stop. Journal of soil and water science 27, 242-243.

HARDING, D.M. (1974): Public relations and water resource management Informal discussion of the Hydrological Group, Institution of Civil Engineers. Review by P.A. Smith of Harding and Lillicrap (1973).

HARDING, D.M. and R.J. LILLICRAP (1973): Public relations and water resource management. Informal discussion of the Hydrological Group, Institution Civil Engineers.

HARDING, D.M. and D.J. PARKER (1972): A study of the flood hazard in Shrewsbury, Shropshire, United Kingdom International Geographic Union, 22nd International Geographical Congress, Commission on Man and Environment.

HARDING, D.M. and D.J. PARKER (1975): Flood loss reduction : a case study. Preprint. Published in Water Service (1976) 80, 24-28.

HARROLD, T.W., E.J. ENGLISH, and C.A. NICHOLASS (1973): The Dee weather radar project : the measurement of area precipitation using radar. Weather 28, 332-338.

HAVEMAN, R.H. (1965): Water resource investment and the public interest. Vanderbilt University Press.

HEMPSELL, M.S. (1962): The assessment of flood risk in the United Kingdom. Journal of Chartered Insurance Institution 59, 115-137.

HERTZLER R.A. (1961): Corps of engineers : experience relating to flood plain regulation. In White, G.F. editor, Papers on flood problems, University of Chicago, research paper 70, Chicago University Press.

HINDLEY, D.R. (1968): The development of the telemetry rain-gauge. Journal of the Institution of Water Engineers 22, 201-204.

HOLDGATE, M.W. (1956): A history of Appleby. Appleby : J. Whitehead and Sons.

HOLGATE, H.T.D. (1973): Rainfall forecasting for River Authorities. Meteorological Magazine 102, 33-48

HOLLIS, G.E. (1974): The effect of urbanisation on floods in Canon's Brook, Harlow, Essex. In Gregory, K.J. and D.E. Walling, Fluvial processes in instrumented watersheds, Institute of British Geographers special publication 6. Alden Press.

HOLMES, R.C. (1961): Composition and size of flood losses. In White, G.F., editor, Papers on flood problems, University of Chicago, research paper 70, Chicago University Press.

HOME OFFICE. (1972): Home Office Circular No. 1, Government publications. H.M.S.O.

HORNER, W.W. (1955): The Hoover Commission on Organisation of the Executive Branch of the Government. Report by Task Force on Water Resources and Power, volume 2, Washington.

HOWE, G.M., H.O. SLAYMAKER and D.M. HARDING (1967): Some aspects of flood hydrology of the upper catchments of the Severn and Wye. Transactions of the Institute of British Geographers 41, 33-58.

HOYT, W.G, and W.B. LANGBEIN (1955): Floods, Princeton : Princeton University Press.

HUDLESTON, F. (1935): The floods of the Lake District. Printed for private circulation by the River Derwent Catchment Board, unpublished.

HUTCHINSON, W. (1974): The history of the County of Cumberland, Volumes I and II. Copy of the 1794 and 1797 editions by E.P. Publishing.

INSTITUTION OF CIVIL ENGINEERS (1966): River flood hydrology. Proceedings of the Symposium March 1965, London.

INTERNATIONAL SYMPOSIUM (1973): International symposium on river mechanics, Proceedings of the International Association for Hydraulic Research, Volume 2 January 1973, Asian Institute of Technology, Bangkok, Thailand.

JAMES, L.D. (1967): Economic analysis of alternative flood control measures. Water Resources Research 3, 333-343.

JAMES, L.D. (1973): Surveys required to design non-structural measures. Proceedings of the American Society of Civil Engineers, Journal of the Hydraulics Division 99, 1823-1836

JAMES, L.D. (1974): The use of questionnaires in collecting information for urban flood control and planning. Environmental Resources Center 0274, Georgia Institute of Technology. Atlanta

JAMES, L.D., E.A. LAURENT and D.W. HILL (1971): The flood plain as a residential choice, resident attitudes and perceptions and their implications to flood plain management policy. Georgia Institute of Technology. Atlanta.

JAMES, L.D. and R.R. LEE (1971): Economics of water resource planning, New York : McGraw-Hill.

JAMIESON, D.G. (1972): River Dee research programme 1. Operating multipurpose reservoir systems for water supply and flood alleviation. Water Resources Research 8, 899-903

JEEPS, M.D (1971): Essex River Authority : Notes on fresh water flood warning system. Paper presented at Cranfield Conference 1971, unpublished.

