GEOGRAPHICAL PERSPECTIVES OF THE DROUGHT AND FLOOD HAZARD IN THE ARID AND SEMI-ARID REGION OF THE CAPE PROVINCE

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ABSTRACT

Droughts and floods in South Africa have been studied from various points of view but not from the perspective of how humans respond to their being a hazard to life and property. The research for this thesis was undertaken as a first step towards reducing this deficiency. The purpose has been to provide a broad perspective of these two hazards to serve as a base of information and understanding, and a context for further research, rather than to focus on specific problems in detail. It has been conducted within the general paradigm of hazard geography. Its main emphasis is to identify the full range of human adjustments and adaptations to the hazards of drought and flood in the local context, and it attempts to evaluate and find explanations for these responses.

Firstly the geographical patterns of drought and flood are examined. A method is devised for quantifying the flood hazard. Attention is also given to the role humans have played in increasing the level of hazard by their modification of relationships in the natural environment.

Personal interviews and structured questionaires delivered by mail were used to collect data mainly from farmers, urban dwellers, local and central government agencies and certain

private organizations. Contingency tables were employed to assist in the identification of relationships.

Responses are examined within the framework of six major types: affecting the cause, modifying the hazard, modifying the loss potential, spreading the losses, planning for losses, and bearing the losses.

An important finding is that farmers' responses, whether taken singly or in combination, prove to be ineffective in the provision of adequate protection for them against the adverse consequences of serious drought.

The explanation of response behaviour is found to be rooted in the perceptions that people and institutions have of these hazards, and in a variety of other factors including previous experience, attitudes towards nature and God, attachment to place, social and cultural constraints, personality, economic and political factors, environmental fit and technical feasibility.

INTRODUCTION

Throughout the history of South Africa recurrent droughts have been the cause of hardship and loss. To those living off the land, whether by agriculture or pastoral farming or a combination of both, reduction in the availability of water below the critical levels required for their economic pursuits, has brought financial loss which has deepened as the period of drought has advanced and has ended in disaster if it has persisted too long.

Disastrous floods have also occurred at various times but their effect has usually been limited to small tracts of land along the banks of rivers. Extensive sheet-flooding such as that which occurred in the south-western Orange Free State and adjacent areas during 1988 is less common. However, the fact that the zones of inundation are usually limited to flood plains does not detract from the seriousness of their effect because in a dry environment it is precisely along river banks, where flood plains exist, that human economic activity and settlement is concentrated.

About two-thirds of South Africa may be classified as arid or semi-arid. This dry region is given mainly to extensive livestock farming. Along rivers where irrigation is possible some agriculture is practised, the main products being fodder crops, especially lucern, and deciduous fruit. In this region droughts result mainly in losses of grazing land and livestock and the general deterioration of the environment, while the losses suffered as a consequence of floods include crops, fruit trees and agricultural land, structures such as buildings and bridges, and due to the suddenness of their occurrence, also human lives.

0.1 Need for the study and objectives

Many studies have been devoted to the subject of drought in South Africa; a lesser number to floods. These studies have been undertaken mainly from the point of view of the administrator (especially Government), the hydrologist, the engineer, the agriculturalist and the meteorologist. Major emphases have been placed on evaluations of the material effects of droughts and floods, efforts to find ways of reducing their detrimental consequences and attempts to understand their causing mechanisms. Studies in South Africa, in contrast to countries such as the USA, Great Britain and Australia, have paid very little attention to drought and flood as environmental hazards in which the concern is with human response and processes of adjustment, adaptation and behaviour in the utilization of environmental resources and patterns of settlement.

In spite of the prevalence of these two major natural hazards in this country, South African geographers have done no substantial work in the field of natural hazards research. The major contribution in this field which emanated from the USA following the pioneering leadership of Gilbert F. White, embodied a large volume of published work, especially on various aspects of flood hazard (e.g. White, 1939, 1942, 1964, 1973 and 1974; Murphy, 1958; Scheaffer, 1960; Burton, 1962; Kates, 1962 and 1965; Sewell, 1965). Interest in natural hazards research emerged somewhat later in Britain where the emphasis also fell on floods. It should, however, not be summarily assumed that the findings of natural hazards research elsewhere should fit the South African scene in every detail. Parker and Penning-Rowsell refer to the pitfall of such an assumption in a review of the British contribution in the field of flood hazard studies. They note that although there were apparent similarities between United States and British flooding problems, important differences sometimes went unseen. Consequently some explanations of British flooding problems and policies remained superficial and erroneous, being insufficiently tuned to the unique British circumstances (Parker and Penning-Rowsell, 1983).

In the light of the British experience it is essential not only that hazard research be undertaken in South Africa but that it be tailored to fit local circumstances.

Two major events in the early 1980's precipitated the need for studies of droughts and floods as hazards to human life and property. These were the protracted drought in the Karoo and northwestern Cape that began in some parts in 1977 and was not finally broken until 1986, and the disastrous Laingsburg Flood of January 1981. Subsequent droughts and devastating floods in other parts of South Africa have vindicated the necessity of the analysis of these phenomena from various points of view.

The relevance of studying the flood hazard in an environment deficient in rainfall might be questioned. Yet, paradoxically, some of the world's most devastating floods are experienced in dry regions where people are concentrated in riparian locations and flood protection schemes have been thought unnecessary (Whittow, 1980). The disastrous floods in the area east of the Great Dividing Range in Australia in January, 1974 and the Laingsburg Disaster of January, 1981 are two examples. Moreover, studying the two hazards of drought and flood together is not inappropriate, especially considering that drought can be a contributory cause to flooding. By the destruction of the natural vegetation of an area, runoff is accelerated and the potential for flooding increased.

The nature of the occurrence of the rainfall is a significant factor in this context. While the nature of the rainfall is analysed in more detail in chapter 4, it is sufficient to note here that rainfall in the region is subject to great variability both in its amount and in its distribution. The occurrence of concentrated falls in a short space of time occasionally produces flash floods which are particularly hazardous because they are infrequent and come as a surprise. Human adjustment to them is therefore often inadequate.

This study seeks to contribute to an understanding of why people inhabit hazardous areas; to gain some insight into the variety of adjustments and adaptive responses they make, and to evaluate the success of some of these responses. The perspective of human response provided by the results of such a study, is seen to be of great potential value to management authorities and individuals concerned with the identification of the most appropriate measures needed for the minimization of the detrimental effects of these two hazards. In view of the absence of studies on the subject of droughts and floods as hazards in South Africa, a major objective is to provide a broad base on which further research in this field can be conducted in a local context.

0.2 Limits of the study area

The rationale and detailed argument for the delimitation of the study area is dealt with in chapter 2. At this point it is sufficient to indicate that the study is restricted to the arid and semi-arid part of the summer rainfall region of the Cape Province south of the Orange River, co-inciding roughly with that part of South Africa generally known as the Karoo. The region with a winter rainfall maximum adjoins it in the west while the all-season rainfall zone lies to the south. The eastern limits are formed by the 600 mm isohyet (fig. 0.1).

0.3 Conceptual framework

Since human response and adjustment to natural hazards is an important concern of this study it is necessary to consider the theoretical context of this emphasis in some detail. Human adjustment to natural hazards has been represented by Kates (1971) in the form of a general systems model. The model is illustrated in fig. 0.2. It incorporates four major subsets: the human use system, the natural events system, natural hazard effects which result from the interaction of these two systems, and the adjustment process-control which governs the adoption of adjustments. The adjustments modify the human use system, the natural events system and the hazard effects through emergency adjustments.

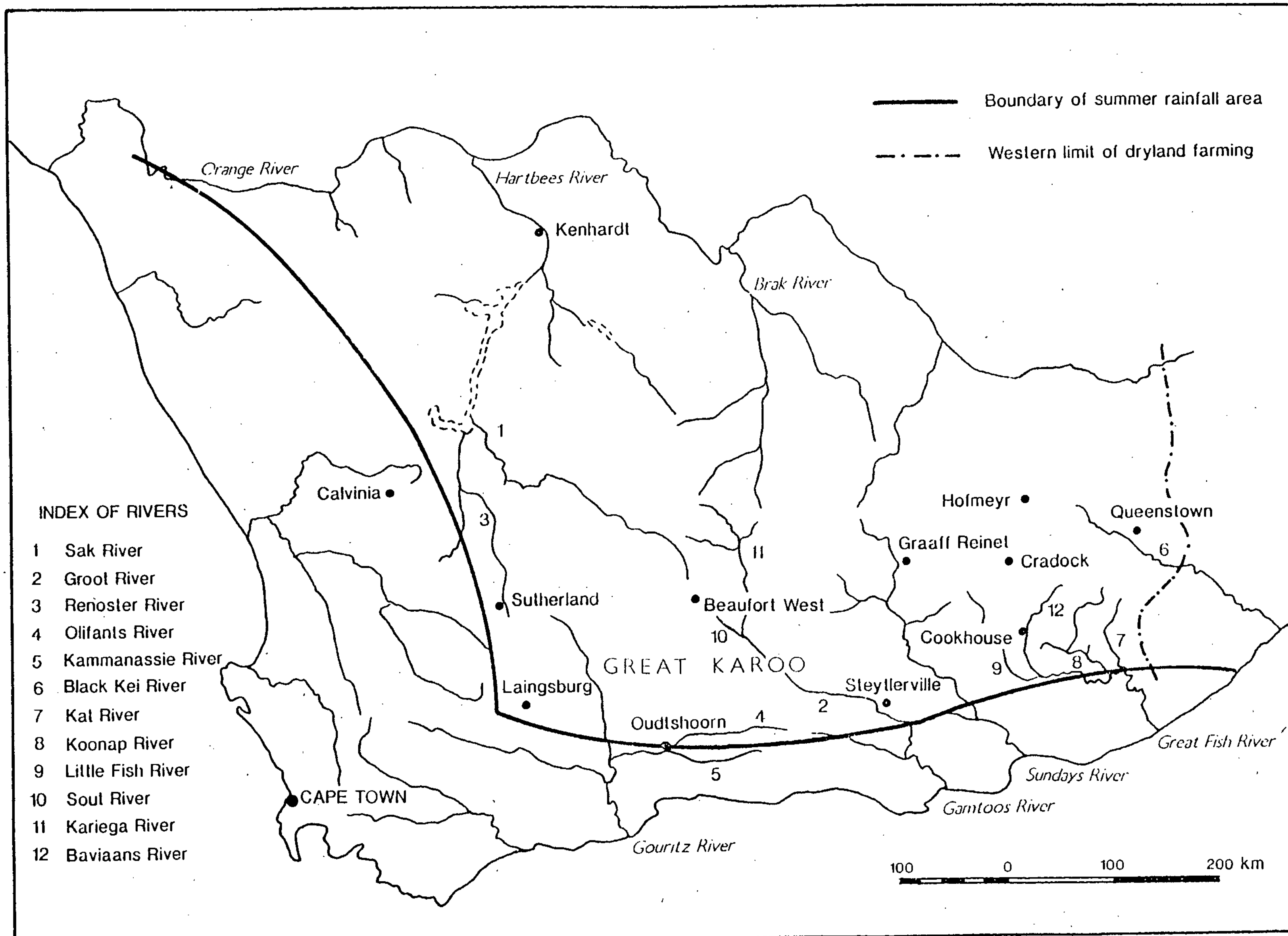

Fig. 0.1 The Karoo region

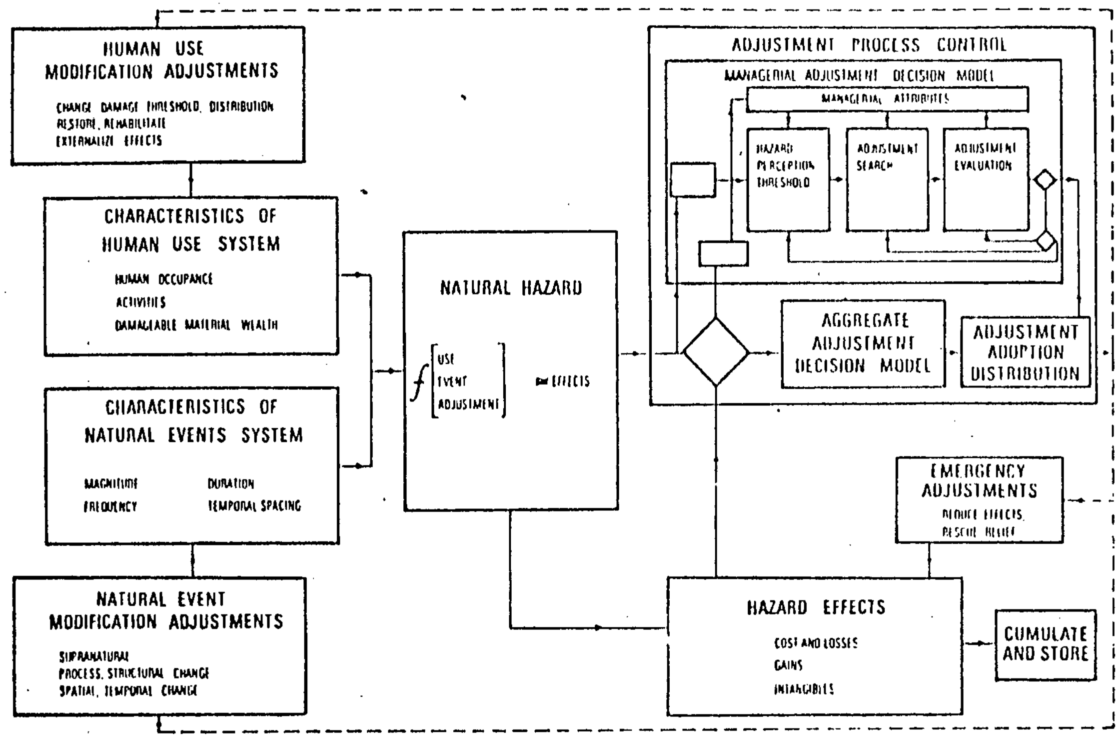

Fig. 0.2 Human adjustment to natural hazards: a general systems model (Source: Kates, 1971)

The Kates model has served as a standard context within which natural hazards research has been conducted, though its subsections have been extended and developed, e.g. O'Riordan (1986). In this study some of the concepts of the model are drawn together into a framework in which the state of the natural environment and increasing levels of hazard are emphazised as major issues, and against which background human response to hazard is viewed.

The natural environment consisting of the climatological and meteorological, pedological, biotic (botanical and zoological) constituents, geomorphological processes, and hydrological elements, is seen to exist in a state of dynamic equilibrium. Extreme events involving substantial variations in rainfall above and below the average amount resulting in protracted periods of dryness, on the one hand, and excessive moisture and the overtopping of river channels, on the other, exist as normal features of this natural environment.

Human intrusion of this natural environment is related to man's perception of its potential for farming and rural and urban settlement. Patterns of economic activity and settlement are a function of the cultural, social, economic and political base of such settlers, these factors being reflected in their attitudes and approaches to land utilization. The presence of man immediately creates a potential state of hazard with respect to extreme periods of deficient or overabundant moisture. His adaptive response to these potential hazards is filtered through his perception of them.

By human intrusion the natural environment can be subjected to stress. Provided the resilience* of the natural environment is not exceeded, its equilibrium is not disturbed and it continues to retain its essential character. However, if human activities are sufficiently pervasive, the resilience of the natural environment is exceeded and changes occur. Hydrological, geomorphological, biotic, pedological and possibly climatological responses produce a modified environment. If human understanding of the changes resulting in concomitant adjustment responses does not keep pace with the changed (usually deteriorated) environmental conditions, an increased level of natural hazard with respect to moisture relationships will occur.

Human response can have either positive or negative features. Negative response is associated with a lack of adjustment and an acceptance of the status quo, which in itself further intensifies the hazard and exacerbates the process. Positive response is expressed in amelioration attempts, adaptive change, conservation planning, and hazard planning and management. Possible consequences are progress in hazard prediction and hazard minimization.

In Western capitalist society a complication in this response situation is the prevalence of human rising expectations. This proceeds from the competitive nature of relations and rising levels of consumption which are inherent in the capitalist mode of production. An outcome is a tendency for human activities to be exploitive rather than conservative as man seeks to obtain maximum short-term profit from the resources of his environment. Heightened environmental stress is the consequence. Rising expectations related to his own aspirations and the system of values engendered by the society of which he is a part, are therefore seen as an important source for the perpetuation of a process of which increased natural hazard level is a significant feature.

The approach and main constituent elements of this perspective have been adopted as the conceptual framework of this study. A summary is given in diagrammatic form in fig. 0.3. The specific components in the various stages of the framework are the natural environment of the Karoo biome which is seen to have been in a state of dynamic equilibrium prior to the coming of European settlers. Environmental stress followed the coming of these settlers and their introduction of commercial capitalism which served as the source of the striving for economic advancement. Exploitive practices resulted in a deteriorated natural environment, exacerbating the detrimental effects of drought and flood and elevating the levels of associated hazard. A wide

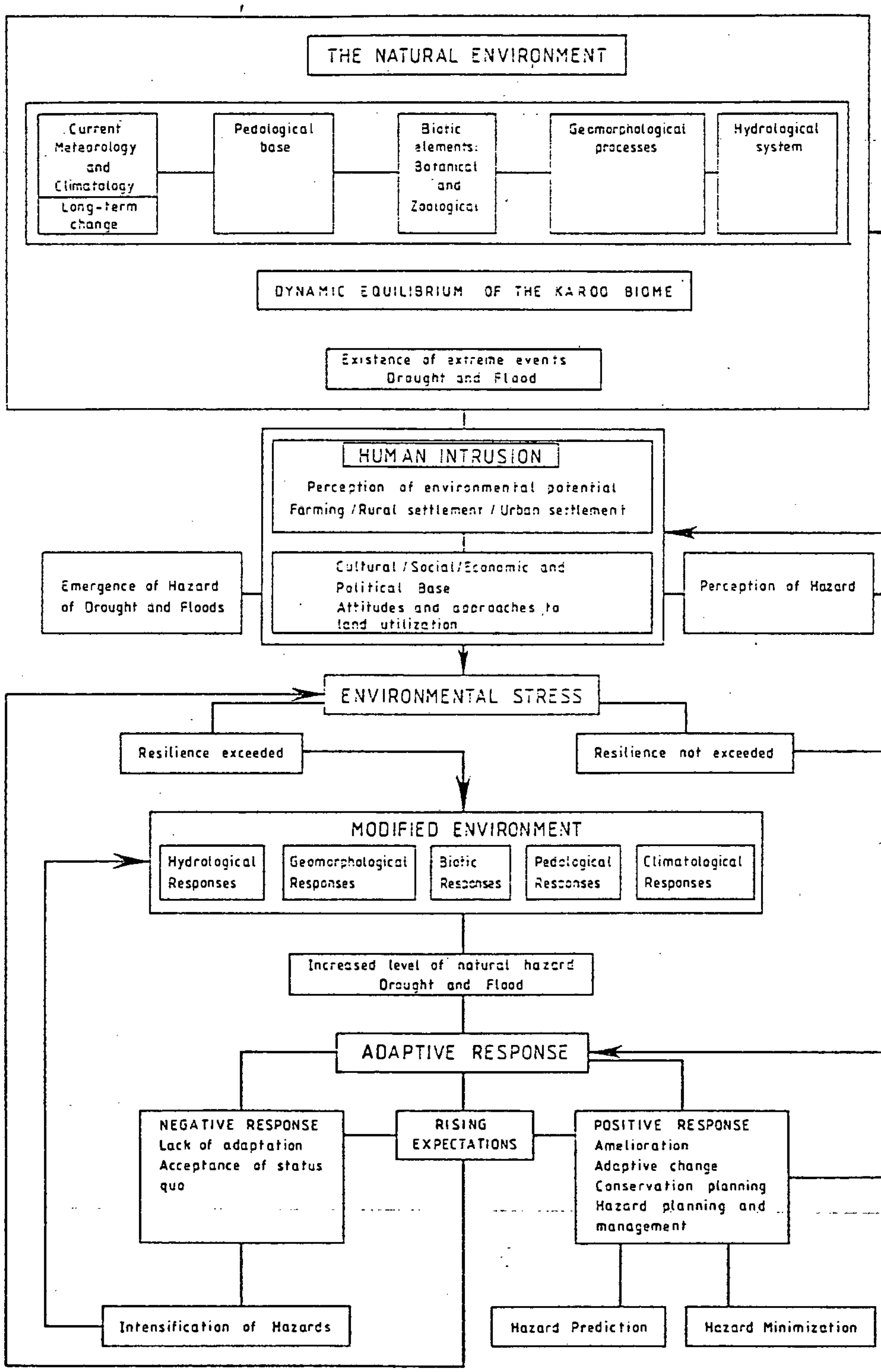

Fig. 0.3 Diagram of conceptual framework

spectrum of human responses to these hazards ensued.

0.4. Definition of the problem

Within the context of this framework this study focuses on three specific problems:

1. The process of increased hazard under the impact of more intensive human occupance in the Karoo environment;

2. The nature and full spectrum of human responses to the hazard situation; and

3. Explanation of these responses as a basis for hazard reduction measures.

The first of these proceeds from the evidence presented by research such as that of Acocks (1975), legislation aimed at the conservation of the environment and the regular need for government financial assistance to distressed farmers and other groups as a consequence of the occurrence of a drought or flood. The other two are corollories of the first. Man has responded to the hazard situation in accordance with his perception of it and the means at his disposal. The full spectrum of these responses must be documented and the factors influencing his perception and response identified and recorded as accurately as possible so that they can be evaluated. Only once this has been achieved can meaningful hazard reduction principles be formulated and effective measures be proposed.

Chapter 5 deals with the first of these problems, chapters 6 and 7 with the second, and chapter 8 with the third.

Before proceeding with an analysis of these problems it is necessary to clearly define the terms hazard, drought and floods since they are fundamantal concepts in the study, and to review the state of knowledge relevant to these problems from the available literature on the subject.

NOTE

* Resilience, in this context, refers to the ability of the natural environment to maintain a state of equilibrium without experiencing fundamental structural changes, in spite of modifying influences brought to bear by the presence of humans and their activities.

CHAPTER 1

THE NATURE OF HAZARD AND NATURAL HAZARD STUDIES

1.1 Definition of hazard

Terms such as natural disaster, risk, calamity, accident, extreme or unscheduled events are all closely allied to hazard in meaning. Each concept has been the subject of individual study and has generated its own specific literature and, since *hazard* is the subject of this study, it is necessary to clearly define what it means in the context of geographical enquiry.

Hazard refers to danger or a source of danger. It is the threat of an event with more or less disastrous consequences. Inherently it implies the presence of humans because without their presence danger cannot be experienced; the event constituting the source of the danger might still occur but there would be no hazard in the absence of threatened human life or property. Hewitt states: "It may be accepted that `hazard', strictly speaking, refers to the *potential* for damage that exists only in the presence of a *vulnerable* human community" (Hewitt

1983 : 5). Hazard may be distinguished from risk because it can exist without the knowledge of those threatened by it whereas risk implies some calculated decision to accept a dangerous situation, therefore incorporating an element of gamble. This element of gamble is, however, also present in the concept of hazard where those under threat may be aware of the existence of the danger. Hazard differs from the concept of disaster or calamity which is really one form of the realization of the hazard; it is the final event to which the hazard relates. Hazard refers to a state or condition whereas disaster refers to an event or occurrence accompanied by great loss of property or life or both. (It should be mentioned here that usage of the term hazard in the literature is inconsistent and frequently refers to an objective geophysical process, such as an earthquake or volcanic eruption, as the hazard.)

Hazards have their origin in both the natural and cultural environment. Geographers have shown far greater interest in *natural hazards* than in hazards of other types, such as technological and social hazards. Oliver defines a natural hazard as "an extreme geophysical event greatly exceeding normal human expectations in terms of magnitude or frequency and causing major human hardship with significant material damage to man and his works and possible loss of life" (Oliver, 1975: 99). "By definition, such hazards are a function of both the geophysical world and human society" (Smith and Tobin 1979 : 1). Perry

(1981) emphasises the process and states that "natural hazards can be viewed as processes whereby energy is transferred rapidly from the environment to the works of Man, inflicting damage to both life and property". This is similar to the view of the Soviet geographers Gerasimov and Zvonkova (1974 : 243) who note that "natural hazards derive from highly dynamic processes whose elemental essence consists in their indefinite and equivocal manifestations".

The types of natural hazard that have been investigated fall mainly into three categories:

The largest group consists of those that may be classified as geophysical (climatological and geological) hazards which include avalanches, coastal erosion, tidal waves, cold spells and hot spells, snowstorms, hail, droughts, floods, tropical cyclones, severe windstorms, tornados, earthquakes, volcanic eruptions, landslides, fogs, frost, and sand and dust storms.
Biological hazards include plant diseases and pests.
Forest and veld fires occupy an intermediate position and the slow destruction of soil by erosion may also be classed as a hazard.

Technological hazards and social hazards have more recently assumed a place alongside natural hazards as a focus of geographical research, especially after events such as those of

Bhopal and Chernobyl, involving a poison gas leak from a chemical plant and radioactive contamination following an explosion in a nuclear power plant, respectively.

Droughts and floods are the two types of natural hazard that have been given most attention by geographers.

Droughts are notoriously difficult to define. Scores of different definitions exist reflecting the various emphases of human activity in relation to which drought is seen. Recent literature (e.g. Steila, 1983) indicates that the quest for an appropriate definition of the concept has not yet been rewarded with one that is universally applicable. Tannehill (1947 : 15) writes "What is a drought? In the United States drought brings to mind withering crops, parched fields, dusty roads and failing water supplies. In its extremes in some other countries it means hunger, famine, starvation, human emaciation and death, skeletons of animals and mass migration of peoples. Sometimes it has led to war. But we have no good definition of drought." He sagely defines drought simply as "a spell of dry weather" (Tannehill 1947 : vii).

As the literature suggests, drought has different meaning to different people. "To a farmer, it occurs when soil moisture is incapable of maintaining crop development and expected yield. To the forester it is perceived relative to a reduction in biomass production and to increased forest flammability potential. To the hydrologist, drought is recognized by the decline of water tables, reservoir levels, and baseflow of streams. The urbanite basically views its occurrence as an (water restrictive) imposition on his/her lifestyle" (Steila, 1983 :194). Saarinen (1966) includes a glossary of some 43 drought definitions in his pioneering work on the drought hazard, classifying them under the headings: General, Variations in Precipitation, Effects on Vegetation, Economic and Social Effects, and Some Types of Drought. While recognizing the value of quantitative models for drought identification Steila (1983 : 194) concludes his discourse by defining drought as "a temporary negative deviation of an environment's moisture status from its expected amount." Since the emphasis of this study is on the hazard rather than the phenomenon itself, this latter definition is accepted as sufficiently comprehensive to leave no doubt as to its intended meaning.

Drought hazard may therefore be defined as the threat of a temporary negative deviation of an environment's moisture status from its expected amount to such a degree that it has an adverse effect on human activity. Inherent in this definition is the recognition that drought is essentially a perceived phenomenon and its meaning will therefore of necessity differ according to the variation of individual perceptions.

Floods are easier to define with accuracy. Since this study is confined to riverine flooding, within its context a flood can be defined as any relatively high streamflow which overtops the natural or artificial banks in any reach of the stream. It is therefore a condition in which the discharge exceeds the channel capacity of a river and then proceeds to inundate the adjacent flood plain (Smith and Tobin, 1979).

Flood hazard has been defined as "the risk to which a particular individual or piece of property is exposed by the inundation of land used or valued for a particular purpose" (Douglas, 1979: 143).

1.2 Literature review

1.2.1. The evolution of natural hazards research

Several reviews of natural hazards research have been published, e.g. those by White (1973), Gold (1980) and Hewitt (1983). Research in this field had its foundation in the United States when, in 1927, the Corps of Engineers was authorized to conduct a series of comprehensive investigations for the purpose of managing the river basins of the country. Part of these investigations was aimed at finding a range of alternatives with respect to flood loss reduction. This led to the initiation of work by Gilbert F. White at the University of Chicago. Papers by him in 1939 and 1942 were followed by the establishment of a study group in 1956 to examine the question of human adjustment to floods.

The research precipitated a series of papers by White (1964) and his colleagues, including Murphy (1958), Scheaffer (1960), Burton (1962) Kates (1962, 1965) and Sewell (1965) which focussed initially on riverine flooding. Interest rapidly spread to other types of hazard such as coastal flooding (Burton and Kates 1964; Kates, 1967) and drought (Saarinen, 1966).

At this time natural hazards research was given further impetus by the support of the National Science Foundation, which provided financial aid to Clark University and the University of Colorado to carry out work based at Worcester, Mass., Boulder, Colo., and at the University of Toronto in Canada. The Commission on Man and the Environment of the International Geographical Union (IGU) also identified natural hazard investigations as one of its main concerns. Several national foundations in the United States and Canada also provided financial aid in the form of grants. Examples of work that proceeded from this assistance are *Man and Environment* (Pecsi and Probald, 1974) and *Natural Hazards: Local, National, Global* (White, 1974).

Outside of North America the IGU collaborative programme generated studies in the United Kingdom, Norway, the Soviet Union, East Africa, Sri Lanka, Bangladesh, Japan, Australia and New Zealand, which might be regarded as still being part of an expanded "Chicago school". A significant contribution was made by the symposium sponsored by the Australian Academy of Science, the Institute of Australian Geographers and the Academy of the Social Sciences in Australia in 1976 (Heathcote and Thom, 1979).

1.2.2 Theoretical context

Natural hazards research has developed within the context of fairly well defined objectives:

1. To estimate the extent of human occupancy in areas subject to extreme events in nature;

2. to determine the possible range of adjustments by social groups to those extreme events in nature;

3. to examine how people perceive extreme events and resultant hazard;

4. to examine the process of choosing damage-reducing

adjustments; and

5. to estimate what the effect of varying public policy would be upon that set of responses (Kates *et al.*, 1968).

1.2.3 Behavioural approach

Natural hazard studies clearly reflect the behavioural approach in human geography. The behavioural approach grew out of disillusionment with the positivist paradigm in which human behaviour was seen to be governed by purely ecomomic motives where the prime objective is to optimize economic utility. The assumptions of this approach were that the actors in these functional and spatial systems had perfect information about all opportunities and that they acted homogeneously for the optimization of utility. Work by Simon (1952), Wolpert (1964) and others demonstrated that the information available to individuals, and on which behavioural decisions were based, was far from perfect and that decisions were not always economically motivated. This led Simon (1952) to formulate his concept of satisficing rather than optimizing in decision-making processes.

Various emphases developed within the context of this approach. These are summarized by Golledge and Timmermans (1990 : 57) as follows:

1. "A search for models of humanity which were alternatives to the economically and spatially rational beings of normative location theory;

2. a search to define environments other than physical reality as the milieu in which decision making and action took place;

3. an emphasis on processural rather than structural explanations of human activity and relationship between human activity and the physical environment;

4. an interest in unpacking the spatial dimensions of psychological, social and other theories of human decision making and behaviour;

5. a change in emphasis from aggregate populations to the disaggregate scale of individuals and small groups;

6. a need to develop new data sources other than the generalized mass-produced aggregate statistics of government agencies which obscured and overgeneralized decision-making processes and consequent behaviour;

7. a search for methods other than those of traditional mathematics and inferential statistics that could aid in uncovering latent structure in data, and which could handle data sets that were less powerfull than the traditionally used interval and ratio data; and

8. a desire to merge geographic research into the ever-broadening stream of crossdisciplinary investigation into theory building and problem solving."

1.2.4 Environmental perception

One stream of thought that has pervaded behavioural studies, stresses man-environment relations as expressed through man's perception of the environmennt. "Perception is not a sub-branch of the discipline of geography, but an all-pervasive and supremely important intervening variable in any analysis of the spatial expression of human activities. Such importance has long been acknowledged in geography and other fields but it awaited the decade of the sixties before attempts to incorporate elements of man's perceptual transformation of his environment into explanations of his spatial behaviour were produced within the discipline" (Golledge, Brown and Williamson, 1972 : 73).

The role of human perception in the adjustment to natural hazards was an early focus of investigations in this context. Investigation of the role of attitudes in human adjustment indicated a lack of substantial association of attitude toward future flooding with measures of socio-economic class or the amount of information known about protective structures. The flood plain dweller's perception of a flood hazard was described by Kates (1962) as the "prison of experience" and the apparently irrational behaviour explained by resorting to Simon's concept of satisficing or boundedly rational behaviour. Consideration of a wider range of natural hazards including drought followed this initial focus. Saarinen's pioneering work (Saarinen, 1966) indicated that perception by occupants of hazardous situations varied with respect to three main factors, namely the relation of the hazard to the dominant resource use, the degree of personal experience of the hazard and the frequency of the occurrence of the threat.

1.2.5 Major findings

Subsequent studies which have confirmed these initial conclusions in relation to perception, also reveal the following broad findings with respect to people inhabiting hazard-prone areas:

1. People did recognize that they were in danger.

2. Their judgement as to the likelihood of damage and/or injury did not noticeably differ from "official" estimates for the more probable events but were more variable for the less probable events.

3. Their response to preventive measures was dependent in part on whether they had experienced a hazard before (or at least lived in a locality that had suffered damage).

4. They tended to make the uncertainties of hazard probabilities more certain by simple devices such as reducing low probabilities to zero, dividing probabilities into absolute fractions, passing the blame onto some other agency (a diety or the government), or simply ignoring the notion of uncertainty altogether.

5. They knew of a number of possible preventative measures which could be adopted individually or collectively.

6. Their knowledge and evaluation of the various damage-reducing measures open to them were influenced by such factors as experience, social communication, and their understanding and trust in the accuracy of warnings and the

competence of civil defense, police, and postdisaster relief organizations (O'Riordan, 1986 : 281).

1.3 Paradigmatic perspectives

1.3.1 The traditional approach

Important hypotheses investigated within the general context of natural hazards research (see paragraph 1.2.2 above), include the the following:

a. "that rational explanations can be found for the persistance of human occupance in areas of high hazard by examining the perception of the occupants of such areas and searching out their views of the alternative adjustments and the likely consequences of adopting any one of those opportunities" (White, 1973); and

b. that variations from place to place in hazard perception and estimation could be accounted for largely by a combination of factors embracing certain physical characteristics of the hazard, the recency and severity of personal experience of the hazard, and the situational characteristics of the decisions regarding adjustments to the hazard, and personality traits (Kates, 1971).

Given these hypotheses research attempted to describe choice of adjustment in terms of a perception model dealing with the individual manager's subjective recogition of the hazard, the range of choice open to him, availability of technology, the relative economic efficiency of the alternatives, and the likely linkages of his action with other people. It was noted that there were differences in the way which these factors interact in relation to community action in contrast to individual action (White, 1973).

Deductions of research suggested that actual response may be seen to be of three major types:

(1) Folk or pre-industrial response involving a range of adjustments with more modifications in behaviour and harmony with nature than control of nature, having flexibility and low capital requirements.

(2) Modern technological or industrial response with a more limited range of technological actions, inflexibility, resistance to change, high capital requirement and with the necessity of

interdependent social organization.

(3) Comprehensive or post-industrial response combining features of both the other types.

These three types can be combined to form what O'Riordan has called the transition thesis in which he emphasises a developmental or maturation approach. By this thesis response is seen to pass sequentially through the three stages listed above (Burton *et al.*, 1978).

At the stage, in the early 1970's, when geographical research began to be critically evaluated as part of a more general movement which has come to be known as the radical approach, natural hazards research was also subjected to critical scrutiny.

In a review essay which he considers to be a prologue to a full-blown critique of hazard studies, Torry (1979) points to many failings in conventional positivist natural hazards research. He calls for "a house cleaning exercise" and points to a necessity to challenge the premises, methods, findings, and conclusions of the field of study, and the value of producing some form of "quality control".

Fuller articulation of this critique and the formulation of alternative points of view are given by such authors as Hewitt, Waddell, Morren, Warrick, Copans, Regan, Watts, Susman, O'Keefe and Wisner, in Hewitt's *Interpretations of Calamity* (Hewitt, 1983). Some of the major points of these views are given in the following paragraphs.

1.3.2 The dominant view

Hewitt describes contemporary natural hazards research as being characterised by a convergence of opinion or approaches with sufficient concensus to justify the identification of "a dominant view". This he sees as a construct depicting the shaping hand of a contemporary social order. "Dominance is evident in the resources allocated; in the numbers of highly trained personnel involved and the volume of their published works; in the public visibility and acceptance of these works; and perhaps most of all in the attachment of this view to the more powerful institutions of modern states" (Hewitt, 1983 : 4).

In the dominant view the sense of causality or the direction of explanation runs from the physical environment to its social impacts. Most actions, and scientific literature recommending action, are concerned mainly with geophysical monitoring, forecasting and direct engineering or land-use planning in relation to natural agents. Though social and economic factors or habitat conditions are not ignored, the direction of argument in the dominant view relegates them to a dependent position. "The initiative in calamity is seen to be with nature, which decides where and what social conditions or responses will become significant" (Hewitt, 1983 : 5). "In the dominant view disaster is attributed to nature. The structure of the problen is seen to depend on the ratios between given forces of nature and advanced institutional and technical counterforce" (Hewitt, 1983 : 6).

The bulk of work undertaken and expenditures disbursed within the dominant view may be summarised as falling into three main areas:

(1) The monitoring and scientific understanding of geophysical processes as the foundation for dealing with their human significance and impacts and with the goal of prediction;

(2) Planning and managerial activities to contain these processes where possible; and

(3) Emergency measures, involving disaster plans and the establishment of organizations for relief and rehabilitation.

The dominant view constitutes essentially a technocratic approach. "Hazards are taken as natural events that destabilize or violate ordinary life and relations in the habitat. Research normally takes the idea of failure in social systems as a fairly exact analogue of that in mechanical systems" (Hewitt, 1983 : 11).

In summing up this approach Powell is quoted as calling disaster "the impinging upon a structured community of an external force on a scale wide enough to exite public alarm, and to disrupt normal patterns of behaviour" (Hewitt, 1983 : 11). Hazards research in its main stream is seen to have invented its problem field to suit its convenience. "It does not reflect upon the extent to which the institutions it serves - the societies that have made such technocratic authority possible - could be part of the problem. It does not reflect upon the flaws in itself except in relation to what is deemed sophisticated in the current fashions of the scientific community" (Hewitt, 1983 : 14).

1.3.3 Alternative viewpoints

In introducing an alternative viewpoint Hewitt indicates that

(a) natural hazard is not entirely explained by nor uniquely dependent on the geophysical processes that may initiate damage;

(b) human awareness of and responses to natural hazards are not fully dependent on the geophysical conditions, either in relation to their mechanisms, frequency or past experience of them. Hazard is seen to be related to the concerns, pressures, goals, risks and orchestrated social changes that are indifferent to the particular society - environmental relations where disaster has occurred. Hazard reduction measures are found to depend on the ongoing organization and values of society and its institutions.

(c) natural disaster, its causes, internal features and consequences are not adequately explained by conditions or behaviour peculiar to calamitous events but rather depend on the ongoing social order, its relations to the habitat and historical circumstances.

Hewitt calls upon the social scientist to consider seriously whether the dominant view does not have the problem of disaster back to front and expresses his view that

(a) "most natural disasters and most damages in them, are characteristic rather than accidental features of the places and societies where they occur.

(b) the risks, pressures and uncertainties that bear upon awareness of and preparedness for natural fluctuations flow mainly from 'ordinary life', rather than from the rareness and scale of those fluctuations; and

(c) the natural extremes involved are, in a human ecological sense, more expected and knowable than many of the contemporary social developments that pervade everyday life". (Hewitt, 1983 : 25).

1.3.4 The radical approach

The ideas put forward by Hewitt have been articulated in terms of the radical approach in work conducted by Waddell (1983). He states that "the naive determinism and technocratic optimism of Kates and White is now challenged by the revolutionary zeal of O'Keefe, Westgate and Wisner who account for the incidence of disasters in the Third World in terms of political economy - penetration of capital and marginalisation of entire populations. The analysis is Marxist, the causes are structural and the solution is one of `guerilla warefare'. Acts of God become acts of capital and the disaster that struck the highlands of Guatemala in February 1976 is characterised by one as an earthquake and by the other as a classquake".

In this work the ultimate cause of environmental problems is seen to be traceable to the structural imbalances between rich and poor countries and it is thought appropriate to replace the term *natural* with the more appropriate terms *social* or *political* disaster (Susman, O'Keefe and Wisner, 1983). Susman *et al.* summarise the radical interpretation with reference to the theory of marginalisation. The process of underdevelopment is seen to be linked imtimately with the control and exploitation of indigenous resources by the governing elite and outside interests. "The management of surplus required to maintain a peasant economy's flexibility in the face of crisis is incompatible with the expropriation of surplus value. Thus the underdevelopment process forces the peasantry into a more vulnerable position which, in turn, directs them to look for another source of livelihood in areas where security may be less and hazard more severe or to change their resource use in ways that exacerbate vulnerability" (Susman *et al.* 1983: 278).

The interpretation is applied within the specific politico-economic context of developing societies and remains essentially a critique. The view has not been universalized and it is not considered to be applicable in the context of developed society, such as the one in which this study is conducted. In the context of this study, farmers cannot be regarded as peasants occupying hazardous areas for reasons related to the underdevelopment process but, in the study area, form part of developed society in South Africa.

1.3.5 A unified view

A less radical alternative is one offered by the ecological anthropoligist Morren. His concern is to identify and describe the main environmental problems confronting particular groups of people. The problems are not limited to initiating agents such as geophysical events or predisposing factors such as settlement patterns, though these are certainly included. An emphasis on group history, and economic and political causes of environmental problems is an important requirement. In Morren's view the traditional distinction between *natural* and *man-made* disasters should be dispelled (Morren, 1983).

Morren's approach is consistent with long-standing principles in ecological studies which maintain that environmental problems arise, not from the environment *per se*, but from the interaction of organisms with their environment. "Thus, particular hazard events must be put in a social, material and historical context including other hazard events and environmental problems and responses" (Morren, 1983 : 285). Morren believes that a wide range of environmental hazards are the consequences of human activity or more specifically emerge as a result of the interaction of people and their environment. This is seen to hold true in four senses:

"(a) That the hazard proceeds directly and principally from human activity;

(b) That the acuteness of the damaging effects is related to the magnitude of human exploitation and modification of the environment and population density;

(c) That development tends to foster dependency and specialisation on the part of individuals and communities, reducing their ability to respond effectively, or narrowing the range of normal environmental variability with which they are able to cope on their own;

(d) That the involvement of outside, supra-local groups may render permanent the effects of an otherwise short-duration local problem" (Morren, 1983 : 288).

It is essentially within this approach put foreward by Morren, that the current study is undertaken.

1.4 Literature on droughts and floods in South Africa

In South Africa published geographical studies of hazard within the context of the selected paradigm or any other paradigm (except physical explanation) are conspicuously absent. This should not be interpreted as an indication of the general absence of hazards in this country but rather that the field has not attracted the specific attention of researchers. A wide variety of natural hazards exist in South Africa though the degree of hazard displays considerable regional variation. Snow, frost, tropical cyclones, hail, tornadoes, duststorms, sandstorms, veld and forest fires, fog and earthquakes are among the main ones that may be listed.

Biological hazards are also present in most of South Africa in the form of insect pests and plant diseases. Soil erosion is an extremely serious hazard especially in parts of the independent and self-governing national states where traditional agricultural practices and population pressure heighten the threat it poses.

Technological and social hazards such as those posed by the Koeberg nuclear power station and politically inspired riots are hazards that are likely to increase, at least in the short term, as the country continues to develop technologically and as partisan political aspirations demand fuller expression more urgently.

In terms of their prevalence and economic singificance, however, droughts and floods are perhaps the most important of all the natural hazards in South Africa.

The problem of **droughts** and **floods** in South Africa has not been studied as a hazard within the context of the paradigm outlined above and no literature with this perspective has been generated. The recurrence of disastrous droughts and floods has, however, left no doubt as to their importance as hazards in the country. What has been published has a meteorological, agricultural or hydrological application or is in the form of reports following official investigations.

An early publication on drought that falls into the latter category, is the report of the Drought Investigation Commission appointed in September 1920 by the Union Government, to investigate ways and means by which losses due to drought could be prevented. Under the chairmanship of H.S. du Toit the Commission conducted a very thorough investigation of the problem and the final report was published in October, 1923 (UG 49 - 23). The report focuses attention on inappropriate farming practices including the kraaling system, overstocking and insufficient watering points with its consequences of deterioration of pastureland and soil erosion. It recommended the introduction of a variety of conservation measures to preserve the environment and improve the lot of an impoverished farming community. A similar report, the Report of the Drought Investigation Commission of South West Africa followed in June, 1924.

In 1941 the extent, severity and frequency of droughts was analysed by Levinkind in an article published in the journal *Farming in South Africa*. It was followed by two further articles by De Swardt and Burger dealing with drought relief measures and the idea of a fodder bank scheme (De Swardt and Burger, 1941). Other publications dealing with drought in relation to agriculture are the series of leaflets available from the Department of Agriculture and Fisheries, dealing essentially with farming practice and management under conditions of drought, e.g. Steenkamp and Hayward (1975), Hayward and Jacobs (1979 and 1981) and Jacobs and Hayward (1981).

Studies of meteorological aspects that relate to both droughts and floods are most notably those by Tyson, Dyer and Mametse (1975), Dyer (1975 and 1976), Dyer and Tyson (1977), Louw (1982 and 1983), and Preston-Whyte and Tyson (1988). These studies are directed mainly towards the identification of patterns of recurrence of wet and dry periods and the explanation of the meteorological factors that produce such periodicity.

The proceedings of a symposium on drought in Botswana are of marginal interest in the context of this study. The focus on social aspects such as traditional responses, social hibernation, migration and poverty, however, produced some principles of response that are noteworthy (Hinchey, 1979).

In September, 1984 a conference on Business and Drought sponsored jointly by the University of South Africa and Financial Mail focused particularly on the financial implications of the widespread drought that prevailed at that time (Unisa, 1983).

Occasional, more popular articles have appeared in farming magazines, an example being the recent dyad by Reynolds (1986) in which responsibility for the disastrous consequences of the drought is placed squarely on the shoulders of the farmers themselves.

Published work on floods in South Africa falls into the meteorological, hydrological and engineering fields of interest. In the meteorological field, as in the case of droughts, investigations focus on the cyclic occurrence of wet years and the explanation of mechanisms which lead to precipitation conditions that produce floods. Alternatively, analyses focus on specific flood events, e.g. Taljaard (1952 and 1961), Hayward and Taljaard (1953), Triegaardt (1961), Gouws (1963) and Hayward and Van den Berg (1970). A single event that generated a substantial number of publications is the Laingsburg flood of 1981. The most important papers discussing this disastrous event from various points of view are those by Alexander and Roberts (1981), Dewar (1981), Estiè (1981), Hallward (1986), Harmse and Ellman (1981), Roberts and Alexander (1982), and Van Zyl (1981).

Floods constitute an integral part of any comprehensive hydrological study but the emphasis is on physical relationships and the development of models of rainfall and run-off processes. The numerous publications of the former Hydrological Research Unit and its successor, the Water Systems Research Group, in the Department of Civil Engineering of the University of the Witwatersrand exemplify work in this category. Publications by Pitman and Midgley (1967) and Midgley (1972) indicate the applied nature of much of the research for the field of engineering.

A number of reports on the problem of assessing flood damage were published by the Institute for Social and Economic Research at the University of the Orange Free State in Bloemfontein. Examples are the work by Smith, Viljoen and Spies (1980), Viljoen, Vos, Smith and Prinsloo (1980), and Vos (1982).

From this brief review of published work on droughts and floods in South Africa it is evident that these phenomena are not considered from the perspective of their being hazards to human life and property. This surprising deficiency is of great importance considering the frequent occurrence of serious floods and droughts in South Africa.

The danger of transferring the explanations of flood and drought problems from one country to another (Parker and Penning-Rowsell, 1983) and especially cross-culturally (Torry, 1979) without proper tuning, stresses the need for local work in this field. Considering the volume of published material on droughts and floods as hazards elsewhere, but most notably in the United States of America, Canada, Britain and Australia, the absence of such work in South Africa is conspicuous. A broad perspective of droughts and floods as hazards in South Africa is clearly called for and this study is undertaken as a first step towards correcting this deficiency.

Chapter 2

RESEARCH PROCEDURE AND RATIONALE

Although the general boundaries of the study area were outlined in the Introduction, no argument was presented in explanation of the limits that were set. In this chapter the rationale and procedure for the delimitation of the study area is explained and details are given of the method followed in trying to find answers to the problems posed for research in this work.

2.1 Delimitation of the study area

No part of South Africa is free of the hazard of drought. Local flooding is also possible throughout the country. Drought and floods can therefore be expected to occur in a wide variety of different environmental circumstances. While the purpose of this study is essentially to assess human adjustment to hazard, conducting it in an area as vast as the country as a whole and as variable as its local environmental conditions render it, the usual constraints of finance and time make it imperative to scale down both the area and the variables involved.

A first step is to restrict the study area to the arid and semi-arid part of the country where climatological conditions firmly limit human activity. The 600 mm isohyet, which is regarded as the limit of dryland agriculture in the summer rainfall area is taken as a primary boundary. A further constraint is imposed by restricting the area to that part of the region which lies within the Cape Province.

The western and south-western part of the region has a winter rainfall regime. It contrasts with the central and eastern summer rainfall area and is characterised by different land use emphases. For the sake of homogeniety the winter rainfall area is excluded and the study area defined as the summer rainfall region lying within the Cape Province south of the Orange River, bounded in the east and south by the 600 mm isohyet (fig. 0.1).

The Orange River and area to the north of it are excluded mainly for two reasons. Though there are no great contrasts on either side of the Orange River the environment to the north becomes increasingly sandy in patches and merges into the Kalahari Desert. While the Orange River does not represent a significant boundary in respect of contrasts in drought conditions it is an exotic river having its source in the Drakensberg Plateau far to the east and has an entirely different flood regime to the rivers that rise in the study area and are essentially ephemeral or intermittant in character. The entire hazard and response situation is assumed to be sufficiently different along the Orange River as to justify its exclusion from the study area in which the very unpredictability and suddenness of flooding are the essential characteristics.

The greatest direct impact of extreme events of a climatological origin such as droughts and floods, is usually on the rural sector of the economy. A further step towards attaining greater homogeniety is therefore to restrict the area to one in which a single type of farming economy is completely dominant.

The basis of the farming economy is an important variable in determining the effect of a hazard in a region. The occurrence of a drought in an environment where farming economy is based on dryland agriculture is different in its effect from one occurring in a region of irrigation agriculture or where the economy is based on extensive livestock farming, or where mixed farming is practised. A maize farmer producing under dryland conditions is likely to suffer the loss of his entire crop and only source of income as a result of a year long drought, and his options to mitigate its effects are very limited. He is very largely at the mercy of climatic conditions for a favourable crop. In a mixed farming operation where, for example, wheat and sheep are the economic base, the farmer might lose his wheat harvest but be able to keep his flock by artificially feeding it. A protracted drought or flood as a result of which a fruit farmer's fruit trees are lost is not only the source of a loss of his income for the years of drought but also for the years required to reestablish his orchard. Perceptions and responses are different in these various conditions (Saarinen, 1966). It is therefore necessary to limit a study such as this one to one type of farming economy.