JOHNSON, P. (1975): Snowmelt. Paper presented at the Conference on the Flood Studies Report, London : Institution of Civil Engineers.

JOHNSON, P. and D.R. ARCHER (1972): Current research in British snowmelt river flooding. Bulletin of the International Association of Hydrological Sciences 17, 443-451.

JONES, D.E. (1971,a): Urban water resources management affects the total urban picture. In Albertson, M.L., L.S. Tucker and D.C. Taylor, editors, Treatise on urban water systems, Fort Collins : Colorado State University.

JONES, D.E. (1971,b): Some urban resources management dimensions. Research Conference, Urban water resources management. American Society of Civil Engineers and Urban Water Resources Research Council.

KADOYA, M. (1973): Predictive study on urbanizing effect of drainage on flood runoff. In Schulz, E.F., V.A. Koelzer, and K. Mahmood, editors, Floods and droughts. Proceedings of the Second International Symposium in Hydrology 1972, Fort Collins, Colorado. Water Resources Publications.

KATES, R.W. (1962): Hazard choice and perception in flood plain management. University of Chicago, Department of Geography, research paper 78. University of Chicago Press.

KATES, R.W. (1970): Natural hazard in human ecological perspective : hypotheses and models. Natural Hazard Research, working paper 14, University of Chicago.

KATES, R.W. and G.F. WHITE (1961): Flood hazard evaluation. In White, G.F. editor, Papers on flood problems. University of Chicago, Department of Geography research paper 70. University of Chicago Press.

KAWABATA, Y. (1960): Meteorological services in Japan for flood warning and control. In Hydrological Networks and Methods, Flood Control Series 15. Bangkok : World Meteorological Organisation.

KAZMANN, R.G. (1972): *Modern hydrology*, New York : Harper and Row Publishers.

KELWAY, P.S. and C. WARNER (1973): *Rainfall analysis and radar prediction*. Informal discussion of the Hydrological Group. Institution of Civil Engineers.

KISH, L. (1965): Selection of sample. In Festinger, L. and D. Katz, editors, *Research methods in the behavioural sciences*, New York : Holt, Rinehart and Winston

KLARMAN, H.E. (1965): Syphilis control programmes. In Dorfman, R., editor, *Measuring benefits of Government investments*, Washington : Brookings Institution.

KNEESE, A.V. and S.C. SMITH, editors (1965): *Water research*, Baltimore : John Hopkins Press.

KOHLER, M.A. (1969): Keynote address. *Proceedings of the W.M.O./U.N.E.S.C.O. Symposium on Hydrological Forecasting*, technical paper 122, World Meteorological Organisation 228.

KOLLMORGEN, W.M. (1953): Settlement control beats flood control. *Economic Geography* 29 208-215.

KRUTILLA, J.V. (1966): An economic approach to coping with flood damage. *Water Resources Research* 2, 183-190.

KUIPER, E. (1971): *Water resources - project economics*, London : Butterworths.

KUNREUTHER, H. and J.R. SHEAFFER (1970): An economically meaningful and workable system for calculating flood insurance rates. *Water Resources Research* 6, 659-667.

LOCAL AUTHORITIES MANAGEMENT SERVICES AND COMPUTER COMMITTEE (1972): (LAMSACC) *Computer installations in Local Government and River Authorities*. Report of the computer panel, London.

LAURENSON, E.M. (1973): Effects of dams on flood frequency. Proceedings of the International Association for Hydraulic Research - International Symposium on river mechanics. Asian Institute of Technology, Bangkok, Thailand.

LAW, F. (1957): The effect of afforestation upon the yield of water by catchment areas. Journal of the Instutution of Water Engineers 11, 269-276.

LAYARD, R. editor, (1972): Cost-benefit analysis : selected readings. (Introduction 9-70) Harmondsworth, Penguin.

LEOPOLD, L.B. and T. MADDOCK (1954): The Flood control controversy, New York : Ronald Press Company.

LIEBMAN, E. (1973): Legal problems in regulating flood hazard areas. Proceedings of the American Society of Civil Engineers, Journal of the Division of Hydraulics 99, 2113-2123.

LIND, R.C. (1967): Flood control alternatives and the economics of flood protection. Water Resources Research 3, 345-357.

LINDSAY, D. (1975): Flood warning by computers. Water 2, 11-14.

LLOYD, J.G. (1968): River Authorities and their work. Journal of the Institution of Water Engineers 22, 343-383.

LLOYD, J.G. (1971) Development of the Mersey and Weaver River Authority's flood prediction and warning system. Paper presented at the Cranfield Conference 1971, unpublished.

LOUGHLIN, J.C. (1971): A flood insurance model for sharing the costs of flood protection. Water Resources Research 7, 236-244.

LOWNDES, C.A.S. (1968): Forecasting large 24 hour rainfall totals in the Dee and Clwyd River Authority area from September and February. Meteorological Magazine 97, 226-235.

LOWNDES, C.A.S. (1969): Forecasting large 24 hour rainfall totals in the Dee and Clwyd River Authority area from March to September. Meteorological Magazine 98, 325-340

MANIAK, U. (1973): Model for calculating floods in urbanised watersheds. In Schulz, E.F., V.A. Koelzer, and K. Mahmood, editors, Floods and droughts Proceedings of the Second International Symposium in Hydrology 1972, Fort Collins Colorado : Water Resources Publications.

MANNERS, I.R. and M.W. MIKESELL, editors, (1974): Perspectives on environment. Association of American Geographers : Publication 13.

MATSON, H.O., W.L. HEARD, G.E. LAMP, D.M. ILCH (1955): The possibilities of land treatment in flood prevention. In United States Department of Agriculture, Water, the year book of agriculture. Washington : USDA.

MATTHEWS, R.P. (1972): Variations of precipitation intensity with synoptic type over the Midlands. Weather 27, 63-72.

McDONALD, A.T. (1972): The flood problem in relation to agriculture in the Lower Nith Valley, Dumfriesshire. Institution of Civil Engineers, Scottish Hydrological Group. Report.

McINTIRE, W.T. (-): Guide to Carlisle and neighbourhood, Carlisle : Chas. Thurman and Sons.

MIDDLESEX POLYTECHNIC (various): Flood studies. Papers on flood problems.

MILETI, D.S. and S. KRANE (1973): Countdown : response to the unlikely. Warning and response to impending system stress. Paper presented at the Annual Meeting of the American Sociological Association, August 1973, New York.

MILLWARD, R. and A. ROBINSON (1972): Cumbria, London : Macmillan.

MINISTRY OF HOUSING AND LOCAL GOVERNMENT (1962): 2nd Circular, London : H.M.S.O.

MINISTRY OF HOUSING AND LOCAL GOVERNMENT (1964): North Lancashire rivers : hydrological survey, London : H.M.S.O.

MINISTRY OF HOUSING AND LOCAL GOVERNMENT (1966): Cumbrian rivers : hydrological survey, London : H.M.S.O.

MINISTRY OF HOUSING AND LOCAL GOVERNMENT (1969): Natural emergencies : Circular 69/76, London : H.M.S.O.

MINISTRY OF HOUSING AND LOCAL GOVERNMENT (1969): Circular 69/94, London : H.M.S.O.

MINISTRY OF TOWN AND COUNTRY PLANNING (1947): 1st Circular, London : H.M.S.O.

MITCHELL, J.K. (1974): Natural hazards research. In Manners, I.R. and M.W. Mikesell, Perspectives on environment, Association of American Geographers, Publication 13.

MOLCHANOV, A.A. (1960/3): The hydrological role of forests. Academy of Science of U.S.S.R., Institute of Forestry, Moscow. Translated by A. Gourevitch, 1963.

MONTHLY WEATHER REPORTS (1970-1973) London H.M.S.O.

MOORE, J.A. (1968): Planning for flood damage prevention. Georgia Institute of Technology, Special Report 35.

MOORE, J.A. and C.W. MORGAN, editors, (1969): Effects of watershed changes on streamflow, University of Texas Press.

MORGAN, H.D. (1965): Estimation of design floods in Scotland and Wales. Proceedings of the symposium, River flood hydrology. Institution of Civil Engineers, London.

MORGAN, M.A. (1969): Overland and flow and man. In Chorley, R.J., Water, earth and man, London : Methuen.

MOSER, C.A. and G. KALTON (1971): Survey methods in social investigation. London : Heinemann Educational Books.

MUSHKIN, S.J. (1962): Health as an investment. Journal of Political Economy 20, 129-157.

NAKANO, T. (1973): Natural hazards and field interview research. Japanese Progress in Climatology, Tokyo University of Education, Japan

NELSON, J.G. and M.J. CHAMBERS, editors, (1970): Water, London : Methuen.