As indicated earlier the arid and semi-arid part of the country is an area of extensive pastoral farming. Sheep are the most important component but other types of livestock include goats, found mostly in the driest western parts, angora goats mainly in the south-east, and cattle in the south, east and north.

The method used to isolate the sheep farming region was that developed by Weaver (1954) as a solution to the problem of sorting out major crop combinations and eliminating minor ones from a range of crops grown in different rotational combinations. Using a series of model situations he argued that in a one-crop model situation 100 per cent of the cropland would be in the crop and 0 per cent in the others; in a two-crop situation the percentages would be 50 for each of the two crops and 0 for the others; in a three-crop situation the percentages would be 33.3 and 0, and so on. Curves representing each of the model situations (where per cent of cropland was plotted against crops in rank order) were used as standards of comparison with actual curves. The differences were expressed by the method of least squares. The lowest least squares value (zf^2) indicates the closest correspondence to the model, and its rank position the number of crops that form the combination. In this case the three major types of livestock were substituted for the various crops, the objective being the identification of those districts in which sheep was the dominant element and the other types of livestock the recessive elements. The figures used were those of the 1981 Census of Agriculture.

The analysis identified 25 districts in which sheep were significantly predominant (fig. 2.1).

Further confinement of the area to more manageable proportions for more detailed study was achieved in different ways with respect to the two hazards. In relation to the drought hazard a random sample of 4 out of the 25 districts (16 per cent) was drawn for closer study. The districts identified were Sutherland, Noupoort, Britstown and Kenhardt. In relation to the flood hazard, zones of greatest hazard were identified after devising a flood hazard index. The method used in the formulation of this index is dealt with later in this chapter.

2.2 Research methods and procedures

In the investigation of the problem of rising hazard under the impact of intensified human occupance of the Karoo environment (the first of the problems identified in paragraph 0.4), some

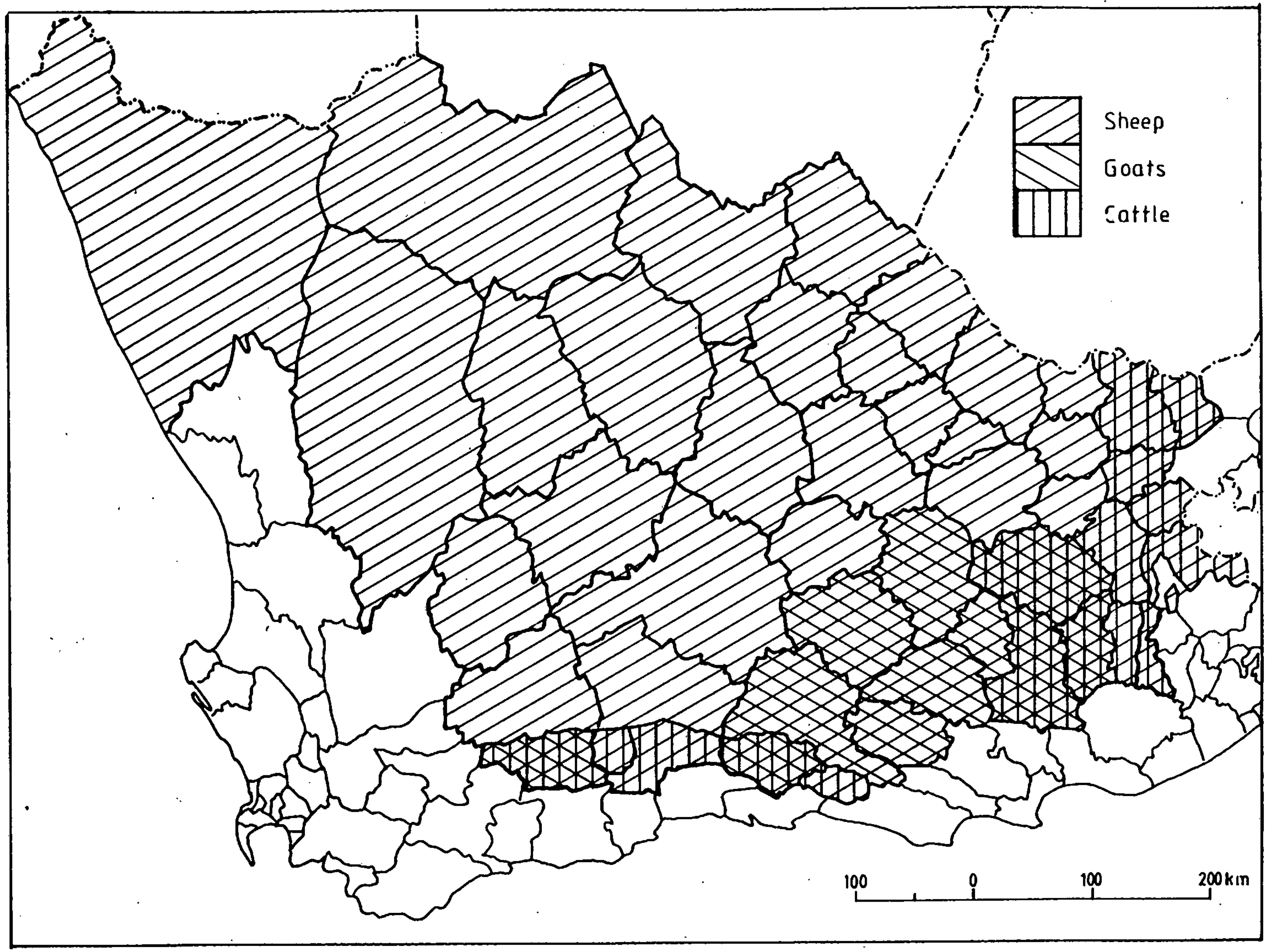

Fig. 2.1 The basis of the farming economy

answers are available from the study of bibliographic sources on such aspects as the spread of human settlement, increase in occupational density and intensity of land use, exploitational farming practices and changes in the natural environment. Other answers to this question and on the nature and full spectrum of responses to the hazard situation, can be found only by referring to those actually in a position to experience the hazard. Clearly, the solicitation of such information requires that personal interviews be conducted and that suitable questionaires designed to provide the information be completed.

Although the method of data collection was similar for both droughts and floods in some respects, the approach differed in many others and the two hazards are dealt with separately in this explanation.

2.2.1 Drought

Data in respect of personal perception and responses to drought essentially involved three major source groups:

(1) farmers who were directly dependent on the availability of water for their production,

(2) managers of water affairs, on whose success the users of

water in other fields depended. The latter included local authorities, especially municipal authorities who are responsible for an adequate supply of water for urban residents, and central government departments that manage water affairs centrally, and

(3) central government departments that provide advice on farming practice and management techniques in the context of a water deficient environment, or assume responsibility for co-ordinating aid to the victims of a particular disaster. Government perceptions and responses could be deduced from the nature of former action taken in response to the drought hazard and from existing operative programmes. For data on individual and municipal authority perceptions and responses, interviews and questionaires were required.

The data collection was carried out in two stages. Firstly, field research was undertaken to gain first-hand knowledge of the area, to conduct interviews, and to personally apply preliminary questionaires with structured and open-ended questions. The personal application of a number of questionaires assisted in the identification of any problems of clarity in the formulation of the questions and also in pointing to other questions that ought to have been included in the questionaire.

During this field survey questionaire-based interviews were conducted with 56 farmers: 27 in the Sutherland district, 10 in the Noupoort district, 10 in the Britstown district and 9 in the Kenhardt district. Answers to the open-ended questions were recorded on tape. Further interviews were conducted with the Town Clerks of the respective towns, managers of Farmer's Co-operatives and business enterprises in the towns, leading residents with particular knowledge of the area, chairmen of the local farmer's associations, and the Agricultural Extension Officers responsible for the four districts. The extension officers supplied names and addresses of all the farmers in these districts. The opportunity was also used to secure the co-operation of extension officers and leaders of farmer's associations in the form of an undertaking to encourage farmers to complete a questionaire that would be mailed to them at a later date.

Secondly, revised questionaires were mailed to the 653 farmers named in the address lists. An example of this questionaire is given in Appendix A.

The questionaire was designed to provide information that would allow the construction of a farm profile (questions 1 to 3), a farmer profile (questions 4 to 8), a farming enterprise profile (questions 9 to 12, 18, 19 and 21), an indication of the perception of drought and the condition of the environment (questions 13 to 15, 16.1, 16.2, 17.1, 17.2 and 22), the effect of the previous and current droughts (questions 16.3 to 16.4 and

17.3 to 17.4), and an analysis of responses to the drought (question 20, parts 1 to 13).

Answers to these questions would provide the basic information to satisfy the requirements of the second of the three problems posed in paragraph 0.4, i.e. to identify the full spectrum of responses to the hazard situation.

Besides being an attempt to identify variables that affected responses, a major objective of the questionaire was to attempt to identify a combination of response measures that would indicate optimal adjustment to drought; in other words to identify the characteristics of a farming enterprise displaying the ability to withstand the detrimental effects of drought. Correlation of one or a number of attributes of the farm, farmer or farming enterprise with drought effects and ameliorative responses would therefore allow the last of the three problems identified in paragraph 0.4 to be addressed, i.e. to identify appropriate hazard reduction measures.

Of the questionaires originally mailed 27,6 per cent (180) were eventually returned. Due to the nature of most of the answers, non-parametric methods of statistical analysis had to be employed, and cross tabulations were carried out in an attempt to establish association amongst the variables. The results of this analysis are set out in chapter seven. Tables displaying the basic data contained in the returned questionaires, are given in Appendix D.

2.2.2 Floods

In contrast to droughts which are areally wide-spread in their occurrence and effect, floods are much more localised. Interviews with farmers and other inhabitants of the study area confirmed that a low level of flood hazard, associated with sudden heavy downpours occurred widely throughout the area. Losses attending such floods were very small and included damaged fences, small-scale soil erosion, the possible loss of a few sheep and the erosion of farm roads. Flood hazard on this scale was accepted as a characteristic of the environment and either regarded as being of little consequence or largely ignored by the farmers.

Studying the flood hazard and the response of humans to it therefore required a procedure which would first of all identify those areas where a significant level of the hazard existed. An obvious approach, yet one which would be restricted in its scope would have been the direction of attention to those areas inundated by major historical floods. In view of the fact that most major floods in South Africa have an estimated return period of as long as 100 or even 200 years, the predictive value of such an approach would have been very limited. With reference to floods in Australia, Askew and Pilgrim (1979) confirm that the study of major historical floods was an inappropriate base for the future planning of such inundated areas. What was required as a starting point was the identification of flood-prone areas and the degree of human occupance of these areas in a way that would render the occurrence of any floods significantly hazardous. A means of quantifying the magnitude of the hazard was implied as an important requisite.

There is no co-ordinated information on the occupation or utilisation of flood-prone land in South Africa. Stream-flow data is recorded at numerous gauging stations situated at various points along the main rivers. Flood peaks are calculated by indirect methods and expressed in m^3/s. Flood heights in metres are also recorded at certain stations and this data is available from official sources. It is standard practice to compute the peak discharge at the sites of all important dams and bridges across rivers and streams so that the design of the structures can be adapted according to the recurrence interval of peak floods. No information is, however, readily available on the horizontal component of floods. Yet the horizontal extent of flooding is of great significance as a hazard to the human occupation and utilization of flood plains.

Two essential prerequisites to a study of the flood hazard in the area are therefore the quantification of the hazard and the identification of the geographical patterns of the hazard.

2.3 Quantifying the hazard

White's comment that "no natural hazard exists apart from human adjustment to it" (White, 1974: 3) highlights the fact that two categories of influences are basic to the flood hazard. These are the natural environment in which the fundamental determinants of floods are found and the cultural environment in which the effects of the flood are experienced. The two groups of influences are not mutually exclusive but for the sake of analysis they are considered separately. The factors from the natural environment are essentially those of runoff and its variability and are easily quantifiable. Quantifying the human factors which relate to the nature of the occupation of flood-prone areas and the effect of floods on human lives and property is far less easy.

To begin with, the value of human life cannot be expressed in numerical terms. It is also important to realise that the magnitude of the hazard is not always a simple function of the capital value of the endangered property. High capital value structures such as bridges are often less prone to damage by floods than fords, culverts or causeways because they are designed to withstand the force of the water. By the same argument it is inappropriate to base budgets for flood losses on the capital value of property. Indeed, assessing the value of threatened property for hazardous events of uncertain magnitude and occurrence requires inputs of data from a number of different sources, much of which is not readily available. Clearly, quantification of hazard following these lines would be possible only for small areas and for the identification of macro-patterns, which are required for this survey, a different approach is required.

2.3.1 The natural environment as a factor

Of the various factors in the natural environment that play a role in the generation of floods, climate and more specifically rainfall is the most fundamental. Quantity, duration and intensity of the rainfall are important initial causes while consequent runoff depends on the physiography, hydrography, vegetation, soils and substrata of the catchment. More detailed analyses of these factors and the role they play in the occurrence of floods in the region, are given in chapter 4.

Here it is merely necessary to be reminded that the area under consideration has already been described as being arid to semi-arid, receiving a rainfall of less than 600 mm annually. Also to note that the rainfall is subject to great variability, and that that condition this being reflected in the runoff patterns of rivers originating in the area. Large positive runoff deviations are responsible for floods and to quantify the hazard some measure of variability is required. The following method was employed:

The areal unit of measurement was a square of 15' of latitude by 15' of longitude, coinciding with the area covered by a sheet of the S.A. 1:50 000 topographical series. For each unit area (1:50 000 sheet) containing a gauging station a **runoff variability index** was calculated:

$$V = \frac{100\,\sigma}{x} \qquad (1)$$

where x is the average annual runoff and σ the standard deviation of the set of data. The multiplication factor of 100 was introduced to express the variability index as a percentage. The index was calculated from published data on the flow of rivers as recorded at the various gauging stations along the main river courses. A number of the stations have a recording period of less than 15 years and these were disregarded for the purpose of the calculations. Due to the absence of recording stations in some parts of the region, values for such gaps in the network were interpolated. The pattern of runoff variability is discussed in chapter 4.

2.3.2 The cultural environment as a factor

In the whole of the extensive sheep farming region in the Karoo the climate precludes any significant cultivation of agricultural crops except under irrigation and cultivated land is more or less limited to scattered, narrow tracts along river courses. Tiny patches near strong boreholes occur here and there and the main crops are fodder, especially lucern, cereals and small quantities of fruit.

Sites close to rivers are often the most attractive for human settlement and many farmsteads and towns are located on the banks of some of the larger rivers. In relation to the flooding of these rivers, the location of the cultivated land and human settlements is hazardous.

Not all inundations are detrimental. In the north-western panveld zone, especially along the Sak River, occasional flood waters are diverted into shallow basins bordered by low earthen walls forming so-called *saaidamme*. When the water has subsided or drained away, the crop, generally wheat, is sown on the mud

floor and good harvests can be reaped even from one such inundation (Wellington 1955).
Other features of the cultural environment that are subject to damage by floods are the road and railway crossings of rivers. Bridges span the rivers at all the main road and railway crossings and these are designed to withstand the force of floodwaters usually of the 50 or 100-year return magnitude. However, many of the minor and farm-road crossings are simply fords across the rivers and even relatively minor floods can cause considerable damage to the approaches and traverses, and often disrupt communication. The deposition of large quantities of silt can be as damaging as the force or effect of the flood water itself.

In order to identify areas of greatest hazard in general terms, the use of simple indices derived from readily available data is desirable. The most relevant sources of input data relate to aspects of urban and rural settlements, road and rail crossings and cultivated land along rivers.

Topographical maps of the SA 1:50 000 series served as the basis for measurements made along streams and rivers. It is assumed that flooding, caused by a stream overflowing its banks, is not likely to occur within five kilometres of its source. Catchments are assumed to be too small for sufficient concentration of runoff to cause flooding by stream headwaters shorter than 5 km.

Any flooding is likely to be as much a direct consequence of a heavy downpour as of a stream overflowing its banks so close to its source. No measurements were therefore made above this point.

While elevation above the level of a channel is a prime factor in the hazard of flooding, the contour interval of 20 metres used on 1:50 000 sheets is too great to permit meaningful use of these maps for vertical measurements. For the same reason it is impossible to identify small flood plains on these sheets and a horizontal surrogate had to be used. In respect of structures in urban or rural settlements, therefore, a site is considered to be hazardous if it is located within 50 metres of a river or stream channel.

A simple count was made of rural settlement structures situated within 50 metres of a river channel. A rural settlement structure is defined as any building, outbuilding, shed, pumphouse or windpump without any distinction being made between individual types following the argument set out in a previous paragraph. The number of road and rail crossings of rivers and streams was also determined, whether they are constructed bridges or merely fords. Urban settlements situated on streams and rivers were identified and then the number of settlement structures counted by referring to aerial photographs, since individual structures on urban sites are not indicated separately on the 1:50 000 sheets. A final measure of hazard to human occupation is the river frontage of cultivated land. It is assumed that such cultivated land will show a distinct predilection for location on the level land of a flood plain. Frontage was measured in kilometres by means of an opisometer.

2.3.3 Flood hazard index

A flood hazard index F_H for each unit area was then calculated as a relative measure of the threat of floods to human life and property. Since floods are associated with large positive variations in runoff, the flood hazard increases with increasing variability V and hence was assumed to be proportional to it:

$$F_H \propto V \qquad (2)$$

The concept of hazard implies the presence of human activity and the magnitude of flood hazard is also assumed to be proportional to the extent to which human activity intersects with flood-prone regions. Using the measures: number of rail crossings N_{rail}; the number of road crossings N_{road}; the riparian land frontage in km L_{rip}; the number or rural settlement structures N_{rur}; and the number of urban settlement structures N_{urb}, it can be stated that

$$N_{tot} = N_{rail} + N_{road} + L_{rip} + N_{rur} + N_{urb} \quad \text{----} \quad (3)$$

and that

$$F_H \propto N_{tot} \quad \text{----------------} \quad (4)$$

The proportionalities can be combined in the single equation

$$F_H = VN_{tot} \quad \text{------------------} \quad (5)$$

where V and N_{tot} are respectively defined by (1) and (3). Although both V and N are taken as time-independent functions of area, it should be noted that V especially can change considerably with variation of the time interval over which basic runoff measurements are taken. As indicated earlier, measurements in this analysis have been taken over periods of a year.

The individual indices and the composite index F_H were then mapped to reveal the geographical patterns of the hazard. These patterns are discussed in chapter 3. Eleven areal units comprising the area covered by the 1 : 50 000 topographical sheets Kruisrivier 3321BD, Vleiland 3324BA, Graaff Reinet (North) 3224BA, Adelaide 3226CB, Fort Beaufort 3226DC, Letskraal 3224BB, Cradock 3225BA, Niekerksberg 3225DC, Cookhouse 3225DB and Somerset East 3225DA emerged with high F_H values of more than 50.

Further study of the flood hazard focused on the area covered by these sheets.

2.4 Research procedure

Farmers, urban dwellers in flood-prone locations, urban and provincial administrators and the government departments of Water Affairs and Agriculture are the main groups affected by the flood hazard.

The names of the farms with hazardous locations were extracted from the sheets mentioned in the paragraph above and the addresses of their owners obtained from the relevant Agricultural Extension Officers. A questionaire was sent to each of the 124 farmers indentified in this way. An example of this questionaire is contained in Appendix B. The questions were aimed at providing information on the farm (questions 1, 2, 8 and 10), the farmer (questions 3 and 4), the farming operation (6, 12 and 13), the farmer's experience of flooding (questions 5, 14, 15 and 16), his perception of the flood hazard (questions 7, 9 and 11), and adjustments to the flood hazard (question 17 parts 1 to 8). As in the case of the questionaire on drought the information provided in the answers could be analysed for possible correlations to serve as a basis for explanation.

Of the total of 124 farmers to whom a questionaire was sent, 38 (30,6 per cent) returned the completed questionaire. The information was analysed by cross-tabulation procedures. Tables displaying the basic data contained in the returned questionaires are given in Appendix E.

Graaff-Reinet and Cradock were the two towns with the greatest number of residents inhabiting hazardous flood-plain land. The sites likely to be inundated by flood water were identified in consultation with the respective town engineers and town clerks and the addresses of residents obtained from the telephone directory. A 50 per cent random sample of names was drawn and 80 questionaires sent to the residents by mail. Only 16 (20,0 per cent) responded with a completed questionaire. An example of the questionaire is contained in Appendix C. The questions provided basic information on the householder (questions 2, 3, 4, and 7), his/her perception of the hazard (questions 5, 8, 9,and 10), his/her experience of flooding (question 6), the householder's anxiety level with respect to the flood hazard (questions 11 and 13) and his/her response (question 13). Appendix F contains tables displaying the basic data furnished by these questionaires.

The response of municipal authorities to the hazard was elicited by a letter to all town clerks in the study area as a whole containing questions relating to both the drought and flood hazard. Specific interviews were conducted with the town clerks in Graaff-Reinet and Cradock. Interviews with the Provincial Roads Engineer and the Chief Civil Engineer of the S.A. Transport Services provided information on the response of these two institutions to the flood hazard affecting their field of administration.

Laingsburg was not included as a major element in this study. As mentioned earlier the emphasis is placed on human response to *hazard*. The devastating floods of 1981 left Laingsburg an area in which the hazard of flooding had been realized. People had been relocated to an area in which the hazard no longer existed. The adjustments that had been made, were related to the disaster rather than the hazard as the first cause. Indeed, it was the lack of appropriate responses to the hazard that had lead to the disaster, and it is in this context that Laingsburg is referred to in the study. The absence of a high current level of hazard, however, disqualifies the town from being studied on the same basis as the others identified earlier.

CHAPTER 3

GEOGRAPHICAL PATTERNS OF THE DROUGHT AND FLOOD HAZARD

3.1 The Historical Record

Droughts and floods occur with varying degrees of severity. Moreover, the perception of when a drought is thought to exist is also subject to individual variation. This makes the interpretation of historical records on floods, and droughts in particular, ambiguous and often difficult to interpret. Vogel (1986) has analysed travellers' journals, settlers' diaries and other historical sources for the Cape Colony in the nineteenth century, and dry and wet periods have been distinguished.

Reports of droughts characterised the periods 1825-29, 1834-43, 1849-51, 1872-78 and 1881-85, whereas flood conditions were reported during the period 1830-33 and further wet conditions occurred between 1844 and 1848, and 1852 and 1860. The climate during the nineteenth century appears to have been very similar to that of the twentieth century (Preston-Whyte and Tyson, 1988).

From meteorological records it is evident that wet years occurred from 1918-19, 1924-25, 1937-44, 1953-61 and 1971-82, and dry spells during the periods 1926-33, 1945-52, 1962-70 and 1978-83.

Preston-Whyte and Tyson (1988 : 262) note that "in general, dry spells have been more persistently dry than the wet spells wet." Also that "Dry spells have had a greater areal extent and spatial homogeneity than wet spells. With each successive wet spell since the turn of the century the areal extent of the excess-rain areas has increased". As a physical source of hazard, droughts and floods appear to be increasing rather than decreasing on the grounds of this evidence.

A number of studies, notably those by Tyson, Dyer and Mametse (1975), Dyer (1976) and Louw (1983), have shown that although the general pattern of rainfall variability is random, significant non-random components are clearly identifiable. An 18 to 20 year rainfall oscillation has been found to exist in the main summer rainfall region in the eastern half of South Africa. It appears to break down into an oscillation having a wavelength of 10 years in the southern part of the country, part of which is included in the study area. A further oscillation with a wavelength of 2-3 years also occurs, this periodicity being most prominent in the region falling within the northern half of the study area. Tyson *et al.* (1975) point out the striking similarity between the distribution of seasonal rainfall regimes and the distribution of the dominant regional oscillations. The spells of wet and dry years have not always affected all regions equally, neither at the same time. However, as a whole wet and dry periods clearly exist. Since both droughts and floods are rainfall related phenomena their occurrence is likely to coincide with dry and wet periods respectively.

3.2 Geographical patterns of drought hazard

The geographical extent of drought conditions was investigated by De Swardt and Burger (1941), and Verbeek (1966) for the periods 1926 to 1939 and 1948 to 1962 respectively. These studies are based on the analysis of the districts declared to be drought-stricken during the respective 14 year periods. Their findings are summarised in figures 3.1 and 3.2. During the 1926 to 1939 period no part of the study area escaped the drought. The drought was the most protracted in the western half of the study area where it persisted for 60 months and longer. During the period 1948 to 1962 much of the western half suffered drought conditions for between 36 and 72 months, while extended drought conditions persisted in a zone surrounding this western core.

Comparing these two patterns with the wet and dry cycles in the occurrence of rainfall it is clear that the 14 year period 1926 to 1939 co-incided largely with the dry years 1926 to 1933, only approximately two years of the ensuing moister cycle 1937 to 1939 being included in this period. Essentially, therefore, it coincided with a dry spell in the occurrence of rainfall. The 14

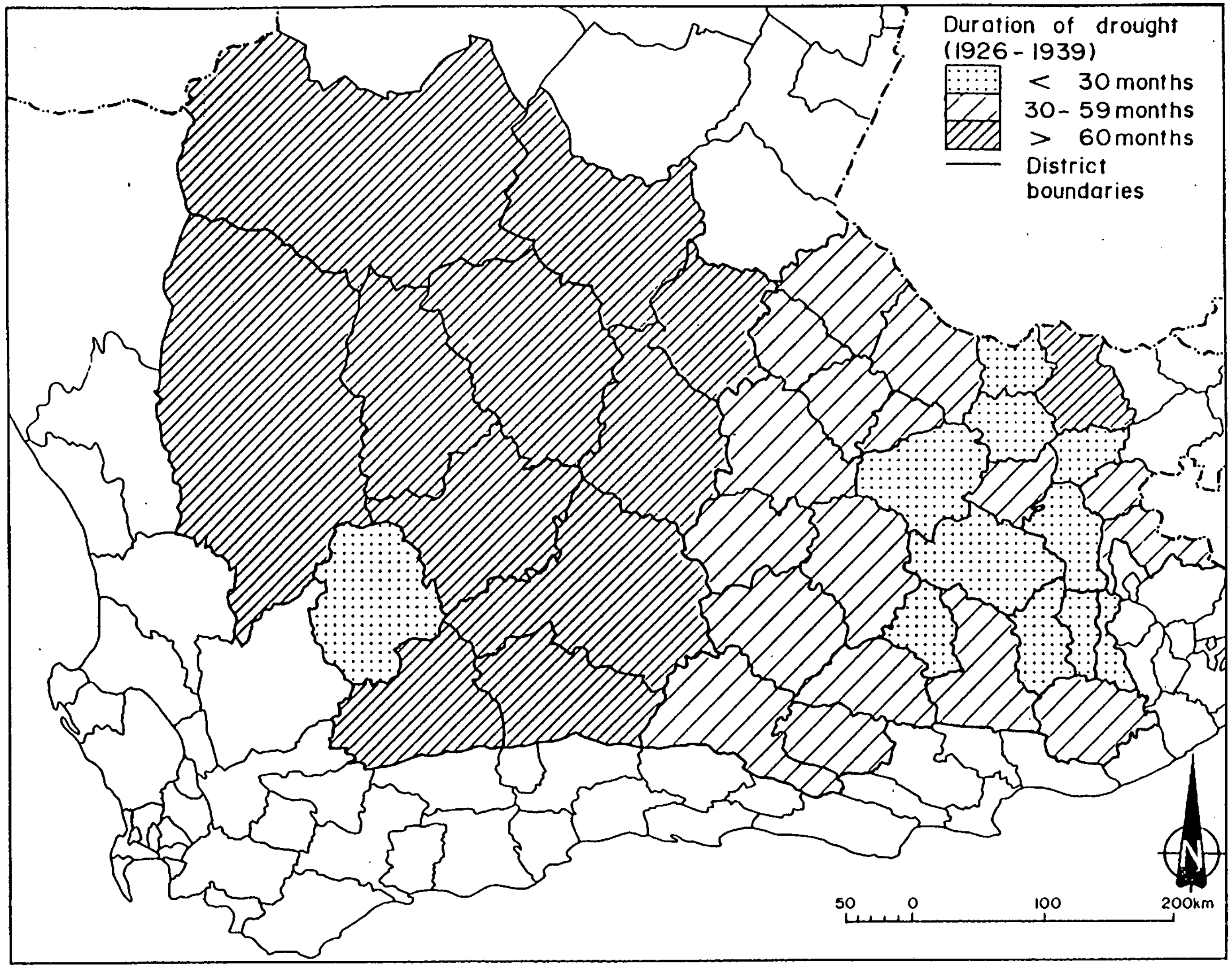

Fig. 3.1 Duration of drought: 1926 - 1939

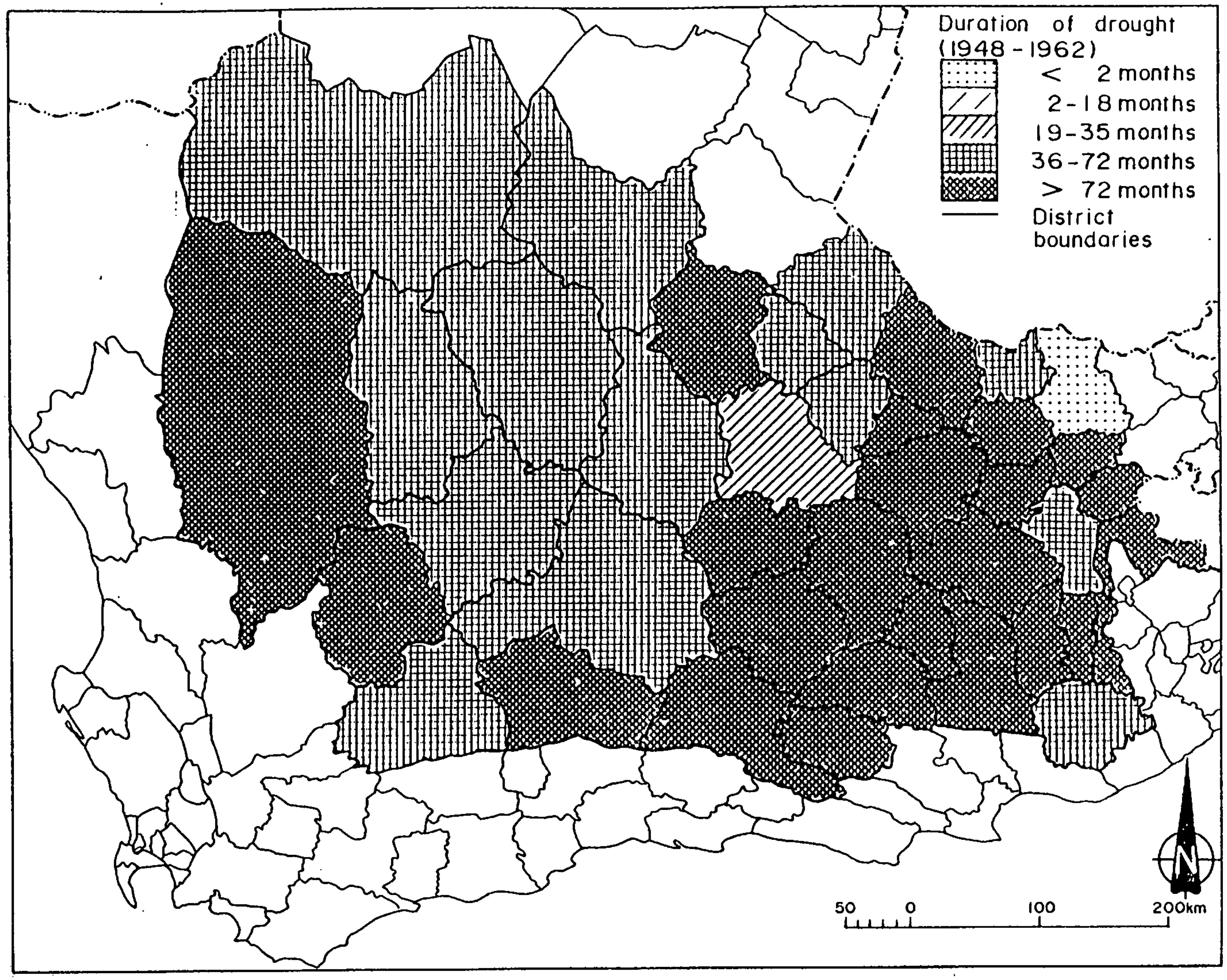

Fig. 3.2 Duration of drought: 1948 - 1962

year period 1948 to 1962 included four years of the 1945 to 1952 dry cycle, but also eight years of the 1953 to 1961 wet cycle. Drought conditions during this period therefore appear to be less protracted than those of the period represented by the previous map.

In figure 3.3 the distribution of drought conditions in the 1977 to 1986 period is shown. This period coincides with the most recent dry spell in the study area. It clearly shows that the area with the most protracted drought (those districts declared drought-stricken) for six years and more, are those situated in the zone of lowest average rainfall and greatest rainfall variability, and also emphasises the western, particularly north-western part of the study area as the longest affected by drought.

A further perspective of the geographical distribution of drought conditions during the 1977 to 1986 drought is given in figure 3.4. Here districts are classified according to the highest category of drought aid granted in this period. A comparison of maps 3.3 and 3.4 indicates that not only was the drought the most protracted in the north-western part of the study area but that it was also the most severe in this locality, with districts here receiving phase 5 drought aid.

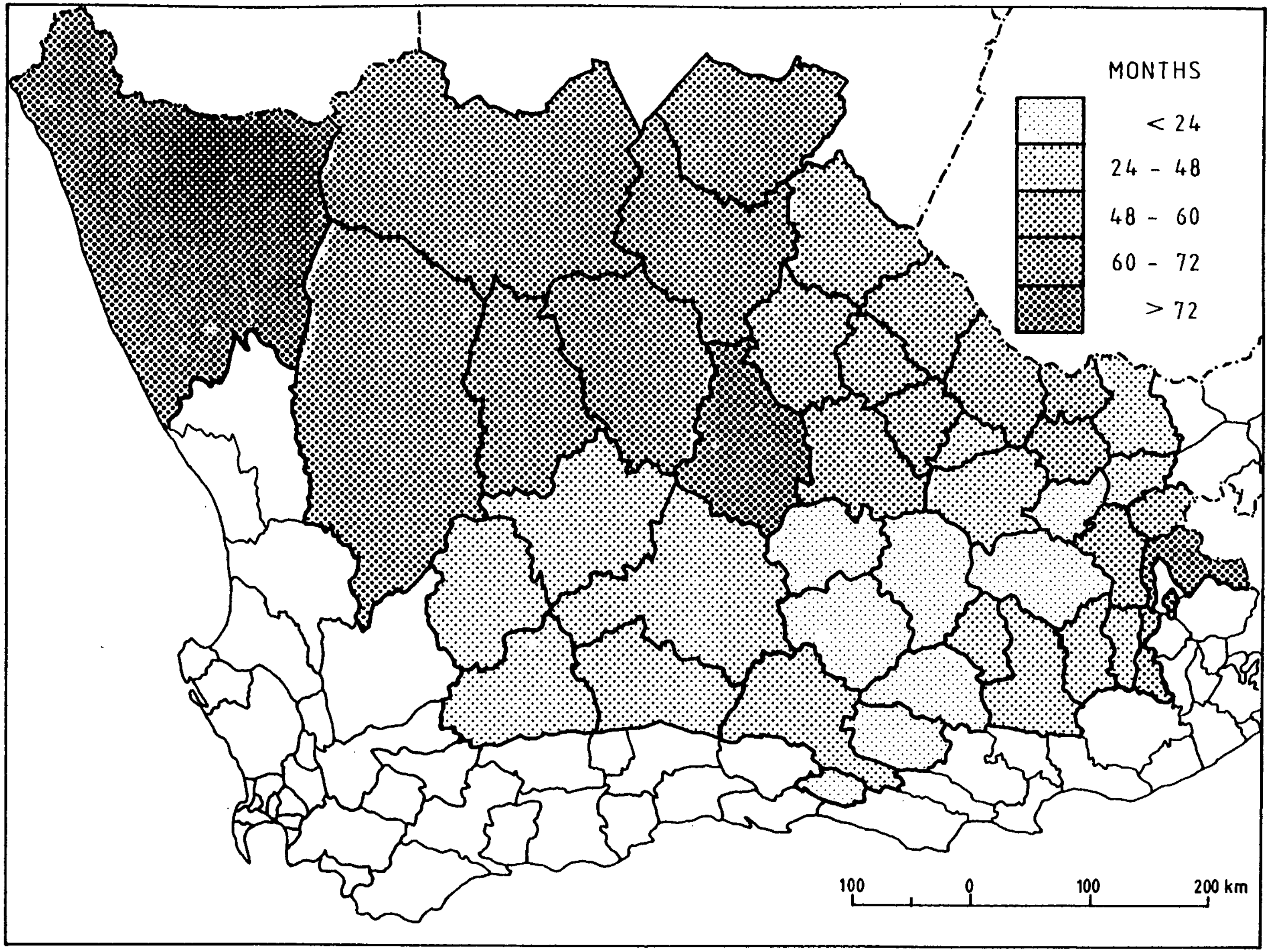

Fig. 3.3 Duration of drought: 1977 - 1986

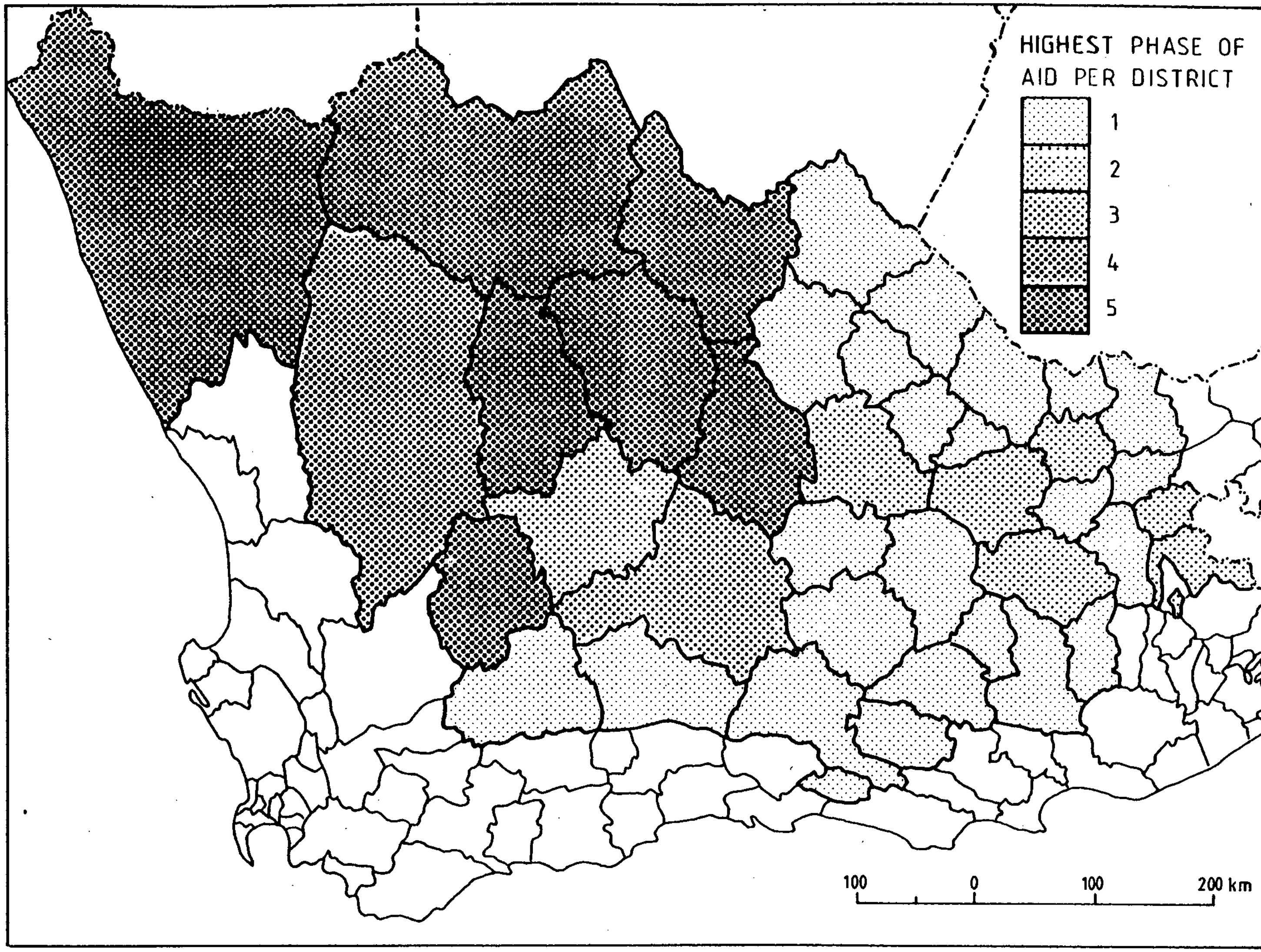

Fig. 3.4 Distribution of drought conditions (highest phase of aid)

It is beyond the scope of this study to analyse further the geographical patterns of drought. It should, however, be clear that no part of the study region can be seen to be without the hazard of drought, though droughts appear to be more prolonged and severe in the western than in the eastern half.

3.3 Geographical patterns of flood hazard

The geographical patterns of flood hazard discussed here are the results of the application in the study area of the various measures identified in chapter 2 and used in the quantification of the hazard. Figures 3.5 to 3.10 show the pattern of distribution of hazard according to each of the individual measures used.

3.3.1 Runoff variability (figure 3.5).

For the region as a whole runoff variability (V) is lowest in the north-east and east and increases towards the west, culminating in a high of 130 per cent in the Renoster River area north-east of Sutherland. However, this general pattern is disrupted by two areas of high variability in the south, one centred on the upper part of the Groot River in the southern Great Karoo, the other in the valley of the Little Fish in the south-east. The two areas are located immediately downstream from two zones of maximum

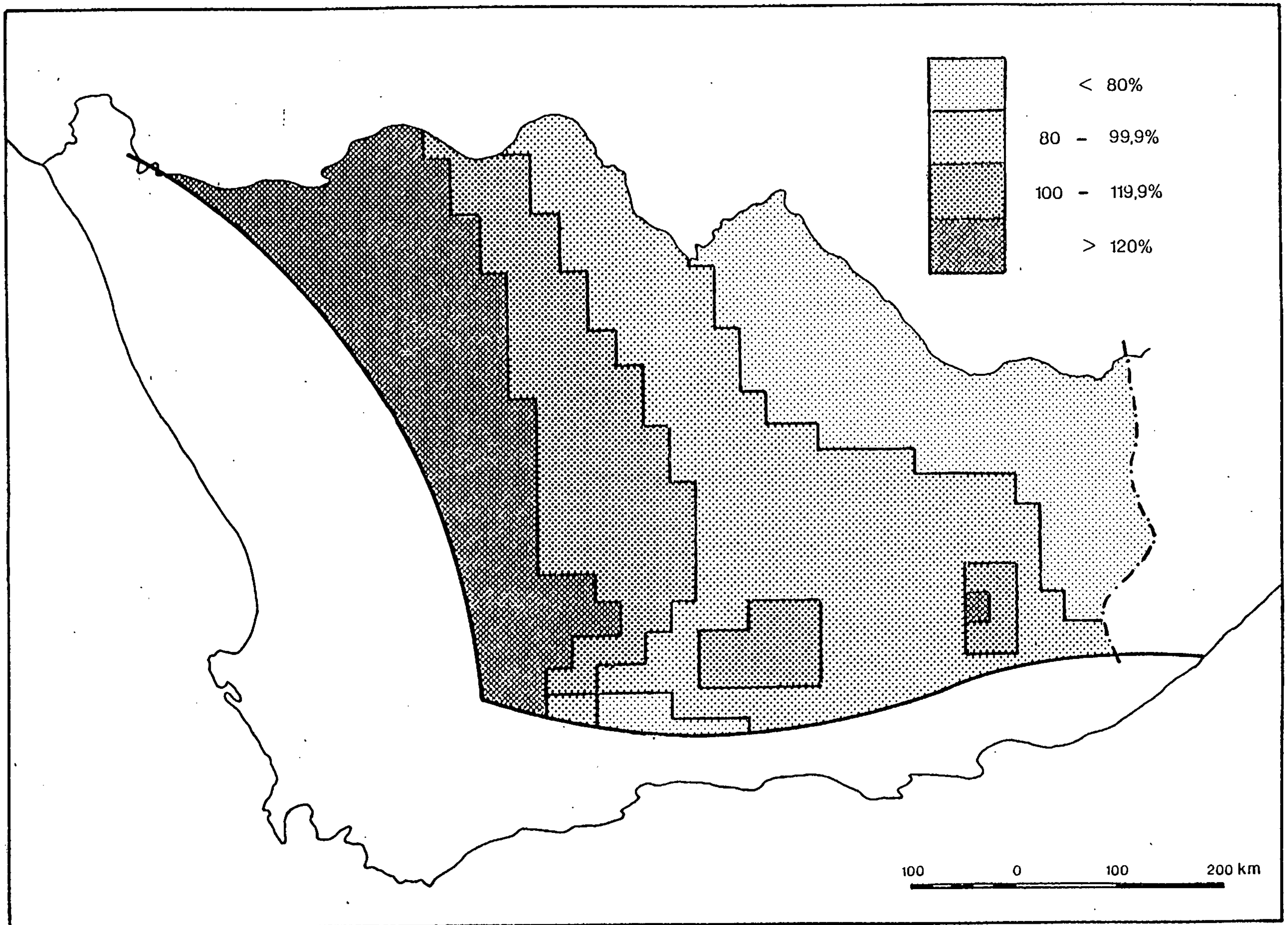

Fig. 3.5 Percentage runoff variability (100 σ / x)

observed storm rainfall with a yield of more than 100 and 200 mm respectively (Midgley, 1972 : Appendix D). Occasional synoptic conditions favouring the triggering of unstable air along the edge of the Great Escarpment can be offered as a possible explanation of this pattern. Van Zyl has noted that thunderstorms along the escarpment edge in the Komsberg region played a significant role in the devastating Laingsburg floods of 1981. Estiė (1981) also notes the significance of the role played by mountain barriers in increasing the rainfall at the time of the Laingsburg flood.

3.3.2. Length of riparian land frontage (figure 3.6).

Low rainfall, irregularity of stream flow, high rates of evaporation and an absence of irrigation dams exclude the possibility of agriculture on a significant scale over most of the western part of the region. The hazard of flood damage to cultivated fields in this area is therefore negligible. This observation is confirmed by the experience of farmers interviewed in the area during the field survey. Only on the western margin where winter rainfall becomes significant is there a narrow belt of higher hazard values which follows the course of the Renoster River. A belt of high values also occurs along the flood plains of the Olifants and Kammanassie rivers. Hazard in relation to cultivated land is clearly a problem in the eastern part of the

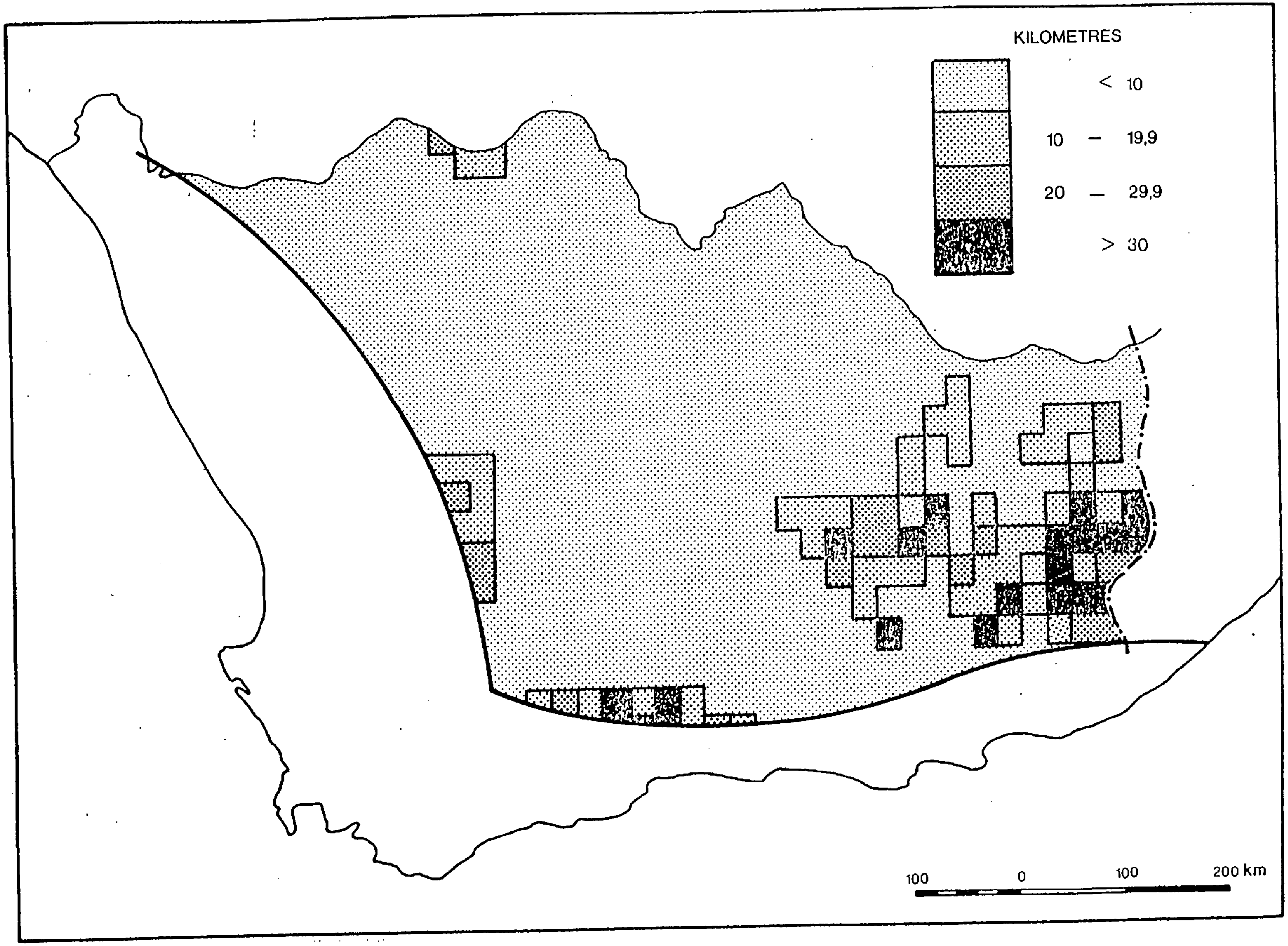

Fig. 3.6 Riparian land frontage (km)

region. Here the somewhat higher rainfall makes agriculture more feasible and rivers, which are less episodic in their flow, provide water for irrigation more reliably. Zones of high hazard are concentrated along the Sundays, Kat, Great Fish, Black Kei, Great Kei and Koonap rivers where flood-plain land is used more intensively for agricultural purposes.

3.3.3 Number of rail crossings of rivers (figure 3.7).

Expectedly, hazard zones are linear and follow the routes of the railway lines through the region. Elevated hazard values occur where drainage density is high or where the railway line is routed through a narrow valley and repeatedly crosses the same stream.