NICHOLASS, C.A. and T.W. HARROLD (1975): The distribution of rainfall over subcatchments of the River Dee as a function of synoptic type. Meteorological Magazine 104, 208-217.

NIXON, M. (1966): Flood regulation and river training. In Thorn, R.B., editor, River engineering and water conservation works, London : Butterworths.

O'RIORDAN, T. (1971): Perspectives on resource management, London : Pion.

O'RIORDAN, T. and R.J. MORE (1969): Choice in water use. In Chorley, R.J., editor, Water, earth and man, London : Methuen.

PAINTER, R.B. (1973): The potential application of satellites in river regulation. Water and Water Engineering 77, 487-490.

PARKER, D.J. (1976): Socio-economic aspects of flood plain occupance. University of Swansea, Ph.D. Thesis, unpublished.

PARKER, D.J. and E. PENNING-ROWSELL (1972): Problems and methods of flood damage assessment. Flood hazard research project, Progress report 3, Middlesex Polytechnic

PARTEN, M. (1950): Surveys, polls and samples : practical procedures, New York : Harper and Brothers

PEAK, H. (1965): Problems in objective observation. In Festinger, L. and D. Katz, editors Research methods in the behavioural sciences, New York : Holt Rinehart and Winston.

PENNING-ROWSELL, E. (1972): Flood hazard research project, Progress report 1. Middlesex Polytechnic.

PENNING-ROWSELL, E. and J.B. CHATTERTON (1976): Constraints on environmental planning : the example of flood alleviation. Area 8, 133-137.

PENNING-ROWSELL, E. and D.J. PARKER (1973): The control of flood plain development : a preliminary analysis. Flood hazard research project, Progress report 4, Middlesex Polytechnic.

PENNING-ROWSELL, E. and D.J. PARKER (1974): Improving flood plain development control. The Planner : Journal of Royal Town Planning Institute 60, 540-543

PENNING-ROWSELL, E. and L. UNDERWOOD (1972): Flood hazard and flood plain management : survey of existing studies. Flood hazard research project, Progress report 2, Middlesex Polytechnic.

PIERCE, B.T. (1970): The flood management project for Aitchson, Kansas. Proceedings of the Symposium : Interdisciplinary aspects of watershed management, Bozeman, Montana : American Society of Civil Engineers.

POPOV, I.V. and Y.S. GAVRIN (1970): Use of aerial photography in evaluating the flooding and emptying of river flood plains, and the development of flood plain currents. Soviet Hydrology : selected papers 5. English edition 1972, American Geophysical Union.

PORTER, E.A. (1970): The assessment of flood risk for land-use planning and property insurance. University of Cambridge, Ph.D. thesis, unpublished.

PREST, A.R. and R. TURVEY (1965): Cost-benefit analysis : a survey. Economic Journal 75, 683-735.

PRICE, R.K. (1975): Flood routing methods. Paper presented at the Conference on the Flood Studies Report, London : Institution of Civil Engineers.

RADLEY, J. and C. SIMMS (1971): Yorkshire flooding : some effects on man and nature, York : Ebor Press.

RAINBIRD, A.F. (1969): Some potential applications of meteorological satellites in flood forecasting. Proceedings of the W.M.O./U.N.E.S.C.O. Symposium on Hydrological Forecasting, Technical paper 122, W.M.O. 228.

RATCLIFFE, R.A.S. (1974): The use of the 500 mb anomalies in long-range forecasting. Quarterly Journal of the Royal Meteorological Society 100, 234-244.

RELPH, E.C. (1968): Methods of flood loss reduction - with reference to the Devon River Authority. University of London, M. Phil. thesis, unpublished.

RENSHAW, E.F. (1961): The relationship between flood losses and flood control benefits. In White, G.F. editor, Papers on flood problems, University of Chicago, Department of Geography, Research paper 70, University of Chicago Press.

RODDA, J.C. (1970): Controlling flood and drought. Geographical Magazine XLII, 112-115.

RODER, W. (1961): Attitudes and knowledge in the Topeka flood plain. In White, G.F. editor, Papers on flood problems, University of Chicago, Department of Geography, Research paper 70, University of Chicago Press.

ROSENBERG, M. (1970): Test factor standardisation as a method of interpretation. In Forcese, D.P. and S. Richer, editors, Stages of social research : contemporary perspectives, Englewood Cliffs : Prentice Hall.

RUSSELL, C.S. (1969): Losses from natural hazards. Natural Hazard Research, Working paper 10. University of Chicago

SAARINEN, T.F. (1974): Environmental perception. In Manners, I.R. and M.W. Mikesell, Perspectives on environment. Association of American Geographers : Publication 13.

SALTER, P.M. (1972): Areal analysis by computer. Paper presented at the Cranfield Conference 1972, unpublished.

SANDS, K.J.T. and D.G. WILKINSON (1974): The meteorological transmission system operating between Beaufort Park and Meteorological Headquarters. Meteorological Magazine 103, 74-81.

SCHULZ, E.F., V.A. KOELZER and K. MAHMOOD, editors, (1973): Floods and droughts. Proceedings of the second international Symposium in Hydrology, Fort Collins, Colorado, Water Resources Publications.

SERRA, L. (1969): Applications of discharge and water level forecasts. Proceedings of the W.M.O./U.N.E.S.C.O. Symposium on Hydrological Forecasting 1967, Technical paper 122, W.M.O. 228.

SEWELL, W.R.D. (1969): Human response to floods. In Chorley, R.J. editor, Water, earth and man, London : Methuen.

SEWELL, W.R.D. (-): Human aspects of weather modification and weather forecasting. Preprint of paper, unpublished.

SEWELL, W.R.D., J. DAVIS, A.D. SCOTT, D.W. ROSS (1962): A guide to benefit cost analysis. In Burton, I. and R.W. Kates, editors, Readings in resource management and conservation. University of Chicago Press.

SHEAFFER, J.R. (1967): Introduction to flood proofing. The Center for Urban Studies, University of Chicago.

SHEAFFER, J.R., D.W. ELLIS and A.M. SPIEKER (1970): Flood hazard mapping in Metropolitan Chicago: Geological Circular, Survey 601 C, Water in the urban environment. Washington : US Department of the Interior.

SIBBALD, W.I. (1970) Flood planning - an introduction to storm hydrology and the problems of flood plain development. Institution of Municipal Engineers 97, 22-26.

SIEGEL, S. (1956): Non parametric statistics for the behavioural sciences, New York : McGraw Hill.

SIMON, J.L. (1969): Basic research methods in social science. The art of empirical investigation, New York : Random House.

SIMPSON, W.D. (1950): The town and castle of Appleby : a morphological study. Transactions of the Cumberland and Westmorland Antiquarian and Archaeological Society 49, 118-133.

SKEAT, W.O. editor (1969): Manual of British water engineering, Volume II : engineering practice. Cambridge : Heffer and Sons.

SMAILES, A.E. (1968): North England, London : Nelson.

SMITH, H.F., W.D. ANDREWS, J.H. BROWN, R.E. CYPHERS, M.D. DOUGAL, C.K. OAKES, R.F. THOMAS and G.R. WILLIAMS (1969): Effect of urban development on flood discharges - current knowledge and future needs. Proceedings of the American Society for Civil Engineers, Journal of the Hydraulics Division 95, 287-309.

SMITH, Kenneth (1973): Carlisle - a pictorial study. Dalesman Books.

SMITH, Kenneth (1973,a): Cumbrian villages. London : Robert Hale.

SMITH, N. (1971): A history of dams, London : Peter Davies

SOCIAL AND COMMUNITY PLANNING RESEARCH (1972): Sample design and selection, technical manual 2, London.

STRANGEWAYS, I.C. and L. LISONI (1973): Long distance telemetering of data for flood forecasting. In Nature and resources, (Newsletter about scientific research on environment, resources and conservation of nature). IX, 18-21. U.N.E.S.C.O.

STRUYK, R.J. (1971): Flood risk and agricultural land values : a test. Water Resources Research 7, 789-797.

SURVEY RESEARCH CENTER (1966): Interviews manual. University of Michigan.

TAYLOR, B.C. (1974): The development of prototype system for the processing transmission and remote display of data from a weather radar. Malvern. Royal Radar Establishment.

TAYLOR, B.C. and K.A. BROWNING (1974): Towards an automated weather radar network. Weather 29, 202-216.

TAYLOR, J.A. editor (1972): Weather forecasting for agriculture and industry, Newton Abbot : David and Charles.

THEILER, D.F. (1969): Effects of flood protection on land-use in Coon Creek, Wisconsin, watershed. Water Resources Research 5, 1216-1222.