3.3.4 Number of road crossings of rivers (figure 3.8).

Linearity is largely absent in the pattern here. This is because there is a vastly denser network of roads than railway lines and crossings are more widespread throughout the region. The threat of flood damage to property is often greater on farm roads which frequently cross rivers at fords or low level causeways that have to be repaired after even very moderate floods, while major roads are tarred and along them streams are bridged with structures built to withstand floods of considerable magnitude. Clearly, here high values are a function of total road and drainage density.

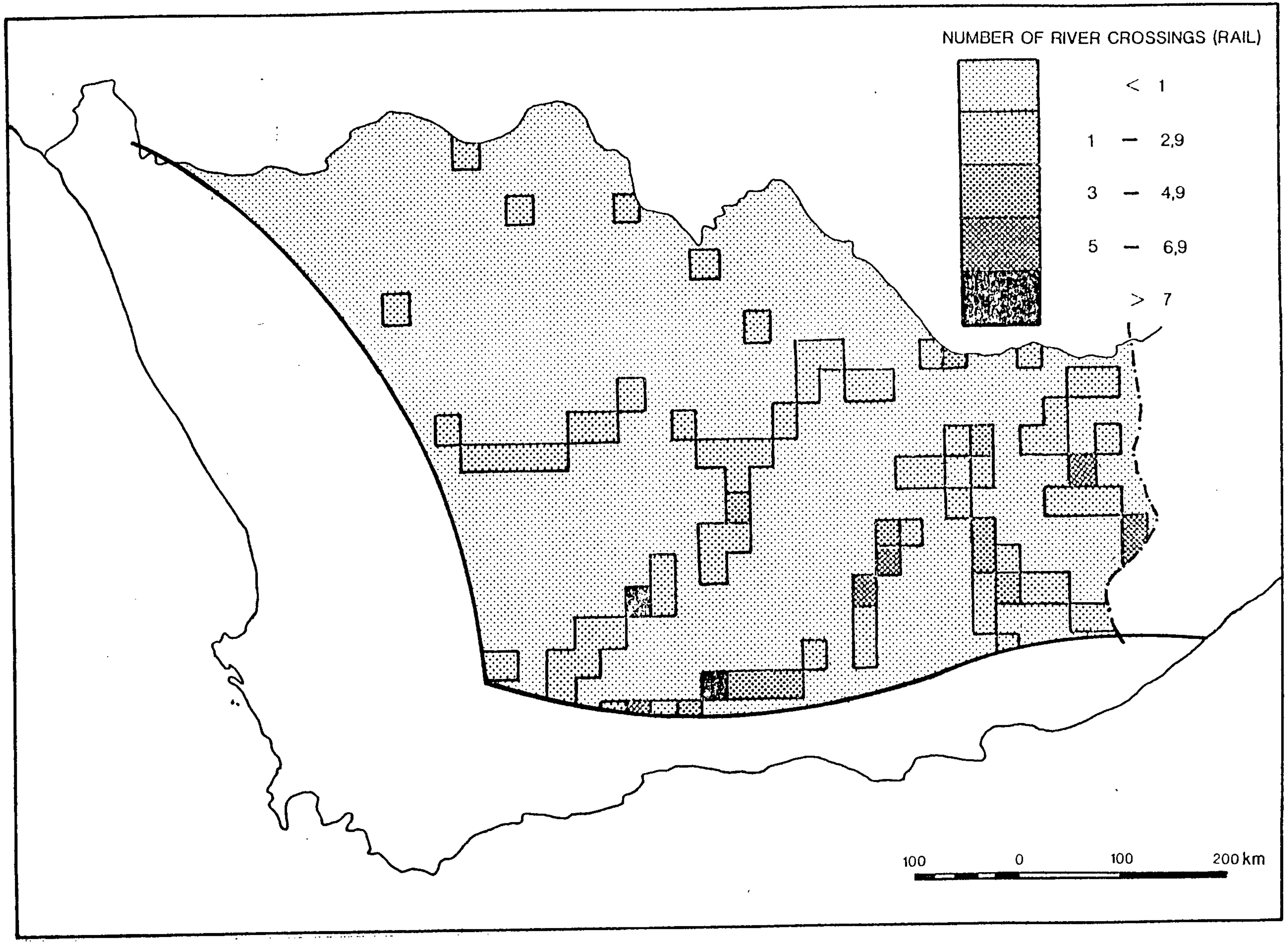

Fig. 3.7 Number of river crossings (rail)

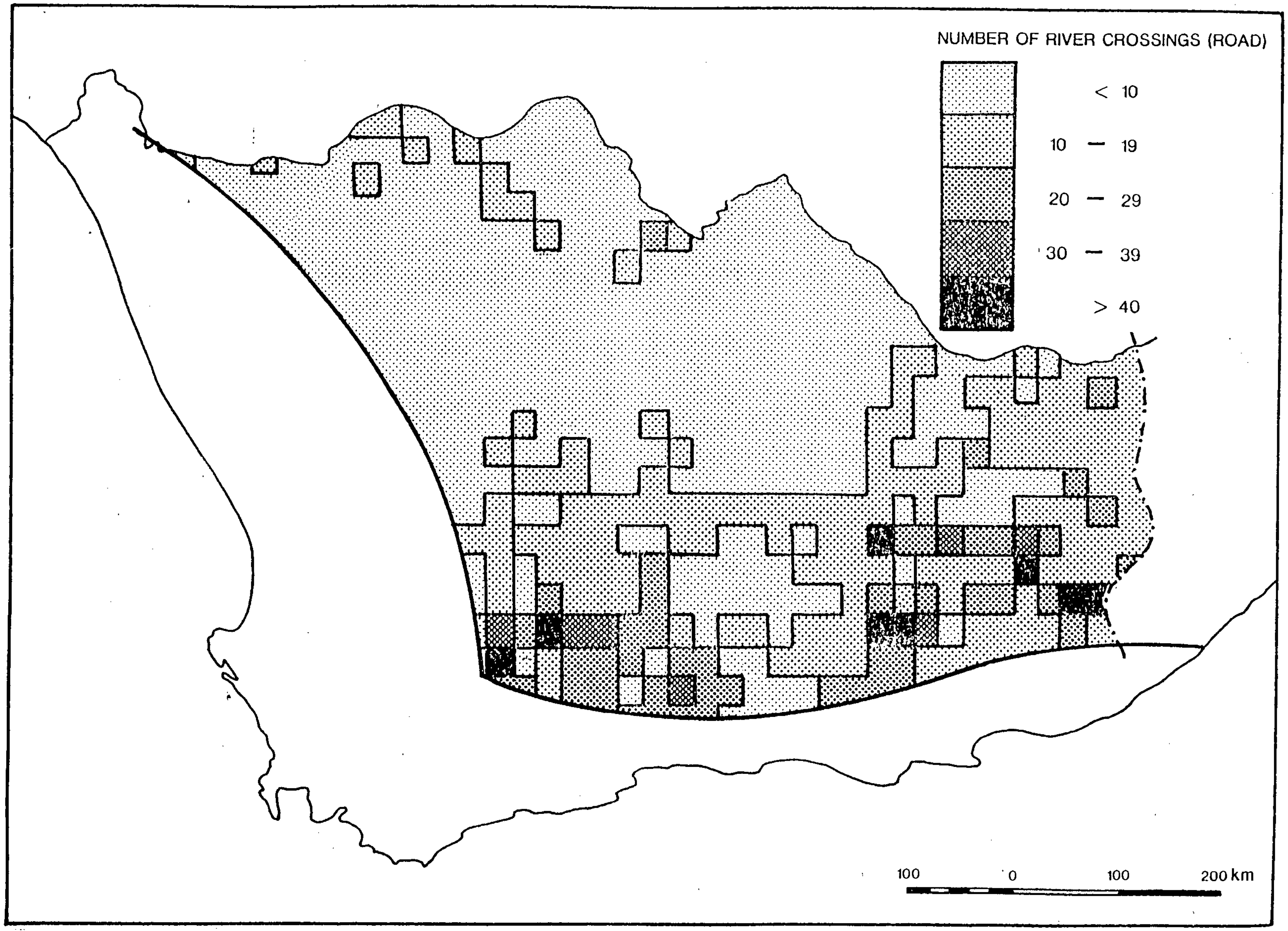

Fig. 3.8 Number of river crossings (road)

3.3.5 **Number of rural settlement structures** (figure 3.9).

The pattern of hazard relating to rural settlement structures closely resembles that of riparian land frontage. Higher rainfall (though still inadequate for dryland agriculture) and streams and rivers that are more reliable in their flow, encourage the planting of crops and the erection of structures necessary for irrigation (e.g. pumphouses) on river banks. Dwellings and other farm buildings are also occasionally located on flood plains close to the river channel where the hazard of flooding is not perceived to be significant.

3.3.6 **Urban settlement structures** (figure 3.10).

The following urban settlements have structures (mainly houses and outbuildings) that are situated in hazardous locations: Graaff-Reinet, Beaufort West, Laingsburg[1], Steynsburg, Queenstown, Kenhardt, Cradock, Sterkstroom, Fort Beaufort, Merweville, Prieska, Noupoort, Bedford, Richmond, Victoria West, Pearston, Carnarvon, Jansenville, Molteno, Jamestown, Adelaide, Steytlerville, Nieu-Bethesda and Vosburg. The first six in the list all have more than 20 structures situated in hazardous locations (Beaufort West more than 30 and Graaff-Reinet more than 40). It should be remembered that the availability of water in a generally arid environment was an important consideration in the

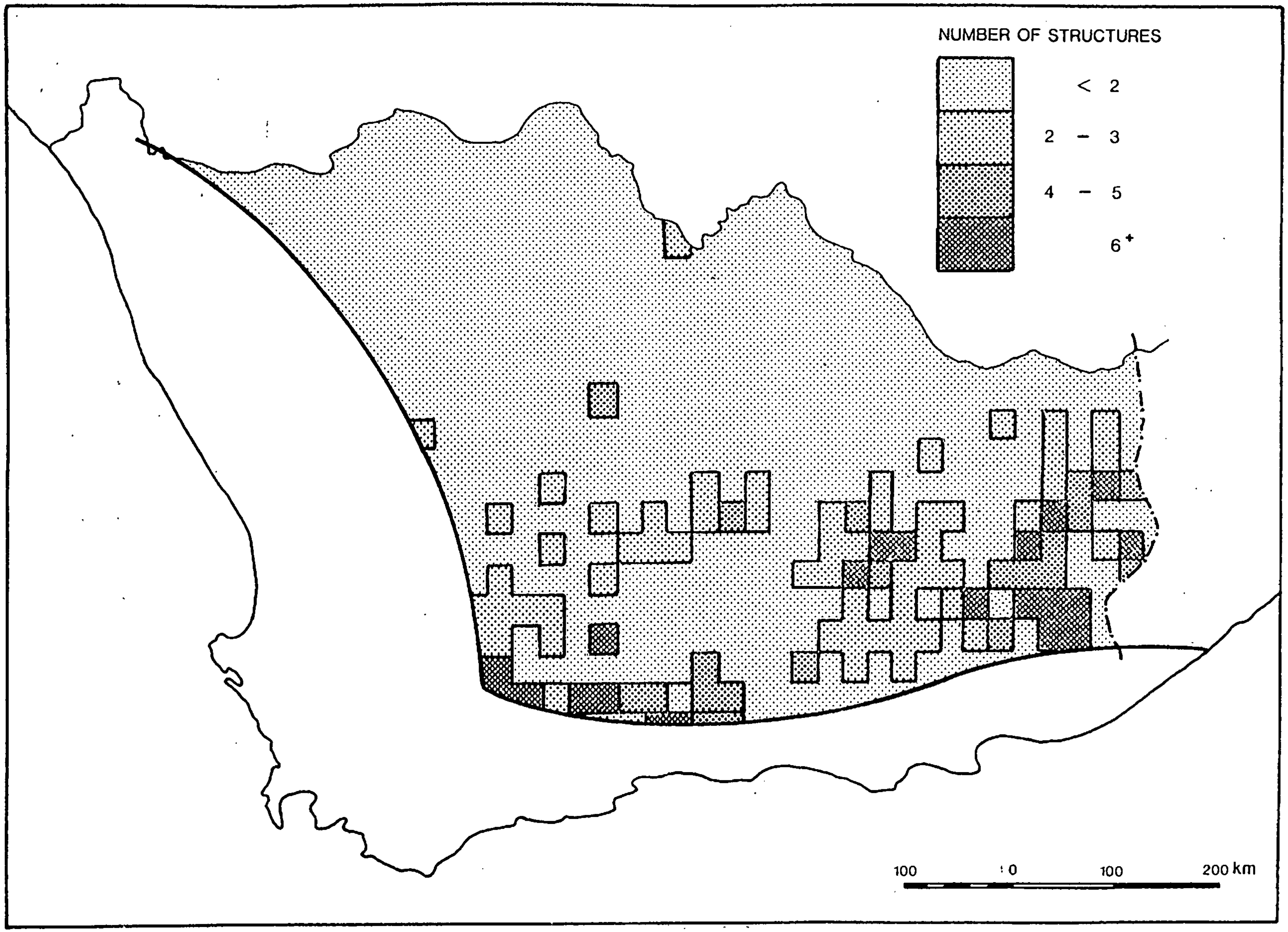

Fig. 3.9 Number of rural settlement structures within 50 metres of a river channel

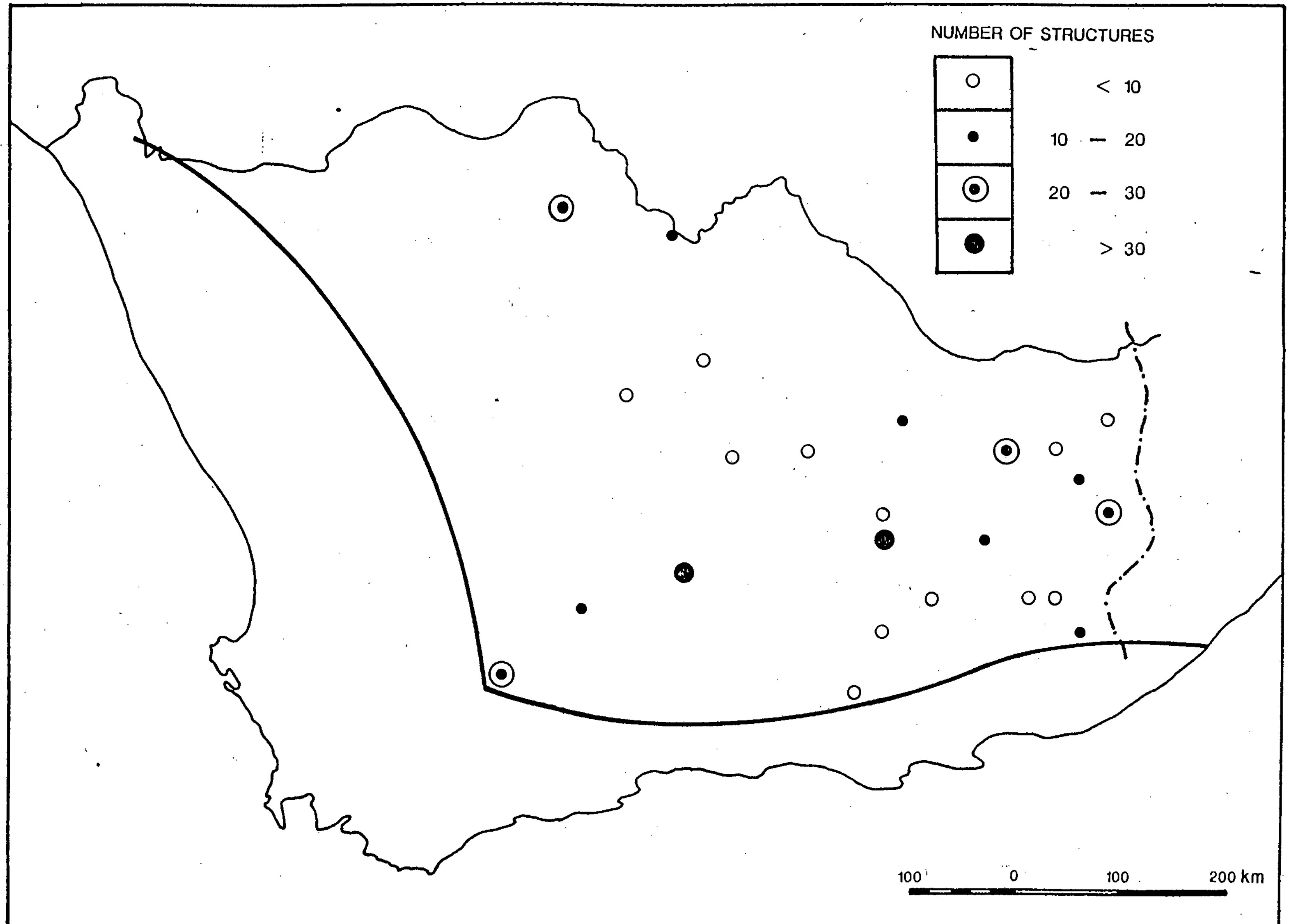

Fig. 3.10 Urban settlements with structures in hazardous locations

siting of these towns. Level flood-plain land adjacent to rivers was therefore a favoured location. The episodic flow of the rivers and the general aridity of the environment no doubt left the threat of flooding (the very reason for the existence of the level site) far from the minds of the early founders of these towns.

The towns can be classified into 3 groups according to their location with respect to the streams or rivers which flow through them:

(a) Towns on small rivers with short reaches upstream and small catchments. The danger of flooding in these towns is low. The towns in this category are Sterkstroom, Steynsburg, Bedford, Somerset East, Nieu-Bethesda, Merweville, Dordrecht, Molteno, Queenstown, Vosburg and Victoria West.

(b) Towns situated on the banks of larger rivers. These are Prieska on the Orange River, Fort Beaufort on the Kat River, Aberdeen on the Kraai River, Jamestown on the Skulpspruit, Pearston on the Voël River, Cradock on the Great Fish River, Steytlerville on the Groot River and Graaff-Reinet on the Sundays River. Due to much larger catchments and a much greater volume of water carried by these rivers, the danger of flooding is greater if the channel capacity is exceeded and water spreads onto the adjacent banks. The Orange, Great

Fish and Sundays rivers are the largest of these rivers. Flood control measures on the Orange have assisted in greatly reducing the hazard of flooding at Prieska. Graaff-Reinet and Cradock are the two towns most seriously threatened by flooding in this category.

(c) Some towns are situated at the junction of two or more streams. Laingsburg is situated at the confluence of three rivers, i.e. the Buffels, Wilgehout and Bobbejaans rivers. Other towns in this group are Kenhardt (Hartbees and Driekop rivers), Carnarvon (Carnarvonleegte and Bloudrif rivers), Noupoort (several tributaries of the Noupoortspruit), Richmond (Ongers River and Osfonteinspruit), Beaufort West (Gamka and Kuils rivers) Jansenville (Sundays and Brak rivers) and Adelaide (Cowie and Koonap rivers). The streams affecting Carnarvon, Noupoort and Richmond are fairly small, making the danger of flooding from them less serious.

Some of these towns where the danger of flooding is regarded to be more serious can be examined a little more closely.

Laingsburg is the classic example and the effect of the junction of the Wilgehout and Bobbejaans rivers with the Buffels River at the town was dramatically and tragically demonstrated as a major factor in the disastrous flood that struck the town in 1981. An important geographical factor that contributed to the damage is the east-west orientation of the topography to the south of the town (fig. 3.11). The Buffels River flows throught a gap in a ridge which flanks the town on the south. The two large tributaries (Wilgenhout and Bobbejaans rivers) join the Buffels River immediately upstream of the gap, and the ridge directed the flow of the tributaries towards the southern part of the town on the opposite bank. "It was the combined effects of all three rivers and the constriction of the poort which accounted for much of the damage in the southern part of Laingsburg between Zwartberg Street and the river" (Alexander and Roberts, 1981 : 14).

Futhermore the town is situated on flood-plain land on the inside of a bend in the Buffels River. Alexander and Roberts (1981) have given the reminder that when a river is in flood it tends to straighten its course, short-circut bends and scour out channels through deposits of smaller previous floods. This happened at Laingsburg resulting in buildings literally being swept away.

Another factor to be taken into account is the road and railway bridges crossing the Buffels River at the town. The openings of these bridges became choked with debris impeding the flow of water. This resulted in a raised upstream water level and additional flow being directed toward the town (Alexander and Roberts, 1981).

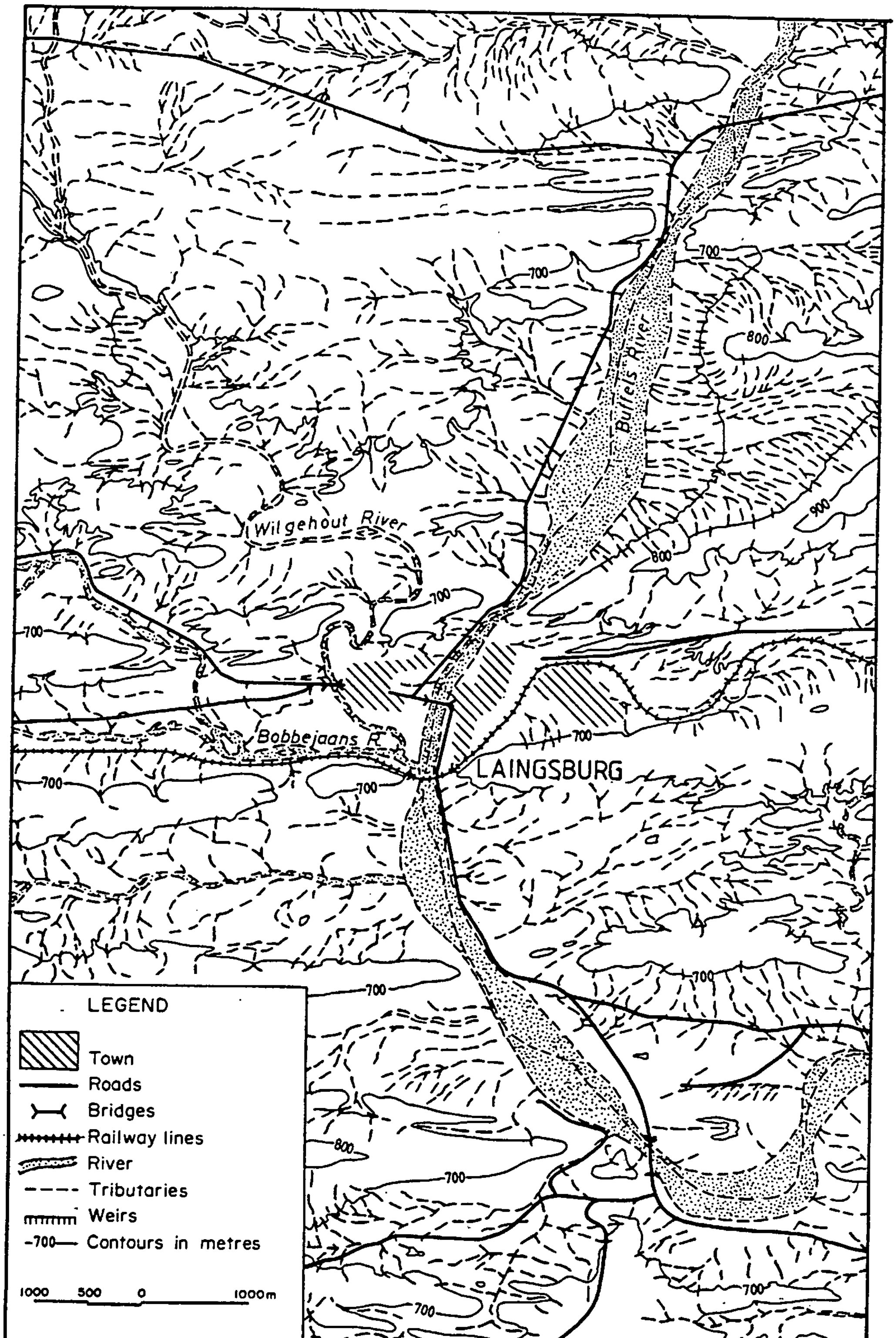

Fig. 3.11 Location of Laingsburg in relation to flood hazard factors

Much of the town of Graaff-Reinet is situated on a piece of flood-plain land almost entirely enclosed by a deep meander of the Sundays River (fig. 3.12). The levelness and low-lying nature of the site renders it susceptible to flooding when the Sundays River overtops its banks. The effect of short-circuiting a curve, as described with respect to Laingsburg, also applies here. The road bridge at the upstream end and the railway bridge near the downstream end of the loop could both increase the depth of inundation if they become choked with debris, and simultaneously promote the process of channel short-circuiting.

The construction of the Van Ryneveids Pass dam, just outside the town to the north-west, reduced the hazard of relatively small floods, since it served as a flood control dam as much as an irrigation reservoir. At the same time, however, it has raised the hazard of a potentially more disastrous event that would attend the failure of the dam wall. The accumulation of silt in the dam since its completion in 1925 has also reduced its effectiveness as a storage reservoir. Originally the wall rose some 23 metres above the floor of the dam. It now has a deposit of more than 12 metres on its floor, reducing the effective height of the wall to a mere 11 metres.

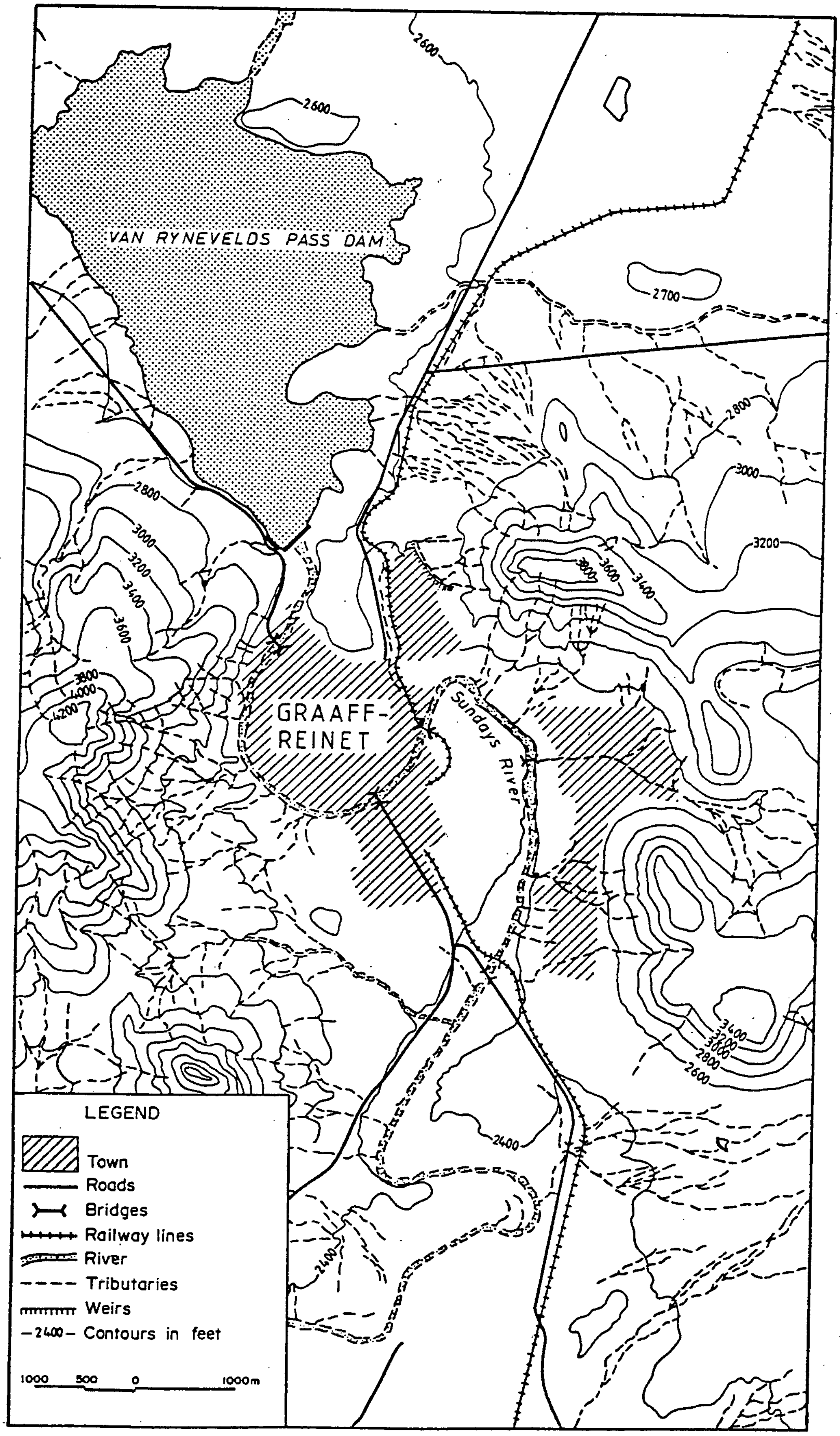

Fig. 3.12 Location of Graaff-Reinet in relation to flood hazard factors

Part of Cradock is situated on low-lying land on the inside of a curve in the Great Fish River (fig. 3.13). Here too, straightening of the river course by erosion during a flood could lead to the migration of the channel eastwards into the town. Choking of the openings in the two bridges across the river at the town could aggravate the effect of the river coming down in flood.

The Gamka River flows through Beaufort West and it is joined at the town by the Kuils River (fig. 3.14). Location of part of the town on the adjacent flood plain makes flooding a hazard. Inundations of parts of the town occurred in 1837, 1857, 1869, 1881, 1918, 1941 and 1972 (Viviers and Viviers, 1969). Here too, bridges across the river potentially aggravate the effect of flooding. However, the construction of the Beaufort West Dam upstream of the town and the Springfontein Dam on the Kuils River just outside the town has substantially reduced the likelihood of inundation.

Kenhardt occupies a site on the banks of the Hartbees River, the southwestern part of the town being subject to flooding (fig. 3.15). At the town two bridges cross the Hartbees River. Between these two bridges the river is joined by the Driekop River which divides into a number of channels near the junction. The lower part of this "delta" area adjacent to the Hartbees River, called the "Rooiblok" suffered severe damage in 1941 as a result of the flooding of both the Hartbees and Driekop rivers. Approximately 20 dwellings were swept away. Six people lost their lives while trying to cross the swollen river in a boat. A few houses in the town on the eastern side in the river were also destroyed. The Rooiblok was re-occupied after the flood and today it accommodates some 30 dwellings.

Ten kilometres upstream on the Hartbees River is the Rooiberg Dam. It was constructed to serve a small irrigation scheme, but the dam is frequently without water. The dam was breached by flood water in 1902 and repaired during the depression of 1933. The flood hazard for the town is in many respects similar to that of Laingsburg. The bridges could in a similar way form obstructions to the flow of flood water in the Hartbees River. The situation is aggravated by the extensive growth of mesquite (*Prosopis glandulosa*) in the Driekop River bed which could choke bridge openings. Water from the Driekop River could be diverted towards the town leading to elevated water levels there. If a flood were to follow a period of rainfall sufficient to have filled the Rooiberg Dam, the wall could fail and a sudden large quantity of water be released which would very quickly reach the town.

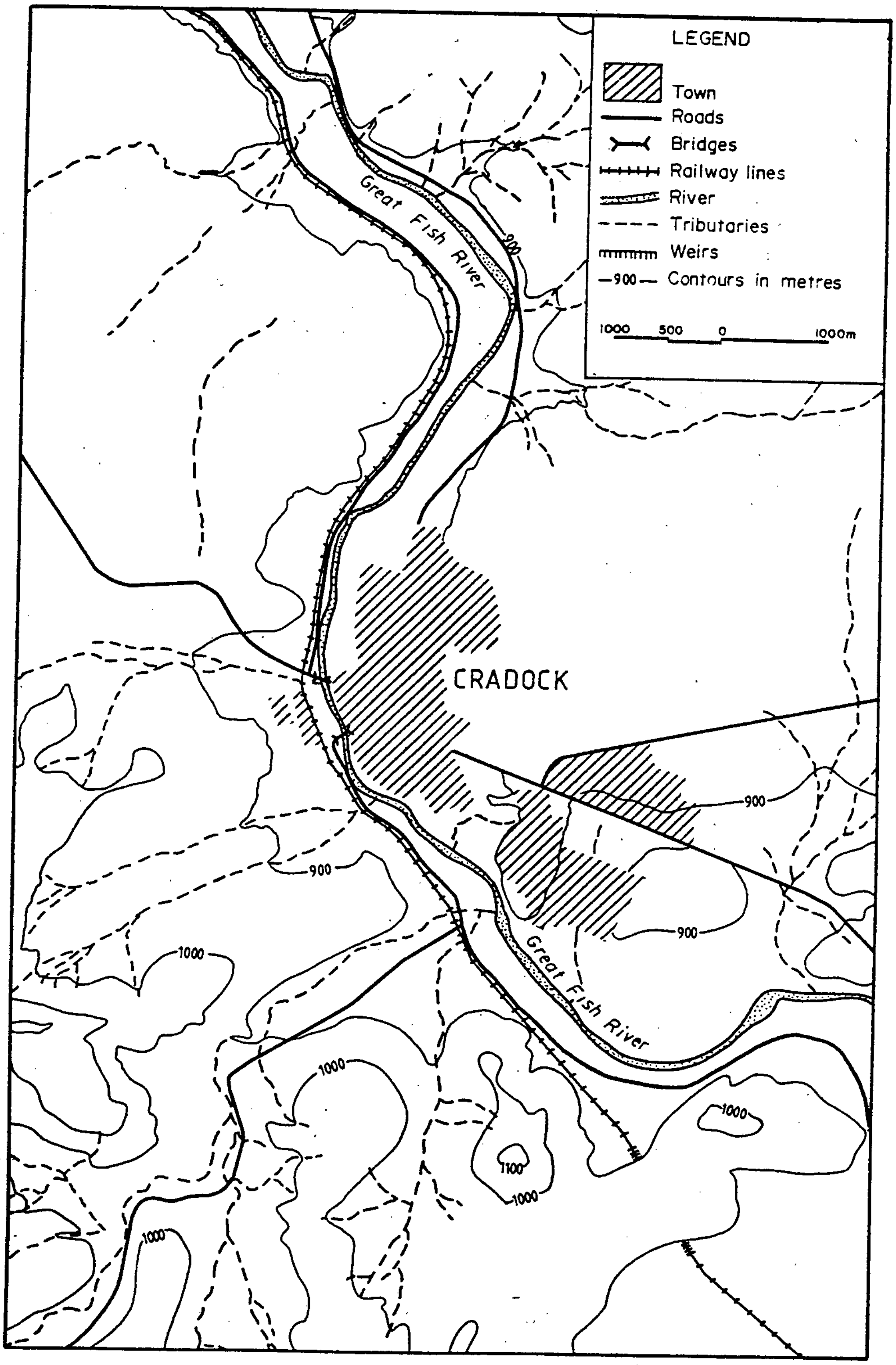

Fig. 3.13 Location of Cradock in relation to flood hazard factors

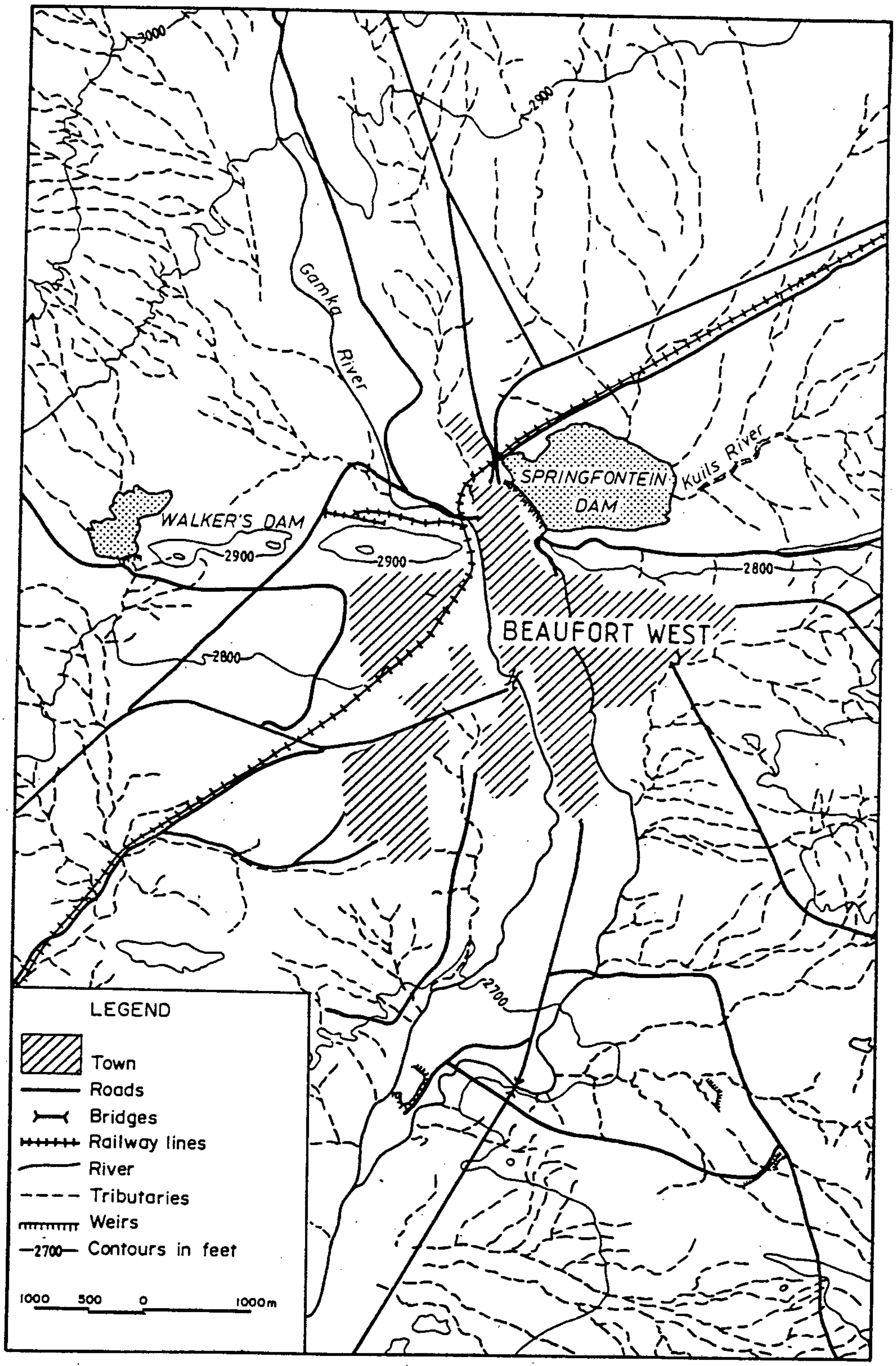

Fig. 3.14 Location of Beaufort West in relation to flood hazard factors

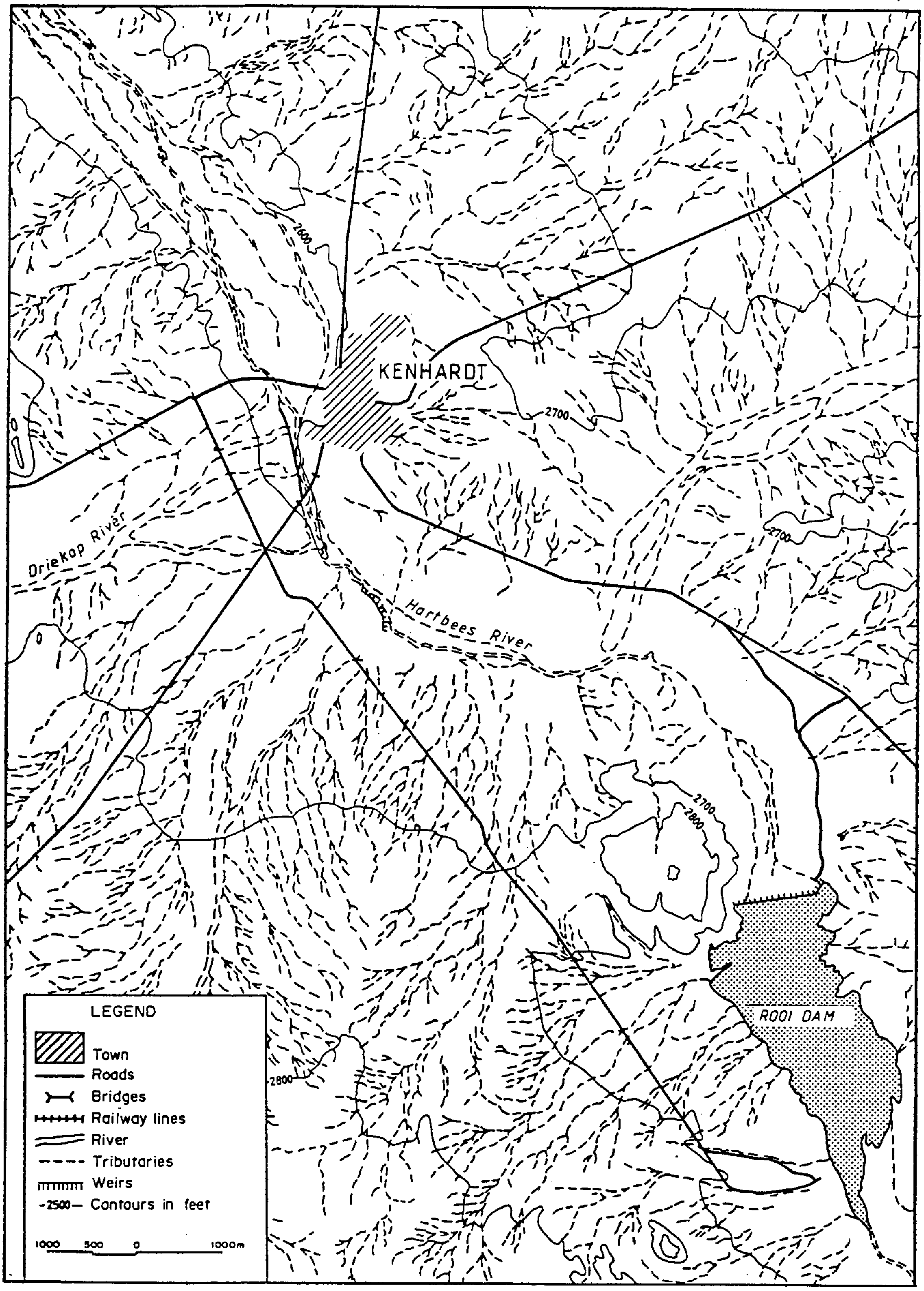

Fig. 3.15 Location of Kenhardt in relation to flood hazard factors

3.4 The pattern of hazard

Figure 3.16 shows the pattern of hazard in terms of the flood hazard index F_H. The northern half of the region consists of a surface of low hazard with a value of less than 10. Only along the Orange River are there slight rises in two areas. Increased hazard in these two areas is primarily attributable to a greater number of crossings of streams draining into the Orange River by roads which tend to run parallel to this river which acts as a north-south barrier. While the lower Orange is notorious for its floods it might be something of a surprise that F_H values here are so low. It should be explained that the Orange River forms the boundary of the study area and measurements were made only along its south bank. The occupied land on the northern bank was therefore not taken into account at all. Apart from this the numerous dams impounding water in its catchment area have gone a long way towards reducing the danger of flooding.

In the southern half the pattern is more complicated. Here the level is generally higher than 10 except in two areas:

1. A southern Karoo area co-inciding with but somewhat more extensive than the similarly situated zone of high run-off variability. It also incorporates part of the basins of the Sout and Kariega rivers. The apparent enigma of low hazard

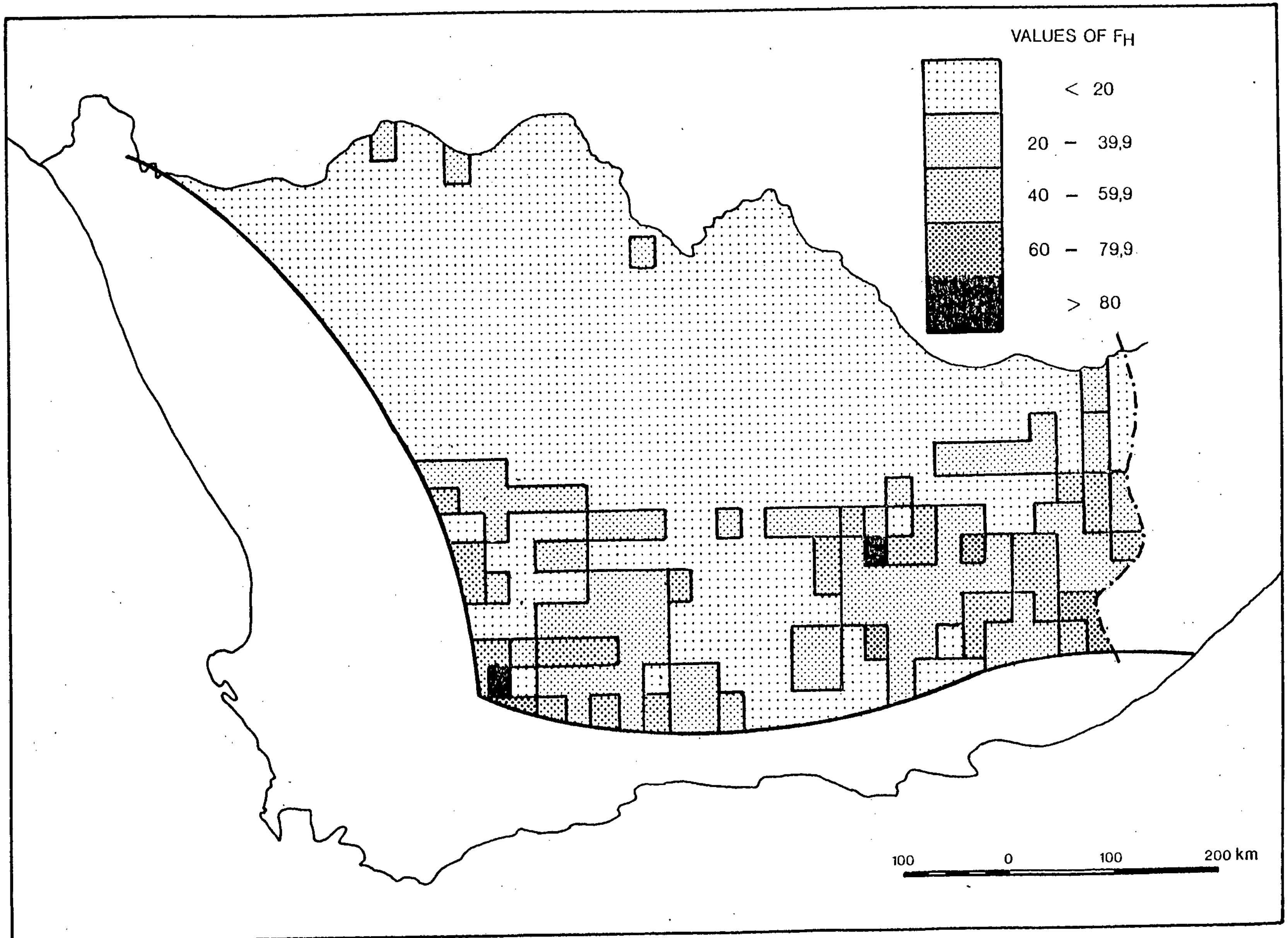

Fig. 3.16 Magnitude of flood hazard (F_H)

co-inciding with high runoff variability can be explained by the sparse occupance and utilization of these areas.

2. A small area around Hofmeyr where moderate variability of runoff combines with low values of the other components of the index.

More important are areas of high flood hazard, i.e. peaks of high F_H values:

1. In the extreme south-western corner of the region centred on Laingsburg[1] where high runoff variability together with high index values for river crossings and rural and urban settlement structures are responsible.

2. In the eastern Cape midlands centred on Graaff-Reinet where runoff variability of between 90 per cent and 100 per cent in combination with high values of all the other indices is responsible.

Intermediate F_H values occur in the Olifants River valley east of Oudtshoorn, the Groot River valley west of Steytlerville, the Great Fish River and Baviaans River valleys north-east of Cookhouse, around Cradock, and in the area east of Queenstown.

NOTE

[1] The base data for the Laingsburg area are for those conditions that existed prior to the floods of 1981.

CHAPTER 4

THE PHYSICAL BASIS OF DROUGHTS AND FLOODS

With the exception of some types of coastal floods in which tectonic processes and high winds play a role, droughts and floods that occur in nature have their origin in the variation of the rainfall beyond expected limits in which both amount and time are definitive factors. These limits are gradually (and often cognitively) established in relation to the human occupation and utilisation of a region and in time come to be regarded as "normal" for that region. Drought in particular can only be defined adequately in relation to human factors but its source is rooted in a deficiency of moisture in the atmosphere. Floods can be defined more easily in terms of purely physical factors, excess of precipitation being at least one of the contributors. In this chapter the role of physical factors in the generation of droughts and floods is considered while the following chapter is devoted to a consideration of human factors.

4.1 Droughts

4.1.1 The Climatological Basis

While the concept of drought itself is not easily defined, and drought can have its causes in both the physical and human sphere, some deficiency in precipitation is at least one of the requirements for the occurrence of a drought. The immediate cause for such a deficiency is invariably found in the existence of a state of increasaed air subsidence and anticyclonic development. Explanation extending beyond this immediate cause to more scientific foundations, however, becomes progressively more conjectural. Nevertheless the climatological basis of droughts has been the subject of a large number of studies and some progress has been made toward explanation, though much of it provides only partial answers to the problem.

Gregory (1986) identifies several commonly adopted approaches though many of them overlap and interact.

(a) Synoptic climatology

The first of these is the synoptic climatology approach in which the weather of a given place is seen to be a function of the atmospheric circulation systems affecting that place, and any changes in the location, intensity and frequency of those systems are regarded as the proximate cause of any moisture deficiency or drought. This requires the specification of normal circulation conditions against which anomalous characteristics related to drought occurrence can be assessed. A serious hindrance to progress in this approach is the lack of long-term records of circulation conditions and while models of such normal conditions are still inadequate, a number of studies have been conducted with this perspective.

In his investigation of conditions pertaining to Southern Africa Tyson (1984) shows that regional variations in annual rainfall are significantly linked to variations in both low latitude forcing, associated with tropical easterly airflow and cyclonic disturbances in it, and mid-latitude forcing, associated with a variety of cyclonic and anticyclonic perturbations in the westerlies. He further shows that it is primarily variations in the atmospheric field of motion at the 500mb level that are responsible for year to year differences in annual rainfall totals.

In another study Schulze (1983) points out that conditions of general rain over South Africa are produced by the combination of a strong, slowly moving high south and southeast of the country and a well developed low over the central interior which favours the inflow of warm, moist air from the north and northeast. He explains that during the drought of 1982/83 the synoptic conditions of the summer season were characterised by a series of rapidly moving frontal lows which followed a course further north than their usual one and that they alternated with weak highs. This pattern was associated with great air pressure anomalies in the region southwest and south of the subcontinent.

Other studies have identified a blocking high situation as a common immediate cause for drought in the temperate latitudes. In his investigation of droughts in western Canada, for example, Dey (1982) refers to a quasistationary mid-tropospheric ridge which acted as a block, displacing the jet stream, cyclones and moist air masses northward, while anticyclonic circulation under the high pressure ridge produced atmospheric stability and dry conditions in the region.

Lamb (1983) (West Africa) and Pittock (1975) (Australia) investigated the location and intensity of major pressure centres in an attempt to relate deep or shallow monsoonal flow to the occurrence of drought. No clear-cut relationship was identified in either of the studies. Investigations based on mathematical modelling of atmospheric circulations (e.g. Druyan, 1981) have proved to be similarly inconclusive.

Consideration has also been given to the role of upper atmospheric circulation in relation to drought. Examples of such studies are those by Ratcliffe (1978) for the drought of 1975-76 in the United Kingdom and Kidson's investigation of African rainfall (Kidson 1977). Kidson concludes that "low rainfall in the Sahel is associated with the virtual disappearance of the 850mb trough near 8°N and weakening of the easterly jet above it". This finding accords with Tyson's recognition of the importance of variations in the upper atmospheric field of motion with respect to South African rainfall conditions.

Changes in ocean surface temperatures modify the moisture-holding capacity, vertical stability and local circulation patterns of the atmosphere in contact with it, and the intermediary role of ocean surface temperatures in atmospheric circulation studies has also received attention. Examples of work in this field are those by Hastenrath (1976), Hastenrath and Heller (1977), Lamb (1978) and Chung (1982). While Lamb focused on possible relationships between tropical Atlantic surface circulation patterns and weather anomalies in Subsaharan Africa, the other works indicate that positive anomalies in surface temperatures in the North Atlantic and eastern Pacific oceans, coinciding with negative anomalies in the south and equatorial Atlantic areas, correspond with drought conditions in north-eastern Brazil. The subject of ocean surface temperatures is also a major component of the investigation being conducted by the World Climate Research Programme (Gregory, 1986).

(b) Teleconnections

A category of causes that operate less proximately (sometimes referred to as teleconnections) relates to "the delayed impact of atmospheric circulation changes far from the drought area of concern, with a long chain of intermediate effects." (Gregory 1986 : 100). The possible role of the southern hemisphere temperate and subtropical circulation in producing northern hemisphere droughts or the relationship between changes in Arctic conditions and Subsaharan drought are examples. Studies in this category include such early work as that by Blanford (1884), Craig (1910) and Walker (1928). Unfortunately the relationships postulated in these studies have not been maintained with time. More recent attempts to discern teleconnections have focused on the role of El Niño and the influence of the Southern Oscillation. El Niño refers specifically to the warm ocean current that flows southward off the coast of Ecuador but the term is generally applied to the sudden warming of a large part of the Pacific Ocean at apparently irregular intervals. The Southern Oscillation is a see-saw of atmospheric pressure between the Pacific and Indian oceans. El Niño and the Southern Oscillation occur in such close association with each other that it has become customary to refer to them together, giving rise to the coining of the acronym ENSO.

The impact of El Niño on conditions in the adjacent regions of

Central and South America is not difficult to accept. Here the physical relationships between ocean surface temperatures and local circulation systems and associated precipitation conditions, can be readily appreciated. However, a number of investigations have demonstrated the existence of strong relationships between ENSO patterns and rainfall conditions elsewhere in the southern hemisphere as well as positive relationships in ENSO - Indian monsoon rainfall interactions (e.g. Vines and Tomlinson, 1985; Schulze, 1983). In his investigation of the possible connection between ENSO phenomena and drought in the summer rainfall regions of South Africa, Schulze (1983) concludes that a positive relationship exists. The phenomenon appears to be related to negative pressure anomalies south-west of the country, and a connection between ENSO, the circumpolar vortex and the ITCZ over Africa is suggested as the possible mechanism by which drought occurs, but Schulze concedes that the physical processes involved are as yet imperfectly understood.

It should be remembered, however, that other studies such as that of the Indian drought by Ramage (1983) demonstrate the existence of a positive relationship with ENSO in one period and a negative one in another. Such on-off relationships emphasise the need for caution in interpreting teleconnections of this nature, especially in the absence of sound explanations of the exact nature of the processes involved.

(c) Changes in atmospheric composition

Possible causes of drought have also been sought in changes in the composition of the atmosphere and presence of aerosols and other pollutants in it. The basic premise is that an increased concentration of carbon dioxide or ozone, or the presence of pollutants such as sulphur dioxide and volcanic dust filter out a portion of the incoming solar radiation, which, in turn, lowers temperatures where they are present. Circulation patterns may ultimately be modified. Examples of studies are those by Lockwood (1981), and Mitchell (1983). These factors are usually considered in relation to climatic fluctuations but are thought to at least exacerbate drought if they do not serve as direct causes. They are regarded as significant in the process of desertification which, in turn, may cause droughts to be self-perpetuating. It is argued that a reduction in vegetation results in increased albedo, which causes sinking motion and additional dessication, thus perpetuating arid conditions.

(d) Changes in solar radiation

Changes in solar radiation constitute another line of enquiry into the origin of droughts. Numerous studies such as those reviewed by Willett (1965) and King (1973) have sought to correlate solar activity with meteorological parameters. A South African example is Dyer's investigation (Dyer, 1975) of the relationship between cycles of high sunspot occurrences and deficient rainfall in the country. He concludes that "there is a statistically significant correlation between some rainfall series of South Africa and the two (20 and 10 year) solar cycles." The reason for this apparent relationship is not clear but it is suggested that during periods of maximun solar activity atmospheric temperature increases and hence rainfall decreases, and *vice versa*.

(e) Lunar declination

Similar correlations have been shown to occur with respect to lunar declination and periods of drought e.g. Rawson (1908) and Louw (1982). However, the underlying causal mechanisms by which these effects operate remain unexplained. Clearly, many questions about the climatological foundations of drought are still without answers.

4.2 Floods

Most riparian floods have their source in a rainfall that is excessive to the extent that it is not possible for the runoff produced to be contained within the channels of rivers. In such circumstances water overflows river banks inundating the adjacent land. There are, however, a number of intermediate physical factors that operate between the occurrence of rain and the inundation of riparian land and these must be seen within the context of that part of the hydrological cycle that occurs within the drainage basin. In the ensuing discussion climate, as the primary physical source of floods, is dealt with first. The discussion is followed by a consideration of the intermediate factors.

4.2.1. The climatological basis of flooding

Unlike droughts most floods are not simply the result of rainfall that is beyond the expected annual amount. Periods of years that are very much wetter than "normal" are not necessarily attended by floods. The climatological source of floods has to be sought in those exceptionally heavy downpours or storms that are so intense and are spread over a period of time so short that the consequent runoff cannot be accommodated in the channels of existing watercourses.

"The predisposition of a climate to storms producing excessive precipitation is the fundamental basis of the flood hazard. [However,] the immediate cause might more properly be termed meteorological since actual flooding results from specific weather situations rather than long-term climatic conditions" (Critchfield, 1961). Since very few climates are entirely without storms of one type or another, analysis of the source of floods in relation to climatic factors is better directed at a study of the conditions surrounding storms rather than an attempt to identify flood related climatic regimes. Tropical and subtropical regions that are visited by tropical cyclones, for example, tend to be flood-prone. Nevertheless Critchfield notes that certain types of climate are characterised by conditions that are more favourable for the production of floods than others (Critchfield, 1961). Seasonality in the distribution of precipitation can be a significant factor in rain-caused floods. Where rainfall is concentrated in one season floods tend to be more frequent, e.g. the monsoon tropics. A particular type of seasonal flooding occurs in northward-flowing rivers in high latitudes where melting begins in the headwaters while the lower reaches are still frozen or choked with ice. Here permafrost is a contributary factor because very little infiltration into the soil is possible. Arid climates are notorious for their erratic rainfall and the flash floods that follow sudden storms. In these regions an entire year's rain can fall in a single day.

The immediate causes of floods fall into two categories of meteorological activity: violent storms and prolonged general rain.

Examples of flood producing storms are thunderstorms and tropical cyclones. They are often accompanied by heavy downpours which result in flash floods of relatively short duration. The origin of the storm is unimportant. Rather it is its intensity that matters. Floods caused by convective storms tend to be fairly localised while more extensive flooding can be the result of frontal thunderstorms which extend along the line of the front. Tropical cyclones (hurricanes or typhoons) are notorious for their violence and the deluges that accompany them. Their occurrence is usually limited to coastal areas where they can produce disastrous floods, especially if they move fairly slowly.

Extensive flooding is usually the result of long continued rainy weather. Synoptic conditions favourable for the occurrence of such protracted rainfall are encountered in the humid climates of the middle latitudes when frontal systems occlude or become stationary for a number of days. Rainfall can continue for as long as moist maritime air is fed into the system.

In South Africa floods are caused by both of these meteorological situations. Thunderstorms are more characteristic of the interior and eastern coastal regions where they occasionally produce flash floods. Tropical cyclones are limited in their occurrence to the northern coastal lowlands of Natal and KwaZulu and extend their influence to the adjacent interior. The disastrous flood produced by Domoina in 1985 is an outstanding example. Protracted rains frequently occur in the south-western, southern and eastern parts of the country and occasionally continue long enough and are sufficiently heavy to result in flooding.

Most floods that occur in the study region are caused by thunderstorms and are usually quite localised. Occasionally, however, more extensive floods which are the result of other synoptic conditions occur. Climatic and synoptic conditions that have a bearing on floods in the study region are now examined more closely.

(a) Rainfall relationships

The region receives an annual rainfall that is nowhere higher than 600mm. Moreover, its occurrence is subject to great variability. Figure 4.1 illustrates the mean deviation as a percentage of the average annual rainfall. Variability of

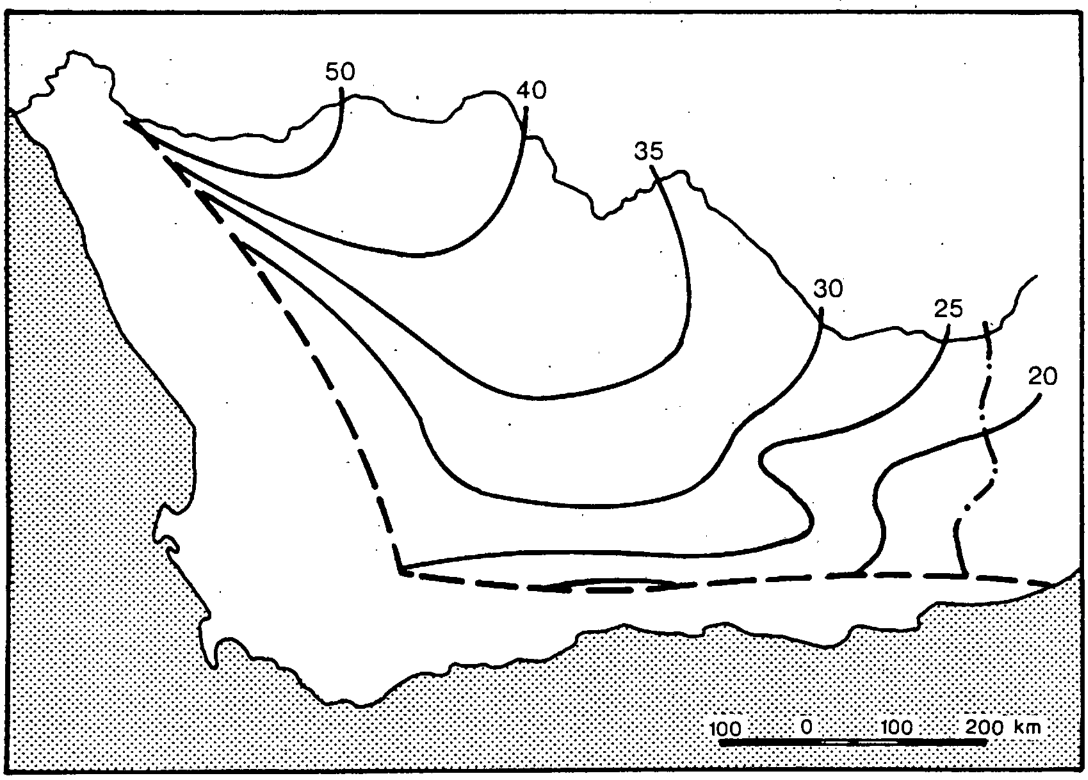

Fig. 4.1 Variability of annual rainfall

(Standard deviation of annual rainfall as a percentage of the average annual rainfall) (Source: Weather Bureau, 1957) rainfall, which is as low as 20 per cent in the extreme south-east, increases to more than 50 per cent in the northwest. In any year roughly half of the study area can expect to receive 35 per cent more or less rain than its annual average.

Further, the expected maximum 24-hour rainfall expressed as a percentage of the annual total for various return periods is shown in figures 4.2 to 4.5. With a recurrence interval of 5 years up to 40 per cent of the annual total can be expected to fall in 24 hours in the extreme north-west of the region. This figure increases to 70 per cent for a 20-year return period, 90 per cent for a 60-year return period and more than 100 per cent for a 100-year return period. The extent of the area in which higher percentages can be expected also increases as the recurrence intervals become longer, so that for a 100-year return period more than half of the study area can expect to receive more than 50 per cent of its rainfall on a single day. Under climatic conditions like these, it is self-evident that the occurrence of periodic floods should be regarded as inevitable.

As has been pointed out by Taljaard (1952), Lippe (1962), Hayward and Van den Berg (1970), Estiè (1981), and others, the synoptic conditions that favour flood producing rain are

(i) an intense anticyclone south of the country following the passage of a cold front. The anticyclone constitutes a

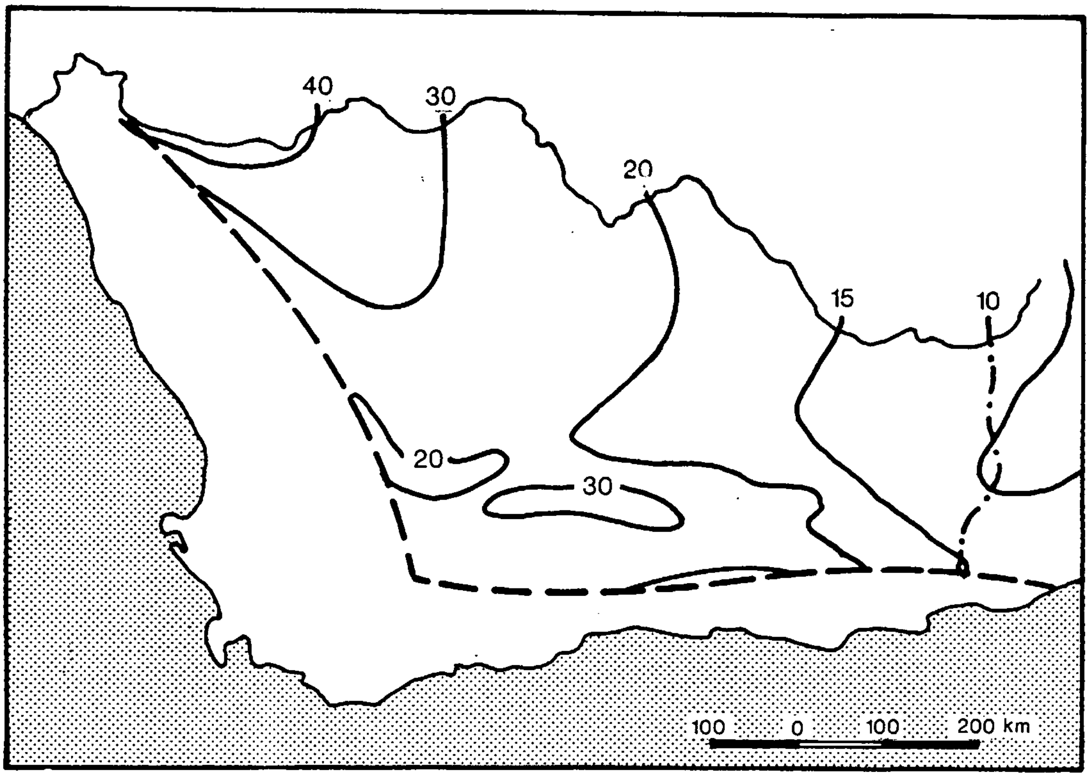

Fig. 4.2 Maximum 24 hour rainfall as a percentage of the annual total (5 years)
(Source: Weather Bureau, 1956)

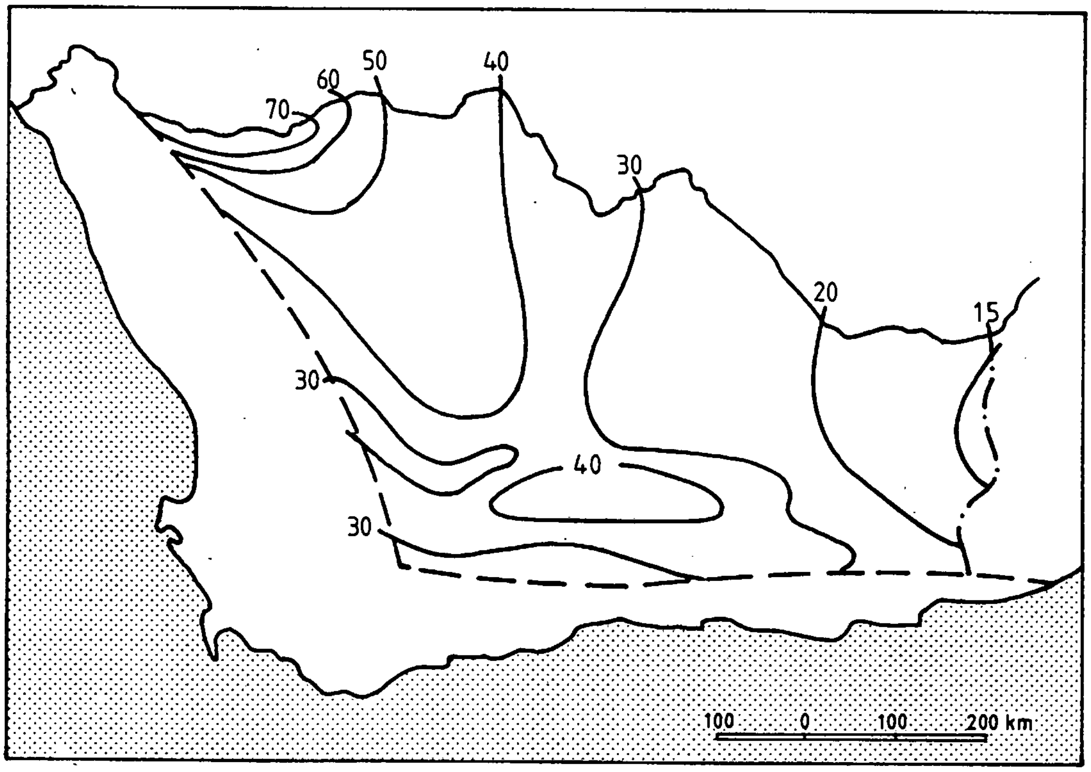

Fig. 4.3 Maximum 24 hour rainfall as a percentage of the annual total (20 years)
(Source: Weather Bureau, 1956)

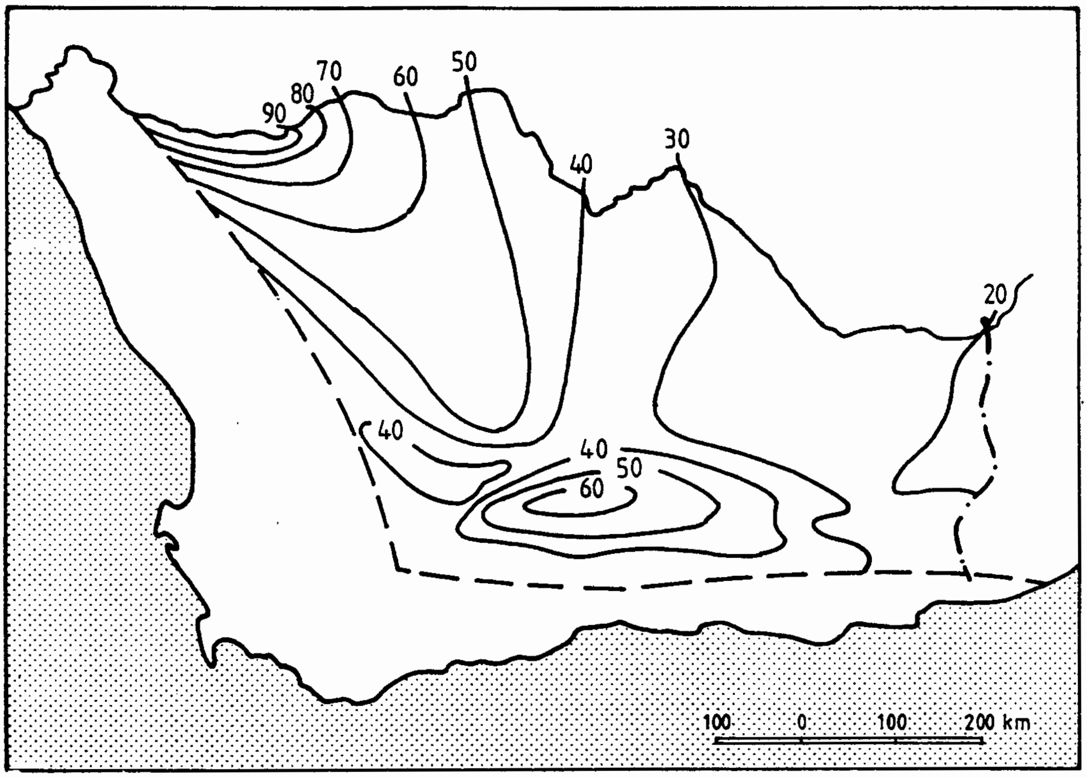

Fig. 4.4 Maximum 24 hour rainfall as a percentage of the annual total (60 years)
(Source: Weather Bureau, 1956)

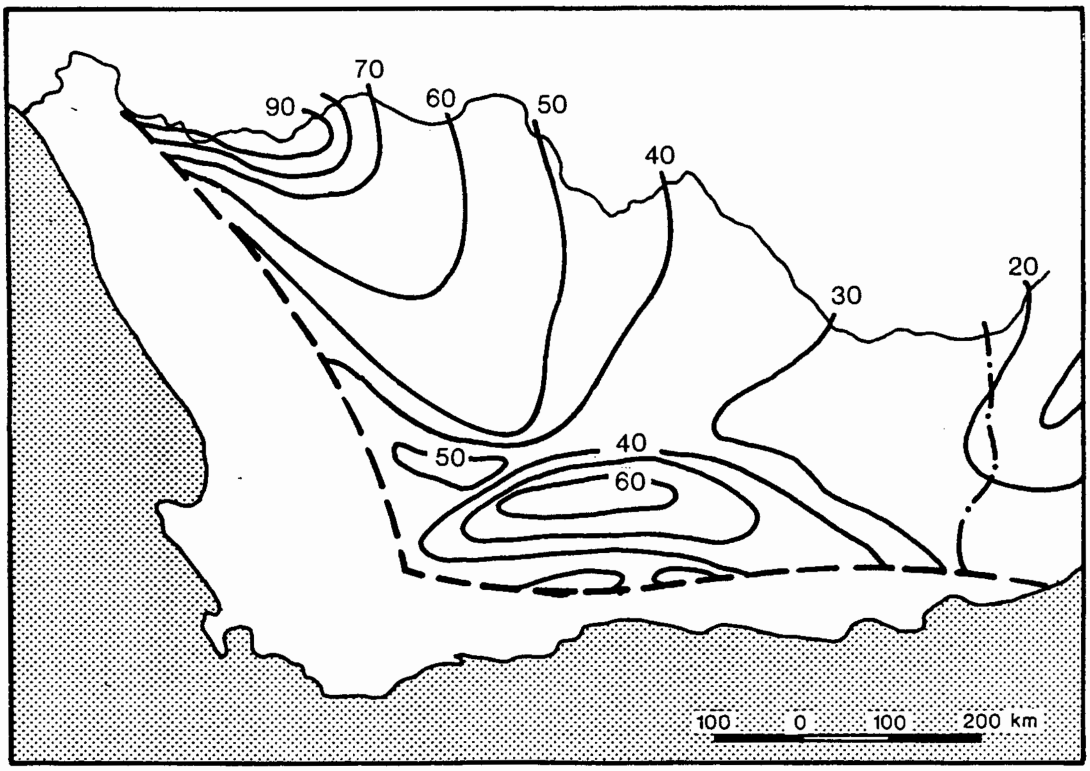

Fig. 4.5 Maximum 24 hour rainfall as a percentage of the annual total (100 years)
(Source: Weather Bureau, 1956)

blocking high.

(ii) A deep low pressure system over the southern and eastern interior. The low extends well into the upper atmosphere, usually to at least the 200mb level and may become a cut-off low.

A meridionally paired blocking high and cut-off low result in an onshore circulation which feeds in moist, warm air. These conditions constitute what is colloquially known as a Black Southeaster. As the air is advected into the interior it experiences topographic uplifting and heavy falls of rain may occur especially if the system as a whole moves very slowly.

While rainfall might be regarded as the initial factor in the generation of floods, the amount of runoff and its concentration in a certain time period is what actually constitutes a flood. The conversion of precipitation into stream discharge includes a number of processes in which either the amount of water is reduced or its progress retarded. In figure 4.6 the process is represented diagrammatically.

4.2.2. Land-based processes

When precipitation occurs some of the water evaporates directly into the atmosphere and some is intercepted by the leaves and branches of plants. From there it is either subject to further evaporation or is absorbed by the plant and returned to the atmosphere by the process of transpiration. The remainder reaches the ground surface. A certain amount collects in hollows on the surface and some infiltrates into the soil. The rest constitutes what is known as overland flow and moves downslope towards drainage channels which temporarily retard the flow of water due to their storage effect. It is in the channels, however, that water collects and is concentrated as tributaries join to form progressively larger streams. Some of the water that infiltrates into the soil is also released either as a result of throughflow or as groundwater flow and finds its way into the rivers. Overland flow, throughflow and channel flow together constitute runoff and it is excessive runoff beyond that which the channels are able to contain that causes flooding. Floods, therefore, differ from simple runoff only in degree.

The amount of water "lost" through the processes of evaporation and transpiration and the amount added to the runoff by throughflow and groundwater flow is negligible with respect to flooding because these are slow processes while the generation of floods involves the rapid build-up of runoff. The flood related

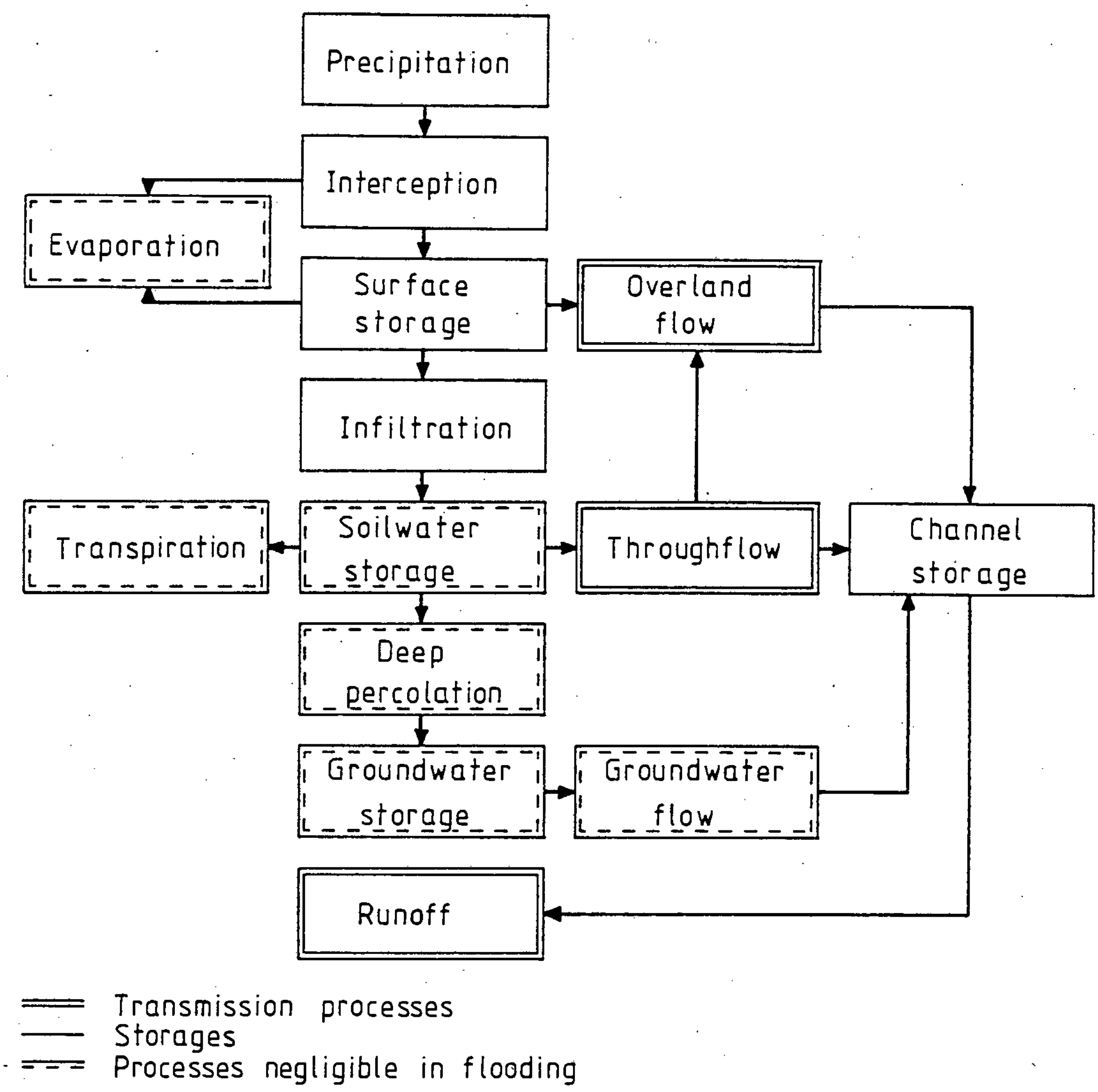

Fig. 4.6 The hydrological cycle in relation to floods

processes following precipitation in the hydrological cycle are therefore interception, surface detention, infiltration, overland flow and channel flow.

(a) **Interception**: The amount of water intercepted by the leaves and branches of plants can be an important factor in reducing runoff, not only by direct interception but also by enhancing surface retention. Interception loss varies with the type of vegetation but unfortunately no rigorous method is available for the estimation of precipitation loss by this means and when figures are required they have to be obtained by carrying out empirical studies. The significance of forests as interceptors is obvious but even in grasslands interception loss can be as high as 60 per cent during moderate rainfall (Weyman, 1975).

The vegetation of the study region is characterised by a sparse cover of scattered bushes, succulents and annual grasses that spring up after good rains. Acocks (1975) describes much of the western part of the region as man-made desert. Due to the sparseness of the vegetation its role in reducing surface runoff is insignificant. The response of runoff to heavy precipitation is therefore determined to a much greater extent by other factors.

(b) **Surface detention**: Surface detention or depression storage is one of the ways in which runoff is reduced or delayed. During heavy storms water collects in hollows on the surface, varying in size from inter-particle spaces to depressions many metres across, and these have to be filled before runoff can begin. The accumulation of water on the ground surface is either the result of rainfall intensity in excess of the infiltration capacity of the soil or of an already saturated soil which prevents further infiltration. In time the water that collects in this way gradually sinks into the soil and is added to the store of ground water or is evaporated back into the atmosphere. Either way it is lost from the flood generating system.

While surface storage is an important factor in reducing the amount of rainwater available as runoff, it is not easy to compute due to the variation of ground surface characteristics even over short distances. There are a number of large dams in the region, however, which play a significant role in absorbing much of the runoff caused by storms of short duration. Major dams have the ability to reduce peak discharges of moderate return period floods but are less efficient for extreme events i.e. 50-year floods or more (Alexander and Roberts, 1981). In the Laingsburg event the Floriskraal Dam, situated a short distance downstream from Laingsburg, reduced the discharge to 67 per cent of the inflow. Flooding below the dam was less severe, but it still occurred and resulting damage was considerable.

(c) **Infiltration**: At the soil surface precipitated water is drawn into the soil by a combination of gravity and capillary forces. As the spaces between soil particles near the surface become filled with water the rate of infiltration decreases until a constant rate is reached which represents the rate of movement of a wetting front through the topsoil. The rate of movement of the wetting front controls near-surface moisture and hence the infiltration rate (Young, 1957 and 1958). Total porosity appears to be relatively unimportant in determining infiltration capacity. More important is soil texture. Clays show the lowest infiltration capacity (approximately 0-5mm/h) and sands the highest (more than 25mm/h). Obviously the existence in the soil of many large vertical paths facilitates the process of infiltration.

The soils of the study region are essentially desert soils (Wellington, 1955; MacVicar, 1977). Kalahari soils occupy a small part of the region in the extreme north along the Orange River. As a whole the soils of the region are characterised by a sandy surface layer underlain by a layer of lime or silica accretion. Soils in the west tend to be more sandy than they are in the east. In the north, especially in the belt between Kenhardt and Calvinia, rock fragments and pebbles on the surface have been swept clean of sand by the wind and form a desert pavement. The soils in the north-western Cape region are also shallow and sandy and partly covered by a desert pavement of quartz fragments

(Wellington, 1955).

The importance of soils in flooding is related to the degree to which the weathered surface and subsurface materials are able to absorb water and serve as a temporary reservoir. Although it is beyond the scope of this review to analyse in detail the infiltration capacity of the ground in the region, it should be noted that the ability of the soil and substrate to absorb rainfall can easily be exceeded under conditions of heavy or prolonged downpour. In the example of the Laingsburg flood the antecedent rainfall of Friday night (24 January) and Saturday (25 January), which varied from 38 to 57 mm, was sufficient to completely saturate the soil and leave all of Sunday's (26 January) rainfall to become part of the surface runoff (Van Zyl, 1981).

(d) Groundwater storage and throughflow: The fact that many rivers continue to flow long after the surface of the drainage basin is completely dry, indicates that throughflow can be a major runoff process. The process, however, is very slow. An experiment by Weyman in an area where downslope flow of soil water was a major source of river flow, demonstrated that throughflow velocity was so slow (less than 0,0001 m/s) that it could not be responsible for the generation of the river flood peak (Weyman, 1973). But there is some evidence that under certain circumstances throughflow velocity might not always be so slow that it does not contribute to the flood peak. In some areas soil water moving through larger spaces in the soil body erodes these spaces into subsurface routes called pipes which may be anything from several centimetres to several metres in diameter. The observed flow velocity of water in these pipes has been around 0,1 m/s which is sufficiently rapid to be part of the flood generating process. There is, however, no record of the existence of such channels in the study region and it can be accepted that water retained on the surface in hollows or dams, or water "lost" from the surface through infiltration, does not contribute materially to the rain-caused flood peak.

(e) **Overland flow:** Overland flow is initiated once all the surface irregularities are filled and the addition of water is more rapid than the rate of infiltration. Since surface irregularities promote the concentration of water into rills, overland flow in the form of a sheet is probably rare under natural conditions. In a rill, depth and velocity increase rapidly and overland-flow velocities of 0,01 to 0,1 m/s have been recorded (Emmett, 1970). "At this speed overland flow is obviously capable of transmitting water across basin hillslopes well within the duration of flood runoff and should therefore be a major stormflow contributor" (Weyman, 1975).

As a whole the relief of the region is subdued, much of it being described by Van Zyl (1985) as high plains and high plains interrupted by isolated hills, mountains and dolerite ridges. The north-western part includes Bushmanland, an extensive peneplain where pre-Karoo rocks and intrusives were smoothed by the Dwyka ice-sheet. To the east and south lie the Upper Karoo and Great Karoo regions in which the relief forms are either scattered buttes and mesas resulting from the erosion of horizontal strata or are ridges produced by resistant dolerite intrusions. The Great Escarpment is the only prominently mountainous zone in the area. Where slopes are steep drainage is rapid but in areas of subdued relief and gentle slopes, runoff is slower and, if the channel capacity is exceeded, more prolonged flooding can occur.

(f) **Channel processes**: The river channel serves as the receptacle for ground water draining into it as well as for water added by throughflow and overland flow. Direct channel precipitation also contributes a certain amount. Although the total area occupied by a channel is not large, there is no time delay in the addition of precipitation to the volume of water in the channel and it therefore contributes directly to the flood peak.

Water collected in the channel immediately begins to move downstream in response to the force of gravity. As more water is added along the course of the river the increase in volume results in an increase in flow velocity. Various factors retard the progress of water downstream. The most fundamental of these is the gradient along which the force of gravity operates. Where gradients are steep runoff is rapid while under conditions of gentle gradient, flow is sluggish and a greater volume of water is temporarily held in the channel. The second is friction along the bed and sides of the channel where roughness is the major determinant. Roughness prevents laminar flow and causes turbulence which, in turn, introduces internal friction in the water itself. A third factor is the accumulation of sediments on the river bed. During periods of diminished flow deposition of some of the river load occurs on the bed thus decreasing the cross-sectional area of the channel. The result of such deposits includes a temporary restriction of flow during a flood, absorption of some of the water and consequently increased channel storage, and a change in the frictional co-efficient of the river bed. Another factor might be the growth of vegetation. Vegetation grows on exposed channel deposits or it might encroach on the channel from the banks. This pattern is quite common in areas where river flow is episodic and sufficient time elapses between floods for even trees to grow to considerable size. Besides trees, shrubs and frequently thick reed beds can develop. Many of the rivers in the study area display these characterisitcs in varying degrees. Due to these factors the channel has a reservoir effect and tends to spread the flood wave from upstream (Linsley, Kohler and Paulhus, 1949).

4.2.3. The storm hydrograph

The response of a drainage basin to a single storm can be represented by the storm hydrograph which also summarises the purpose of much of the above discussion (figure 4.7). "The typical flood hydrograph assumes an asymmetrical form but the detailed shape and timing of individual events depends on a complex combination of drainage basin characteristics and hydrometeorological factors" (Smith and Tobin, 1979). The curve shows a steep rise to a peak in discharge following rainfall and a negative exponential recession limb. The main dimensions of the hydrograph are the volume of water and the distribution of that volume in time.

In relation to floods the response of the drainage basin to precipitation of given duration and intensity depends on the losses to the flood generating system of water by interception, surface storage and infiltration, on the one hand, and the rate of overland flow, throughflow and channel impedance, on the other. The area covered by the drainage basin is the fundamental determinant of the lag time and recession period of the flood. Transpiration and evaporation have already been identified as processes which are too slow to have a siginficant effect on flooding. Obviously surface storage and infiltration capacity are affected by prior moisture conditions and will be less significant if surface hollows and inter-particle spaces were

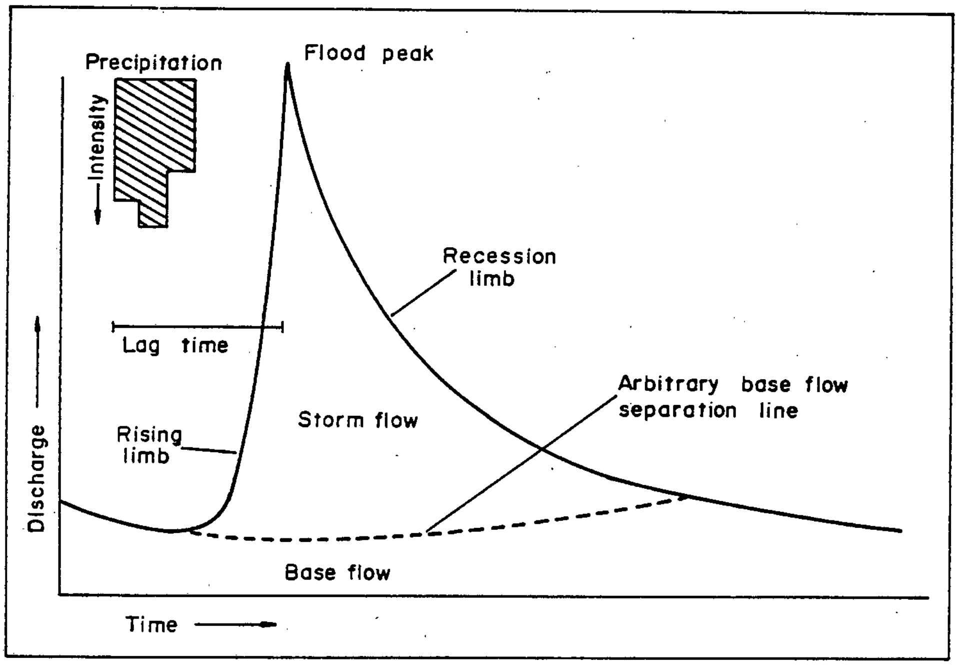

Fig. 4.7 The main components of a flood hydrograph resulting from an isolated rainstorm

filled by antecedant precipitation.

The rivers of the study area fall into two categories: those draining into the Orange River and those draining towards the south and south-east coast. They are all primarily episodic in character. Endoreic and semi-endoreic basins occur in the north-west of the region. The Sak River system is semi-endoreic and as a consequence of the evenness of the terrain the gradient of the streams is slight. Where they cut across dolerite outcrops downward erosion is retarded and vast shallow pans are formed. Occasionally flood waters spread across the surface of these pans or *vloere* to produce large temporary lakes. At such times these endoreic basins overflow and feed water into the Hartbees River which in turn empties into the Orange. The Brak River and its tributaries form the only other major system that feeds into the Orange River.

The remaining rivers in the area, the Gouritz, Groot, Sundays and Great Fish all rise south of the Great Escarpment and empty into the sea. Only the upper parts of their drainage basins fall within the study area. An important response of these rivers to the great variability of the rainfall is their erratic flow. River beds which can be dry for months in the less arid areas and for years in the more arid northwest can very rapidly become raging torrents in response to local storms and overflow their banks.

Combining the various meteorological and hydrological parameters in the region in order to create a model of flood discharge is no simple task due to the wide variation in the basin characteristics of the river systems and a lack of detailed data relating to many of the features. The necessity of a sound basis for structural design in engineering projects has, however, resulted in the development of design flood hydrographs which are used wherever floods are a factor in construction programmes.
The various methods used for the estimation of flood discharge are discussed by Midgley (1972). The methods fall into two main categories: the statistical and the deterministic approaches.

The first of the statistical approaches involves the use of **experience envelopes**. These comprise peak flood experience diagrams for a set of regional subdivisions on which the highest peak discharges to be found in the records are plotted against catchment area. These diagrams take only catchment area and general geographical location into account, ignoring all other parameters known to affect flood runoff and can therefore be no more than a rough guide to general flood experience in a region. The second uses the results of probability analysis of recorded peak discharges for the construction of **co-axial graphs** from the variables: recurrence interval, locality, catchment area, and peak discharge. These diagrams are used to quickly read off the peak discharges associated with a range of recurrence intervals for a particular locality. The process is facilitated by reference to a map of homogeneous flood regions for South Africa (figure 4.8), where flood regions are identified on the basis of their having similar flood peak probability values.

In the deterministic approaches the endeavour is to determine the result (flood discharge) from the cause (storm precipitation and wetness state of the catchment) using the hydrological equation

$$\text{Output} = \text{Input} - \text{Change of storage.}$$

For small catchments of less than 15 km^2 the **Rational Method** is employed using the formula:

$$Q = CIA$$

in which Q is the peak discharge in m^3/s; C is a dimensionless catchment coefficient; I is point rainfall intensity in m/s; and A is catchment area in m^2. For catchments of intermediate size (15 km^2 to 5000 km^2) the **unitgraph** approach is preferred. Large catchments in excess of 5000 km^2 have to be divided into sub-catchments and for each of them unitgraphs synthesized. Appropriate parts of the effective design storm are then applied to these unitgraphs in order to yield a flood hydrograph at the mouth of each sub-catchment which are lag-routed in the correct queuing order to the locality in question.

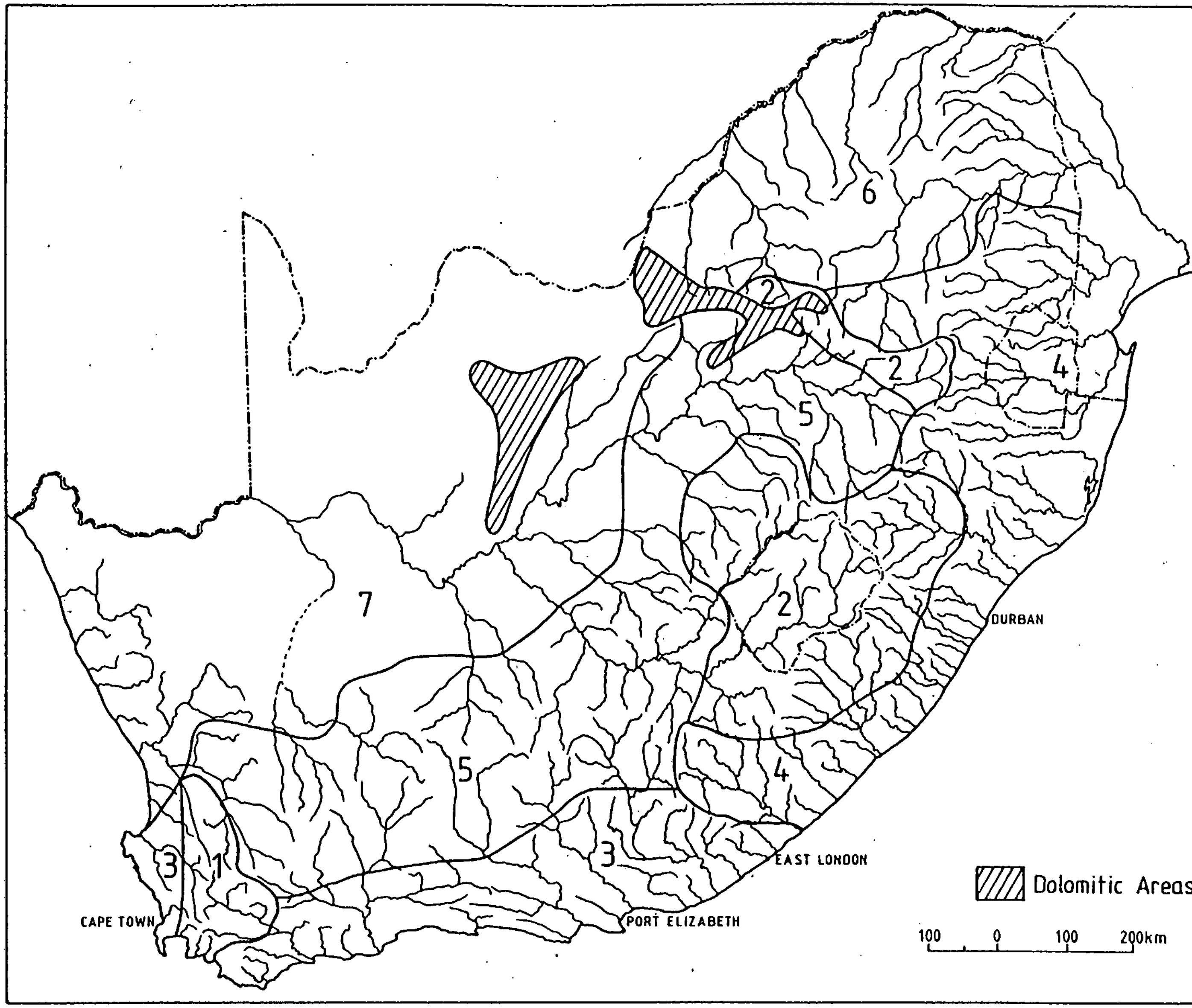

Fig. 4.8 South Africa: homogeneous flood regions
(after Midgley, 1972)

It is not the intention of this study to examine in any detail the application of these models in the region. Rather, it is necessary to emphasise that they are all directed at the estimation of flood discharge at a particular point along a river. Flood stage can only be estimated by relating discharge to the cross-sectional area of the channel and the use of a computer programme to determine water-surface elevation at that point. The usefulness of these methods is therefore limited to the characterisation of floods along small stretches of river land for which valley profile measurements can be made. While this is necessary for the design of structures threatened by potential floods the methods are too laborious for application on a geographically extensive scale. Nevertheless they do adequately combine the various physical parameters of floods into a useful tool for estimating flood magnitude.

The physical environment may therefore be seen as an intial source of the hazard of droughts and floods. But as indicated earlier, a natural hazard implies a two-way relationship demanding the presence of man. The next step is therefore to examine the role of man in the hazard relationship.

CHAPTER 5

THE HUMAN FACTOR IN DROUGHT AND FLOOD HAZARD: DEGRADATION OF THE NATURAL ENVIRONMENT

This chapter addresses the problem of the role played by man in constituting a drought and flood hazard in the Karoo region. The analysis is based on the premise that the Karoo region is an ecosystem which has been subjected to stress and modification by the presence of man and his exploitive practices, resulting in the heightening of the hazard of natural processes present in his environment. An attempt is made to show that the spread of human settlement and with it the more intensive use of the land, occasioned by socio-economic pressures associated with a system of production and a set of values which is out of harmony with the dynamic equilibrium of the environment, has been responsible for these conditions.

An ecosystem consists of abiotic and biotic components. The abiotic components considered relevant to this study of the Karoo environment have been dealt with in the previous chapter. There have been numerous suggestions in published material that significant changes are occurring in the realm of the abiotic components of the global ecosystem especially in respect of the climate. It is known that the average global levels of carbon dioxide in the atmosphere increased by 26 per cent between 1860 and 1986 primarily as a result of the burning of fossil fuels and the extensive clearing and burning of tropical forests (Miller, 1988). There is also evidence of depletion of the ozone layer. Both of these gases play a key role in the greenhouse effect and meteorological models predict a warming of the atmosphere as a consequence of these changes. Increasing amounts of pollutants in the atmosphere are also seen as threats to climatic stability due to their effect on the receipt of radiant energy at the earth's surface.

Investigations by researchers such as Tyson (1986) have shown that in South Africa claims of an increasing or decreasing temperature or rainfall trend are without foundation. Examination of tree rings for the period preceeding the recording of meteorological data, and the more thorough analysis of specific temperature and rainfall data from the historical record, reveal no evidence to support such views of short-term climatic change. Rather, a cyclic variation with a period of about 18 to 20 years has been identified. The effect of conditions fostering global change in rainfall or temperature in the short term should therefore be interpreted to be potential rather than universally prevalent.

There are no indications that other abiotic elements such as the chemical composition of the hydrospheric and lithospheric components of the Karoo ecosystem have been subject to significant variation. Given a solar constant it therefore seems reasonable to exclude general change in the abiotic components of the ecosystem as a source of any deterioration that might have occurred in the Karoo environment in the recent past. An explanation of the source of change should rather be sought in the biotic components of the system.

Any ecosystem has the ability to withstand or recover from externally imposed stresses. The stability it possesses is maintained amidst constant change that occurs within the system. It exists in a state of dynamic equilibrium. Its resilience to recover from outside disturbances if they are not too drastic, and to restore itself to an original condition can, however, be exceeded. If this happens a variety of consequences are possible. There can be changes at the organism or population level, an example of which is a change in the composition of the population. Changes at the community level can also occur, one of these being simplification, in which there is a reduction in the number of species, reduction or elimination of habitats and filled ecological niches, less complex food webs and lowered stability. There is evidence of such changes in the Karoo environment.