THOMPSON, G. (1966): The use of balancing reservoirs and flow regulating reservoirs in dealing with runoffs from urban areas. In Thorn, R.B., editor, River engineering and water conservation works, London : Butterworths

THORN, R.B. editor (1966): River engineering and water conservation works, London : Butterworths

TRAUTMAN, W.R. (1970): A case study of water supply and flood plain zoning. Proceedings of the Symposium on : Interdisciplinary aspects of watershed management, Bozeman Montana, American Society of Civil Engineers.

TROOP, R. (1976): Price of a river view : homes. Sunday Times 16th May 1976

UNITED STATES - DEPARTMENT OF AGRICULTURE (1955): Water : the yearbook of agriculture. Washington USDA

WALTERS, R.C.S. (1971): Dam geology London : Butterworth

WEATHERS, J.W. (1965): Comprehensive flood damage prevention. Proceedings of the American Society of Civil Engineers, Journal of the Hydraulics Division 91, 17-27.

WHELLAN, W. (1860): History and topography of Cumberland and Westmorland, W. Whellan and Company.

WHIPPLE, W. (1969): Optimizing investment in flood control and flood plain zoning. Water Resources Research 5, 761-766.

WHITAKER, R.J. (1974): Flood warning system. Bristol Avon River Authority paper, unpublished.

WHITE, G.F. editor, (1961): Papers on flood problems, University of Chicago, Department of Geography. Research paper 70, University of Chicago Press.

WHITE, G.F. (1964): Choice of adjustments to floods. University of Chicago, Department of Geography, Research paper 93, University of Chicago Press.

WHITE, G.F. (1965): Optimal flood damage management : retrospect and prospect. In Kneese, A.V. and S.C. Smith, editors, Water Research. Baltimore John Hopkins Press.

WHITE, G.F. chairman (1966): Federal flood control policy - Task Force. A unified national programme for managing flood losses, House Document 465, 89th Congress, 2nd Session, Washington.

WHITE, G.F. (1970): Recent developments in flood plain research. The Geographical Review 60, 440-443.

WHITE, G.F. (1973): Natural hazards research. In Chorley, R.J. editor, Directions in Geography. London: Methuen.

WHITEHEAD PAPERS: Record of local affairs maintained by one Appleby family 1850-todate, unpublished.

WILKES, D. (1973): Legal factors in econometric modeling of local flood plain management devices in the Connecticut River basin. Water Resources Research Center, publication 34, University of Massachusetts.

WOLMAN, M.G. (1971): Evaluating alternative techniques of flood plain mapping. Water Resources Research 7, 1383-1392.

WORLEY, D.P. and J.H. PATRIC (1971): Economic evaluation of some watershed management alternatives on forest land in West Virginia. Water Resources Research 7, 812-818.

YEVJEVICH, V. (1973): Analysis of risks and uncertainties in flood control. In Schulz, E.F., V.A. Koelzer, and K. Mahmood editors, Floods and droughts. Proceedings of the second international Symposium on Hydrology, Fort Collins, Colorado, Water Resources Publications.

River Authority records and papers

BRISTOL AVON RIVER AUTHORITY (1974): Details of radio based telemetry system-proposals, unpublished.

DEVON RIVER AUTHORITY (1974): Devon River Authority : flood warning scheme; general outline and situations, unpublished.

KENT RIVER AUTHORITY (1971): The Kent River Authority's river flood warning service. Paper presented at the Cranfield Conference 1971, unpublished.

LANCASHIRE RIVER AUTHORITY (1974): Lancashire River Authority : flood warning scheme : phase 1, unpublished.

THAMES WATER (1975): Thames Water : annual report and accounts 1974-75.

TRENT RIVER AUTHORITY (1969): Trent River Authority : annual report.

YORK RIVER AUTHORITY (1967): Don catchment area, unpublished.

Other Sources:

CENSUSES: Various reports between 1801 and 1971 for Cumberland and Westmorland, London. H.M.S.O.

CRANFIELD CONFERENCES: Ministry of Agriculture, Fisheries and Food: River Authority Engineers' Conference, Cranfield. Various annual conferences since 1961, especially 1968 to 1973.

Newspapers

APPLEBY OBSERVER
CARLISLE JOURNAL
CARLISLE PACQUET
CARLISLE PATRIOT
CUMBERLAND AND WESTMORLAND HERALD
CUMBERLAND NEWS
GUARDIAN
THE TIMES
WEST CUMBERLAND TIMES AND STAR