5.1 Initial environmental equilibrium

From early descriptions of the interior of Southern Africa by travellers such as Lichtenstein (1812), Baines (Van Riebeeck Society, 1961), Somerville (Van Riebeeck Society, 1979) and Thompson (1827), it is possible to deduce only some general characteristics of the Karoo ecosystem as it was at the time of the arrival of Europeans in the region. While it is beyond the scope of this study to attempt a detailed reconstruction of conditions of that time, it is necessary to identify certain aspects that are relevant to the question of whether ecological stability existed at that time.

5.1.1 The natural components

Acocks (1975) has endeavoured to indicate the distribution of vegetation as it is envisaged to have been at the beginning of the fifteenth century. The study region was characterised by four main types of vegetation. Covering most of the central and western parts was the vegetation of the Karoo community. About one quarter of the region in the east was covered by sweet grassveld. Scrubby mixed grassveld occurred along the Great Escarpment in a zone beginning around Calvinia in the north and stretching southwards almost to Laingsburg and then extending eastwards as far as the vicinity of Murraysburg. Along the margins of the Karoo community in the south there was a narrow zone of bushveld, widening in the Jansenville area and becoming more patchy in the east between Graaff-Reinet and Somerset East. In the extreme east around Bedford, Adelaide and Fort Beaufort there was some forest and scrubforest.

Large herds of antelope and other wild animals abounded throughout the region, as is attested by early written accounts.

5.1.2 The human components

At that time the Karoo region was peopled by two groups, the Khoi-Khoi and the San, known at the time as the Hottentots and the Bushmen. It is impossible to reliably estimate the numbers of these people but is it clear that they were encountered widely throughout the area. Their economy was Late Stone Age and accounts of their way of life indicate that they lived simply and close to nature. The Bushmen lived on roots and berries gathered in the veld and on game hunted with their bows and poisoned arrows or trapped in concealed holes in the ground. The Hottentots were nomadic herdsmen possessing cattle and sheep, which they reared on the abundantly available natural grazing (Nurse *et al.*, 1985).

The impact that these two groups had on the natural environment is undocumented. Christopher (1982) notes that the herding economy apparently became well organized with marked seasonal migrations according to the availability of grazing and other foodstuffs. Indeed, an absence of any barriers imposed by rights of ownership or sedentary lifestyle made overgrazing unnecessary. Wild game did not appear to have been overhunted. The presence of large herds of antelope and other wild game was consistently mentioned by travellers through the region, e.g. Somerville (1799-1802), Thompson (1824) and Baines (1842-53). This evidence supports an assumption of ecological balance between the human and natural components of the ecosystem that still existed at the middle of the previous century.

Of course, the hazard of drought existed. Floods were probably far less significant. Such events were part and parcel of the natural environment inhabited by the Khoi-Khoi and San. The settlements of the Khoi-Khoi were at best no more than semi-permanent, while the San constructed only the most rudimentary of shelters or inhabited caves. There was no cultivation and loss of property as a result of floods was probably negligible. Drought constituted a greater hazard because it brought about a reduction in the food base. As grazing was reduced the existence of the herds may have been threatened and the game was caused to migrate from the area. There were no artificial barriers to movement and migration was a natural response for both wild game and humans with their herds.

That drought imposed stress and hardship is without question. Thompson refers to conditions that prevailed during the great drought in the western interior in the early 1820's. He had expected to find plenty of game but discovered that the great drought that had long prevailed in the region had driven almost all of the game to other quarters (Thompson, 1827). The indigenous people had also moved away from the drought-stricken area. The aged and infirm had been left behind to eke out an existence until nature took its course. Thompson describes the miserable condition of two Koranna women, one advanced in age, the other young but a cripple and nursing an infant. They had been left to perish by their relatives and because they were unable to provide for themselves, were completely emaciated and close to death (Thompson, 1827 : 250). In the absence of an advanced technology man was very much part of nature and subject to its vicissitudes, not excluding even a degree of natural selection on the human level.

Migration in response to pressure from extreme natural events appears to have been an important principle in the maintenance of dynamic equilibrium in the ecosystem.

5.2 The rise of hazard

The occupation of the Karoo region by the White man signalled the onset of a period in which the hazards of drought and later floods gradually increased. Several factors were responsible for this.

5.2.1 The spread of permanent settlement

The Bushmen retreated before the Hottentots and were pushed into progressively more remote areas. The spread of European settlers toward the interior after the establishment of the settlement at the Cape also forced the hunter-gatherers to retreat and they were eliminated from the Karoo region in the course of the nineteenth century.

The arrival of the Whites was disastrous for the Khoi. Competition for grazing land followed the acquisition of sheep and cattle by the Whites. Contact with diseases introduced by the settlers, especially smallpox, against which the indigenous peoples had no immunity, resulted in epidemics which decimated their numbers. The notorious smallpox epidemic of 1713 broke their clan organization and hence their ability to resist in the conflict with White settlers (Van der Walt *et al.*, 1966). Consequently their traditional grazing grounds were appropriated by the White graziers in the course of the eighteenth century (Christopher, 1982).

The graziers were granted exclusive grazing land by the Dutch East India Company for which a small rental had to be paid. They could select the land they desired by demarcating a middle point and then riding on horseback from it at walking pace for half an hour in several directions. In this way the boundaries of an approximately circular farm could be marked out. The area so enclosed was approximately 2500 ha. This system of land allocation operated throughout the eighteenth century and appears to have worked well as long as there was unlimited land and numbers involved were small.

With the British occupation of the Cape came a process of land reform (Fisher, 1983). In 1814 the British government introduced the concept of perpetual leases with surveyed boundaries in an attempt to end the stock farmers' nomadic habits and give them greater security of tenure. The standard farm of 2500 ha was established widely over the southern Cape of Good Hope (Van der Walt *et al.*, 1966).

It became apparent, however, that in the drier interior these farms were too small, and after 1829 greater flexibility was allowed in the surveying of farm units, some units of 50 000 ha having been allocated. Christopher (1982) remarks that the theme of most legislation was to encourage families to settle on the land. Large commercial companies were never encouraged and consequently a far closer pattern of settlement developed than would have been the case under company farming.

The quit-rent system by which land was leased to the farmers was abolished in 1934 and today some four-fifths of farmers own the land they farm in freehold tenure.

The closer settlement of the Karoo region brought with it an increase in the level of natural hazard, particularly of drought. Many of the farm units, especially those in the northern parts, had no permanent sources of water during periods of drought. Moreover, due to individual ownership and the enclosure of farm units with fences, increasingly since the beginning of the present century (Grosskopf, 1932), the traditional system of trekking with livestock to areas unaffected by drought was no longer possible[1]. No longer could stock farmers escape from the

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[1] **Migration** still occurs today in certain areas such as between Namaqualand and Bushmanland, and the Roggeveld and Tanqua Karoo in the Sutherland region. While such migrations are essentially seasonal and thus constitute a form of transhumance, the advantage of a farmer having land in contrasting regions is clear in times of local drought as well.]

drought; it had to be endured and the losses suffered. These were new circumstances which they had probably not anticipated and to which they had to adjust as best they could. That their adaptation to these changed circumstances was inadequate is evident from the necessity of the Government to provide some financial relief in the form of the Abolition of Quit Rent Act of 1934.

Fisher (1983) refers to the traditional indigenous system of land tenure, in which community interests are paramount and ownership

is vested in the family or tribal group, as cognatic tenure. A system of cognatic tenure is seen to be in a state of symbiotic equilibrium with its ecological conditions. "The state of symbiotic equilibrium that a cognatic system holds with its ecological environment is thrown out of balance when the amount of land available is no longer sufficient to sustain the community. Population growth, overuse and denudation of the land will destroy the system. A precarious rebalancing may be achieved by the importation of resources, but once the self-sustaining qualities have failed the process of change becomes inexorable" (Fisher, 1983 : 442). None of these destructive processes obtained prior to the spread of European people into the Karoo ecosystem. Whatever change has occurred must therefore be attributed to influences associated with their presence.

5.2.2 The emergence of commercial pastoralism

The needs of the indigenous Khoi-Khoi and San peoples were met within their subsistence economy and a surplus was neither required nor was it of any particular value to them. If nature was extraordinarily bountiful at a particular time it merely eased their burden of effort and they could enjoy the abundance with simple acceptance. Similarly, when nature imposed conditions of dearth and hardship, these were either borne with resignation or avoided by migration.

The occupation of the land by European settlers brought with it a system of commercial pastoralism. The essence of the change in relation to the environment was that now man no longer existed in a state of symbiotic equilibruim with nature. The motive of the economy had changed from one based on the fulfilment of needs to one founded on the pursuit of profit. Man began to extract from nature what he could get, rather than receive what it gave him. While this practice operated within the bounds of the resilience of the ecosystem the dynamic eqilibrium was maintained but any transgression of these limits ensured the onset of deterioration. Several such stress producing factors can be identified.

(a) The demand for land

The most suitable and productive land in terms of distance relationships or productive potential was occupied first. Demand for land increased as less and less land became available and increasingly men were directed to attempt to make a living in areas that were unsuitable for farming. Increased demand also had the effect of driving up land prices to levels little related to its economic potential and farmers were tempted to sell off part of their land, especially during poor years. The remaing land was often transformed into uneconomical units (Christopher, 1982). As a consequence it became a necessity for the very survival of farmers to extract as much as possible from the land, either to make a living or, if they purchased land at an inflated price, to compensate for the high price they paid.

The tendency of farmers to purchase additional land adjoining their own was often to counter declining profits per unit area. High prices for land, in some instances, however, had the effect of increasing debt per unit area and therefore turning an economic unit into an uneconomic proposition.

(b) Expansion of the world economy

The expansion of the world economy during the nineteenth century had a profound effect on the pastoral farmers of the region. Associated with it was an increased demand for wool, ostrich feathers, hides and skins. The transportation system had expanded sufficiently to facilitate the marketing of products even from the more remote areas and pastoral farming changed from a semi-subsistence state to a commercial undertaking.

5.2.3 Social and cultural factors

(a) Farming as a way of life

The spirit of independance that characterised the *trekboer* who moved away from the Cape settlement into the interior to attenuate control of the Dutch East India Company over him, has passed down to later generations of the Afrikaner farmer. It has been an important factor in his attachment to the land. Land of his own increased his self-sufficiency and gave him security (Grosskopf, 1932). On his own land, subject only to his Maker and as little control by government authority as possible, he could be master of his own destiny. Farming as a way of life became an important element in Afrikaner culture, and even today the vast majority of Karoo farmers are Afrikaans speaking. Viewed in this light it is understandable that farming as a way of life was to be abandoned only as a result of failure. It is likely, therefore, that today many people continue to be farmers even though they might be more suited to some other occupation and that the farm might be run inefficiently. In the long term inefficiency, coupled with exploitive farming practices, could lead to a deterioration of the natural environment, increasing the hazard of drought and floods.

(b) The subdivision of holdings

The great value attached to landownership is also reflected in the custom of a farmer's land being divided amongst his children as their inheritance. This led to excessive subdivision and the creation of uneconomical units. Exploitive practices, occasioned by the necessity to make a living from too small a unit, promotes environmental deterioration and leads to a rise in the level of hazard.

(c) Rising standard of living

The changeover from subsistence to commercial farming and the emergence of secondary industry in South Africa broadened the wage base and brought with it a higher standard of living for many. Grosskopf (1932) refers to the rapid rise in the demand for a higher standard of living that characterised the first two decades of the present century and associates the depopulation of the rural areas with it. As has been pointed out, leaving the land did not occur lightly. Due to his attachment to the land the farmer would resort to such action only when all else failed. It is therefore not unreasonable to deduce that this would have occurred only after he had taken the land to the very edge of its capability to provide him with as good a livelihood as possible.

5.2.4 Inappropriate farming practices

In 1923 the report of the Drought Investigation Commission was published. Its message was clear. Unless something was done to curb the deteriorating conditions South Africa was destined to become a desert uninhabitable by man. Bad farming practice is mentioned as one of the main contributory factors.

The kraaling of sheep was identified as one of these practices. Kraaling was necessary to protect sheep from jackals but was very detrimental to the veld. The main grazing time of sheep is in the early morning and late afternoon. Yet this was the time they were being driven out to the pastures or back to the kraal for the night. The energy expended in moving over long distances every day was compensated for by an increased intake of food and this placed an unnecessary burden on the grazing, especially in times of scarcity. Apart from the damage the vegetation suffered as a result of repeated trampling, it was also heavily overgrazed in the vicinity of the kraals or other overnight places.

Overstocking and associated overgrazing was identified as another contributory cause. The climate is subject to great variations. Farmers tended to be optimistic and, following the desire to derive the maximun benefit from their land, stocked their land according to its perceived carrying capacity in good years. It followed that the land was overstocked at all other times, with disastrous consequences for the grazing.

A third major problem was insufficient watering points for stock. Sheep had to move over long distances to find water. Here too, the consequences of the increased expenditure of energy and heightened demand for food, were the trampling of the veld and destruction of the grazing around the watering points.

5.2.5 The establishment of towns

The **rise** of hazard should not be seen only in relation to the effect of a deteriorated natural environment on a farming population. By the end of the first decade of the twentieth century all the towns that exist in the area today had been founded. With them a new dimension to the hazard of drought and flood was introduced.

A reliable permanent water supply had to be found for both domestic and industrial purposes. The hazard of drought remained a problem until subterranean water could be tapped and storage reservoirs could be constructed to provide sufficient water during periods of drought. Today, apart from the necessity to occasionally impose restrictions on the use of water, the hazard of drought to urban dwellers is not great.

The recognition of the importance of a water supply is clearly evident from the sites chosen for the first towns in the region. Nowhere is this better illustrated than in the example of Graaff-Reinet which was the first to be established in the Karoo in 1786. As indicated in chapter 3, the site was a section of flood-plain land almost enclosed by a meander of the Sundays River. Cradock, the second town to be established, is situated on the banks of the Great Fish River. Other towns situated on the banks of rivers or water courses are Kenhardt, Prieska, Vosburg, Carnarvon, Victoria West, Richmond, Noupoort, Steynsburg, Molteno, Jamestown, Sterkstroom, Queenstown, Nieu-Bethesda, Beaufort West, Merweville, Laingsburg, Aberdeen, Jansenville, Pearston, Steytlerville, Bedford, Adelaide and Fort Beaufort, though the streams are without water for most of the year in many instances.

The establishment of towns in riparian locations magnified another hazard that had previously been relatively insignificant.

Although some farmers had sought to augment their income by cultivating small tracts of riparian land in favourable locations, the total amount of land was small and very few depended on it for a livelihood. Losses due to floods were not great. However, with townspeople inhabiting sites on the banks or rivers and streams, floods now became a very real hazard to lives and property.

5.3 The state of the natural environment

"Damage to the environment is seldom the deliberate act of evil men, nor is it the inevitable by-product of advancing technology; it is very much due to man's lack of restraint and demand for resources far in excess of his biological needs, omitting to plan for the side-effects of his actions, and placing his own short-term interests far ahead of his responsibilities" (Fuggle, 1983 :5) It is clear that the Karoo environment has deteriorated as a consequence of man's presence. The following paragraphs summarize some of the evidence of damage to the environment and note its effect on the hazards of drought and flood.

In its report in 1923 the Drought Investigation Commission repeatedly emphasised the deteriorated state of the veld. It was recognized that much of South Africa had been dry long before the coming of the white man, as attested by the name "Karo" and the natural vegetation that was well adapted to conditions of drought. Since his coming, however, the original vegetation had been either fully or partly destroyed over vast areas of the country with the consequence that rivers, fountains, pools and marshes which were known to earlier travellers, had disappeared. Moreover, the process of desertification was seen to be progressing rapidly.

The Carnegie Commission of enquiry into the poor-white problem confirmed the existence of these conditions in 1932 (Grosskopf, 1932).

Writing in the foreword to the first edition of Acocks's Veld Types of South Africa (1952), R.A. Dyer, Head of the Division of Botany and Director of Botanical Survey of South Africa states: "Mr Acocks endorses the grave warning so often heard in these times that unless the Department does succeed in this vital matter of soil and veld conservation the country faces ruin by the general advance of desert conditions" (Acocks, 1975).

Degradation of the natural environment is evident with respect to three main categories: vegetation and fauna, soil erosion and water resources.

5.3.1 Vegetation and fauna

The virtual disappearance of grass from the Karoo is one of the important consequences of man's carelessness (Meadows, 1985). The notion that the Karoo is characterized by "bare soil dotted with Karoo bushes and occasionally covered with annual grasses and succulents is a completely false one" (Acocks, 1975 : 5). The condition of bareness is artificial. The grasses, even those that tend to be unpalatable, are eaten off to the ground, indicating that they are preferred to the Karoo bushes. Karoo bushes are valuable mainly as reserves for winter or droughts when there is no green grass left. Furthermore, the majority of the Karoo bushes are unpalatable and since the more palatable ones are eaten preferentially, the unpalatable ones are steadily on the increase.

Selective grazing is seen to be responsible for this. The wild animals that were formerly present in large numbers were of many different varieties, each with its own grazing habits. They were also free to move about when water and grazing grew scarce and did **not** return until grazing had recovered. Sheep that have replaced the game graze selectively and flocks are maintained in an area, whether the state of the grazing justifies it or not. In this way a change occurs in the composition of the veld, reducing its value as grazing for sheep.

On a regional scale Acocks recognizes several major changes (Acocks, 1975). The sweet grassveld that formerly characterized the eastern third of the study region has completely disappeared, its place being taken by Karoo vegetation. Another change is the invasion of the Upper Central Karoo by Arid Karoo. The Arid Karoo and Western Mountain Karoo has also been invaded by the Succulent Karoo. Most significant is the desertification of the west where there is no longer a permanent, unbroken vegetation cover, and only rarely a temporary cover.

5.3.2 Soil erosion

"Accelerated soil erosion is the loss of soil due to man's use of the land in ways that are maladjusted to the natural environment" (Rabie and Theron, 1983 : 143). That soil erosion is a serious problem in South Africa is without question. The problem has received attention in many studies, been identified by several commissions of enquiry, and been the subject of legislation in numerous acts of parliament. A brief review of some of the most significant references to it as a problem will serve to emphasize the role that man has played as a causative factor in the related rise of natural hazard more particularly in the semi-arid and arid environment of the study area.

One of the earliest authoritative documentations of the seriousness of soil erosion was the Report of the Select Committee on Droughts, Rainfall and Soil Erosion of 1917 (Senate SC 2-1914). The Commission indicated that drastic destruction of the natural vegetation had occurred and concluded that the dessication that was evident in certain areas of the country was the result of soil erosion.

The report of the Drought Investigation Commission (UG 49-23, 1923) reiterated the statements of the Select Committee and found that faulty veld and stock management, especially kraaling of stock, overstocking and destruction of the natural vegetation were principal factors in drought losses and that these factors were also responsible for soil erosion.

The seriousness of the situation is evident from the legislation that was deemed necessary to control soil erosion. The first substantial legislation aimed at combatting soil erosion was the Forest and Veld Conservation Act 13 of 1941. This was followed by the Soil Conservation Acts of 1946 and 1969. Other related legislation includes the Water Act 54 of 1956, the Forest Act 72 of 1968, the Mountain Catchment Areas Act 63 of 1970, the Common Pasture Management Act 82 of 1977, the Unbeneficial Occupation of Farms Act 29 of 1937, and the Subdivision of Agricultural Land Act 70 of 1970. The Stock Reduction Scheme that operated during the 1970's was also an attempt to allow the natural vegetation to recover and reduce the process of soil erosion.

Referring to the outcome of environmental stress in a semi-arid country such as South Africa, Allanson and Rabie (1983) draw attention to the very considerable load of sediment carried by the rivers, this being particularly evident where the shales and mudstones of the Beaufort and Molteno beds of the Karoo sediments are exposed and subject to poor land-management practice. They point out that the parts that are most seriously affected in this way are the karroid regions of the Eastern Cape.

In summing up the state of soil erosion in South Africa, Rabie and Theron (1983 : 159) maintain that "despite the fact that official and other action has been directed at soil erosion control in earnest since 1914; that action has continued throughout; that numerous soil conservation campaigns have been launched through the years; that extensive soil conservation legislation was introduced in the 1940's; that the dangers of soil erosion have been repeated ad nauseam; and that the solutions to soil erosion problems have been repeatedly pointed out, soil erosion in South Africa has steadily increased." As a consequence of soil erosion there is less grazing per unit area and direct runoff is more rapid. Together with soil erosion the hazard of drought and floods has therefore also increased.

5.3.3 Water resources

A consequence of the destruction of the vegetation has been a reduction of surface detention and the capacity of the land surface to absorb water. Enhanced sheet-flow initiated a process of erosion which has opened up, multiplied and enlarged channels by which the water reaches the sea, resulting in a lowering of the water table, and a drying up of waterholes and rivers. The silting up of dams and the deposition of silt during floods is also increased.

In his account of the past and future ecological condition of South African rivers Chutter (1973) stresses the deterioration that has occurred in these rivers over the past three hundred years, pointing out that once perennial rivers have become seasonal and carry increased silt loads. Apart from the loss of valuable topsoil that this silt load represents, it adversely affects the water resources of the region. One of the most serious consequences is the deposition of silt in the river beds and more importantly in the dams built to impound the water of the rivers. Several dams in the eastern part of the Karoo have been filled with silt to such an extent that the walls have had to be raised to extend their period of usefulness. The wall of Lake Mentz in the Sundays River, completed in 1922, had to be raised twice to compensate for the 104 million m^3 of silt that by

1966 had reduced its capacity by a half. The impounding wall of Lake Arthur in the Great Fish River has also had to be raised twice due to an accumulation of silt (Barnard et al., 1972).

The consequences of this pattern for the drought and flood hazard are clear. Diminished surface water and a reduced water table mean that even relatively small negative deviations from an expected amount of rainfall produce shortages of water that would previously have been unknown. Similarly, positive deviations produce accelerated and increased runoff response with the danger of flooding greatly enhanced. Exceeding the resilience of the natural environment has destroyed the built-in "cushion" which absorbed the normal variations in rainfall and by which the dynamic equilibrium was maintained. As a consequence the natural environment has become far less stable, a condition which will continue and deteriorate further as long as the pressure that produced it is maintained.

A downward adjustment of the standard of living in response to reduced circumstances is a measure rarely taken voluntarily. Man tends to pursue all other possible avenues to maintain the standard to which he has become accustomed. Finally he might be forced to accept lower standards when all else has failed. A degraded environment, if left to nature, would induce a lowered standard of living for those dependent on it. In his attempt to maintain his standard of living, however, man hastens the process of deterioration by exploitive practices, and he can only continue to be sustained in it by importing resources from elsewhere. The natural environment becomes increasingly hazardous to him as he continues to live on the very margins of its ability to sustain him at the level he demands of it. The hazardousness of the Karoo environment to the farmer living in it relates at least partly to the proximity of his farming operation to the frontier of environmental resilience.

CHAPTER 6

INSTITUTIONAL RESPONSES TO DROUGHT AND FLOOD HAZARD

Response to the hazards of drought and flood in the Karoo region is dealt with under the two main headings: institutional responses and individual responses. The first refers to the responses of organized bodies, which include government bodies at both central and local levels, and certain private organizations. Central government's response is mainly related to its political and legislative capacity. Government departments included are Agriculture Economics and Marketing, Environmental Affairs and Conservation, Water Affairs, Transport, and National Health and Population Development (and in the past their predecessors). The responses of various statutory bodies falling under the jurisdiction of these departments as well as those of provincial, divisional and municipal authorities and other organizations such as the Civil Defence Corps are also evaluated in their relevant contexts.

The second are the responses of individuals such as farmers and urban residents who are affected by these hazards. This latter aspect is dealt with in chapter 7. The division between the two is not always clear-cut, for example a farmer might construct dams on his farm as a hedge against drought, but the project might be carried out with government aid, making it a joint response. For the sake of convenience, however, they are dealt with separately.

Another point to which attention is drawn is that in many instances the action taken by institutions and individuals might have had a direct bearing on the effect of these two hazards in their fields of operation, but that the action might not have been in direct response to either of the hazards in the first place. The example of the construction of large storage reservoirs can be used to illustrate this point. A large dam might be constructed to provide water for irrigation purposes, not because of the hazard of droughts but on account of the ambient aridity of the environment. In effect, however, the scheme would possibly serve to reduce the hazards of both droughts and floods. In fact it is not always possible to distinguish what the prime objective of such schemes was since they are frequently multi-purpose developments. While the existence of such complications is not lost from sight, in this study such actions are regarded as responses to hazard even though hazard might have been a secondary source of motivation.

"In pursuing a policy of hazard reduction, community authorities have three broad areas in which they can function. First by setting laws, regulations, incentives and penalties they provide guides to the choices made by citizens in a `private' capacity. Second they make decisions concerning the use of resources and response to hazards, including the deployment of large-scale, expensive technology, such as dams, that can be undertaken only as large indivisible applications. And third, they dispense hazard adjustment services" (Burton, Kates and White, 1978: 113).

In their comparative analysis of three natural hazards (earthquakes, floods and snow) Hewitt and Burton (1971) suggested six possible response types. The categories are broad enough to encompass a wide spectrum of other natural hazards including drought and also incorporate the three areas identified in the previous paragraph. They are

- affecting the cause
- modifying the hazard
- modifying the loss potential

and adjusting to the losses by

- spreading the losses
- planning for losses and
- bearing the losses.

The first three fall mainly in the field of technological and semi-technological adjustments, while the latter three involve adjustments in the field of human response. Responses in this study are considered within the framework of these six categories.

6.1 Affecting the cause

6.1.1 Technological adjustments

As pointed out earlier the source of the hazard of both droughts and floods is partly to be found in basic atmospheric proceses. Man is unable to control these processes in any significant way and most projects aimed at affecting the cause of the hazards require intervention in non-atmospheric processes. In South Africa, as in the USA and elsewhere, some government sponsored experimentation has been done in the field of weather modification using cloud-seeding techniques for the artificial stimulation of rain. Suitable clouds are seeded with various substances such as sodium iodide or dry-ice crystals to trigger the precipitation process. The success of such experiments has been very moderate (Garstang *et al.*, 1981; Henderson-Sellers and Robinson, 1986) and the prospects of applying this technique for drought alleviation are not good since suitable clouds are a basic prerequisite. These are usually absent when droughts prevail. Prospects for success in preventing floods or modifying their severity by means of cloud-seeding appear to be somewhat more favourable. Especially with respect to localized floods an areally more equitable distribution of rainfall might be effected by this method, and inundations due to falls that are too concentrated might possibly be averted.

While man's ability to affect the cause of these two hazards in the geophysical realm is clearly limited, intervention in the field of human occupation and activity in hazardous areas does present some options.

6.1.2 Abatement schemes

One such option is the reduction of flood flows by land-use design or flood abatement schemes. The purpose of these adjustments is to alter the volume of runoff and timing of the flood hydrograph by changes in the land use of catchments. Afforestation is one important means by which this is achieved (Smith and Tobin 1979). Forest stands increase interception and also return water directly to the atmosphere through evapotranspiration.

Although the effectiveness of such measures for flood alleviation has been questioned by some researchers (e.g. Flemming, 1973; Worley and Patric, 1971), others (e.g. Clark, 1987; Institute of Hydrology, 1981) provide evidence of the positive effect of afforestation. Hoyt and Langbein (1955) quote an example from the Tennessee Valley Authority area which demonstrates the effectiveness of such a scheme. During a twelve-month period of active afforrestation the flood hydrograph was altered so that peaks were reduced by 85 per cent and lag time increased from $1^1/_2$ to 8 hours, without there being any difference in the volume of total runoff.

In the study area the catchments of all the rivers (except the Orange, which forms the northern boundary and is exotic) are situated in the arid or semi-arid environment of the Karoo region. Here the climate is unsuitable for afforestation and this option cannot be pursued. As was pointed out in chapter 4, however, there is a clear relationship between the nature of the vegetational cover and runoff. The deterioration of the cover and the consequent increase in the rate of runoff was also referred to in chapter 5. This process was recognized by the Departments of Environment Affairs and Conservation, Agriculture, and Water Affairs and its predecessors and various attempts have been made to arrest the progress of deterioration of the vegetational cover in the region.

6.1.3 Environmental conservation

One of the major responses has been by the introduction of legislation directed at the conservation of the environment. Much of this legislation has promoted the abatement of both floods and drought. Relevant acts passed by parliament are

The Unbeneficial Occupation of Farms Act 29 of 1937
The Forest and Veld Conservation Act 13 of 1941
The Soil Conservation Acts 45 of 1946 and 76 of 1969
The Water Act 54 of 1956
The Forest Act 72 of 1968
The Mountain Catchment Areas Act 63 of 1970
The Subdivision of Agricultural Land Act 70 of 1970
The Common Pasture Management Act 82 of 1977
The Environment Conservation Act 100 of 1982
The Environment Conservation Act 73 of 1989

Apart from legislation, environmental conservation has been promoted by less formal means based on the dissemination of conservational information and the benefits to be derived from it. This information has been most actively promoted among farmers through the efforts of Extension Officers via Soil Conservation Committees. The goals of such extension work are

- the promotion of agricultural development and the protection of natural resources;
- management of pastureland;
- monitoring of suspected defaulters;
- promotion of the planting of drought-resistant fodder crops.

The chief means by which these goals are sought to be effected are by holding mini farmers' days and field days for farmer's associations during which farmers are addressed by researchers in conservation practice, by personal efforts to persuade farmers to adopt appropriate veld management practices, and by follow-up visits (Coetzee, 1983).

6.1.4 Livestock Reduction Scheme

Another attempt by the government to encourage conservation was the livestock reduction scheme that operated from 1970 to 1975. This scheme provided compensation for farmers in the extensive grazing areas who voluntarily reduced their livestock numbers in order to allow the pastureland to recover, especially as a result of the drought of the 1960's. The ultimate objective was to reduce the number of stock to one-third of the normal carrying capacity of the veld, especially on the smaller farms where grazing was most intensive. In badly eroded or denuded areas complete withdrawal of stock was advocated.

The scheme proved to be so popular amongst farmers that by 29 February, 1972, which was the final date for the receipt of applications, the number of small stock units identified for withdrawal totalled 5 million. This was well in excess of the goal of 3 million set at the beginning of the scheme. From the Karoo region 3481 farmers had applied to participate in the scheme involving 15 398 027 ha of land. Most of these withdrew one-third of their stock, only 335 farmers (occupying 630 245 ha) taking up the option of withdrawing all their stock.

Due to the problem of identifying unweened stock, the conditions of the scheme were changed on 23 May, 1972 and farmers were given the option of reconsidering their participation in the scheme. Only some 10 per cent withdrew.

After only three years of the operation of the scheme the Secretary of Agricultural Technical Services was able to report that

- the veld of participants was, in general, considerably better than that of non-participants;

- farmers had become much more aware of the condition of their veld, especially with respect to its carrying capacity;

- farmers were pleased with the improvement of their veld; and

- that there was good co-operation on the part of most farmers.

By the end of the scheme, more than R45 million had been spent on veld improvement, some 45 per cent of the total having been paid for the Karoo region (RSA, Department of Agricultural Technical Services, 1979).

The timing of the scheme was fortuitously most appropriate because it was followed by one of the most serious droughts in the region in many decades. If it was successful as an abatement measure, it should have reduced the detrimental effect of the 1978 to 1986 drought. No material is available on its effect in this respect, not least because the scheme's prime purpose was conservation rather than drought alleviation. What is clear, however, is that as a single measure it was inadequate for averting the detrimental effects of the drought.

The livestock reduction scheme, though successful in assisting the natural pasturage to recuperate while it was in operation, appears to have been less successful in the longer term. The Extension Officer in charge of the Karoo region indicated that by the early 1980's, 99 per cent of the farmers had reverted to stocking their farms with the same number of livestock that they had prior to the introduction of the scheme. Though farmers could see the evidence of improved veld conditions during the operation of the scheme, they were not convinced that there was a real advantage in building up a natural reserve of pasturage. If pasturage was there it had to be utilized (Coetzee, 1983).

6.2 Modifying the hazard

6.2.1 Technological measures

Modifying the hazard is another approach to hazard reduction. In the Karoo region the institutional response that falls into this category has been the construction of reservoirs and dams. The rationale with respect to flood control is that a substantial amount of water is held in storage in the upper reaches of the catchment and released in a controlled way, such that inundation of floodplain areas lower down is prevented or at least reduced. Protection is effected up to the design standards of the reservoir.

Besides the obvious benefits of such schemes there are a number of associated disadvantages. The construction of dams is expensive. Reservoirs also require large tracts of land. According to Hewlett and Nutter (1969) the ratio of inundated to protected land in the USA is 1 : 2,6. The presence of a dam furthermore tends to engender popular belief that complete protection from flooding is afforded, while extreme flood events can exceed the design limits of the structure. If this belief leads to additional investment on the floodplain the hazard to life and property may increase. The problem of silt accumulation has already been alluded to in the previous chapter.

A gamut of problems also arises from the fact that most of the storage dams in the Karoo region are dual or multipurpose schemes. For flood reduction it is important that water levels in storage dams be kept as low as possible so that maximum interception of flood flow can be effected. If reservoirs are also used as a source of water supply for irrigation to reduce the hazard of drought, or for the generation of hydroelectricity, the converse is required. Such conflicting management priorities necessitate a compromise which reduces the effectiveness of the scheme. Economics, however, usually necessitates the construction of multipurpose schemes.

Thirty-three major reservoirs have been constructed in the region. Their distribution is shown in figure 6.1. The prime purpose of all these schemes has been to provide irrigation water but they also serve the dual purpose of flood control and the provision of water when natural sources fail in times of drought. The only multi-purpose scheme is the Orange River Project incorporating the Hendrik Verwoerd and P.K. le Roux dams. The White Paper on the subject (RSA, 1962) states the following

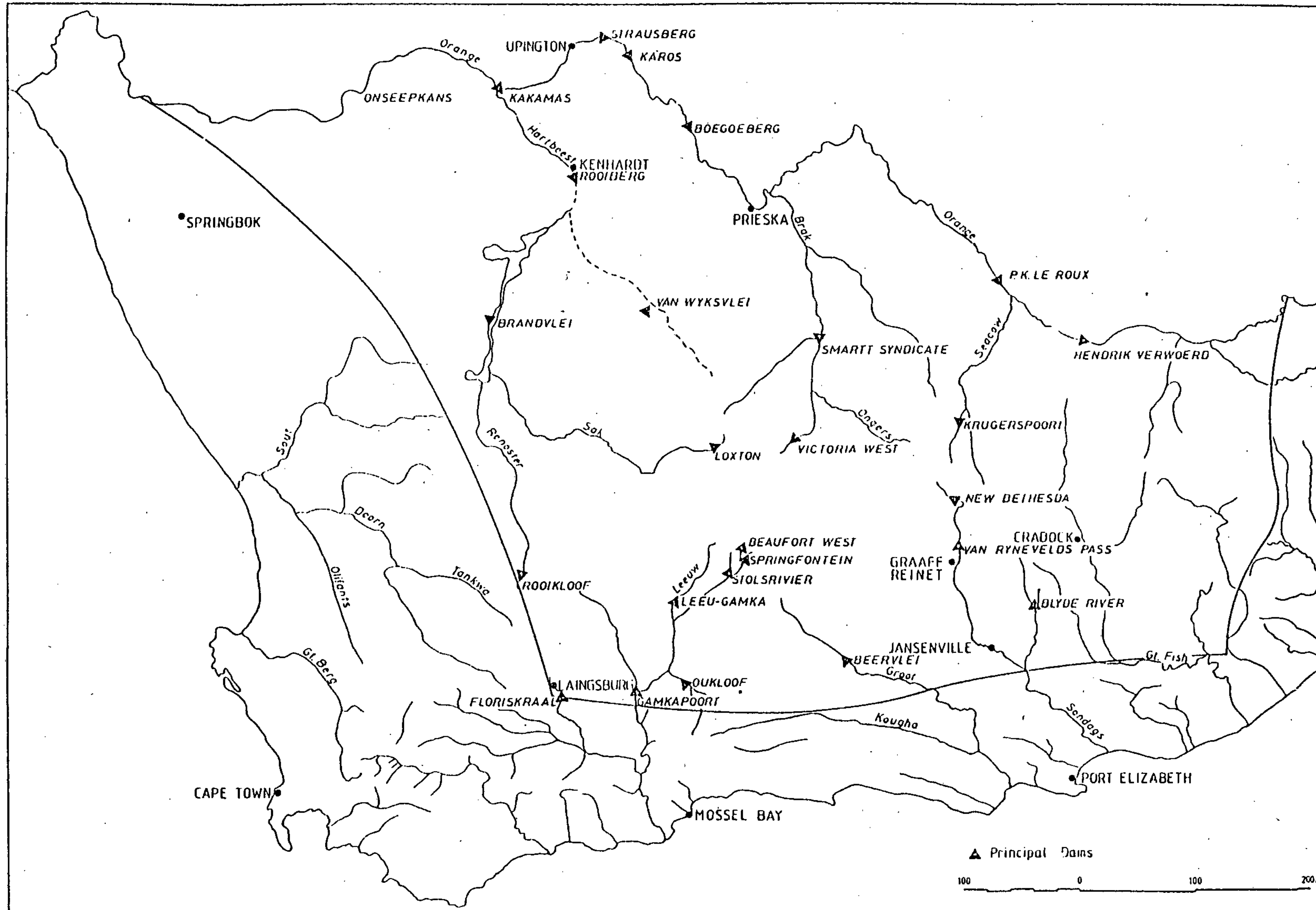

Fig. 6.1 Irrigation and flood control reservoirs

advantages of the scheme:

- the provision of irrigation water for an area of 310 000 ha;
- urban water supply with Port Elizabeth as the main user;
- the generation of hydroelectricity;
- an ultimate reduction of 50 per cent in the occurrence of flooding along the Lower Orange River; and
- expansion of recreation facilities.

The reduction of flooding along the lower Orange River benefits not only irrigation agriculture in this area but also the town of Prieska, which suffered flooding in 1925, 1934, 1956, 1967 and 1974. During the 1974 flood 20 undeveloped stands and 15 developed properties were inundated although only two dwellings and the purification works of Prieska Copper Mines suffered some damage. The municipal authority is, however, confident that with the completion of the Hendrik Verwoerd and P.K. le Roux dams any future inundation will be limited to freak events.

The specific role of dams in the rivers that are potential sources of flooding in Beaufort West (Beaufort West Dam and the Springfontein Dam), Graaff-Reinet (Van Ryneveld's Pass Dam), and Kenhardt (Rooiberg Dam) were dealt with in chapter 3. Other towns that have benefited from large or small dams situated upstream are Cradock, Queenstown, Victoria West and Steynsburg. Once again the reduction of the capacities of these dams by silt deposition must be high-lighted as a major drawback. The tremendously reduced capacity of the Grassridge Dam upstream of Cradock is perhaps the best example.

The value of such schemes as a measure against the hazard of drought is far more limited. A source of water supply can be assured for urban dwellers and riparian farmers involved in intensive irrigation farming but the distribution of water to users engaged in extensive farming is uneconomical.

6.2.2 Financial assistance

Within the category of modifying the hazard another response by the government is the financial assistance given to farmers for the construction of smaller farm dams and the sinking of boreholes. Smaller dams in minor streams, though they are more widely distributed sources of water, are less effective measures against drought not only because of their smaller capacity but also because they are fed by surface water rather than by base flow. In times of drought when rain is absent, they are not recharged and are therefore only temporarily useful.

Boreholes to tap subterranean water sources are characteristic of the arid and semi-arid Karoo environment. They are a general source of water but also serve as safeguards against specific periods of more severe drought.

6.3 Modifying the loss potential

Much of the response of institutions to hazard is in the area of modifying the loss potential. In this respect South Africa is no exception. Central government and its various departments, local government, and other institutions seek to achieve this with respect to floods by enacting restrictive legislation, setting certain design specifications for structures, land-use regulation and setting up warning systems; and with respect to droughts by the imposition of water restrictions and disemination of information on appropriate farm management practice.

6.3.1 Statutory requirements and guidelines

The Water Act 54 of 1956 and the Water Amendment Act of 1978 lay down certain requirements for development in flood-prone areas. Any plans for township development, where a water course with a known and defined channel having a catchment area of more than one square kilometre is present, must include lines indicating the maximum level likely to be reached by floodwater on average once in 20 years. While it is a mandatory requirement to also include the 1:50 year floodline under certain circumstances, such as for low-lying land without surface drainage, provincial and municipal town planning authorities are increasingly requiring the inclusion of such lines on all new development plans. Development is anticipated below the 1:50 year floodline, but in accordance with guidelines set by the Department of Community Development (RSA, Department of Community Development, 1983), special care is taken and engineers consulted for advice on design and legal restrictions.

An important problem associated with these requirements is the accurate determination of the floodlines which are, at best, probability lines. Insufficient data exists to make accurate determination possible, and different engineers frequently arrive at different conclusions regarding the position of these lines. Another problem is the false sense of security given by such lines constraining development. The public does not always fully understand the meaning of the terms 1:20 or 1:50 year floodline and might be led to believe that there would be no danger of flooding for the next 20 or 50 years. This, of course, raises the question of the local authority's moral and legal obligations with regard to development of floodprone land. Some legal experts are of the opinion that "the local authority is ultimately responsible for the prevention of loss of life and damage to property resulting from stormwater within its area of jurisdiction, and subject to its technical and financial resources" (Carter and Ritchie, 1985 : 30).

6.3.2 Design specifications

Design specifications for structures in danger of damage by flood water are set by the various institutions responsible for their erection. Optimum specifications of a structure, from an engineering point of view, are set to minimize the sum of construction and repair costs. Repair costs are difficult to estimate since they are related to damage as a result of extreme events which cannot be predicted accurately. Consequently the calculations are based on the probability of return periods of floods of a particular magnitude.

As indicated in the previous section, municipal and provincial authorities use the 1:20 year floodline as the minimum specification for township development. It is, however, recognized that normal street stormwater drainage systems cannot be designed economically to cope with extreme floods. It has therefore been suggested that the design of the street system should be such that it would itself function as a secondary drainage system and convey large rare flows safely to the watercourses. The lessons learnt from the Laingsburg disaster are important in this respect. Roberts and Alexander (1982) indicate that the streets of Laingsburg aligned parallel to the river, served as unobstructed paths which were followed by the flood water. As the flood rose they became strong-flowing streams of water and could not be used as escape routes. They advocate a system of streets angled down towards the river which would provide calm-water escape routes to higher ground. They also advocate an upward revision of the 1:20 year floodline to one of 1:50 years as a restriction on township development.

In addition to municipal authorities, design restrictions are also imposed by provincial and National Roads authorities in respect of road drainage and bridge structures. The S.A. Transport Services also have their own design specifications for railway structures.

The guidelines followed by the Directorate of National Roads are set out in the Road Drainage Manual (RSA, National Transport Commission, 1986). A graphic representation of the costs for optimum design are given in figure 6.2. Using these parameters accurate determination of optimum design economy is possible. Due to the difficulty of assigning precise values for the variables, however, sound judgement rather than pure calculation

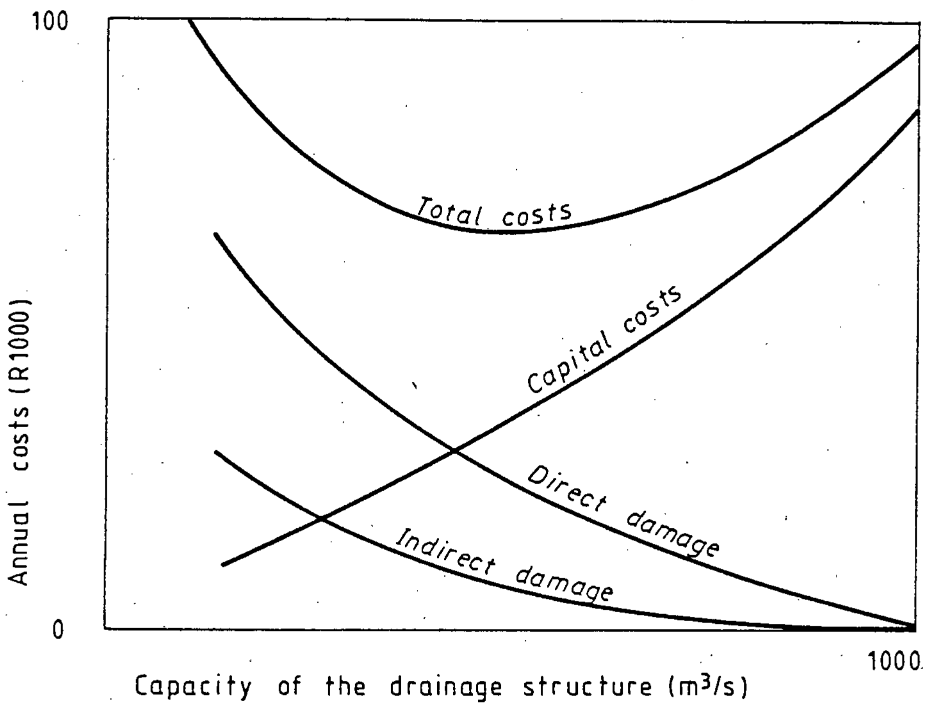

Fig. 6.2 Representation of costs for optimum design

is regarded as the only meaningful approach. As a point of departure, however, standard flood frequencies for various structures, which represent approximately optimum design features following years of experience, are used for roads and associated structures. Multiple discrepancies occur if the type of structure or structure span, cross-sectional area and size of catchment are used for the classification of design frequencies. Rate of flow varies relatively little over short distances and is therefore the most significant parameter in damage to roads and the disruption of traffic. Therefore peak flow, as calculated for a flood with a 20 year return period, is used as the basis for classification. From table 6.1 it is evident that return periods accepted for basic design vary from 1:5 to 1:100 years and that they increase with the capital investment of the structure involved.

Table 6.1

Basic design return periods
(National Roads)

1:20 year peak discharge (m^3/s)	Design return periods (years)		
	Local Road	Main Road	Through Road
0 - 20	1:5	1:10	1:20
20 - 150	1:10	1:20	1:50
> 150	1:20	1:50	1:100

(Source: RSA: National Transport Commission, 1986)

The Cape Provincial Administration Department of Roads has its own specifications for bridge and culvert waterway design. The authority recognizes "that during droughts engineers tend to err on the side of waterway inadequacy in proportioning their structures while after severe floods the tendency is to make bridges too large" (CPA, Department of Roads, 1987 : 2). The design philosophy adopted is therefore one which attempts to smooth out the approach fluctuations brought about by alternate cycles of droughts and floods and is basically an economic one. In calculating the design discharge the following flood recurrence intervals are used:

<u>For structure waterway areas not exceeding 30 m^3</u>:

for freeways and/or in built-up areas - 25 years;

other roads and locations - 10 years.

<u>For structure waterway areas exceeding 30 m^3</u>:

for freeways and /or in built-up areas - 50 years;

for a design discharge exceeding 500 cumecs on a 25 year probability - 50 years;

for a design discharge exceeding 3 000 cumecs on a 50 year probability - 100 years;

minor roads- 15 years;

other roads, locations and discharges - 25 years.

(Source: CPA Department of Roads, 1987 : 5)

These recurrent intervals are seen as firm guidelines but are not applied rigidly to every case.

The SA Transport Services essentially follows the guidelines set out in the Technical Report 137 of the Department of Water Affairs. For small catchments of less than 10 km² the Rational Method is empolyed. For intermediate catchments of between 10 km² and 100 km² the regional maximum flood of a 1:50 year return period is used. For larger catchments the method of flood routing is used and design is based on 60 per cent of the regional maximum flood with a 1:100 year return period (SA Transport Services, Water Engineer's Department, 1990).

6.3.3 Land-use control

Apart from the general restrictions that apply to the erection of structures in riparian locations elaborated in the previous paragraph, land-use control is applied by individual local government authorities on an *ad hoc* basis. Such regulatory measures are usually applied only after some extreme event has demonstrated that a hazard of considerable magnitude exists. Of the towns identified in chapter 3 as having structures threatened by flood, only four: Beaufort West, Cradock, Victoria West and Laingsburg effect land-use control as a precautionary measure.

In Beaufort West the 50 year floodline is used as a basis for limiting residential land use. A limited number of dwellings are situated below this line and only in an exceptionally serious flood are these dwellings expected to be inundated to a depth of 600 mm.

Floods that struck Cradock in 1974 caused serious damage estimated at R3 062 640 (Spies, 1977). All the buildings along Canterbury Street were destroyed. The showgrounds and all its associated structures as well as a park between Canterbury Street and the river were also destroyed. Other buildings suffered such serious damage that they had to be demolished or suffered such persistent dampness that they became uninhabitable. The event induced the municipality to impose restrictions on land use in the zone adjacent to the Great Fish River. Since this event residential development is no longer permitted along Canterbury (Achter) Street north of its intersection with Church Street (fig. 6.3). Some 14 houses and a business enterprise had previously occupied this land (Myburgh, 1976). Although many dwellings in Bree and Dundas streets were inundated and damaged to the extent of having to be demolished, these streets have not been closed to development and many stands here have changed ownership and been developed. On the eastern bank of the river the offices and goods shed of the S.A. Transport Services were also relocated to a safer position.

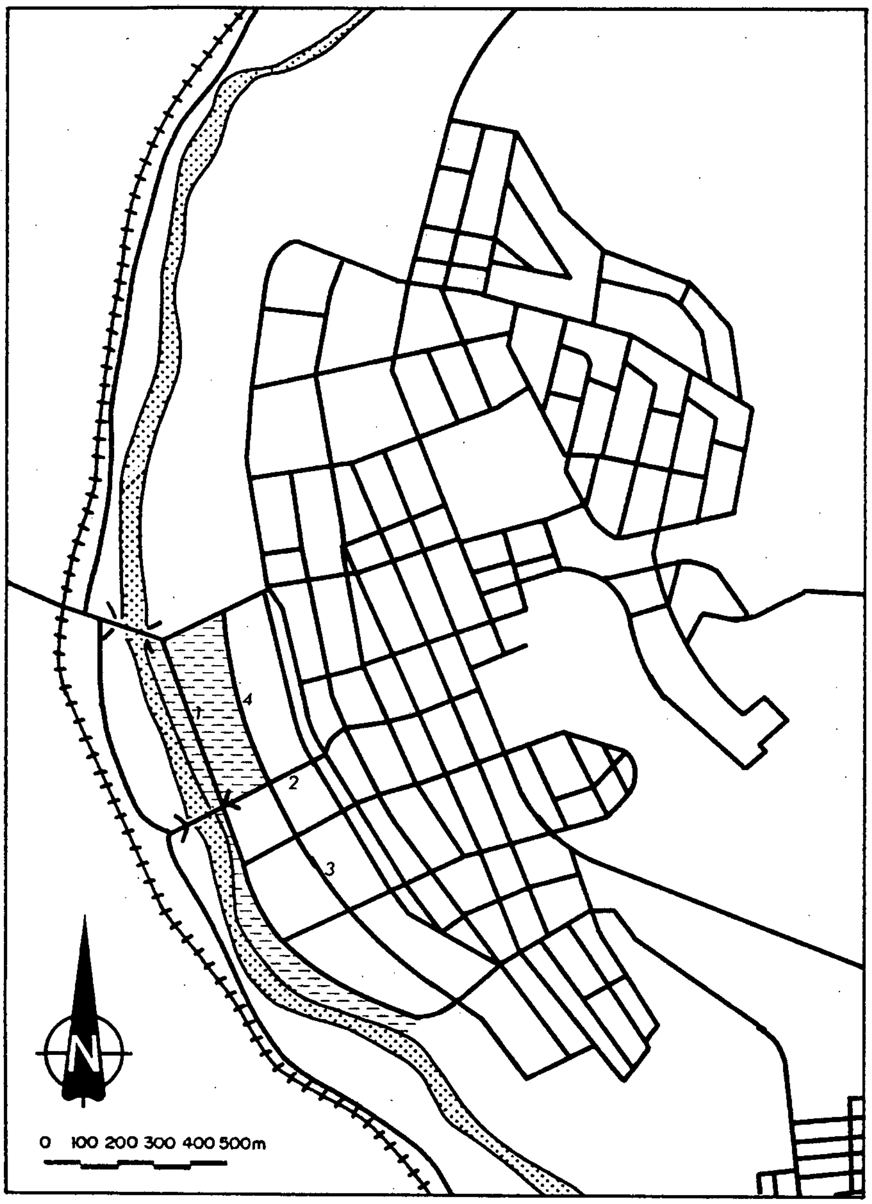

Fig. 6.3 Cradock: Land closed for residential development due to flood hazard. 1: Canterbury (Achter) Street; 2: Church Street; 3: Bree Street; 4: Dundas Street.

The disastrous floods that devastated a large part of Laingsburg in 1981 similarly demonstrated the necessity to impose land-use control to prevent a recurrence of the disaster. On the recommendation of Roberts and Alexander (1982) no redevelopment was permitted below the 200-year floodline. This area has been set aside for sports fields, a memorial garden and horticultural purposes (fig. 6.4).

6.3.4 Warning systems

A third category of institutional response aimed at modifying the loss potential is the use of forecasting and warning schemes. The objective of flood forecasting and warning schemes is to induce remedial action by floodplain occupants. To be successful these programmes must meet three requirements. First there must be a thorough understanding of the meteorological and hydrological processes that produce floods so that accurate information about the impending danger can be disseminated. The second refers to the need for an effective system of disseminating the warning message to floodplain occupants, while the third presupposes an appropriate response by occupants to the warning. While considerable success and a high level of sophistication has been achieved in the former two fields, especially by resorting to flood routing techniques and the use of telemetry gauges, radio,

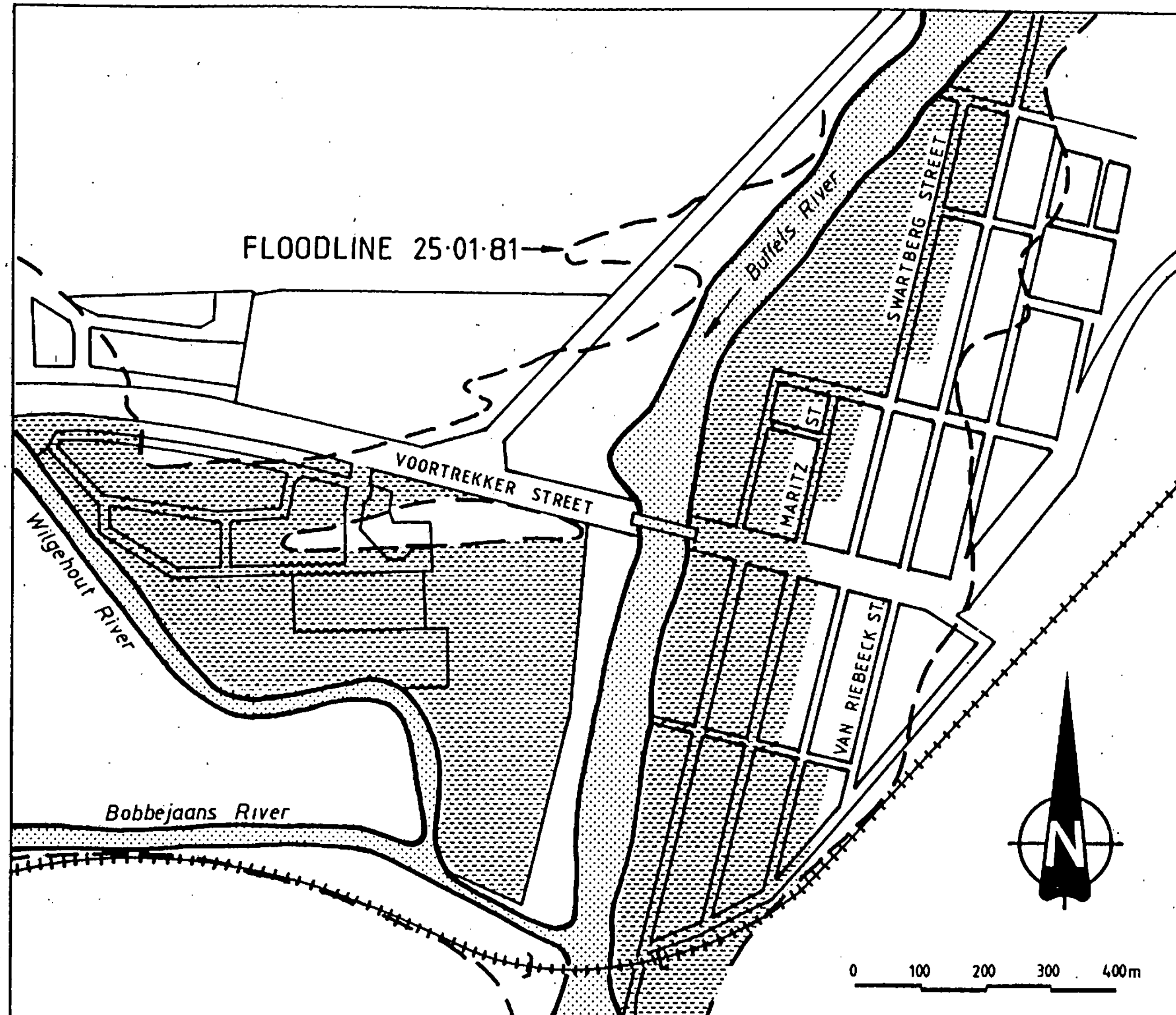

Fig. 6.4 Laingsburg: Land closed for residential development due to flood hazard

radar and satellite transmitted data, human response has proved to be unpredictable.

The establishment of a central Flood Control Office in the Directorate of Hydrology at the Head Office in Pretoria during 1987 has been a step in the direction of a co-ordinated warning and information system operated by a central government institution in South Africa. The Office supplies flood information to joint operation centres, the media, local authorities and other bodies. It processes flood information, makes flood forecasts and releases warnings.

At a local level, warnings of floods are issued to riparian water users downstream of dams controlled by officials of the Department of Water Affairs. Urban settlements threatened by floods mostly rely on Civil Defense Organizations to co-ordinate information and issue flood warnings. These organizations also have contingency plans to meet emergencies resulting from various projected scenarios.

The Civil Defence Organizations of the Kamdeboo Regional Services Council and Graaff-Reinet exemplify the nature of the action and planning involved. The area falling under the jurisdiction of the Regional Services Council is divided into wards with depots centred in Jansenville, Aberdeen, Waterford and Pearston. Communication with the depots is by two-way radio and operations are co-ordinated from the Emergency Control Centre situated in Graaff-Reinet. The municipal area of Graaff-Reinet is also divided into a number of wards with an appointed leader for each ward. The Municipal Protection Services Division has well equipped quarters for co-ordinating operations.

The most serious hazard situation is seen to be the collapse of the Van Ryneveld's Pass Dam (see figures 3.12 and 8.1). With the assistance of the Department of Water Affairs the Organization has established the position of the probable floodline through the town should the dam break and envisages the entire area below this line to be inundated within 12 minutes from the time of the breach. Emergency action is aimed at the most rapid evacuation of this area through the agencies of the ward leaders and with the assistance of all the branches of the municipal protection services. Action also includes closing various roads and the railway line between Rosmead and Klipplaat, this being effected by the Kamdeboo Civil Defence Corps.

Predictive capability with respect to floods has advanced to the point where flood heights can be calculated for specific areas with reasonable accuracy. Models based on such techniques as the Gumbel method or the Rational Method applicable to individual catchments, combined with routing techniques make short-term flood warnings a very viable response option if others such as total prohibition of the occupation of flood prone land are inappropriate. Timeous warnings at least provide for evacuation and allow the removal of some possessions, even if fixed property has to suffer the damage.

Most municipal authorities of towns threatened by flooding rely largely on warning systems as a response to the hazard. In both Graaff-Reinet and Kenhardt, however, where the breaching of the Van Ryneveld's Pass and Rooiberg dams respectively is the most serious source of danger, there might be insufficient time for these systems to be put into operation. Their success hinges very much on the accurate prediction of the failure of these dams. Incorrect prediction could have disastrous consequences for these towns.

Whether a warning system is an adequate and appropriate response, in view of the problem of prediction and the narrow time limits within which to put the system into operation, is a question of vital importance. The behaviour of residents at the time of floods in Laingsburg and Cradock is both revealing and relevant in this context.

Laingsburg had experienced flooding in 1958 and 1978 but without loss of life or serious damage. This no doubt contributed to a false sense of security in the people of the town. Had people evacuated the parts of the town that were inundated by the 1981 flood earlier, the loss of life would have been far less.

At the time of the 1974 flood in Cradock warnings were sent out to people living near to the river. Many of the dwellings were evacuated and possessions transferred to higher ground. In some instances, however, occupants refused to move, believing that the water would not reach them. Eventually they escaped only with their lives.

Failure of people living in threatened areas to heed warnings is a factor municipal authorities have to consider in their decisions regarding the adoption of only warning systems as a response to the flood hazard, particularly in these two towns.

Droughts, with respect to their exact timing, severity and duration cannot as yet be predicted with sufficient accuracy for early warning to have the same kind of impact as flood early warning systems have. The attitude of statutory institutions to the hazard of drought is therefore one of acceptance that recurrence of droughts in the relatively short term in the Karoo environment is inevitable and that those affected by them should be prepared to face them in the most appropriate way.

6.3.5 Drought management principles for farmers

The approach to the modification of the loss potential with respect to droughts is to influence individual managers to adopt options that will render their ventures as resilient to the adverse effects of drought as possible. Responsible institutions seek to achieve this by the dissemination of information appropriate to this strategy.

Through the agency of its Director of the Karoo Region, the Department of Agriculture has made available to farmers a manual on drought management principles (RSA, Department of Agriculture, 1983). The manual contains a summary of all information on sound farm management practice relevant to the hazard of drought.
It is the tacit assumption of the publication that strict adherence to the principles it annunciates will render the farmer more immune to the ravages of drought and help him to successfully bridge drought periods. Droughts are seen as natural and characteristic phenomena of the Karoo region. They are defined on the basis of deficient rainfall and the deterioration of natural vegetation, and a distinction is drawn between seasonal, periodic, disastrous and false droughts. It is recognized, however, that in times of severe drought complete withdrawal of stock from the veld is necessary and pen feeding is required. Application of the management practices will have the effect of shortening seasonal droughts, rendering drought periods

easier to bridge economically, and the onset of the effect of periodic and disastrous droughts will be delayed. The emphasis throughout is on the conservation of available resources and the most efficient exploitation of them.

Areas covered in the manual are

- Veld management
- Stock management measures
- Supplementary feeding
- Feeding and care of lambs
- The use of drought-resistant fodder crops
- Rounding off sheep for the market
- Health measures
- Drought aid listing

Conserving the natural grazing by reducing stock to below its carying capacity, good rotational grazing practice and partial or complete withdrawal of stock from the veld in times of serious drought is advocated. The chapter on stock management measures emphasises the importance of sound planning of the composition of a herd and the management of production systems during drought. In the next two chapters advice is given on appropriate supplementary feeds in respect of its composition, daily rations and the management of lambs.

The planting of drought resistant fodder crops is strongly advocated and much attention is given to the methods of establishing spineless cactus (*Opuntia sp.*), agave (*Agave americana*) and "old man salt bush" (*Atriplex nummularia*). Details are given of methods of preparing each of these sources of food, their nutritional value and the degree to which they are able to support flocks in times of drought.

Two further chapters deal with practice relating to the preparation of sheep for the market and ensuring the good health of flocks under drought conditions. The final chapter contains details of the requirements of the Drought Aid Scheme of the Department of Agricultural Economics and Marketing and of benefits available to farmers under this scheme.

6.3.6 Water restrictions

At municipal level response in the category of modifying the loss potential is achieved essentially by the imposition of water restrictions. Of the 24 municipalities that responded to a questionaire sent to them, only 5 (20,8 per cent) indicated that they had insufficient water during times of drought and had to regularly impose water restrictions. It is significant to note that these towns: Adelaide, Bedford, Fort Beaufort, Jamestown and Steytlerville are all situated in the eastern, moister part of the study region. A plausible interpretation of this pattern is that in the presence of generally higher rainfall conditions drought is not accepted as a normal characteristic of the area to the same degree as it is in the drier western parts where inhabitants are more accustomed to drought in general. Consequently, planning for droughts is not in phase with the normal processes of the natural environment and human adjustment to them is inadequate.

Size of place could also be a factor. These towns are small and they do not have the capacity to meet ideal strategies for adequate water provision in severe drought conditions.

6.3.7 Permanent evacuation

The only remaining adjustment within the category of modifying the loss potential is permanent evacuation of the hazardous area. In relation to flooding this could be achieved by the removal of all rural and urban settlement from flood-prone locations and would be effective in securing lives and settlement structures. It is not, however, possible to completely remove all development from hazardous locations. Bridges across rivers and roads which traverse the area would have to be re-routed along divides with unacceptable increases in route distance and at a cost that would be economically unjustifiable. Indirect costs associated with the withdrawal of productive land, and loss of income and employment as a result, would contribute further to the diseconomy of such action.

With respect to drought it would mean the depopulation of the entire Karoo. The economic and social costs of such action relegate the option firmly to the realm of theory.

6.4 Adjusting to losses

Adjustment to losses is effected by spreading the losses, planning for losses or simply bearing the losses. Institutional response in this field embraces all three possibilities though specific response does not always fit neatly into a single category without overlap. The provision of public relief at a time of crisis following a disastrous event is a form of spreading the loss over society as a whole. The operation of a permanent aid scheme to subsidise losses suffered by individuals involves not only spreading the loss but also careful planning for it both in terms of its structuring and by budgetary provision. All floods and droughts that are serious enough to have been attended by losses to individuals, automatically also involve losses for the country as a whole. In this sense central Government as an institution can be seen to bear the loss on the country's behalf.

Since responses overlap, adjusting to losses as an institutional response will not be dealt with separately as it is in Hewitt and Burton's scheme (Hewitt and Burton, 1971 : 19). Rather it is treated under the headings of specific response actions.

The role of government institutions in spreading the losses incurred by individuals and organizations following disastrous floods or droughts is evidenced by the application of relief measures using public funds as a source of revenue. With respect to floods, relief is only given after the occurrence of an event which is classified as having been more or less disastrous. Droughts, which are slow and protracted events are met with relief according to structured schemes while they are in progress.

6.4.1 Flood relief schemes

Losses incurred by farmers as a consequence of floods are met with financial assistance, for which individuals may apply to the Departments of Agriculture Economics and Marketing, and Water Affairs. Flood relief schemes provide for loans, subsidies and *ex gratia* payments to farmers in flood-stricken districts, subject to the Ministers' approval.

Under the Soil Conservation Act a subsidy is payable to all farmers for repairs to essential internal and boundary fences and to water works. The subsidy on the repair of flood-damaged soil conservation works is payable only for works constructed with state aid. This proviso is intended to serve as an incentive to farmers to plan their farms properly under the giudance of qualified Extension Officers. Only works essential to the running of the farm or the conservation of the soil qualify for subsidies.

Ad hoc assistance is also given to farmers in certain instances. Subsidies of up to 50 per cent were paid on an *ad hoc* basis for the reclamation of riparian land, the re-establishment of works and purchasing the necessary factors of production, following the 1966 flood and the loss of land and crops along the Lower Orange River (RSA, Commission of Enquiry into Agriculture, 1972). Following the Laingsburg flood, subsidies of up to 80 per cent (subject to various maxima according to the nature of the losses), loans, and *ex gratia* payments were made available to farmers as compensation for losses of crops, soil, and for the restoration of farming operations (RSA, Department of Agriculture and Sea Fisheries, 1982).

Where flood damage is so extensive that agriculture is affected on a regional scale, relief aid administered by the Department of support, other institutions providing aid are the Red Cross, businesses and industries rendering aid to their employees, newspapers setting up relief funds and co-ordinating donations from private sources, and The State President's Disaster Fund which works toward the same end.

6.4.2 Drought relief schemes

Over the past decades a state drought relief scheme has evolved for the provision of assistance to farmers in the form of rebates and subsidies on stock feed and transport. The current scheme which is applicable to the extensive livestock-farming areas of the country, was adopted on 1 January, 1988 and is administered by the Department of Agriculture and Water Supply. It differs from its predecessors in that it is founded firmly on conservation principles.

The stated primary objective of the scheme is to protect the natural resources and to assist stock farmers financially during a disastrous drought (RSA, Department of Agriculture and Water Supply, 1988). The preservation of the natural grazing is a specific aim and aid is given in accordance with the long-term goals of conservation farming.

Appropriate conservational response is expected from the recipient of such drought aid. Farmers are expected to be self-sufficient during short drought periods and also during the early part of protracted droughts. Only when disastrous drought conditions prevail will assistance under the scheme come into operation. For the purpose of the scheme a disastrous drought is is defined in terms of rainfall, condition of the pastureland, condition of the livestock, the availability of water and the availability of stock fodder (RSA, Department of Agriculture and Water Supply, 1988 : 2).

When the amount of rainfall drops to 70 per cent or less than the average in two consecutive seasons, a disastrous drought is seen to exist. The additional criterion is that the condition of the pasturage deteriorates to such an extent that its carrying capacity falls below the calculated long-term average for the area. As a consequence production declines and the condition of the livestock deteriorates so rapidly that stock losses would occur unless a full-time feeding programme is introduced.

The weakening of water sources is taken as a further criterion of the intensity and extent of drought, especially when open water sources dry up and the yield of springs and boreholes declines. The decline in the condition of livestock, especially lactating ewes and young animals is regarded as a very good indication of the availability of natural pasturage and when it becomes necessary to begin supplementary feeding. The situation is regarded as very serious when full-scale feeding of animals is essential. This is reflected in an increase of the purchases of stock fodder from co-operatives and other suppliers as the farmers' own reserves are depleted. It serves as a further indication of the nature and extent of the drought.

It is clear that with the exception of moisture deficiencies, which can be accurately determined, the other criteria are largely subjective. In assessing the drought it is the preferred policy to examine all the criteria together, but, if for example the condition of the pasturage and stock has drastically declined in spite of a relatively small negative deviation from the normal rainfall, these two would be given greater diagnostic significance.

The scheme has various preconditions for participation in its benefits. One of the most important is that which requires a farmer to reduce the number of his stock by at least one-third of the number officially calculated to be the carrying capacity for that area. As an incentive compensatiopn is paid to farmers who maintain stock levels below this calculated figure or who reduce stock numbers in accordance with this principle. After the lifting of assistance under the scheme famers are required to maintain their stock numbers at this reduced level for at least two months and they continue to receive benefits for that period.

They may voluntarily retain numbers at that level for a further four months and also receive compensation at a somewhat reduced rate.

Benefits available to farmers under the scheme are:

- a rebate of 75 per cent on the transport of registered stock feeds and licks transported by the SA Transport Services or other authorized and licenced carriers;

- a short-term feed loan for rounding off livestock to reduce numbers and for the maintenance of a nuclear flock of a maximum of 125 large stock units, following a two-thirds reduction below carrying capacity.

- incentive payments payable as stock numbers are reduced according to a scale coupled to the concept of average net farming income. The effect of this concept is essentially that it enables differentiation between income derived from large as against small stock units, making provision for a somewhat higher subsidy in respect of small stock units.

- state contributions to the cost of feeds for the maintenance of a nuclear flock up to a maximum of 125 large stock units (LSU) at a rate of R27.50 per LSU.

- loans for the purchase of stock feeds for a nuclear flock, up to a maximum of R27.50 per LSU per month.

- financial aid for the establishment of approved feedlot facilities at a rate of 25 per cent of the cost of erecting the facility.

The scheme is administered by the Directorate: Financial Assistance of the Department of Agriculture and Water Supply. It operates under the control of the National Drought Committee, based in Pretoria, which decides on the introduction and lifting of the scheme, and advises the Department on its application. This committee is composed of representatives of the

South African Agricultural Union;
Agricultural Credit Board (a farmer member);
Conservation Advisory Board (a farmer member);
Meat Board;
Department of Water Affairs and
Department of Agriculture Economics and Marketing.

This committee receives recommendations regarding the introduction if the scheme in a particular area from the District Drought Committee of the area, which considers applications by farmers. The latter committee is composed of three members of the Agricultural Credit Committee, three members of the Conservation Committee, the Assistant Director (Agricultural Extension), the Agricultural Extension Officer and the Magistrate as Chairman. Provision is made for the weekly submission of applications in order to facilitate the speedy processing of submissions (RSA, Department of Agriculture and Water Supply, 1988).

CHAPTER 7

INDIVIDUAL RESPONSES TO THE DROUGHT AND FLOOD HAZARD

Two categories of individual responses are investigated in this chapter, i.e. those of farmers and those of urban dwellers, these two groups being the main ones affected by these two hazards.

Whereas responses by institutions are mainly in the field of adjustments affecting the cause, modifying the hazard and modifying the loss potential of the hazard, responses of individuals are predominantly adjustments to the losses related to these hazards.

7.1 Affecting the cause

Affecting the geophysical causes of droughts and floods is normally a measure that is beyond the means of the individual. As shown in the previous chapter the technological and financial requirements for efforts in this realm of response place it firmly in the hands of institutions.

In respect of the human causes of the drought and flood hazard, however, the individual does have a very definite part to play, particularly in relation to the endeavours of institutions in this field. In the context of this study the major institutional response in the category of affecting the cause has been shown to be legislation on environmental conservation. While the readily definable aspects of such legislation can be enforced, implementation is frequently a matter of degree. This is particularly evident in such aspects as the degree to which individual farmers respect soil conservation legislation, accept and adhere to recommended veld management practices or the extent to which they plant drought-resistant fodder crops as a means of conserving the natural pasturage in times of drought.

Promotion of the spirit of conservation and its acceptance by farmers to the point of full implementation, which is promoted by conservation officers using informal means, has met with limited success. In the Middelburg Division, for example, an average of one (very rarely two) successes per year are reported (Coetzee 1983). There are various problems to which this low success rate is attributable. They include

- limited funds available to Soil Conservation Committees, which restricts the number of visits they can make;
- reluctance of Soil Conservation Committee members to take action individually against a fellow farmer. They wish to be accompanied by an Extension Officer;

- even younger farmers with a better education in agriculture infringe the conservation laws.

- the farmer's conduct is largely determined by his bank. Banks are unwilling to grant credit facilities without sufficient surity. The number of livestock held by a farmer is an important source of security and reducing stock numbers in the interests of veld conservation deprives farmers of a very valuable means of negotiation.

In assessing the effect of soil conservation legislation the Commission of Enquiry into Agriculture (1972) states:

"On the whole, the Soil Conservation Act has had little, if any, effect on soil losses over the twenty-five years since 1946. Admittedly, financial assistance under the Act has in many cases helped to keep farmers going, but obviously this is not what the assistance was intended for. No evidence can be found that the silt charge of our rivers is decreasing, while the veld is steadily deteriorating and natural grazing, is for the most part a sadly neglected asset." (RSA, Commission of Enquiry into Agriculture, 1972 :107). Clearly, the acceptance and practice of the principles of conservation as a necesary individual response to the hazards of both drought and flood leaves much to be desired.

Urban dwellers as individuals have no response at all in the category of affecting the cause.

7.2 Modifying the hazard

On the geophysical side of the equation, modifying the hazard is beyond the means of both farmers and urban dwellers. On the human side, however, some response is evident.

7.2.1 Water conservation

In the Bushmanland panveld region, local floods are turned to advantage. The area is essentially flat and the flow velocity of flood water very low. The flood hazard is therefore associated with shallow inundation rather than erosion or washaways. While the area also suffers the burden of drought far more heavily than floods, low embankments are constructed across the lowermost rims of suitable pans in order to impound flood water. The water is fairly rapidly lost by evaporation, but increased infiltration is induced locally. As soon as is possible the silt-covered floor of such pans is cultivated and cereal crops sown. The moisture conserved in this way is usually sufficient to allow the crops to mature and harvesting of some grain is possible by this means.

In a sense therefore, floods are locally used as a hedge against short-term drought.

The construction of farm dams in the Karoo is not a very efficient way of conserving water to effect drought hazard reduction. The rate of evaporation from exposed water surfaces is more than 1750 mm per annum everywhere in the Karoo region, far in excess of the annual rainfall. The loss of water by evaporation is too rapid for stored water to be available when protracted drought conditions prevail. Dams do, however, assist in delaying runoff and play a valuable role by enhancing infiltration and augmenting subterranean water supplies.

Of the farmers who responded to the research questionaire, 23,3 per cent indicated that they had adopted this option as a measure against drought. Some saw it as being of great importance stating that the more dams one had the better. The expense of constructing them, however, was seen to be a major deterrent. Some farmers stated that if a large dam in the district, e.g the Rooiberg Dam in the Kenhardt district, had been without water for six years, small farm dams would be of even less value. The ground was seen to be too porous and the water therefore drained away too rapidly to be of any use.

The perceptions of the farmers who did not adopt this option were clearly limited to the immediate and direct utility of farm dams as a means of alleviating the effects of drought. A longer view of the secondary benefits of this option are exemplified by the response of a farmer living in the Roggeveld region of the Sutherland district. His farming enterprise consists of three units covering more than 20 000 ha of land, approximately one-third of which is situated in the Tanqua Karoo. On his land he has constructed a total of 72 dams. The expense is deductable from income for the purpose of tax calculation and he regularly uses half to two-thirds of the amount he would have to pay in income tax for the construction of dams. Although much water is lost by evaporation, infiltration is greatly increased and groundwater reserves augmented. The water can be drawn to the surface when it is most needed in times of drought. An additional benefit of his method is that he sows grass behind the embankments which improves his pasturage when the dams contain no water. This aspect is dealt with in somewhat greater detail under the heading of veld improvement in paragraph 7.2.4. Boreholes that dried up in former droughts now continued to yield water even during the severe drought of the 1980's.

Although the response of this farmer is invaluable in demonstrating a principle relating to water and veld conservation, it must be regarded as something of an exception. Local conditions on his property favour the construction of dams as an appropriate response. A considerable part of one of the farmer's units of land situated in the Roggeveld region has an area that tends to be marshy while the Karoo areas contain slopes of the Roggeveld escarpment with numerous kloofs that are suitable sites for small dams.

7.2.2 Boreholes

A universal response by individual farmers is the sinking of boreholes to provide water for everyday needs in a generally arid environment, but also for times of drought. With respect to the drought preceding the one of the 1980's, 37,6 per cent of farmers had found it necessary to sink additional boreholes as an emergency measure. This response may be interpreted as an indication of inadequate adjustment to the hazard of drought and it would be expected to have resolved the problem of sufficient water for subsequent droughts. Yet, during the next and most recent drought in the area, only a marginal reduction in the number of boreholes sunk was recorded, 34,7 per cent of 147 respondent farmers still having found it necessary as an emergency measure. Some farmers indicated that the yield of water from existing boreholes had declined as a result of the drought and that some boreholes had failed completely. This might be attributed to the fact that the drought of the 1980's was particularly severe and was more protracted than the preceding one. Another reason for sinking additional boreholes is to provide more watering points. This reduces the distance livestock have to walk to obtain water and helps to conserve their energy. Simultaneously it reduces damage to the veld by eliminating excessive trampling.

7.2.3 Limiting the number of livestock

The value of limiting the number of livestock kept by a farmer in relation to the drought hazard is effective in terms of the conservation of the veld. Natural grazing land which is maintained in a state of balance with the natural conditions of the environment will also survive a climatic drought and rapidly return to its normal condition once the drought has disappeared. Stress makes the natural pasturage less resilient and subject to more rapid deterioration after the onset of a drought. It is also more likely to suffer permanent damage from a long and heavy drought. The converse of the argument is that well-preserved veld will, if it is lightly stocked, sustain flocks for longer than if it was already heavily grazed or overgrazed when the drought began.

In the category of modifying the hazard an important response is that of individuals to the Livestock Reduction Scheme instituted by the Government in 1970 and referred to in the previous chapter. The scheme proved to be so popular amongst farmers that by 29 February, 1972, which was the final date for the receipt of applications, the number of small stock units identified for withdrawal totalled 5 million (RSA, Department of Agricultural Technical Services, 1979). This was well in excess of the goal of 3 million set at the beginning of the scheme. From the Karoo region 3481 farmers had applied to participate in the scheme involving 15 398 027 ha of land. Most of these withdrew one-third of their stock, only 335 farmers (occupying 630 245 ha) taking up the option of withdrawing all their stock.

Due to the problem of identifying unweaned stock, the conditions of the scheme were changed on 23 May, 1972 and farmers given the option of reconsidering their participation in the scheme. Only some 10 per cent withdrew.

After only three years of the operation of the scheme the Secretary of Agricultural Technical Services was able to report that

- the veld of participants was in general considerably better than that of non-participants;

- farmers had become much more aware of the condition of their veld, especially with respect to its carrying capacity;

- farmers were pleased with the improvement of their veld; and

- that there was good co-operation on the part of most farmers.

By the end of the scheme, more than R45 million had been spent on veld improvement, some 45 per cent of the total having been paid for the Karoo region (RSA, Department of Agricultural Technical Services, 1979).

The timing of the scheme was fortuitously most appropriate because it was followed by one of the most serious droughts in the region in many decades. If it was successful as an abatement measure, it should have reduced the detrimental effect of the 1978 to 1986 drought. No material is available on its effect in this respect, not least because the scheme's prime purpose was conservation rather than drought alleviation. What is clear, however, is that as a single measure it was inadequate for averting the detrimental effects of the drought.

The livestock reduction scheme, though successful in assisting the natural pasturage to recuperate while it was in operation, appears to have been less successful in the longer term. The Extension Officer in charge of the Karoo region indicated that by the early 1980's, 99 per cent of the farmers had reverted to stocking their farms with the same number of livestock that they had prior to the introduction of the scheme. Though farmers could see the evidence of improved veld conditions during the operation of the scheme, they were not convinced that there was a real advantage in building up a natural reserve of pasturage. If there was pasturage it was there to be used (Coetzee, 1984).

Although the majority of farmers agree with the concept of veld conservation, views diverge widely on the usefulness of veld conservation as an appropriate measure in the face of the drought hazard. One limiting view is that well-preserved pasturage is useful for only one season of drought; thereafter it is irrelevant because a farmer has to feed his livestock artificially in any case. Another view held by some farmers is that stock should not be withdrawn from the veld since this allows the bushes to become woody and unpalatable to animals. A farmer from the Britstown district cites the example of his withdrawal of all livestock from a portion of his farm during a drought in 1966. The bushes died in this portion of his farm while those in the grazed areas survived. He attributes this to the fact that the bushes that failed to survive were not "pruned" by grazing. The stimulation provided by natural pruning as livestock grazed was absent and this caused the bushes to die.

At the other end of the scale there are those farmers who deliberately farm at well below the carrying capacity of their land. Without exception they report the success of this practice as a measure against short-term drought. What is more, the practice has been shown to produce more profitable returns.

Of farmers sampled, 88,9 per cent indicated that they stocked their farms at levels below the designated carrying capacity of the veld. This high percentage cannot be accepted without question. Farmers guilty of overstocking would feel threatened by a question relating to livestock numbers and be tempted to answer in a way that would place them in favourable light. The researcher anticipated this problem and included two other questions as a means of cross-checking the answers. These were on the size of the farm and the number of livestock kept. Although farmers readily supplied information on the size of their farms some respondents immediately related the number of livestock they kept to the carrying capacity of their land, and gave an answer in accordance with the latter e.g. 4 per hectare rather than the actual number of livestock they kept. Inclusion of this question did not therefore always fulfil the intended purpose. The comment of the Extension Officer for the Karoo region and the argument set out in paragraph 7.1 above also tend to justify some doubt about the accuracy of respondents' answers on stocking below the carrying capacity of the veld.

The doubt raised in the preceding paragraph should not, however, be allowed to detract from the fact that many farmers are sincerely conservation conscious. The example of a farmer in the Sutherland district, though perhaps not typical in the degree to which he carries his conservation principles through, does serve to illustrate something of the success that can be achieved in this field. Having been associated with farming in the district for approximately 50 years and currently the owner of a larger than average farming enterprise (more than 20 000 ha), the farmer stocks his land at a rate of between 5 and 6 hectares per sheep, compared to the official carrying capacity of 4 hectares per sheep. Despite six years of drought in the district he had not yet had to resort to full artificial feeding of his sheep. They were being given a small quantity of supplementary lucern but no maize or other feeds as this was not necessary. His greatest concern was that he was having to keep more livestock than he wished to. He had wanted to sell off 2 000 head but, due to an oversupplied market, could obtain a permit to sell only 700. Consequently, he was having to graze parts of his farm that he had wanted to conserve. It should be added that part of his success in being able to withstand the effects of the drought can be attributed to veld improvement measures which were combined with understocking.

7.2.4 Veld improvement

Closely allied to veld conservation practices are veld improvement schemes. Of the farmers sampled, 20,0 per cent adopt this option as part of their strategy to modify the hazard of drought. Veld improvement in this context is interpreted fairly narrowly, and refers to deliberate efforts to improve the natural vegetation that forms a pasture for livestock and does not include the introduction of alien species as a means of improving carrying capacity. The latter aspect is dealt with in section 7.3.5.

In essence it takes the form of cultivating bare patches of land and then establishing various grasses or bushes in these areas. Some farmers actually remove stands of unpalatable bushes with a bulldozer in favour of planting more valuable species.

The example of a farmer in the Sutherland district who had constructed 72 dams on his property was quoted earlier under 7.2.1. These shallow dams rapidly lose their water by infiltration and evaporation and behind the dam walls or embankments the farmer plants grass, not all species of which are indigenous. Another farmer, also in the Sutherland district ploughs furrows on the floor of shallow pans that occur on his property and plants saltbush species in these furrows. Stock is withdrawn from the areas for two years which provides sufficient time for the bushes to become established.

In the Kenhardt district, much of which is characterised by large shallow pans, some farmers plough the "floors" and sow "gannabos"

(*Salsola* spp.). One farmer claims to have increased the area of grazing land on his farm by one-third using this method but emphasises that the timing of the operation in relation to rainfall is important if success is to be achieved. Many farmers reject the option on the grounds that the rainfall is too low.

7.2.5 Planting drought-resistant fodder crops

Despite the attempts of the Department of Agriculture to promote the establishment of drought-resistant fodder crops specifically as a measure to combat the detrimental effect of drought, it has not proved to be an acceptable option to the majority of farmers. Of the farmers sampled, 41,1 per cent have partially adopted the measure. Very few have established such crops on anything more than small tracts of land, certainly far less than the officially recommended 2 - 4 per cent of the area of a farm (Coetzee, 1983).

The popularity of the different species of suitable plants also varies considerably. Table 7.1 illustrates this variation:

Table 7.1

Planting of drought-resistant fodder crops

Crop	Farmers Number	Farmers Percentage
Old man salt bush (*Atriplex nummularia*)	43	23,9
Spineless cactus (*Opuntia sp.*)	23	12,8
Agave (*Agave americana*)	8	4,4
Total	74	41,1

An important factor relating to the use of these crops is that none of them constitutes a balanced source of food and they have to be supplemented with maize or protein enriched licks and lucern. Old man salt bush requires the least amount of supplements and experimentation has demonstrated that sheep can maintain their mass or even show a slight gain, that wool production is normal and that ewes are able to lactate lambs for up to 42 days on a diet made up exclusively of old man salt bush. Only an energy feed in the form of a small additional ration of maize is required (De Kock, Grootfontein Agricultural College, no date. Also Coetzee, 1983).

The large proportion of water contained by spineless cactus (about 90 per cent) is both an advantage and disadvantage. Its main disadvantage is that it has to be dried at least partially in order to concentrate the the nutritional constituents, and it is also lacking in essential protein. Its high water content is a great advantage especially when, in times of drought, drinking water is scarse or unavailable. Experiments have show that sheep kept in an enclosure without water, are able to survive for longer than 500 days if their daily ration contains sufficient quantities of spineless cactus.

American agave has the least nutritional value but it is palatable and most useful as a supplementary source of feed.

Old man salt bush is by far the most popular of the three. An advantage of this crop is that once it is established it requires no processing before being available to livestock as a feed. Both spineless cactus and agave require a measure of processing before being fed to livestock. Agave is fibrous and least popular among farmers, only 8 (4,4 per cent) adopting this option as a measure against the hazard of drought. Cactus has long been associated with the Karoo environment in relation to drought. It is, however, rejected by many farmers for two main reasons:

1. It has to be chopped into small cubes by a specially designed chopping machine. Because of its fleshy texture it cannot be chopped by conventional machines. Consequently, the farmer has to acquire such a machine at considerable expense and inconvenience, since it has to be specially ordered for him. The cactus cubes then have to be laid out to lose some of their moisture and wither before being fed to livestock.

2. This feed tends to produce diarrhoea in animals, particularly sheep, if they are unaccustoned to eating it, a condition that is aggravated if the cactus is insufficiently dried.

Some farmers find processing feeds irksome and difficult to fit into their programme of activities. Furthermore some effort is required to establish plantations of these crops. Furrows have to be drawn with a plough in suitable locations and either leaves (cactus) or two-year old shoots (agave) or seedlings (old man salt bush) have to be individually planted and watered until they are established. This farmers find to be too time consuming and the value of it in the develpmment of their farms is overlooked. Although the usefulness of establishing drought-resistant fodder crops is recognized by most farmers, the option has not been put into practice as widely as recommended by the Department of Agriculture.

Climatic factors also play a role. In much of the western half of the study region the mean annual rainfall is less than 200 mm. Limited irrigation is required to establish drought-resistant fodder crops in these arid parts, and also periodically in order to increase yields. In the Kenhardt district farmers generally perceive the rainfall to be too low and borehole water too limited to allow for the successful establishment of drought resistant fodder crops. The indigenous "gannabos" is preferred.

7.2.6 Flood responses

Of the farmers sampled, 16 (42 per cent) indicated that they employed earthworks to modify the hazard of flooding. Such earthworks are limited to furrows and low embankments in the zone of cultivated fields in floodplain locations, designed to divert flood water away from crops. Clearly, these measures on such a local scale can be effective only in respect of fairly minor flood episodes.

Seven farmers (18,4 per cent) indicated that they constructed dams in response to the flood hazard. Small farm dams are also relatively ineffective except in reducing very small floods.

River course modification in a very limited way is a third response to the flood hazard in the category of modifying the hazard. Legislation generally prohibits the modification of a river course but 10 farmers (26 per cent) indicated that they attempted to reduce the hazard of flooding by periodically clearing the river channel of vegetation that could impede flow.

7.2.7 Urban response

The sinking of boreholes for domestic water and the storing of rainwater in tanks are fairly common responses of urban dwellers, particularly in the more remote and arid parts of the region. One of the most striking examples is seen in Pofadder where windpumps located in back yards of dwellings is the most dominant feature of the town's profile. In the event of a prolonged drought, however, these sources can only be effective for a limited time. Rainwater tanks have a limited capacity. Furthermore, municipal water supplies in the arid areas are usually drawn from boreholes at sites proven to have good yields. Failure of these boreholes would most probably be preceded by a failure of domestic boreholes which tap ground water at shallower levels.

No other responses are evident among urban dwellers in the category of modifying the hazard.

7.3 Modifying the loss potential

Response of individual farmers in this field is dominated by the adoption of various farming practices reflecting farmers' own resourcefulness and their reaction to the drought management practices propounded by the Department of Agriculture. The former category comprises some adjustments that might be interpreted as responses to a prevailing drought rather than to the hazard of drought. Yet it can be argued that in some instances the difference is one of degree rather than of essential character. The farmers of the region are accustomed to aridity. Droughts in the region occur in varying degrees of severity and when confronted with drier than usual conditions, the farmer has to formulate a plan of action based on his assessment of the situation. If he regards existing dry conditions to be a full-blown drought, a response at that time would be a response to the drought that is prevailing and not to the hazard. If, on the other hand, his assessment is that the real drought is yet to come, such response would be to the hazard of a developing or imminent drought.

7.3.1 Source of income other than farming

While most farmers derive their income solely from farming, a number have chosen to augment their income from a source outside of the farming operation. Table 7.2 gives a summary of the contribution of outside sources to farmers' income packages.

Table 7.2

Income of farmers from sources other than farming

Number of farmers	Percentage of farmers	Amount of income (% of total)
128	75,3	0
20	11,8	< 25
9	5,3	25 - 50
13	7,6	> 50
(N = 170)		

The value of the adoption of this option is quite clear. If a secure source of income that is independant of drought conditions is assured, the significance of the hazard is reduced in proportion to the extent of this income. Table 7.3 indicates the sources from which farmers augment their farming income.

Table 7.3 Sources of supplementary income of farmers

Source of income	Number of farmers	Percentage of farmers
Investments	8	4,4
Involvement in business	8	4,4
Regular salary	7	4,4
Farming elsewhere	8	3,3
Mining related activity	3	1,7
Wife's salary	2	1,1
Part-time employment	2	1,1
Drilling of boreholes	1	0,6
Leasing of property	2	1,1
Pension	1	0,6
Subtotal	**42**	**24,7**
No source of additional income	128	75,3
Total	**170**	**100,0**

Factors that make the adoption of this option difficult are mainly the scarcity of suitable sources of employment. Most of the towns serving the region are small and only limited opportunities for employment (especially part-time employment) exist. Furthermore, great distances separate farms from the nearest towns, especially in the more arid and sparsely populated north-west of the region. The expense and time required to traverse this distance offsets some of the advantages of having an additional source of income.

7.3.2 Diversification of farming

Diversification of farming resulting in a economy associated with anything other than extensive grazing is without significant potential in the face of the severity of the prevailing environmental constraints. But some farmers do see a potential in diversifying the kind of livestock that is reared. While the entire area is geared to sheep rearing, some farmers have found goats, notably angora goats, to yield a higher income. Apart from the inflated price of mohair as a factor, which at the time of survey made angora goats more profitable per head than sheep, angora goats have a smaller body mass than sheep and therefore do not eat as much. It is also argued that the grazing habits of goats differ from those of sheep and keeping the two together facilitates better utilization of the grazing. Goats graze at a higher level than sheep and are able to reach foliage on bushes that is beyond the reach of sheep. Moreover, goats frequent much more rugged terrain than sheep and the mountainous areas can therefore be effectively utilized. Goats are also less selective in their grazing habits and not only the palatable vegetation but also that which sheep tend to pass over is eaten. Angora goats are, however, less able to withstand drought than sheep, and certain breeds of sheep such as "dorpers" are better adapted to drought than others.

Furthermore, not all farmers view the less descriminate grazing of goats favourably. Some emphasize the effect of "pruning" on the less valuable bushes. While they are avoided by sheep they are not pruned by grazing and growth is therefore not stimulated. Grazing by goats on the other hand crops them and stimulates growth. This leads to a change in the composition of the veld and reduces its value for sheep. Careful monitoring is therefore essential if deterioration of the veld is to be avoided.

Goats are not the only option in diversification. One farmer experimented with springbok. He started with 17 in an enclosure of approximately 350 ha. After 12 years the number of springbok had increased to more than 100. Significant change had occurred in the composition of the veld. The plant species that are less palatable to sheep had all but disappeared and grass had reappeared. The adjacent enclosure where only sheep were kept had no grass. Economically, however, the buck were less useful than sheep because the market was geared to sheep and springbok could not be disposed of as easily as sheep.

In the Noupoort district where rainfall is higher cattle are reared successfully especially on farms with significant plantations of drought-resistant spineless cactus.

Of the total, 23,3 per cent of farmers see diversification of livestock as an appropriate option to increase the income from their farm, thereby rendering them somewhat less vulnerable to the detrimental effects of drought.

7.3.3 Producing own stock feed

Production of stock feed is not practicable on many farms in the Karoo region. It has to be grown under irrigation and since most rivers are either intermittent or episodic, conditions for the production of fodder crops are limited. Nevertheless 31,6 per cent of farmers indicated that some fodder was produced for their own use and that the practice reflected their recognition of the drought hazard. Such production is limited mainly to narrow tracts of land adjacent to rivers with runoff regimes that provide sufficient water for irrigation on a small scale. Small patches of land irrigated from borehole water brought to the surface by windpumps, are also found here and there, where yields of water are sufficiently high to make this possible. The main fodder crop is lucern. In the north-west of the region some fodder is also produced by the *saaidam* method outlined under 7.2 above.

Despite a wide spectrum of attitudes to this option varying from "it's a waste of time and money" to "without my 4 ha of lucern I would not have been able to survive the drought" many farmers saw great potential in this option. The practicability of it based primarily on considerations of available water and suitable land varied from farm to farm. Some regions such as the Roggeveld were also redarded as less suitable due to the low temperatures of the winter and the fewer harvests that were possible as a result.

7.3.4 Establishing a fodder bank

With 37,2 per cent of farmers indicating that a fodder bank of their own was an important measure against drought, this option was one of the most widely accepted (third highest percentage). Prejudice appears to be an important factor in the rejection of this practice as a measure against the drought hazard.

Some farmers see it as futile due to the damage done to the stored fodder by termites. Others see it as a fire hazard or as too great a capital investment to be economically viable. The most universal reason is that stored fodder deteriorates rapidly and is therefore a waste of money. There is some truth in the latter view but deterioration is not so rapid that the adoption of this option is not worth while. Lucern is estimated to deteriorate by only about 5 per cent of its nutritional value per year, depending on the conditions under which it is kept. Covered fodder retains its nutritional value far better than if it is exposed to the elements (Coetzee, 1984).

7.3.5 Improving the quality of livestock

Of the total, 85,5 per cent of farmers regard the upgrading of livestock as an important means of reducing the effect of drought. As a response it is surpassed in importance only by stocking the veld at below its carrying capacity. Better quality livestock are not necessarily better adapted to drought conditions. They do, however, provide the basis for an improved farming economy.

Farmers are well aware that a poor quality animal eats just as much as a high quality one. Better quality wool and increased production of wool per sheep, together with the development of the most desirable qualitites for a good carcass ensure greater income from the same investment. Externalities are achieved in the form of veld conservation if a smaller number of better quality sheep can be run on the available land, or in the form of increased income if poor quality sheep are replaced with the same number of good quality animals. The relevance of this response to the drought hazard is the achievement of better economy via these externalities.

Apart from stud breeding which requires considerable initial capital due to the high prices of stud animals, the best scheme by which farmers seek to upgrade their livestock systematically is the group breeding scheme. A typical breeding group consists of 8 - 12 members who farm under similar conditions. An elected selection committee selects a "central flock" consisting of the very best animals selected from the flocks of members. The performance of every animal in the central flock is very carefully recorded.

Only the very best ram lambs are kept in the central flock for breeding purposes each year. The rest of the tested rams are available to the members in exchange for five ewes also carefully selected from the applicant member's flock. In this way a flow of the best ewes to the central flock is ensured. Once again these are mated with only the best rams. Consequently, improved rams are constantly returned to the members' flocks.

All of these rams will be acclimatized to the district and local farming conditions. All will have been performance tested for growth of meat and wool under commercial conditions and all will have been fleece tested for wool quality. Improved rams can therefore be constantly introduced into a members flock at no more than the cost of five ewes (Fiske, 1975).

The scheme, which originated in New Zealand, was introduced to South Africa in 1971. In view of the widespread recognition of the upgrading of stock as a necessity in extensive livestock farming area of the Karoo region, stock quality is expected to improve systematically as more farmers become involved in these schemes.

7.3.6 Increasing size of farming enterprise

In chapter 5 it was indicated that in response to various social and cultural forces, farm size had decreased as a consequence of subdivision. It is the opinion of numerous commentators including Land Bank assessors and Agricultural Extension Officers that the current size of the majority of farms in the Karoo region is approximately that of a minimum economic unit. Any further reduction in size would drive farmers from the land (Coetzee, 1984; Esterhuyse, 1984).

It follows from this view that farming close to the margin of profitability heightens the hazard of adverse circumstances such as those associated with a drought. It also follows that increasing the size of a farming enterprise might provide greater resilience and constitute an appropriate response to the drought hazard. By this means income might be increased leaving a greater disposable amount available for investment in other hazard reducing measures. Veld conservation might also be achieved by operating at below the carrying capacity of the farm in terms of livestock numbers.

Of the farmers sampled, 30,6 per cent indicated that they had sought to reduce the hazard of drought by this means. The high cost of land is the major factor limiting the adoption of this option. Many farmers expressed the opinion that the only way of acquiring additional land was by inheritance. Of the total, 25 per cent of farmers exercised this option of increasing the size of the farming enterprise by renting additional land, almost 75 per cent of which was in units of less than 6000 ha in size. Mean size of owned farm units was 8169 ha while the mean size of units comprising a farming enterprise (i.e owned land plus rented land) was 9578 ha. These figures confirm the necessity to increase the size of the farming operation in many instances.

This conclusion is corroborated by Hattingh (1979) who found that input costs per hectare decreased as the size of farming units increased in the Great and north-western Karoo. Efficiency as measured by the ratio of gross income to the costs of the means of production increased consistantly as farming units became larger. This was due to the more efficient use of both labour and machinery on larger farms.

7.3.7 Responses to the flood hazard

In the survey four responses aimed at modifying the loss potential in relation to the flood hazard were identified.

The most universal of them, adopted by 11 of the farmers, (28,9 per cent) was the avoidance of flood-prone locations. This response is only relevant in respect of the erection of structures, such as farm buildings, that might be damaged by flooding. Clearly, farmers do not always have much choice in the avoidance of floodplain land for the cultivation of fodder crops, due to the scarcity of suitable land elsewhere. In the vast majority of cases, however, cultivation is a very small component of the farming economy.

Another response is the emergency evacuation of livestock from areas threatened by flood water. If the farmer has sufficient warning of an impending flood, livestock can be driven from low-lying areas where the danger of being washed away exists.

Some farmers deliberately practice river bank conservation as a response to the flood hazard. This involves the planting of trees, such as willows, or reeds to bind the soil and prevent its loss by erosion. A similar end is achieved by establishing permanent pastures on river banks. Various species of grass, especially Kikuyu, and lucern are used for this purpose.

One farmer indicated that he had enlisted the services of a qualified civil engineer to determine the specifications required for the construction of a weir that would be strong enough to withstand a flood. No indication of the design flood was given. This single response must be regarded as somewhat exceptional.

7.4 Adjustment to losses

7.4.1 Spreading the losses

As individuals farmers try to adjust to the consequences of droughts and floods by relying on and participating in the aid schemes that operate during droughts or are brought into play after disastrous events. In this way their losses are spread in time, if the aid they receive is in the form of a repayable loan, or the losses are spread through society if their aid is in the form of a lowered interest rate on borrowed finance, a grant, subsidy or any other mitigating gift where the finance has a public source.

There is the view that the existence of an aid scheme exacerbates the hazard for which it exists. It is argued that the knowledge of available aid is a security that is incorporated into an individual's planning with respect to the hazard. As a consequence he can afford to be less careful in the management of his affairs since any mistake resulting in loss can be ofset by contributions from the scheme. In relation to the drought hazard this encourages farmers to be more exploitive in their orientation towards farming and operate right on the margin of the resilience with which nature has endowed their farm. Short-term profit maximization is encouraged at the expense of long-term conservational practices and a real effort to operate in harmony with nature because the consequences of disharmony are diminished and more remote.

The converse of this question also needs to be considered: is it indeed possible for farmers who operate in the face of the drought or flood hazard to continue without aid, given the occurrence of extreme disastrous events? The question is addressed further on in this chapter.

7.4.2 Planning for losses

One aspect of this response has been partly addressed in the previous paragraph but two further responses need to be considered under this heading. These are the establishment of reserve funds by individuals and insurance against losses.

Of the total, 57,8 per cent farmers planned for losses related to drought by setting aside some money for use when drought struck. A number of farmers, though not implementing this option, were of the opinion that it ought to be done. Yet, there were many who reacted negatively to this measure. The comments included statements such as:

> "It is unnecessary; capital must work."
>
> "Practically, it is impossible."
>
> "This is a good option but impossible to implement."
>
> "It is impractical because of inflation."
>
> "The surplus of money each year is insufficient to carry you through a drought, but if you have 5 consecutive good years you can set aside enough for about 2 or 3 years of drought."

Such responses are enlightening about the profitability of farming in these instances. Clearly, estimation of the profitability is dominated by short-term considerations. Droughts as inevitable and recurrent phenomena are not incorporated into the reckoning process and the farming operation is proceeding out of phase with the dictates of the natural environment. Only importation of resources makes it possible to sustain such operations.

No insurance schemes appropriate to the hazards of farming in the Karoo exist in South Africa. There is no scheme that has been designed to indemnify farmers against loss of the means of their production resulting from drought or flood. Insurance is available on standing cereal crops, but due to the nature of production in the Karoo and the negligible area under cereals, it is inapplicable. Such insurance cover is usually restricted to damage by wind, hail or fire.

The main resaon for the lack of insurance cover for drought or flood loss lies in the difficulty of finding appropriate parameters on which to base the actuarial calculation of probabilities. Droughts are gradual in their effects and it is extremely difficult to define the degree of loss at a particular stage. The number of livestock kept by a farmer is also constantly changing. The base for the calculation of premiums is therefore also subject to constant variation. With respect to floods, crops not only vary in type but also in stage of maturity and losses would be similarly variable. Insurance companies have found it impracticable or uneconomical to administer and therefore do not offer insurance against eventualities resulting from flood or drought.

The only flood related insurance available is the normal short-term insurance applicable to losses and damage of fixed property and vehicles. Such standard insurance is available to farmers and urban dwellers and covers losses to buildings and contents of buildings, vehicles and farm machinery, but not loss of farmers' sources of income such as livestock or crops. Special insurance cover is available for stud animals but it relates to mortality as such and not to drought or flood losses (Sentraoes, 1986).

Only 7 farmers (18,4 per cent) indicated that their property was covered by insurance for losses related to the flood hazard.

7.4.3 Bearing the losses

With respect to drought no farmer indicated that no steps at all had been taken to reduce its detrimental effects. Though the number of measures employed varied greatly, no one was prepared to simply bear the losses resulting from droughts without some effort to reduce them.

With respect to floods, however, 26,3 per cent of farmers indicated that they had taken no measures to reduce the hazard of flood. Their only response was to accept the losses brought by floods.

The nature of losses varied from those involving the sources of income such as livestock or crops to damage of property. Table 7.4 shows the percentage of farmers that recorded a loss of livestock, the average number of livestock lost, and the average percentage reduction in the income of farmers during the drought of the 1960's and the drought of the 1980's in the region.

Table 7.4 Losses suffered by farmers

	Drought of 1960's	Drought of 1980's
Farmers that experienced stock losses	63,3%	64,3%
Average head of stock lost per farmer	192	178
Average reduction of income per farmer	40,7%	44,4%

Of the urban dwellers sampled no respondents indicated that they intended to move away from the area due to the hazard of flooding. Since the remaining option open to them in the event of a flood is more or less limited to evacuation of their dwelling, their response falls very largely in the category of bearing the loss.

7.5 Evaluation of responses

A fundamental question underlying the wide spectrum of responses relates to their appropriateness in the face of the drought and flood hazard. How successful are they in reducing the detrimental effects of these hazards?

Losses as a consequence of drought or flood can be either of property such as livestock or crops in respect of drought or both these as well as structures, soil, fences, implements, etc. in respect of floods. Apart from loss of human life which is frequently a consequence of disastrous floods, losses can be converted to financial terms. Reduction of income can be regarded as a measure of the cumulative effects of these losses. With respect to the drought of the 1960's, 95,5 per cent of farmers recorded a reduction in their income while this figure for the drought of the 1980's was 90,1 per cent. Table 7.5 shows the percentage reduction in income for the two drought periods.

Table 7.5 Percentage of farmers with reduced income as a result of drought

Drought period	Percentage reduction of income				
	0-20	20-40	40-60	60-80	>80
1960's	22,6	34,3	30,7	6,6	5,8
1980's	19,8	30,6	30,5	12,2	6,9

The basic pattern of distribution of farmers with reduced income in the five categories is similar for both drought periods. The figures do, however, suggest that the drought of the 1980's was somewhat more severe. The percentage of farmers in the lowest loss category is slightly less (19,8 per cent) while the percentage of farmers in the upper loss categories, especially the 60-80 per cent category, is higher than in the 1960's.

In order to determine the success of responses as measures to ameliorate the effects of drought, contingency tables were drawn up to assess the relationship between percentage reduction in income as a measure of the effect of a drought on a farmer, and his various responses to the hazard of drought. Null hypotheses for this purpose can be stated as follows:

1. *The adoption of any one of the individual measures will not reduce the percentage loss of income of farmers as a consequence of the drought.*

2. *The adoption of all the measures will not reduce the percentage loss of income of farmers as a consequence of the drought.*

The results of this analysis are shown in table 7.6.

Attention is drawn to the following:

The success of measures adopted by farmers in response to the flood hazard cannot be analysed in the same way. Responses are primarily aimed at reducing the detrimental effects of only minor floods. The response to major floods, permanent evacuation aside, is simply to bear the loss, which really constitutes no response at all. Moreover, as was indicated earlier, more than a quarter of all farmers recorded no response other than bearing the loss.

Two responses relating to the drought hazard have been excluded from the analysis. Soil conservation measures have been shown to have met with little permanent success in reducing losses of soil (see 7.1). A source of income other than from farming is regarded as a measure that is neither open to all due to limited opportunities, nor is it related to farming practice. These two have therefore not been included in the analysis.

Null hypothesis 2 is tested by employing an index representing the adoption of more than one of the individual measures. The initial supposition is that the greater the number of measures adopted by a farmer, the greater will his success be in ameliorating the effects of drought. As a means of cross-checking null hypothesis 2, the response of observing the drought management principles as propounded by the Department of Agriculture is included in the analysis. Consciensciousness in the application of these principles is divided into three categories: Meticulous, partial and not at all. These drought management principles represent a basket of responses, many of which overlap with the other responses listed in the analysis. The relationship to loss of income should therefore be similar to that of the combined index of individual responses.

Table 7.6 Probability values of no association between % reduction of income and response variables

Response	Probability values Drought of 1960's	Drought of 1980's
1. Limiting livestock (Veld conservation)	0,3214	0,4980
2. Building more dams (Water conservation)	0,8794	0,2856
3. Veld improvement	0,1318	0,2084
4. Planting salt bush	0,6759	0,9663
5. Planting cactus	0,4884	0,9786
6. Planting agave	0,3719	0,7626
7. Diversification of stock	0,6581	0,9638
8. Producing own feed	0,7628	0,3724
9. Establishing fodder bank	0,6830	0,7870
10. Upgrading livestock	0,4853	0,1009
11. Increasing farm unit size	0,2895	0,5140
12. Establishing reserve fund	0,3315	0,6095
13. Combined response index (All above responses)	0,4488	0,1962
14. Application of drought management principles	0,3101	0,1786

From the table it is clear that all of the probability values are greater than the acceptable significance level of 0,05. There is therefore no association between any single variable or combination of variables and a reduction in the level of income loss.

One possible explanation for this lack of a relationship could lie in the use of the single indicator "Reduction in level of income" as an appropriate measure for assessing the detrimental effect of drought. This problem was addressed by devising a composite index to represent the effect of drought on a farmer. The index is made up of the following components, all relating to the effect of the drought on the farmer:

1. Whether a particular drought was experienced as serious, moderate or mild (scoring 3, 2 and 1 respectively);

2. How long he perceived the drought to have existed, in four categories of < 1 year, 1-2 years, 2-4 years and >4 years, (scoring 1, 2, 3 and 4 respectively);

3. Whether he had been obliged to reduce the number of his livestock as a consequence of the drought (scoring 1 for "yes" and 0 for "no");

4. Whether he had found it necessary to feed his livestock artificially, (scoring 1 for "yes and 0 for "no");

5. Whether he had found it necessary to sink additional boreholes to provide for the needs of his stock during the drought (scoring 1 for "yes" and 0 for "no");

6. Whether his income was reduced as a consequence of the drought (scoring 1 for "yes" and 0 for "no").

Individual values cumulatively make up the composite effect index which has a maximum possible value of eleven. The higher the value, the worse the effect of the drought for the farmer. This index was computed for the drought of the 1960's and the drought of the 1980's and cross-tabulated firstly with the combined response index (item 13 in table 7.6) and secondly with the response of applying the officially recommended drought management principles (item 14 in table 7.6). The results of the analysis are shown in table 7.7.

Table 7.7 Probability values of no association between composite effect index and response variables

Response	Probability values	
	Drought of 1960's	Drought of 1980's
Combined response index	0,0747	0,6977
Application of drought management principles	0,0798	0,1791

From this table it is clear that at the 0,05 level of significance, the null hypothesis cannot be rejected and no association is present between the effect of drought and the two variables. If, however, the level of rejection is lowered to 0,10 some association is evident between the effect of the drought of the 1960's and the two variables. For this drought the adoption of a greater number of ameliorative measures does indicate a reduction in the adverse effects of the drought. Even at this low level of significance, no association emerges between the effect of the drought and the adoption of measures in respect of the 1980's drought.

A possible explanation is that the drought of the 1960's was less severe than the one of the 1980's and that the measures were therefore more effective for that drought. This would also support the argument that measures can be effective in respect of a drought that is relatively mild or of short duration, but that they become increasingly ineffectual as the drought becomes more severe and prolonged. The extension of this argument would suggest that a farmer can do nothing to eliminate the effect of a disastrous drought.

In view of the fact that there is apparently no relationship between precautionary responses and the effect of a severe drought, the possibility of other factors playing a role in determining the detrimental effects of a drought are considered. Examples of such factors are educational status, length of farming experience, knowledge of local environmental conditions, and size of the flock. Using a null hypothesis of no association the relationship between these factors and the effect of drought was analysed by means of contingency tables. The results are shown in table 7.8.

Table 7.8 Probability values of no association between composite effect index and selected characteristics

Characteristics	Probability values Drought of 1960's	Drought of 1980's
Educational status	0,1802	0,6075
Length of farming experience	0,1070	0,1207
Knowledge of environment	0,3262	0,5646
Size of flock	0,1397	0,2487

As in the instances dealt with earlier in the discussion, the null hypothesis cannot be rejected at the 0,05 level of significance and it has to be concluded that there is no association between the characteristics of the farmer or his farming enterprise and the effect of drought. It should, however, be noted that the same pattern of higher probability values for the drought of the 1980's than for the 1960's persists in this table. This appears to confirm the deduction made earlier, that no resources available to the farmer are able to adequately protect him from the adverse effects of a severe drought, the 1980's drought having been more severe than that of the 1960's.

CHAPTER 8

THE FOUNDATIONS OF RESPONSE BEHAVIOUR

In this chapter an attempt is made to explain the responses identified earlier in the study by examining some of the major factors that influence behaviour in the context of the drought and flood hazards in the Karoo environment.

In searching for explanations of response behaviour, studies have focused attention on the question of choice in the decision-making process. The characteristics of the choice process vary with the nature of the decision maker, some being collective actions, others individual actions, and many being consequentially constrained by previous collective or individual choices. No fundamental discrepancy is found between individual and collective behaviour in the ways in which the choice of adjustment is made. Burton, Kates and White (1978: 135) state that "collectives that serve as managers adopt adjustments, much as do individuals, for the self-interest of the group constrained by limits of experience, capital, and the perceived efficacy of said adjustments. Those that dispense hazard services do so in response to professional role, to responsibility, or to customer demand, encouraged or discouraged by need for survival or expansion. The guidance a society exercises on individual or group adoption reflects the prevailing political and social ethos of a society, as well as its organizational ability to handle relatively rare undertakings."

The process of choice involves a consideration of the likely economic outcomes but the resulting behaviour rarely conforms to the expected optimum. Maximization of the expected gains is not usually achieved. Reasons for this include difficulty in appraising the magnitude and frequency of extreme events, deficiency in awareness of all the available alternatives, and difficulty in evaluating the consequences of selected options. Behaviour is seen to be in accord with some form of bounded rationality in which satisficing rather than optimizing is the key factor (Burton *et al.*, 1978).

One of the fundamental factors affecting choice, identified very early in natural hazards research, was the way nature or the hazard itself was perceived (e.g. Saarinen, 1966). While individuals or institutions evaluate adjustments with reference to their environmental fit, technical feasibility, economic gainfulness, and social conformity, considerable variation exists in the perception of hazard.

Perception acts as a filter in the decision mechanism through which independent factors pass before adoption of a response occurs. In their general model of hazard perception and response by individual floodplain residents Smith and Tobin (1979) see perception of the flood hazard as an interface between the relevant independent and dependent factors. In contexts other than hazard the role of perception is similarly highlighted. Lloyd and Dicken (1972) for example, see perception as a coding mechanism which filters information passing between the objective environment and the behavioural environment.

Gold identifies four important factors that influence response: previous experience, personality, attitudes towards nature, and attachment to place (Gold, 1980). Burton *et al.*, (1978) add cultural, economic, and social constraints, as well as the role played by government to the list. In this chapter, an attempt is made first to identify some aspects of the way in which the hazards of drought and flood are perceived and then to assess the role of these factors in the responses that have previously been identified.

From the literature devoted to the explanation of response to hazards it is clear that certain factors keep recurring. Some are aimed at explaining choice or the decision process while others are offered in the context of perception. Still others skip the intermediate steps of choice and perception and are offered in explanation or partial explanation of the response itself. These circumstances highlight the complexity of the behavioural processes involved.

It is not the purpose of this research to extricate the complexities of the decision process. The objective, as stated earlier, is to provide a broad perspective of responses to the drought and flood hazards in the dry regions of South Africa which can serve as a springboard for more detailed research into specific problems. In accord with this objective therefore, the factors referred to above are examined individually and evaluated in relation to their applicability in explaining local responses. Twelve such factors can be resolved from the numerous influences referred to above.

8.1 Perception

A fundamental question that has to be considered is the individual's or institution's perception of extreme events. Is an extreme event in the form of a drought or flood perceived to be a hazard or merely a circumstance to be reckoned with? A perfectly realistic view of such events, i.e. one that reflected a completely harmonious relationship with the natural environment, would hardly regard droughts or floods as hazards but rather as irregularly recurring, albeit disadvantageous, circumstances that formed part of the pattern of things. It is hardly a hazard if an individual takes it into account in his planning and adjusts his way of life to it. It is just one more factor in his existence. It becomes a hazard when he regards it as abnormal and does not account for it in his planning. Then, when it occurs he is unable to cope without adopting some extraordinary measures. Many people in the Karoo region have a deficient view of extreme drought and flood events and they are therefore perceived to be hazardous.

8.1.1 Origin of drought

Many farmers recognize the onset of a drought by a decline in the quality of the grazing and its effect on the livestock. Another way of saying the same thing is evident in the fact that some farmers equate having to feed their livestock artificially with the existence of a drought. A close connection therefore exists between a farmer's ability to detect changes in the carrying capacity of the pastureland and his perception of drought. Evaluating their own ability to gauge the carrying capacity of the veld under changing circumstances, 15,9 per cent of the sampled farmers felt that they were able to very accurately estimate changes, 76,7 per cent that they were able to estimate changes well and 7,4 per cent that their ability in this respect was poor. Extension Officers have the opinion that farmers tend to have a somewhat inflated view of their own ability to gauge carrying capacity. An inaccurate view of their ability to read the veld therefore also leads to an inaccurate perception of drought, which can be perceived to start earlier, be more severe and last longer than otherwise.

Some farmers are well aware of this trap and indeed see drought in the region as being partly man-made. One farmer identifies two sources of drought so clearly that he ascribes relative values to each: overgrazing, which is responsible for 40 per cent of drought, and insufficient rainfall, responsible for 60 per cent of drought.

Generally, luck is not seen to play a role in the occurrence of drought and its effects. Insufficient rainfall is seen by many to be determined by God. The view is encapsulated in the words of of a Britstown farmer: "Here one is dependent on your Creator. You have to constantly look upward. If the rain doesn't come you must go on your knees and pray for rain." The alternate view is expressed in the words of another farmer (also from the Britstown district): "Drought is man-made; you must build up reserves for it and plan for it. Conservation is the answer. You know that drought is inevitable."

8.1.2 Frequency of drought

The following quotations are typical responses to the question of how frequently droughts occur in the region:

> "You must expect a drought every year; a good year is an exception."
>
> "Two good years, then a decline in rainfall; this is a warning. The pattern is two good years, one normal year and then two years of drought."
>
> "Droughts are preceded by two or three dry years; they come in seven year cycles."
>
> "A Vosburg farmer sat by his window looking at the falling rain. Asked by his wife what he was thinking about he responded: The drought that is to follow."
>
> "Drought is a part of us; there is no need to measure rainfall. You expect drought to occur and you must run your farm on the basis of poor conditions. If there is a good year you must regard it as a bonus."

It is evident that considerable variation exists in the perception of the frequency of drought. Of the 180 respondents to the questionaire, 52 failed to answer the question on the expected frequency of the recurrence of serious drought. With respect to the frequency of moderate drought 54 failed to answer the question and with respect to light drought the number rose to 81. While this might be regarded as tardiness in filling in the questionaire, it can at least equally be interpreted as a deficiency in the perception of the hazard.

Severe drought is most clearly perceived by respondents, 71,1 per cent having a definite conception of its occurrence. Of the farmers who responded, 70 per cent also clearly perceive the occurrence of moderate drought but only 45 per cent have any coherent conception of light drought. This is in accord with the findings of other studies where severity of risk has emerged as an significant cognitive variable (Burton *et al.*, 1978 : 106).

Wide variation is evident in the perception of the frequency of the occurrence of drought. Table 8.1 indicates the variation with respect to severe drought.

Table 8.1 Perceived recurrence interval : Severe drought

Recurrence interval (years)	Number of farmers	Percentages Cell	Cumulative
1	5	3,9	3,9
2	2	1,6	5,5
3	7	5,5	10,9
4	6	4,7	15,6
5	14	10,9	26,6
6	6	4,7	31,2
7	13	10,2	41,4
8	6	4,7	46,1
9	4	3,1	49,2
10	43	33,6	82,8
11	4	3,1	85,9
12	2	1,6	87,5
15	5	3,9	91,4
20	6	4,7	96,1
30	3	2,3	98,4
40	1	0,8	99,2
50	1	0,8	100,0
	(N = 128)		

People variously perceive the recurrence period of a serious drought to be from as low as one year to as high as 50 years. more than 90 per cent see the recurrence period as less than 15 years and nearly half of the respondents expect a serious drought in less than 10 years. The largest single group, constituting 33,6 per cent of all respondents, expects a serious drought once every ten years. Independent evidence, as indicated in chapter 3, points to a recurrence interval of 18 - 20 years for serious drought, breaking down to a 10-year cycle in the south (Tyson *et al.*, 1975).

The perception of the return period of moderate drought is also subject to great variation but the range is only half that of serious droughts (table 8.2). Nearly 78 per cent see the return

Table 8.2 Perceived recurrence period : Moderate drought

Recurrence interval (years)	Number of farmers	Percentages Cell	Cumulative
1	5	4,0	4,0
2	11	8,7	12,7
3	33	26,2	38,9
4	12	9,5	48,4
5	37	29,4	77,8
6	6	4,8	82,5
7	12	9,5	92,1
8	2	1,6	93,7
9	1	0,8	94,4
10	4	3,2	97,6
12	1	0,8	98,4
20	1	0,8	99,2
25	1	0,8	100,0
	(N = 126)		

period as 5 years or less. The largest single group constituting nearly 30 per cent of farmers regards the return period as 5 years. This group is closely rivalled by another comprising 26,2 per cent of the farmers who perceive the return period to be 3 years.

Table 8.3 indicates the variation in the perception of light drought. The maximum return period is perceived by some to be 10

Table 8.3 Perceived recurrence interval : Light drought

Recurrence interval (years)	Number of farmers	Percentages	
		Cell	Cumulative
1	26	26,3	26,3
2	26	26,3	52,5
3	33	33,3	85,9
4	3	3,0	88,9
5	7	7,1	96,0
7	2	2,0	98,0
10	2	2,0	100,0
	(N = 99)		

years. Only a small percentage of farmers perceive light droughts to recur at intervals of more than 3 years. A third of all farmers think that a light drought occurs every 3 years, while 26,3 per cent see the return period as 2 years. Significantly, an equal percentage of farmers appear to equate the annual dry period in the cycle of rainfall with a light drought. This deficient view can be interpreted as a non-acceptance of the pattern of nature, even the established annual cycle being regarded as hazardous; a view of "nature against man".

8.1.3 Recollection of drought

Farmers' recollection of the date of the drought immediately preceding the current one varied greatly. Table 8.4 indicates the variation.

Table 8.4 Recollection of drought: Year of occurrence of previous drought

Year	Number of farmers (N = 160)	Percentages Cell	Cumulative	RAINFALL % of long-term normal
1947	1	0,6	0,6	--
1960	31	19,4	20,0	77
1961	3	1,9	21,9	163
1962	2	1,3	23,1	64
1963	3	1,9	25,0	151
1965	2	1,3	26,3	97
1966	18	11,3	37,5	49
1967	6	3,8	41,3	122
1968	11	6,9	48,1	86
1969	8	5,0	53,1	91
1970	17	10,6	63,8	79
1971	9	5,6	69,4	112
1972	8	5,0	74,4	113
1973	11	6,9	81,3	114
1974	1	0,6	81,9	223
1975	1	0,6	82,5	152
1976	1	0,6	83,1	198
1977	2	1,3	84,4	139
1978	7	4,4	88,8	91
1979	7	4,4	93,1	84
1980	3	1,9	95,0	95
1981	4	2,5	97,5	*
1982	2	1,3	98,8	*
1983	2	1,3	100,0	*

* Data unavailable
(Source for rainfall data: Weather Bureau, Annual Weather Reports: 1960-77 and Monthly Weather Reports 1978-83.)

In interpreting the figures in this table it should be borne in mind that they represent a population spread over four noncontiguous districts. Examination of rainfall data for stations in these districts revealed not only a considerable variation in the amount of rainfall recorded at different stations within the same district but also from one district to another. The effect of this geographical spread would be to smooth the variation considerably, since the figures are for the four districts combined.

Three clusters, where more than 10 per cent of the farmers perceived the previous drought to have occurred during a particular year, can be identified from this table: 1960, 1966 and 1970. The greatest agreement in the perception is for 1960 where 19,4 per cent of farmers remembered the occurrence of a drought. During this year offiial records indicate that only 77 per cent of the long-term normal rainfall had occurred. Of the farmers sampled, 11,3 per cent perceived a drought to have occurred in 1966, a considerably smaller percentage than for 1960. Yet, only 49 per cent of the long-term normal rainfall had occurred during that year, a far greater negative deviation than in 1960. A possible explanation is that 1966 was bracketed by years of good rainfall (151 per cent in 1963, approximately normal rainfall in 1965, and 122 per cent in 1967). A further possible perspective is that sufficient residual moisture was available in the soil in 1966 as result of good rainfall in the immediately preceding years. The effect of the low rainfall was therefore not as severe. This would emphasise the need for caution in equating drought with subnormal rainfall in a particular year.

The third cluster is characterized by 10,6 per cent recalling a drought. Here the official records indicate that 79 per cent of the long-term normal rain had fallen. The two preceding years also show a somewhat heightened percentage of farmers recalling the occurrence of drought (6,9 per cent and 5,0 per cent), during which time 86 per cent and 91 per cent of the normal rainfall occurred.

The figures in this table suggest that there is some correspondence in the recollection of the occurrence of a drought and actual rainfall figures, i.e. a degree of accuracy in the perception and recollection of drought. An amomaly is, however, present in the years 1971, 1972 and 1973 where higher than normal rainfall occurred while 5,6 per cent, 5,0 per cent and 6,9 per cent of farmers respectively recalled the occurrence of a drought. The year 1962 is also an anomaly where only 1,3 per cent of farmers recalled the occurrence of a drought while the actual occurrence of rainfall was down to 64 per cent of the long-term normal.

A possible overall interpretation is that one dry year, bracketed by wet or normal years is not perceived as a year of drought. But, as one dry year is followed by consecutive dry ones, perception of drought is more acute and recollection is enhanced. The effect of the drought then continues to be felt for two or three years (see 1971, 1972 and 1973). Perhaps from the condition of the veld, farmers perceive them to be dry despite normal or above normal rainfall. This interpretation is, of course, highly tentative but it does suggest an avenue for further investigation that would contribute to the understanding of the perception of drought and its effects.

8.1.4 Severity of drought

Of the farmers sampled, 62 per cent perceived the previous drought to have been severe, 36,1 per cent as moderate and only 1,8 per cent regarded it as light. Although there is no absolute correspondence, a high percentage (89,2 per cent) also found it necessary to feed their livestock artificially, 95,5 per cent suffered a loss of income during that period and 63,6 per cent suffered stock losses. (The association between the existence of a drought and artificial feeding of animals was noted earlier).

With respect to the current drought 88,1 per cent perceived it to be severe, 10,2 per cent as moderate and 1,7 per cent as light.

Of the total, 93,5 per cent found it necessary to feed livestock artificially, 90,1 per cent suffered a reduction of income and 64,3 per cent lost livestock due to the drought.

The similarity in the perception of the previous and the current droughts is remarkable. This accords with the finding of other studies (e.g. Moline, 1974; Burton and Kates, 1972) that little variation in perception exists where hazards occur frequently, regardless of their severity, apparently due to the firm establishment of perceptions in the course of time.

8.1.5 Duration of drought

Variation is evident in farmers' perception of the duration of the previous and the current droughts. Table 8.5 indicates farmers' perception of the duration of the drought in four categories.

Table 8.5 Perception of drought duration

Duration (years)	Number of farmers		Percentages	
	Previous drought (N = 162)	Current drought (N = 171)	Previous drought	Current drought
< 1	27	19	16,7	11,1
1 - 2	56	18	34,6	10,5
2 - 4	50	28	30,9	16,4
> 4	29	106	17,9	62,0

With respect to the previous drought 34,6 per cent perceived it to have lasted for between one and two years and a further 30,9 per cent perceived it to have persisted for between two and four years. Considering the data in table 8.4 it is not clear which period of drought these perceptions refer to, three main dates having been mentioned 1960, 1966 and 1970. If the most recent date is accepted as the one being referred to by most farmers and the three years of below normal rainfall taken as its duration, there is a fairly clear correspondence between actual and perceived duration.

Lack of complete agreement should not be summarily interpreted as a consequence of deficient or inaccurate perception of the drought. Drought is not always uniform in its occurrence, especially in an area as extensive as the one under consideration. Rainfall is frequently in the form of thundershowers and therefore occurs in patches or bands, alleviating, retarding the onset, or advancing the termination of the drought where it occurs. Farmers are well aware of this, as are state authorities who apply the principle in the drought aid scheme. Drought aid is not necessarily granted to entire districts at once. Rather, aid is granted to parts of districts or even specific farms in recognition of the variation of local conditions that make it necessary. It should also be recognized that those farms, where conservation of grazing has been practised and a real effort has been made to make them less susceptible to the ravages of drought by employing drought management principles, will display the effects of drought less readily than those that are overgrazed and ill-managed.

With respect to the current drought 62,0 per cent of sampled farmers perceived it to have lasted for more than four years. This accords with the rainfall figures which indicate below normal rainfall between 1979 and 1986 in some areas.

Detailed perception of the hazard of drought is as varied as the number of individuals involved. Each farmer has his own unique way of seeing the details of the hazard. At a more general level, however, some agreement in perception is evident. Broad correspondence exists where a majority of farmers display similarity in the way they interpret the existence of a drought, view their own ability to recognize changes in the carrying capacity of the veld, perceive the degree of severity of a current drought and perceive the duration of a drought. There is, however, wide variation in the way they perceive the severity and recollect the date of a previous drought.

8.1.6 Perception of flood

The perception of flood was examined from the points of view of people living in hazardous locations in the towns and that of farmers.

(a) Urban residents

Only 17 urban residents responded to the mail questionaire sent to them. One of these returned the questionaire with only his name and address filled in and it therefore had to be discarded. The small number of returns (16 out of a total of 80 distributed, a sample of 10 per cent of the identified population) makes generalization hazardous but it is of interest to note some of the trends that are evident in these responses.

Only 5 respondents (31,25 per cent) thought that a flood hazard existed at the site of their residence, 11 perceiving no danger of flood at all. This division corresponds well with respondent's previous experience of flood: 12 had no previous experience of flood at that site as against only one who had previously experienced flooding of his property. The low level of perception is, however, inconsistent with the hazard that actually exists. All respondents live either in a zone that is adjacent to the channel of the Sundays or Great Fish rivers, parts of which were subject to disastrous flooding as recently as 1974, or in a zone that has been clearly identified by the Department of Water Affairs and the Municipality as subject to the hazard of flooding.

In Graaff-Reinet the entire area west of Cradock Street and south of Middle Street is officially expected to be inundated in the event of the failure of the Van Ryneveld's Pass Dam (figure 8.1). Yet only 21 per cent of respondents see any possibility of inundation. While it could be argued that the possibility of the dam failing is remote and that this influences the perception of the residents, it should then follow that those residents living adjacent to the river channel would sense a greater danger of flooding. Responses provide no evidence to support this at all.

A partial answer to this question may be found in the fact that none of the respondents had previously experienced flooding of his property. Although the municipal workshop and sewerage pump stations were inundated and the water reticulation system was damaged by the flood of 1974, no houses were inundated in Graaff-Reinet, a fact that contributes to the view held by the majority that future inundation is unlikely. Moreover, the Graaff-Reinet municipality has been at pains to reduce the fear of a flood amongst the residents of the town. This was the only municipality in the study region that refused to respond to the questionaire despite reminders, and its top officials were explicitly reluctant to respond to the researcher's personal enquiry, apparently for this very reason. The researcher was also specifically requested to keep as low a profile as possible in conducting the survey in the town so as to minimize the awakening of unnecessary concern among the residents.

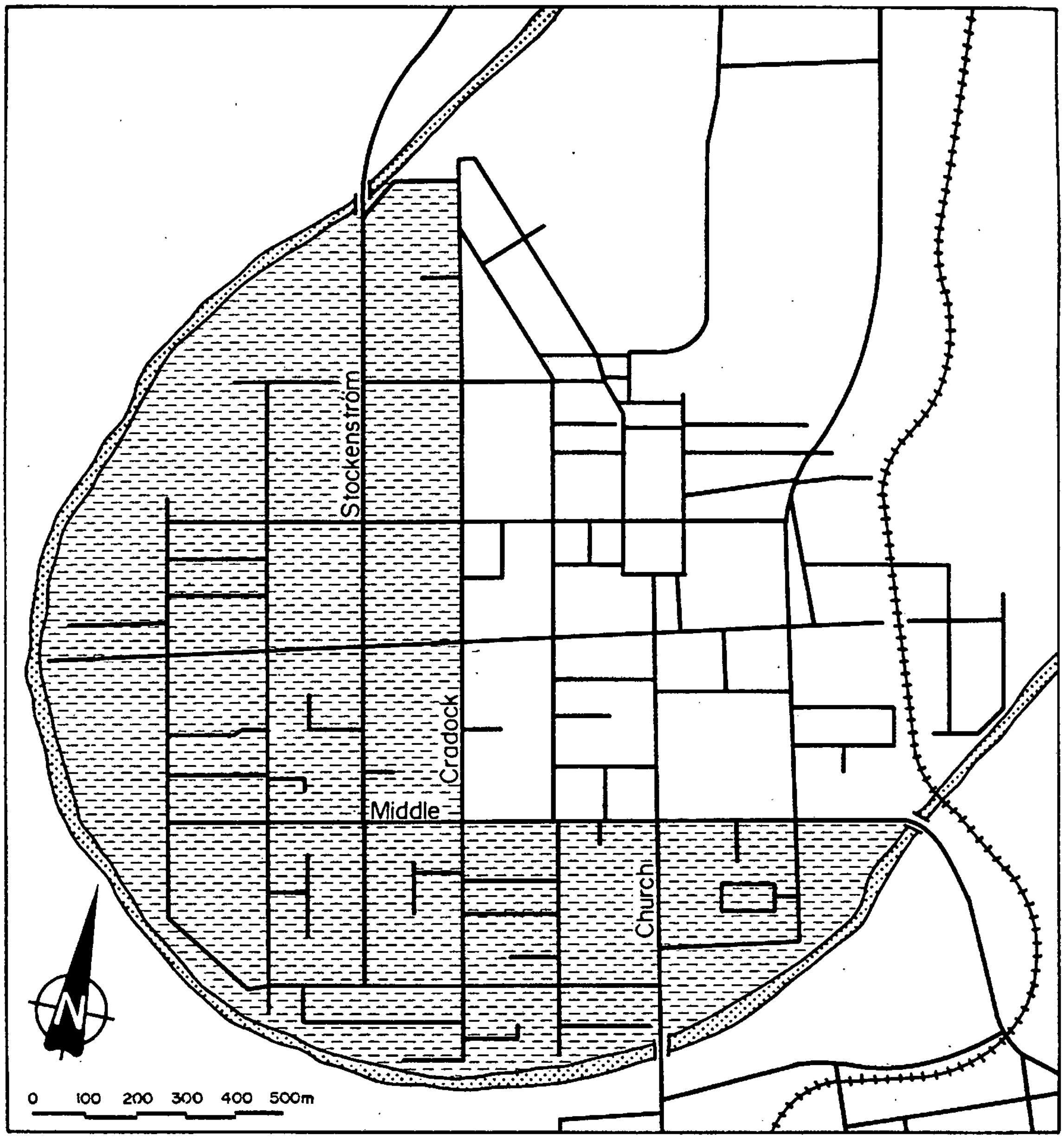

Fig. 8.1 Graaff-Reinet. Area subject to flood hazard

The problem of the depopulation of Karoo towns is well known, and the municipality's attitude is understandable against this background if the exodus of a large number of people is seen as a possible consequence of the fear of a flood. Low perception of the flood hazard can no doubt be attributed partly to the success of the municipality's efforts to play down the possibility of disastrous flooding as far as possible.

Of the 5 residents who indicated that their property was subject to a flood hazard, one perceived the recurrence interval of floods to be 10 years, one perceived it to be 50 years and two to be 100 years. Four out of the five respondents also had prior knowledge of the possibility of the inundation of their properties before they acquired them. This knowledge had not deterred them from occupying the property. The same tendency to ignore the existence of the hazard is evident from the fact that in Graaff-Reinet some 20 sites that had been inundated as recently as the 1974 flood were developed and occupied by residents during the ensuing twelve-year period. A school clinic funded by the government was also erected in this zone during this period.

Perception of the magnitude of the flood hazard is indicated by the response of residents to the question of what they thought would be threatened in the event of a flood. Out of seven that responded to the question three felt that their lives were in danger, three that their house was threatened and one that only his garden would be flooded. Nine residents were able to identify the cause of a possible flood. (It should be noted that this is four more than perceived the possibility of water inundating their property). Three saw the source of a flood as the river only; four as the dam failing and a further two as both the river and the dam.

The level of anxiety experienced by these residents is a further indication of their perception of the magnitude of the flood hazard. Only one spent occasional sleepless nights worrying about the hazard while another one worried about it occasionally. Three were only concerned when it rained heavily and continuously; two sometimes gave it a passing thought. Only one was never concerned about it at all. For none of them was it a matter of such gravity that they contemplated moving to a safer location.

(b) Farmers

Of the 38 respondents to the questionaire a little more than half (57,9 per cent) perceived part of their land to be subject to the hazard of flooding. Of those who perceived no flood hazard, 43,8 per cent had never experienced foooding of their land, while 56,3 per cent of them had experienced flooding of their land before.

Stated in another way, 9 farmers saw no threat to their property by flood despite experience of at least one previous inundation. There are three possible explanations for this apparent enigma. These farmers might consciously or subconsciously ignore the possibility of the recurrence of such floods. Psychologically this is referred to as cognitive dissonance (Gold, 1980). Alternatively, they might have adopted certain measures which they regard as sufficient to prevent a recurrence of fooooding of their property. Thirdly, the previous flood(s) experienced by them might not have significantly damaged any of their property, and they view future floods to be equally benign.

Evidence suggests that, in all but one of the cases, confidence in preventative measures taken, might be a significant factor. These farmers had adopted one or more of the following measures to reduce the effects of flooding: earthworks, river channel modification, dams, and avoidance of flood-prone land. It is noteworthy that seven of these farmers suffered considerable losses during the previous flood (R1 000; R3 000; R10 000; R80 000; R100 000 and R200 000).

Compared to the previous flood, four indicated a reduction in the value of property threatened by flood. One saw no change while two perceived the present value of threatened property to be higher than the value of losses suffered in the previous flood. This contradiction in the perception of the flood hazard: not seeing it to exist on the one hand yet being able to identify and specify in monetary terms possible losses from a flood on the other, can only be explained with reference to cognitive dissonance.

The level of flood hazard was variously perceived. Of the total, 25,7 per cent perceived the flood hazard as serious, 40 per cent as moderate and 34,3 per cent as slight. Statistical analysis revealed no significant association between level of hazard and experience of floods as measured by length of residence in the area.

Perception of the return period of floods is summarized in table 8.5.

Table 8.6 Perception of the return period of floods

Return period (years)	Serious flood % of farmers Cell	Cumul.	Moderate flood % of farmers Cell	Cumul.	Light flood % of farmers Cell	Cumul.
< 10	4,5	4,5	20,0	20,0	45,0	45,0
10	13,6	18,1	32,0	52.0	30,0	75,0
15	4,5	22,6	4,0	56,0	5,0	80,0
20	13,6	36,2	20,0	76,0	15,0	95,0
25	9,1	45,3	0,0	76,0	0,0	95,0
30	4,5	49,8	4,0	80,0	5,0	100.0
50	18,2	68,0	16.0	96,0	0,0	100,0
100	31,8	99,8	4,0	100,0	0,0	100,0

Two features are characteristic of the distribution of the figures in this table. There is a distinct tendency for the clustering of higher values at the round-figure return periods of 10 years, 20 years, 50 years and 100 years. Further, severe floods are seen to occur least frequently, light floods most frequently and moderate floods occupy a position in between. There is, however, considerable variation in the perception of the actual length of return periods.

Similar variation exists with respect to the perception of the date of the previous flood (table 8.7).

Table 8.7 Perceived number of years since last flood

Number of years and date		Number of farmers	Percentage of farmers
< 1	(1988)	3	8,1
2	(1986)	2	5,4
3	(1985)	1	2,7
5	(1983)	2	5,4
11	(1977)	2	5,4
12	(1976)	5	13,5
14	(1974)	21	56,8
27	(1961)	1	2,7
		(N = 37)	

More than half of the respondents identified 1974 as the date of the last flood and it is well-known that widespread heavy rains in the region brought down the rivers during that year. Variation in the perception of the date of the last flood can be attributed to inaccurate memory of the incident, and possibly that some farms are more susceptable to flooding than others. The fact that rainfall characteristically occurs in the form of thunderstorms, producing notoriously patchy falls and locallized flash floods can also be a reason.

It could be argued that perception of the level of hazard, i.e. whether risk was high, moderate or low, might be influenced by the degree to whch a farmer's income was threatened by the hazard. Farmers were therefore asked to identify what percentage of their income was threatened by the floods. An analysis revealed no significant association between the factors of perceived level of flood hazard and percentage of income threatened by flood.

The findings of this study of perception of the drought and flood hazard accord with those conducted elsewhere in that its most characteristic feature is its great variation.

Psychology offers two main sources of explanation for this variation in perception. The first is "cognitive dissonance", producing in an individual an attitude that does not accord with what would be expected from consideration of available information about the objective environment. Cognitive dissonance occurs whenever a person perceives an environment as threatening but expects to continue living in that environment (Preston *et al.*, 1983). A degree of cognitive dissonance is likely to be present with the majority of Karoo farmers since most of them do not view their stay in that environment as temporary.

The second is that human nature tends to distort infrequent hazard conditions (or other conditions associated with stress or pain) and assign to them roles that are more remote and less traumatic than they really are. This is an essential element in adaptation and is probably important for human survival. This observation leads to the need to consider previous experience as it affects hazard response.

8.2 Previous experience

The role of previous experience as a factor in response behaviour was examined as early as 1966 by Saarinen in his study of drought on the Great Plains of the USA. He found that farmers underestimated the frequency of years when drought was experienced and were optimistic about the number of good years; that successes were recalled more frequently than failures. Subsequent research has substantiated this early finding (e.g. Jackson and Mukerjee (1974). "Extreme events tend to act as a fixed point in experience, obliterating memories of earlier occurrences and acting as a standard against which later ones will be compared, although the poignancy of the recollection will fade if the extreme event happens only rarely" (Gold, 1980 : 206).

An indication of this tendency towards optimism and the fading of poignancy is evident in the response of municipal authorities and urban dwellers in Graaff-Reinet and Kenhardt.

Graaff-Reinet suffered damage amounting to R187 519 as a result of the flood that occurred in the eastern Cape midlands in 1974. Of this amount only R12 519 was the cost of damage to residential buildings, R46 500 to educational institutions and R107 206 to property of the municipality (Spies, 1977). The nature and relatively small cost of the damage caused by this flood no doubt influenced the municipality in its view that a warning system was an adequate response to the hazard of flooding and and that land-use control measures were unnecessary or inappropriate. The nature of the event also appears to have given residents a false sense of security as is evident in their construction of dwellings on previously inundated land.

Kenhardt experienced floods in 1941, 1961 and 1974. In the 1941 flood all the dwellings in the Rooiblok area were swept away and peoples' lives were lost. The two subsequent floods were far less serious and today the Rooiblok is once again occupied by a number of permanent residents.

In the study area 73,5 per cent of farmers have occupied their present farm for more than 15 years and 78,7 per cent of farmers previously lived in the same region (see Tables 8.8 and 8.9). It might therefore be concluded that some three-quarters of all farmers had experienced at least two or more serious droughts (assuming an approximate 10-year cycle) and that this experience would influence their response to the hazard. It might be assumed that repeated personal experience of drought events would lead to the adoption of measures to reduce its effects. The degree to which the drought management principles of the Department of Agriculture are adopted can be taken as an indication of the extent of response.

Table 8.8 Length of tenancy

Years	Number of farmers (N = 177)	Percentages Cell	Cumulative
< 5	10	5,6	5,6
5 - 10	21	11.9	17,5
10 - 15	16	9,0	26,6
> 15	130	73,5	100,0

Table 8.9 Location of previous residence

Location of previous residence	Number of farmers (N = 169)	Percentages Cell	Cumulative
Within the region	133	78,7	78,7
Outside the region	36	21,3	100,0

Cross tabulation of these two variables (length of experience and degree of adoption of drought management principles) shows no significant association between these two factors. In this region factors other than previous experience of drought appear to play a more important role in motivating response.

A similar lack of association is evident in relation to the flood hazard. Farmers living in the area for a long time, some of them for more than 70 years, do not record the adoption of significantly more measures against the flood hazard than those that have lived there for only a short while.

8.3 Attitudes towards nature and God

The literature identifies three main attitudes that are frequently held about nature: man as subject to nature, man existing in harmony with nature, and man dominating nature. Culture strongly influences such views and it is thought that prevailing technology also plays a significant role, the view of pre-industrial society and pioneering settlement being associated with man being dominated by nature and him being able to exercise very little control over it. These attitudes are, however, not exclusive, and it is possible for an individual to hold more than one of these views simultaneously. It should be clear that an individual's view of nature will have a significant effect on how he reacts to a natural hazard.

Closely related to man's view of nature is his concept of God as its designer and His role in the occurrence of natural events. The relationship between God and man is a further dimension of possible response but this aspect is considered separately and more appropriately under the heading of religious belief as a factor.

The following quotations, translated freely from the Afrikaans in which the interviews were conducted, epitomize the variation in the views of nature and God that are held by people affected by the hazard of drought in the region. They are the expressions of a farmer in relation to drought. The first expresses his view of nature and of God in it while the second is an anecdote related by him as an expression of his view of the order of things:

> "The Lord wrote the Bible to serve as a framework within which man should stay, live and believe. But man is too stupid for nature; God kept it Himself. He will look after it, and it will not be destroyed; but man, if he refuses to take heed, will most certainly not survive. This you have to take note of."

> "It was at a time when rain had stayed away. An old man, sitting on the stoep in Prieska asked one of the many passers-by where they were going to. `To the church, there's a prayer meeting for rain' was the reply. `Well, my son' he said, `I can't be there myself, but please tell the people to place emphasis in their prayers on drizzle, so that perhaps there will be some of that during the winter, because the normal time for our rain has passed.'"

(It is noteworthy that the same respondent is superstitious about a leap year. He thinks that the unexpected in relation to rainfall happens in a leap year).

These expressions reflect, in the first instance, the view that man is subject to nature, and by implication, that he can not do much about an extreme natural event like a drought. He has to accept it as part of nature and God's design. Such a view will undoubtedly tend to inhibit responses aimed at affecting the cause of the hazard, which, as indicated earlier, are essentially technological and in the hands of institutions rather than individuals.

The second quotation implies man working together with nature. It expresses a degree of resignation and acceptance of the inevitable but it is not fatalistic in its attitude. There is still a ray of hope that as a result of his prayers, man will still be favoured by some light rain, though not in the form of a miracle; a miracle is not asked for or expected. What is asked for is that the more favourable side of nature may prevail.

A wider variety of responses to drought on the level of the individual should be seen in the context of this attitude of subjection to and co-operation with nature. The relative dominance of being subject to or co-operating with nature will be an important factor in a farmer's view of whether a particular adaptive response would be worth while or not, the subjectionist view tending to promote a negative perception of the usefulness of a response. Specific responses that are affected by a farmer's view of nature include:

- stocking at less than veld carrying capacity
- veld improvement schemes, and
- planting drought-resistant fodder crops

all of which are fairly directly dependent on the course of nature.

While the response of institutions to the flood hazard is predominantly a reflection of the view of man ruling over nature, especially where technological and engineering schemes are introduced, that of the individual is frequently one of man being subject to nature and God's role in it. The words of one respondent in Cradock explaining her experience of the most recent flood, support this statement. She recalls that as the waters rose and flooded her house she felt that is was God doing it. She accepted it. Another respondent's attitude reflects this view of subjection even more strongly. The flood water had already entered her house but she refused to evacuate it stating that God would not do such a thing to her or allow it to happen. The lack of any adaptive response on the part of urban dwellers is strongly indicative of this view.

Subjection to nature together with resignation to this position is evident in the fact that 32 per cent of farmers have no response to the flood hazard other than accepting it, in some instances together with only emergency measures or avoidance of flood-prone land. On the other hand, earthworks (42 per cent), dams (18 per cent) and river channel modification reflect attempts to overcome nature.

8.4 Attachment to place

One possible, basic response to a natural hazard is the permanent evacuation of the threatened area. The very fact that the drought-threatened environment of the Karoo region, which also incorporates narrow strips of flood-prone land along some of its rivers, is permanently inhabited, is evidence of the choice that the present inhabitants have made against the permanent evacuation of the area. Many, in previous years, have moved out of the region, some no doubt having found the environment unsuited to their requirements, with droughts and floods having played their part as motivators in the decision to move. Yet the population of the region is very stable. Of all farmers who responded to the questionaire on drought 73,5 per cent have occupied the same farm for more than 15 years, many for considerably longer periods. The average period of tenancy of farmers with at least some of their land threatened by flood is 28 years. Of urban dwellers subject to the hazard of floods, 62,5 per cent have occupied their present dwelling for 10 years or more, at least half of them for more than 20 years. This reflects a population that has chosen to stay.

Tuan (1974: 114) has written about "environments of persistent appeal" and Gold (1980: 287), referring to settlement along such rivers as the Nile, Tigris, Euphrates, Hwang Ho and Indus, notes that "the flood hazard posed by all these rivers has been formidable, but (that) this pales when compared with the economic advantages of living in adjacent areas or the cultural significance with which such places are endowed." While economic factors are certainly not without significance in the Karoo region, despite the losses inflicted on farmers by droughts and floods, sentiment and tradition are of supreme importance in the stability of occupance.

The vast majority of the rural population in the study area are Afrikaans speaking. The importance to the Afrikaner of owning

8.5 Social and cultural constraints

When disaster strikes, the costs to the individuals who suffer the losses are at least partly borne by society as a whole. Droughts are mitigated by government assistance under the Drought Aid Scheme, while major flood events are also alleviated from government funds and public sources, but direct aid from public donations is frequently more significant. This occurs because floods are fairly sudden, extreme events that are clearly localized with distinctly visible and often dramatic consequences. Visual material disseminated by the media is eye-catching and evokes immediate sympathy and response in the form of donations.

The effect of such social aid on the response of people to natural hazards has been debated in the literature. Knowledge by potential victims that aid will be forthcoming in the event of a disaster is likely to engender reduced responsibility and inhibit appropriate adaptive response. The exact extent to which this factor affects response is unknown. That the government is aware of its effect is, however, evident in the changes introduced in the drought aid scheme. The changes have made qualifying conditions more stringent and placed greater onus on the farmer to comply with certain conservation measures as a prerequisite.

An aspect of culture that has a bearing on response behaviour is religious belief. The vast majority of people in the study area have religious affiliation with a denomination that is strongly Calvinist in its foundations. Calvinism forms the basis of doctrine in the Dutch Reformed, Gereformeerde, Hervormde and Presbyterian denominations. Table 8.10 illustrates the dominance of affiliation to these four groups in the region.

Table 8.10 Religious affiliation: Non-urban males (Whites)

District	Religious affiliation (%) Dutch Reformed	Other Calvinist	Total
Kenhardt	91,7	0,3	92,0
Prieska	68,9	4,8	73,7
Carnarvon	93,6	0,6	94,2
Calvinia	97,4	0,3	97,7
Williston	98,5	0,7	99,2
Sutherland	88,9	0,0	88,9
Beaufort West	74,1	1,1	75,2
Prince Albert	93,9	0,6	94,5
Laingsburg	90,5	1,0	91,5
Fraserburg	96,8	0,0	96,8
Victoria West	87,5	1,6	89,1
Murraysburg	87,3	0,0	87,3
Hopetown	87,6	4,4	92,0
Britstown	87,2	0,8	88,0
Philipstown	85,6	7,0	92,6
De Aar	65,0	17,8	82,8
Colesberg	61,1	12,4	73,5
Hanover	71,0	6,9	77,9
Richmond	85,2	3,5	88,7
Noupoort	64,6	24,0	88,6
Queenstown	38,0	7,5	45,5
Tarka	43,8	29,7	73,5
Sterkstroom	54,3	4,6	58,9
Wodehouse	62,2	9,4	71,6
Molteno	63,0	10,1	73,1

Aliwal North	65,9	15,1	81,0
Albert	58,4	27,4	85,8
Venterstad	42,1	38,6	80,7
Steynsburg	48,0	27,4	75,4
Hofmeyr	82,6	2,7	85,3
Middelburg	58,2	10,3	68,5
Graaff-Reinet	47,0	1,0	48,0
Aberdeen	77,9	1,6	72,7
Pearston	70,4	1,0	71,4
Willowmore	80,3	0,4	80,7
Jansenville	71,1	1,6	72,7
Steytlerville	84,8	1,1	85,9
Adelaide	40,5	26,8	67,3
Fort Beaufort	42,6	12,2	54,8
Bedford	59,3	12,2	71,5
Somerset East	67,1	3,4	70,5
Cradock	77,9	1,3	79,2
MEAN	71,7	7,9	79,6

(Republic of South Africa Population Census 1980, Religion by Statsitical Region and District. Report No 02-80-06. Pretoria, Government Printer)

Two of the basic tenets of Calvinism are:

- God's absolute sovereignty in His creation; and
- God as sovereign both foreordains and foreknows all things including man's destiny.

Acceptance of the inevitable rather than fatalism is a characteristic of adherents to this doctrine. Responses in the context of this belief would not reflect a tendency to try to escape from the natural hazards; neither would it reflect attempts to overcome them. Quiet resignation and faith in the security of one's destiny in the hands of a sovereign and loving

God would be essential ingredients of a response foundation. The responses of the two urban residents referred to under 8.3 above, admirably reflect such an attitude.

8.6 Personality

The role played by personality in the perception of hazards and response to them, has long been recognized in hazard research. In his early work on the Great Plains of the USA, Saarinen (1966) attempted to identify some personality characteristics of the local farmers using the Thematic Apperception Test. A few researchers have subsequently focused on the role of personality in human responses (e.g. Golant and Burton, 1970; Simpson-Housley and Bradshaw, 1978) but, as Gold remarks, disappointingly little is known as yet (Gold, 1980: 206).

This is a reminder of the difficulty of defining the relevant dimensions of personality, on the one hand, and the deficiencies of personality research, on the other. Recent research on personality structure has concentrated on finding personality constructs related to achievement motivation, assertiveness, authoritarianism, cognitive styles, extraversion, field dependence, moral development, locus of control, loneliness, mindlessness, etc., but, as London and Exner (1978: xiv) note, "there has been no overreaching plan or theory, implicit or explicit, guiding the selection of topics for trait researchers." This research represents studies of a variety of single dimensions of personality in which binding theory is largely absent. Rorer and Widiger (1983: 432) remark that the related literature constitutes a negligible increment to our understanding of personality structure though they readily concede, that the enormous complexity of personality assessment is insufficiently appreciated.

The debate on whether behaviour is determined by personality as a collection of traits, or whether situations determine behaviour increases confusion. Confusion is increased even more fundamentally by the problem of a lack of agreement on what personality is or whether it exists. Yet, Lamiell's argument that an individual's personality is best described, not in contrast with what others do, but in contrast with what the person does not but could do (Lamiell, 1981), gives the role of personality indisputable relevance in the explanation of hazard response behaviour.

Early studies have indicated that people living subject to the drought hazard might have the personality of a gambler (Saarinen, 1966). Simpson-Housley and Bradshaw (1978) found the constructs locus of control and repression-sensitization to be useful in the assessment of personality in the context of the earthquake hazard. Apart from a few examples, and despite the recognized need for studies of personality in relation to hazard, such studies are conspicuous by their absence.

While studies of aspects such as those listed in the preceding paragraphs are not without relevance, other aspects of personality are considered to be more appropriate for providing insight into the response behaviour of people, especially farmers, in the context of the drought hazard. Two traits which can be stated as coupled opposites, viz., extraversion-introversion and emotional stability-instability can be regarded as more relevant to the understanding of hazard response.

Eysinck and Wilson (1976) recognize that such traits combine to be characteristic of certain groups of people. They find, for instance, that sportsmen, parachutists and commandos in the army are almost all characterized by a combination of emotional stability and extraversion. Criminals tend to be found in the group of traits combining emotional instability and extraversion; scientists, mathematicians and successful businessmen are frequently characterized by a combination of introversion and emotional stability (Eysenck and Wilson, 1976).

It is postulated here that the farmer in the arid and semi-arid regions of the Karoo environment is likely to have a phlegmatic temperament characterized by introversion and emotional stability. It can be argued that a sorting process occurs in the region by which those that are unsuited to living under the prevailing conditions of hazard from drought and in some localities flood, abandon farming as a source of livelihood, in favour of something that better suits their temperament. This is the refining process referred to earlier under section 8.4. Those that move out would include the emotionally unstable who would find the hazards too stressful to cope with and the extraverted who would find them too stultifying to put up with.

The Karoo and Bushmanland farmer would tend to be passive, careful, thoughtful, peaceful, controlled, reliable, patient, even-tempered, calm; all characteristics of a phlegmatic temperament in which introversion is combined with stability.

Well established methods are available for measuring these traits. In the context of this study the method would have to be suitable for application to farmers who already have a questionaire to fill in, no doubt rather reluctantly. One test that is available is the Maudsley Personality Inventory which in its short form measures extraversion and neuroticism by means of some 20 questions. The number of questions is small enough not to discourage respondents from filling it in and is therefore ideal for the purpose. Unfortunately, however, it was not possible to apply the test in this research project for a number of reasons:

Copyright regulations prevented duplication of the questionaire and copies were unavailable in the country at the time of survey. More importantly, however, professional codes prohibited the distribution of such questionaires by mail. A further requirement governing the application of personality inventories is that they have to be applied under the personal supervision of a registered psychiatrist and interpreted by him. Any infringement of these regulations would invalidate results. The widely distributed location of farmer respondents and the great distances involved, together with the prohibitive cost of engaging the services of a registered psychiatrist, as well as the time required for travel and interviews, placed the pursuance of this line of enquiry beyond the reach of this study.

The postulates regarding the personality traits of the Karoo farmer therefore remain unproven. Nevertheless, since this appears to be an avenue of study worth following, a pilot study was conducted on a small group of urban dwellers. For this purpose an unofficial questionaire was used. It consisted of a series of questions drawn up by Mol and tested essentially in group counselling contexts (Mol, 1984). Although it is unregistered it does, in view of this testing, have some credibility. It is emphasised that the findings cannot be regarded as conclusive, but they do reveal an interesting trend which serves to indicate that further study in this direction has the promise of some useful results.

The questionaire was answered by 15 respondents living in Graaff-Reinet and Cradock in areas subject to the hazard of flooding. Emotional stability/instability and introversion/extraversion were measured. Measurement was made on a scale in which a score of 48 points represents the highest degree of emotional stability and zero the highest degree of instability. Similar scores represent extraversion and introversion respectively. Cut-off points between the two opposites therefore lie at 24. The average score of respondents on the introversion/extraversion scale was 19,8, indicating a distinct tendency towards mild introversion. The average score on the emotionally stable/unstable scale, however, was 31,8 indicating a strong tendency towards emotional stability. As in the argument above, a logical explanation could be found in the notion that highly emotional people would find living in an area threatened by flood too stressful and not move into it, or not be able to tolerate the stress for long and therefore move out.

8.7 Economic factors

Economic factors form one of the cornerstones of response to hazard. Finite financial resources of farmers impose very definite constraints on what farmers can do to bolster themselves against the ravages of droughts or floods. As in any business enterprise, farmers have to constantly balance income against expenditure and can only allocate a portion of income for relief works or other hazard related development projects on their farms. Droughts and floods result in a reduction of income and, frequently, substantial losses. Farmers then have to negotiate loans to continue their operations and debts accrue while the drought lasts or until flood-damaged land is restored to normal production.

It is for economic reasons that some farmers in the study area find part-time employment in nearby towns. It supplements their income and makes them less dependent on their farms when droughts prevail. Economic constraints play either a positive or negative role in practically all the responses listed in table 8.11.

Yet, while economic considerations are fundamental to possible response, studies of human behaviour have demonstrated that man does not invariably behave in a predictable way, seen from the perspective of economic optimization. Rather, he will consider a limited number of relevant economic variables and then proceed with a decision, whether this will result in the economically most desirable solution or not. A variety of subjective factors including prejudice will play a role in the decision-making process, resulting in a less than optimal economic response. The situation is exemplified by the following observation by an arid region farmer: "A farmer here does not budget in advance because then he is too aware of how badly he is faring. He doesn't work with detail. This gets on his nerves" (A farmer in the Kenhardt district).

The form of behaviour is one described by Simon (1952) as satisficing or bounded rationality. In their analysis of the decision process with respect to adjustment to natural hazards, Slovic, Kunreuther and White (1974) list five aspects of bounded rationality that are relevant in the context of response to hazard.

(a) The law of small numbers: This is the tendency of people to generalize on the basis of small samples of evidence. With this in mind in relation to hazards Slovec *et al.* (1974) ask: "Do people take conclusions on faith without questioning the amount of data upon which these conclusions were based?" Apart from the quotation above revealing something of the farmers' attitude in this respect, the present study does provide some evidence of the applicability of the law of small numbers. A third of all farmers (33,3 per cent) did not record rainfall on their **farms** at all despite its being the most fundamental factor in drought. Yet, 72,5 per cent asserted that it was possible to plan for drought in their farming enterprise and 80,5 per cent stated that they effected thorough planning proceedures. Apparently such planning is based on evidence other than recorded rainfall figures and rather less prolific data. Great variability in the perception of the frequency of drought (tables 8.1 to 8.4) suggests that subjective heuristic procedures are adopted in preference to rigorous analysis of rainfall data.

(b) Judgements of causality and correlation: This is the tendency for people to misperceive the degree to which causation is present in a probabilistic environment. Relationships are perceived to exist in data because people expect them to be there, even when these relationships are not present. An indication of the presence of such a basis for behaviour in the context of bounded rationality is particularly evident in relation to veld conservation measures.

For example, some farmers perceive heavy grazing of the veld to be necessary for the beneficiation of the natural pasturage and as a hedge against drought. Independent evidence indicates that conservation is more important. Similar prejudice is evident in the resistance many farmers show to the establishment of drought-resistant fodder crops. They perceive their farm to be too dry or too cold or in other ways unsuitable for these crops without having proved this to be so by actually trying to grow them.

(c) Availability: Availability here refers to the mental strategy according to which people estimate probability and frequency by the ease with which relevant instances are imagined or retrieved from memory. Frequent events are more easily recalled than infrequent ones, as are likely ones rather than unlikely ones. Availability is also affected by recency and emotional saliency.

The question of availability was not specifically measured in this study. The extent of the geographical area in which regional differences inhibited standardization and the relatively short time span over which individuals could have been subjected to a limited number of extreme events, made such measurement difficult. But it is clear that an event as extreme and recent as the Laingsburg flood heightened attention to the flood hazard there and elsewhere. In Laingsburg itself the response was clear-cut and drastic: residential areas were relocated and land re-zoned to reduce future risk to life and property. Laingsburg had previously experienced other less severe floods as recently as 1958 and 1976 without making any significant adjustment to the hazard. The emotive salience induced by the great loss of life and property prompted specific and directed responsive action.

Similar though less drastic responsive action followed the flooding of a part of Cradock by the Great Fish River in 1974. An important question that remains unanswered is whether a serious flood in other towns with flood-prone land (e.g. Kenhardt, Graaff-Reinet, Beaufort West) is required before appropriate adjustment is to occur?

As regards imaginability and its influence on the perception of hazard and response to it, the refusal of the municipal authorities of Graaff-Reinet to respond to the questionaire on flood sent to them, and their great reluctance to allow the distribution of a questionaire that could remind residents of the flood hazard to which the town is subject, can be considered.

Imagined scenarios created by emotive reporting or other publicity, could greatly elevate fears of flooding among residents. The resulting stress and its reduction of place utility could be an inducement to residents to relocate. In view of the great capital investment in fixed property in the flood-threatened zone, however, people would be unlikely to move. That no respondent to the questionaire administered to urban residents indicated that they would move in response to the flood hazard, is confirmation of this assertion. Residents would therefore have to live with heightened stress. Having considered the source of serious flooding (the failure of the Van Ryneveld's Pass Dam), and having planned for rapid evacuation should this event appear to be imminent, the assumption of the role of watchdog over the emotional well-being of its residents by the Graaff-Reinet municipality should perhaps not be regarded in an unfavourable light.

(d) Anchoring and insufficient adjustment: This heuristic process is used to ease the strain of integrating information. In it a starting point is used as an approximation to the judgement. This point serves as an anchor which is subsequently adjusted to accommodate the implications of additional information. It implies that people's estimates of uncertainty might be grossly in error. People tend to regard their picture of reality to be far more accurate than it really is. Adjustments to hazards might therefore tend to be far more conservative than they ought to be and might leave too small a margin of error if infrequent events have necessitated repositioning of the anchor too few times.

The implication of this error for hazard situations is that extreme events might occur more frequently and be more disastrous than expected and adjustments therefore be inadequate. Of farmers sampled in the study area, 80,5 per cent indicate that they thoroughly take account of the drought hazard in the planning of their farming activities. Yet only 43 per cent carefully apply the officially recommended farm management principles for drought prone regions. This suggests inadequate adjustment.

(e) Information processing shortcuts: Slovic *et al.*, (1974) summarize this factor by pointing out that "the amalgamation of different types of information and different types of values into an overall judgement or decision is a difficult cognitive process and, in our attempts to ease the strain of processing information, we often resort to judgemental strategies that may do an injustice to our underlying values." Consequently, "even when the risks and benefits are known and made explicit, ... subtle aspects of the decision we have to make, acting in combination with our own intellectual limitations, may bias the balance we strike among the many relevant attributes." (Slovic *et al.*, 1974 : 197). This often leads to a form of behaviour described as a lexicographic process whereby the decision maker proceeds sequentially, trying always to satisfy his more important goals, while relaxing those of lesser importance (Kunreuther, 1974).

Such truncated decision strategies characterize much of the response behaviour of farmers in the study area. The clearest evidence is provided by the limited adoption of hazard reducing options with respect to drought (table 8.11). From a list of at least 20 options which are generally known to farmers, they select a limited number of measures which they regard as most appropriate. The relevance of others is explained away, often summarily and sometimes in a totally irrational manner.

Table 8.11 Summary of farmers' responses to hazard

Responses to drought	Stated adoption of response Number of farmers	% of farmers
1. Source of income other than farming	42	20,6
2. Stocking at below veld carrying capacity	160	88,9
3. Producing own stock feed	57	31,6
4. Building up a fodder bank	67	37,2
5. Saving up reserve capital	104	57,8
6. Veld improvement schemes	36	20,0
7. Planting "old man salt bush"	43	23,9
8. Planting spineless cactus	23	12,8
9. Planting agave	8	4,4
10. Building more farm dams	42	23,3
11. Upgrading livestock quality	153	85,0
12. Diversification of farming	42	23,3
13. Enlarging the size of the farming enterprise	55	30,6
14. Other	20	11,1
Responses to flood		
1. Avoid flood-prone areas	11	28,9
2. Earthworks	16	42,0
3. Construction of dams	7	18,4
4. River channel modification	10	26,3
5. Insurance	7	18,4
6. Emergency measures	7	18,4
7. Accept losses	24	63,2
8. Other	4	10,5

Comprehensive consideration of the economics of responses is clearly absent in the decision-making processes of study area farmers. Behaviour can more accurately be described as conforming to the norms of bounded rationality in which the economics of responses is given limited consideration, and decision-making is strongly affected by the five factors discussed above.

8.8 Political factors and the role of the Government

In a speech to the Lower Orange River Development Corporation at Upington on 6 September 1983, Prime Minister P.W. Botha expressed concern at the depopulation of the "platteland" and said that maintaining a viable rural economy and population was regarded by the government as a high priority. Political issues are frequently at the basis of the role played by the government in affecting responses of farmers to the hazards of droughts and to a lesser degree floods. While the government's expressed concern was undoubtedly related to economic questions it was at least partly determined by the fact that the rural population in most of the study area constituted a stronghold for Nationalist support. National economics and politics at least partly determine the degree of government involvement in hazard related issues in the study area. The government's desire to keep the farmer on the land must be seen in the light of these two factors.

The highest level of government involvement is via the the aid schemes that it maintains. It is clear that without the aid given

to farmers during times of prolonged, severe drought, such as that of the late 1970's and early 1980's in the region, a great number of farmers would not have survived. A cardinal question is what the effect of the availability of such aid to farmers is on their individual response to the drought hazard.

One possible effect is that farmers would be abetted in the adoption of an attitude of reduced individual responsibility with respect to their actions in the face of the hazards. Knowing that aid was at hand would reduce reliance on their own resources in bearing the consequences of any ill-considered actions. Responses involving a high level of financial risk to the farmer or those requiring substantial inputs of effort and energy would be those that the farmer would tend to avoid in favour of others with a more secure promise of return, despite perhaps being less effective.

Changes in the policy of the Department of Agriculture Economics and Marketing with respect to environmental conservation as a measure to combat the detrimental effects of drought has also induced farmers to adopt more responses that are specifically conservation oriented than previously. Aid is only granted to farmers who have complied with conservation measures specified in the conditions of the scheme.

A recurring complaint among farmers is that the policy with respect to the marketing of livestock as effected by the Meat Board, often makes it impossible to sell off livestock for slaughter at a time when drought has made it imperative for them to reduce stock. Restrictions on the intake of livestock at the abattoirs are imposed by the Meat Board considering such factors as abattoir handling capacity and market conditions. If restrictions are imposed, as characteristically happens when drought in the sheep producing areas causes an oversupply of sheep offered for slaughter, the farmers are stranded with excess stock. The choice they face as a consequence, is between artificially feeding their animals, and letting them starve to death.

The Wool Board is not mentioned by farmers as a significant factor affecting their responses to drought, despite the fact that wool production is a basic facet of the farming economy. Unlike the Meat Board, the Wool Board does not have a quota system restricting the intake of wool at certain times. Farmers are therefore able to freely dispose of their wool at any time. Since the need is to reduce numbers of livestock in times of drought, the Wool Board remains involved. It is questionable whether this lack of involvement is necessary and indeed desirable. The Wool Board could assume a more positive role in relation to the problem of excessive sheep numbers in times of drought. This might be achieved by encouraging farmers to improve the quality of their woolled sheep. A higher price paid for better quality wool could allow farmers to reduce the overall number of livestock they keep, without loss of income.

A fundamental question is that of the part played by the prevailing political-economic system under which the people live and work. In the free-market economy which characterizes commercial capitalism, profit-making is one of the main objectives. This is achieved by surplus production, which is marketed in response to an often artificially created demand. The ability to satisfy an individual's needs and wants is directly related to his command of wealth. Wealth is derived from the successful marketing of saleable commodities. It was pointed out earlier that in their response to the need to generate profit, farmers place the natural environment under great pressure as they attempt to extract as much as possible of the resources it offers. As the resilience of the environment is exceeded it deteriorates and hazard increases. Capitalism can therefore be seen to be generative of hazard in this context and the question of an appropriate alternative is posed.

An alternative to capitalism is offered by the socialist mode of production. "The Marxist argument is that capitalism's relationship with the natural world must be essentially destructive, as it is with the fragile `personality of man.' This destructive relationship results in part from a set of characteristic attitudes toward nature produced by the capitalist system: the natural elements are `commodityized' so that the beauty of the earth is experienced as `photographs' while minerals, soil, vegetation and animals are mere `resources'. And in part it results from capitalism's never-ending need to accumulate, to constantly increase production, leading to an expansion in the geographic area of resource exploitation and a deepening of its intensity. The interaction between a set of commodity attitudes and the system's need to expand makes up the dialectic of man's self-destruction. The environmental crises we experience today are the symptoms of man's transformation of the earth from benign home to the cesspool of his last resting place. It is thus that the dialectic materialist approach can be applied to environment-man relations" (Peet, 1977: 258-9).

The contribution of this Marxist approach remains in the form of a useful theoretical critique. Marxist socialism has not been forthcoming with a successful, workable alternative. Socialist countries apparently display no greater ability to cope with the hazards than capitalist ones. The forces that induce people to look for a source of livelihood in areas that are characterized by diminished security or increased hazard under socialism though possibly different, are apparently as strong as those that operate under capitalism.

The effect of capitalism on the possible response of abandoning vulnerable areas is in the form of constraint. In view of capitalism's concomitant private landownership, the cost to individuals of permanently evacuating hazardous areas would amount to total loss of both capital investment and source of livelihood. Living under the threat of drought or flood is clearly interpreted by the inhabitants of the study area as the lesser of the two evils.

8.9 Environmental fit

Response behaviour is in many respects determined by the appropriateness of particular action to prevailing environmental conditions. Many examples of environmental fit as an influence on response exist in the study area.

The construction of farm dams as a means of conserving water is one such example. As pointed out earlier, one farmer in the Sutherland district adopts this option as a priority and already has 72 dams on his property. The nature of the topography and hydrography on his farm, however, are particularly favourable for the construction of dams and the conservation of surface and subsurface water by this method. Elsewhere, as in the northwest of the region, due to low rainfall, limited runoff as a consequence of sandy soils, and high rates of evaporation, dam building would be inappropriate.

Other areas of response in which environmental fit is a relevant constraint are the planting of the most suitable drought resistant fodder crops, appropriate diversification of livestock and production of own stock feeds.

Not all drought resistant fodder crops do equally well under different stressful environmental conditions. Old man saltbush, for example, reqiures more water and is more susceptable to damage by frost than agave. It is therefore less suited to the arid northwestern parts of the study region.

Selection of appropriate types of livestock in relation to the environment is an important response. The region under study was specifically selected on the grounds of its being given over to the extensive rearing of sheep, but other types of livestock such as cattle in the Noupoort district and goats in the northwest have been found to fit the environment fairly well and are advantageous to the farming economy.
Clearly, the production of stock feeds such as lucern, in an environment deficient in rainfall, is not feasible except in areas where irrigation is possible. Here, conditions of the local environment are as important as those on a regional scale. Proximity to rivers that are a source of irrigation water and the

availability of level land suitable for cultivation are necessary requirements.

8.10 Technical feasibility

Technical feasibility as a factor influencing response to hazard is not analysed in detail in this study since it lies essentially in the field of engineering. It is applicable in relation to flood hazard where storage dams are constructed for the purpose of flood control, and in relation to drought for the provision of irrigation water. The numerous dams in the region, most of which are multi-purpose schemes (see figure 6.1) attest to the fact that the factor of feasibility has had to be considered repeatedly in the past and has played a role, not only in the decision to construct dams but also with respect to their location.

Technical feasibility is a problem more commonly confronting institutions than individuals, though on a small scale some farmers have to consider it especially in relation to flood hazard. Technological adjustments are expensive the trade-off between their effectiveness and the implementation costs requires careful consideration. The feasibility of dam construction in streams, channel modification, or earthworks to secure riparian cropland from flooding are all relevant in this context.

CHAPTER 9

CONCLUSIONS

This study, which set out to provide a broad perspective of the hazards of drought and flood in the arid and semi-arid parts of the Cape Province in South Africa, has brought to light information about the patterns of occurrence of these hazards, and revealed a wide spectrum of individual and corporate responses to them. An analysis of these responses has shown that the measures adopted to reduce the adverse effects of the hazards, especially with respect to serious drought, are largely ineffectual. Yet, in spite of this fact, people continue to inhabit these hazardous areas. This is made possible only because the burden of disastrous events is spread through society as a whole. A consequence of this measure is the perpetuation of diseconomies in the farming system and the building in of factors exacerbating environmental deterioration. In this concluding section the perspective that was announced in the Introduction, as the underlying approach to this study, is taken up again. The existence of hazard is interpreted in terms of maladjustments between the patterns of occupation and the system of production, on the one hand, and the natural environment, on the other. The argument is reiterated that the rectification of these maladjustments is a fundamental issue in the quest for appropriate hazard reduction measures.

From the geographical patterns of drought and flood identified in the area, it is apparent that no part of the region is free of the hazard of drought. Evidence from the pattern of distribution of previous droughts in the area, reaching back to 1926, suggests that while occurrences of drought tend to be patchy, with some districts suffering heavily and others being almost free from its effects at a particular time, in the long term no district escapes its ravages.

The geographical patterns of flood hazard display great variation. In the course of the study a method was devised for quantifying flood hazard so that the geographical patterns of flood hazard (as distinct from mere patterns of the occurrence of flood) could be discerned. Based on the resulting Hazard Index which indicates the magnitude of flood hazard, it is evident that there is a general surface of low hazard extending across the entire area. It is most continuous in the northern and northwestern parts of the region and is interrupted by higher levels of hazard in the southern half, culminating in three main concentrations of high hazard in the southwest and southeast. These areas should take priority for closer scrutiny with a view to planning strategies for flood control and relief. Particularly noteworthy is that a number of towns that are subject to the hazard of flooding have been identified, Beaufort West, Cradock, Graaff-Reinet and Kenhardt being the main ones. The priority assumes special relevance in the light of the Laingsburg disaster.

Due to a lack of adjustment to the hazard of flooding, Laingsburg had to suffer the disastrous consequences of an extreme flood event. The adjustments that have followed in the aftermath of the disaster have been in time only to prevent the town from suffering further damage from a similar event sometime in the future. Timeous implementation of appropriate adjustments in the identified towns could avert a possible disaster that could resemble the Laingsburg event.

In general the physical basis of droughts and floods is fairly well understood. There is, however, as yet incomplete comprehension of the exact causative mechanisms involved in the production of wet and dry periods. In view of this deficiency there is very little control over the physical sources of these hazards and little likelihood of it ever being fully achieved. The very limited success achieved in cloud-seeding experiments aimed at modifying the rainfall pattern in South Africa and elsewhere attests to this fact. No support for the contention that the climate is changing could be found. Apart from normal cyclic variations with periods of 2 to 3 years, 10 years and 20 years, rainfall is neither systematically declining nor increasing significantly.

Evidence presented in chapter 5 indicates that the hazard of flood and drought has increased in relation to more intensive human occupance of the semi-arid and arid parts of the Cape Province. From a state of initial equilibrium the natural environment has come under increasing pressure as permanent settlement spread in the area. Increased demands were made of the environment as population density grew. The land was required to yield more and more as simple subsistence farming changed to advanced commercial pastoralism in an expanding world economy.

A social and cultural system emerged in which farming as a way of life and rural landownership were cardinal values. These found expression in the custom of subdividing farm units to provide land for children in the family, often resulting in uneconomical units. Rising standards of living further increased the pressure on the environment as farmers found it necessary to resort to exploitive practices in generating wealth to meet their rising expectations. Increasingly, farming practice became based on conditions which prevailed during favourable years. Thereby the productive capacity of the natural environment was taken to its limits. In less favourable years the demands imposed by such farming practice reached beyond these limits, and the resilience of the environment was exceeded. The degradation of the natural environment that occurred as a result has been attended by increased hazard through the mechanisms of accelerated runoff, soil erosion, a reduced water table, deteriorated pasturage and generally diminished environmental stability.

A great variety of responses to these heightened conditions of drought and flood hazard have been identified as one of the major aims of this study. They have been dealt with under the headings of Institutional, and Individual responses.

In its efforts to restore a degraded natural environment the government has fortuitously also addressed the problem of heightened hazard associated with it. The main thrust of remedial action has been through legislation directed at the conservation of the environment. The thorough enforcement of this legislation is hampered by the difficulty of detecting defaulters, especially in such areas as overstocking. The Livestock Reduction Scheme which was introduced to encourage farmers in the practice of environmental conservation by demonstrating its beneficial effects without the risk of financial disadvantage to themselves was a temporary success. The fact that so many reverted to stocking rates and grazing intensities that prevailed before the operation of the scheme, despite the recognition of the benefits of an improved environment, indicates that other, more powerful factors are at play.

The further approach by the government to promote conservation is characterized by both incentive and punitive measures. The state has itself acted by constructing a large number of multi-purpose water storage reservoirs in the region. Engineering works as a response to the flood and drought hazards in the study area have been employed to the extent that further major developments in this field are unlikely in the near future. Government also provides financial assistance to farmers for the construction of dams on their farms. Pertinent information on effective farm management under drought conditions is disseminated officially.

In the formulation of the new drought aid scheme the government has astutely incorporated conditions designed to encourage environmental conservation among farmers. Drought aid schemes previously made provision for assistance to farmers on the grounds of proof of losses suffered and evidence of the existence of drought of a certain degree of severity. As a result of recent changes to the drought aid scheme applicable to the extensive grazing areas, farmers disqualify themselves from receiving aid if certain specified conservation requirements have not been complied with in the general running of their farms. The scheme places greater responsibility on the farmer himself to conserve the environment if he wishes to participate in the benefits of the drought aid scheme.

Central and local government have also sought to reduce the hazard of floods by specifying certain statutory restrictions on structures and land use and encouraging the establishment of warning systems.

Individual response has been analysed with respect to farmers and urban dwellers. Urban dwellers are relatively unaffected by drought and their response to this hazard is essentially that of providing an emergency supply of water of their own in the form of rainwater tanks or boreholes. In relation to floods they are particularly vulnerable because it is usually their dwellings and associated property that are at risk. Response of these people has been found to be essentially a tacit acceptance of the risk in the nature of a gamble that a devastating flood will not occur in their time, or if a flood occurs, it will somehow not affect them.

Farmers' response is far more diverse. It reflects the multiplicity of individual decisions in accordance with each one's view of the hazard situation and the framework of possibilities available to him. Four categories of response have been identified.

In the category of affecting the cause the only significant response is in relation to flood and involves soil conservation measures. Although farmers are aware of the principles and no doubt generally accept them, actual practice still leaves much to be desired. Defaulting is chiefly in the area of overstocking, which occurs even among the better educated, younger generation of farmers. A major reason for exceeding defined grazing capacities of the veld is that large numbers of stock constitute a source of security which provides farmers with credit-worthiness and enhances their ability to negotiate bank loans.

The second category of responses, modifying the hazard, involves the conservation of water, limiting livestock numbers, veld improvement, and minor earthworks along rivers to locally contain flooding.

Individuality is expressed to a greater degree in the third category of responses, viz., modifying the loss potential, and a wide variety of responses is evident. A major objective of this study was to determine the full spectrum of responses to the hazards of flood and drought and to evaluate them in terms of their effectiveness in rendering those by whom they were adopted less vulnerable to these hazards. A total of 14 main responses to the drought hazard were identified. Evaluation of these responses revealed their ineffectiveness in the provision of adequate protection for farmers against the adverse consequences of serious drought. This negative finding is highly significant because it highlights the importance of the role of the drought aid scheme for farmers in the livestock farming areas of the country. Without it livestock farming in the extensive grazing areas would have to undergo drastic changes to survive.

This points to an imbalance between the demands of farming practice as imposed by the farmers' concept of an acceptable level of living, on the one hand, and the ability of the environment to meet and sustain these demands, on the other. The evidence provided by this study suggests that, in terms of environmental balance, the farming system is overextended, structural relationships within the capitalist mode of production being an underlying cause.

The fourth category of responses involves adjustment to losses and includes spreading, planning for, and simply bearing the losses associated with drought or floods.

An interpretation of these responses has been given by examining them in relation to ten major factors that influence human behaviour. Perception of the hazard by the individual was identified as a behavioural determinant that affects almost every response. It acts as a filter through which information passes between the objective environment and the behavioural environment and as such plays a key role in response. There are indications that personality characteristics play a similar role, though this notion could not be substantiated in the study due to a variety of restrictions governing the measurement of personality dimensions. Most of the other factors can be grouped into three main assemblages which form the context for the interpretation of responses.

The first is a context of social culture which is characteristic of the sheep farmer in the extensive grazing areas of the Cape Province. There is evidence of an arid-land subculture from which deviant or unadjusted members have in time been eliminated. Those that remain in the form of livestock farmers living under the hazard of drought and occasional flood, are the ones that have been refined by the stress and strain of constant threat to their source of livelihood. Their outlook is coloured by the sentiments of previous experience and inherited values in which attachment to the land is of supreme importance. Their steadfastness is strengthened by a strongly Calvinistic orientation in their religious faith which also directs their view of nature.

The second assemblage is economically and cognitively oriented. While economics plays a key role, on the one hand imposing constraints on the extent to which preferred responses are possible, actual behaviour is seldom determined finally by exclusively economic considerations. Rather, responses have been found to occur as a function of boundedly rational behaviour, with people's perceptions being an important factor in the adoption of hazard-reducing measures.

The third is an assemblage of political factors in which both matters of local policy and a general context of capitalism are relevant. The orientation of the government with respect to the continued presence of farmers on the land, as it finds practical expression in the aid schemes that are maintained and the product price protection mechanisms effected by the Meat Control Board, have been shown to have a significant influence on the response behaviour of farmers.

All these factors have been shown to be relevant in the explanation of the response behaviour of individuals but the exact mechanism of the operation of the influence still remains elusive. Further specific, in-depth study is required before a clearer understanding of the detailed working of these influences can be achieved.

At this point it is appropriate to note that the general principles of response identified in this study accord closely with those identified in research on drought and flood hazard conducted elsewhere. Perception has been shown to play a key role in response behaviour. Yet, though important as a factor in the adoption of adjustments, it is clearly not the only one. In this study length of experience (which might be equated with frequency of occurrence of a hazard) as a significant factor in perception, was shown to have no association with the adoption of measures against the hazard. This highlights the fact that there is a gap between the perceptions people have of the hazard and their actual responses to it. While the two are associated to some extent the tie is not a determinative one. One of the fundamental problems of hazard research is emphasised by the fact that people continue to inhabit hazard prone locations and fail to adjust adequately to eliminate the hazard situation, in spite of a recognition of its existence.

Finally, it is necessary to return to the systems diagram : Figure 0.4 and paragraph 0.3.7 of the Introduction which emphasise the interrelatedness of man and his natural environment. The hazard of drought and flood to man can only be eliminated by his returning to a state of equilibrium with nature; a state in which droughts and floods are not seen as threats to his way of life but as part and parcel of the natural order. Such a possibility is prevented by the economic, social and cultural system of which he is a part. Global population pressure excludes the permanent evacuation of hazardous areas as a solution. Great capital investment and entrenched traditions and values further place permanent evacuation beyond the bounds of practicality.

The findings of this study suggest that at least in part, the problem of persistent rural hazard is underlain by and intimately associated with the mode of production within which agricultural and pastoral activities are undertaken. The drive to maximize income through profit as a return on investment is inherent in the capitalist economic system. The principle of competition encourages a striving to increase the return and with it improve the standard of living of the individual concerned. In the hypothetical framework of this study the effects of this principle are identified as the factor of "rising expectations".

During good years heightened returns on their inputs of finance and energy encourage farmers to see their farming enterprise as a success. Expectations of what the operation can produce for them are realized in this success. Their conception of the farming operation's potential is vindicated. Ensuing "average" conditions are accompanied by the memory of the success achieved. (Greater optimism than actual conditions justify, has been found to be characteristic of farmers subject to the drought hazard. Accordingly, the pleasant memories of the good years remain more prominent in the minds of farmers than those of bad years). Farming continues "as normal" despite the onset of less favourable conditions and persists in this manner right into the period of drought that inevitably follows some time later.

Eventually the drought conditions are recognized but they are regarded as abnormal in terms of the farming operation in general and emergency measures are instituted, including the incurring of debts. Attempts by farmers to adjust their operations to deteriorated conditions, well recognizing their effects on the natural environment, are frustrated by structural forces beyond their immediate control. If the drought is widespread, the market for livestock (as units of production of meat) is oversupplied. This is because, in the attempt to maximize returns, farmers have stocked their farms to the capacity possible under more favourable conditions and now have to get rid of excess stock. With so many farmers in a similar situation the market is unable to absorb the excess. Through the mechanism of the Meat Board, the intake of livestock at abattoirs is limited to the Board's view of what the market can reasonably absorb. The rest of the livestock have to be retained by the farmers irrespective of what effect this might have on the natural environment.

The consequences of such overstocking are of course masked by the general effects of the drought, which in itself is attended by deteriorated pasturage. The more permanent damage to the environment is easily and conveniently interpreted as the consequence of the phenomenon of drought rather than inappropriate farming practice. This is so because the difference is not easy to assess in accurate terms while the direct connection to the drought is straightforward. It is unquestionably more comfortable and convenient to blame a natural phenomenon over which nobody has any control than to unravel the complexities of possibly irresponsible acts in the farming process, whether such acts were deliberate, committed unwittingly, or occurred in response to apparent necessity.

At this point it is necessary to note that most farmers are well aware of the advantages of environmental conservation. They are, however, unable to reconcile the cost of measures required to effect it with the idea that it might hold some tangible benefit for them. In keeping with the values of the wider society of which they are a part, the maintenance of their standard of living (if not an improvement in it) is what counts. This is to be achieved by stocking their farms with as many sheep of as good a quality as possible. The practice additionally endows them with creditworthiness if bank loans have to be negotiated, the livestock being a ready source of colateral security. The ideal of conserving the environment is well recognized and perhaps even accepted, but structural relationships inherent in the mode of production, drive farmers in the opposite direction. These relationships that form part of the capitalist economic system, make it virtually impossible for farmers to make the necessary adjustments at the level of their farming operation without sacrificing the values they cherish, at least in the short or medium term.

The very limited success of individual responses in reducing the adverse effects of the drought and flood hazards, emphasises the importance of the role of the state as a mediator of appropriate strategies. While it might not be possible to eliminate these hazards, given the constraints of the prevailing mode of production, the greatest hope of reducing them evidently lies in the promotion of environmental conservation. The new government drought aid policy, applicable to the extensive grazing areas of the country, is a step in this direction since it makes the practice of environmental conservation a prerequisite to the granting of assistance in times of drought. Current programmes of propaganda for environmental conservation are, however, insufficient as they do not address the fundamental material drive of farmers. Farmers need to be convinced that the results of conservation are materially desirable. Programmes of education should be directed towards changing people's images of what is really desirable. Such programmes could be designed to promote the conception that a restored natural environment is an essential mark of the quality of a farm. This would reflect the scrupulous application of conservation principles by the farmer concerned and ought to be construed as an important element of a farmer's status.

Additionally, the rising wave of concern for environmental issues has brought with it evidence that people may respond more readily to appeals for measures that are ecologically sound than to information about potential property damage (Beyer, 1974). Should this prove to be true, it might be fitting to promote more vigorously the current ideas on sustainable development, particularly those relating to the conservation and enhancment of the resourse base, and the merging of environment and economics in decision making (Trudgill, 1990). The actual implementation of these ideas, however, remains a major challenge in practice.

In an urban context, relationships within the capitalist economic system are also relevant in the interpretation of hazard responses. In this study urban residential property has been identified as the main element threatened by flood. (The drought hazard is relatively insignificant in terms of its effect on urban dwellers). In an arid environment river bank locations are amongst the most desirable of all residential sites. Property ownership represents capital investment on which there is a potential for a return of profit. Competition is greatest for the most desirable sites, enhancing the possibility of maximizing profits if property is sold. The risk associated with property located in a hazardous zone would tend to depress the profit potential only if the risk was perceived to be a significant factor in the investment.

Future hazard research, especially with respect to drought, would do well to view responses to hazard from the perspective of the constraints imposed by the capitalist mode of production and the effect of its inherent structural relationships on the natural environment.

APPENDIX A

Questionaire to farmers on drought

VRAELYS : DROOGTENAVORSING

1. Plaasnaam .... 2.Distrik: ....

3. Boerderygrootte: Eiendomgrond (ha) :...............Huurgrond (ha) ....

4. Opvoedkundige status: <Matriek [1] Matriek [2] Graad/Diploma [3] Nagraads [4]

5. Hoe lank bewoon u die plaas? (Jare) <5 [1] 5 - 10 [2] 10 - 15 [3] >15 [4]

6. Waar het u voorheen gewoon? Binne die streek [1] Buite die streek [2]

7. Persentasie van u inkomste uit 'n bron anders as hierdie plaas:

   Geen [0] 1 - 25 [1] 25 - 50 [2] 50 + [3]

8. Aard van bron (in 7)?

9. Persentasie inkomste uit verskillende boerderykategorieë

   Vee [ ] Voergewasse [ ] Graan [ ] Ander [ ]

10. Hoeveel veevoer produseer u op die plaas vir eie gebruik? ....

11. Teken u gereeld reënval op die plaas aan? Ja [1] Nee [2]

12. Hoeveel vee hou u normaalweg aan? (k.v.e.) [ ]

13. Hoe goed kan u veranderings in die dravermoë van die veld by veranderende omstandighede skat?

   Baie akkuraat [1] Goed [2] Swak [3]

14. Hoe dikwels verwag u droogte hier? (elke hoeveel jaar)

   Ernstige droogte [ ] Middelmatige droogte [ ] Ligte droogte [ ]

15. Afgesien van die huidige droogte wanneer was die laaste een? [ ] jaar

16. Vorige droogte:

16.1 Hoe ernstig was dit? Ernstig [1] Matig [2] Lig [3]

16.2 Duur: <1 Jaar [1] 1 - 2 jr. [2] 2 - 4 jr. [3] >4 jr. [4]

16.3 Watter noodmaatreëls moes u weens die droogte instel? ....

16.3.1 Vee verminder? Ja [1] (Met hoeveel [ ]) Nee [2]

16.3.2 Vee kunsmatig voer? Ja [1] Nee [2]

16.3.3 Meer boorgate sink? Ja [1] Nee [2]

16.3.4 Ander: ....

....

16.4 Verliese gely: Vee gevrek? Ja [1] (Hoeveel [ ]) Nee [2]

Inkomste minder? Ja [1] (met hoeveel % [ ]) Nee [2]

Ander: ....

17. Huidige droogte:

17.1 Hoe ernstig is dit? Ernstig [1] Matig [2] Lig [3]

17.2 Duur (tot dusver) 1 Jaar [1] 1 - 2 jr. [2] 2 - 4 jr. [3] 4+jr. [4]

17.3 Watter noodmaatreëls moes u weens die droogte instel?

17.3.1 Vee verminder? Ja [1] (met hoeveel [ ]) Nee [2]

17.3.2 Vee kunsmatig voer? Ja [1] Nee [2]

17.3.3 Meer boorgate sink? Ja [1] Nee [2]

17.3.4 Ander..

....

17 .4/.....

17.4 Verliese gely : Vee gevrek. Ja [1] (Hoeveel [ ]) Nee [2]
Inkomste minder? Ja [1] (Met hoeveel % [ ]) Nee [2]
Ander:...

18. In watter mate neem u die droogtegevaar in ag by die beplanning van u boerderyaktiwiteite?
Glad nie [1] Tot 'n mate [2] Baie deeglik [3]

19. Is dit na u mening moontlik om in die bestuur van die plaas, vir droogte-omstandighede te beplan? Ja [1] Nee [2]

20. Watter van die onderstaande opsies wend u aan ten einde die gevaar van droogte te verminder?

[1] Gemiddelde aantal vee tot minder as die drakrag van die veld te beperk?

[2] Eie voer te produseer?

[3] Eie voerbank op te bou?

[4] Reserwe kapitaal (miskien uit goeie jare) opsy te sit vir droogtetye?

[5] Veldverbetering bv. deur swakker plante te verwyder en nuttiger plante in die plek daarvan te saai?

[6] Aanplant van "oumansoutbos"?

[7] Aanplant van "doringlose turksvy"?

[8] Aanplant van "Amerikaanse garingboom"?

[9] Bou meer plaasdamme?

[10] Verbeter die gehalte van die diere wat u aanhou?

[11] Diversifikasie van u boerdery bv. mengsel van veesoorte?

[12] Boerdery te vergroot deur grond by te koop of te huur?

[13] Ander? (Spesifiseer) ....

21. Pas u die aanbevole maatreëls van die Dept. Landbou t.o.v. droogtebestuurspraktyke toe?
Noukeurig [1] Tot 'n mate [2] Glad nie [3]

22. Afgesien van die huidige droogte, is die algemene toestand van die veld onder normale omstandighede swakker [1] / dieselfde [2] / Beter [3] as vroeër jare?

TRANSLATION OF DROUGHT QUESTIONAIRE

1. Farm name.

2. District.

3. Size of farming operation: Owned land (ha) / Leased land (ha)

4. Educational status: <Matric. / Matric. / Degree/diploma / Postgraduate.

5. How long have you lived on the farm? (Years) <5 / 5-10 / 10-15 / >15.

6. Where did you live previously? Inside the region / Outside the region.

7. Percentage of your income from a source outside of this farm. Nil / 1-25 / 25-50 / >50.

8. Nature of source (in 7)?

9. Percentage of imcome from various categories of farming: Livestock / Fodder crops / Cereals / Other.

10. How much stock feed for your own use do you produce on your farm?

11. Do you regularly record rainfall on your farm?

12. What is the number of livestock you normally keep? (s.m.u.)

13. How well are you able to estimate the carrying capacity of the veld under changing circumstances? Very accurately / Well / Poorly.

14. How often do you expect drought to occur on your farm? (Years) Serious drought / Moderate drought / Light drought.

15. Apart from the present drought, when did you experience the previous one? (Year)

16. <u>Previous drought</u>

16.1 How serious was it? Serious / Moderate / Light

16.2 Duration: <1 year / 1-2 yrs / 2-4 yrs / >4 yrs

16.3 What emergency measures did you adopt as a result of the drought:

16.3.1 Reduce livestock Yes / (By how many?) / No.

16.3.2 Feed stock artificially Yes / No.

16.3.4 Other

16.4 Losses suffered:

16.4.1 Livestock deaths Yes / How many / No.

16.4.2 Income reduced Yes / By what percentage? / No.

16.2.3 Other

17. <u>Present drought</u>

17.1 How serious was it? Serious / Moderate / Light

17.2 Duration: <1 year / 1-2 yrs / 2-4 yrs / >4 yrs

17.3 What emergency measures did you adopt as a result of the drought?

17.3.1 Reduce livestock Yes / (By how many?) / No.

17.3.2 Feed stock artificially Yes / No.

17.3.4 Other

17.4 Losses suffered:

17.4.1 Livestock deaths Yes / How many / No.

17.4.2 Income reduced Yes / By what percentage? / No.

17.2.3 Other

18. To what extent do you take the drought hazard into consideration in the planning of your farming activities? Not at all / Partly / Thoroughly.

19. Do you think it is possible to plan for drought in the running of your farm? Yes / No.

20. Which of the following options do you apply in order to reduce the hazard of drought?

(1) Limit the average number of your livestock to below the

carrying capacity of the veld.

(2) Produce your own stock feed.

(3) Build up your own fodder bank.

(4) Set aside reserve capital in good years for use in times of drought.

(5) Veld improvement e.g. by removing less valuable species and sowing seeds of more useful species.

(6) Planting "old man salt bush".

(7) Planting spineless cactus.

(8) Planting agave.

(9) Building more farm dams.

(10) Upgrading the quality of your livestock.

(11) Diversification of your farming e.g. by keeping various types of livestock.

(12) Increasing the size of your farming operation by purchasing or leasing additional land.

(13) Other.

21. Do you adhere to the recommended drought management principles of the Department of Agriculture: Fullly / Partly / Not at all.

22. Discounting the effects of the present drought, is the general condition of the veld worse / the same as / better than in former years?

APPENDIX B

Questionaire to farmers on flood

LANDELIKE VLOEDGEVAAR
RURAL FLOOD HAZARD

1. Plaasnaam Distrik
Farm name .... District ....

2. Plaasgrootte: Eiendomsgrond Huurgrond
Farm size: Freehold land ....(ha) Leasehold...........(ha)

3. Opvoedkundige status: Minder as matriek 1 Matriek 2 Graad/Diploma 3 Nagraads 4
Educational status: Less than matric Matric Degree/Diploma Postgrad.

4. Hoe lank bewoon u die plaas (jare)?
How long have you lived on the farm (years)? ....

5. Hoeveel ernstige oorstromings het u reeds as boer ondervind?
How many serious floods have you experienced as a farmer? ....

6. Is dele van u grond onderhewig aan periodieke oorstroming? JA / NEE
Are parts of your land subject to periodic flooding? YES / NO

7. Beskou u die oorstromingsgevaar as ernstig, matig, gering?
Do you regard the hazard of flooding as serious, moderate, slight?

8. Wat is die grootte van bewerkte grond op die plaas? ....(ha)
What is the size of the cultivated land on your farm? ....(ha)

9. Hoeveel van dié grond is onderhewig aan oorstromingsgevaar?..........(ha)
How much of this land is subject to the danger of flooding?...........(ha)

10. Persentasie inkomste uit verskillende boerderykategorieë:

Skape & Bokke	Beeste	Voergewasse	Graan	Vrugte	Ander
......	......	......	.....	......	......

Percentage of income from various categories of farming:

Sheep & Goats	Cattle	Fodder crops	Cereals	Fruit	Other
......	......	......	......	......	.....

11. Hoe dikwels verwag u oorstroming van u grond (elke hoeveel jaar?)

Ernstige oorstroming	Matige oorstroming	Ligte oorstroming
....	....	....

How often do you expect flooding of your land (at how many year intervals?)

Serious flooding	Moderate flooding	Light flooding
....	....	....

12. Watter persentasie van u inkomste is afkomstig van gewasse op grond wat deur oorstroming bedreig word? ....
What percentage of your income is derived from crops grown on flood prone land? ....

13. Word enige strukture bv. geboue, pomphuise, ens. deur oorstroming bedreig? Ja / Nee

Indien wel, wat is hulle totale geraamde waarde? R......

Are any structures such as buildings, pumphouses, etc. threatened by floods? Yes / No

If so, what is their total estimated value? R......

14. Wanneer het die laaste oorstroming van u grond plaasgevind? ....(jaar)
When was the last time that your land was flooded? ....(year)

15. Wat was die aard van die skade wat u a.g.v. die laaste oorstroming ondervind het?
What was the nature of the damage you suffered as a result of the last flood?

....
....
....
....
....

16. Wat was die beraamde koste van die skade wat u gely het? R......
What was the estimated cost of the damage you suffered? R......

17. Watter van die onderstaande maatreëls tref u om die nadelige effek van oorstromings te probeer voorkom?
Which of the following measures have you instituted as an attempt to reduce the detrimental effect of flooding?

1 Vermy gevaarsones
Avoid flood-prone land

2 Grondwerke soos walle om water weg te hou
Earthworks such as banks to keep water away

3 Konstruksie van damme
Construction of dams

4 Modifikasie van rivierloop soos verwydering van plantegroei
Modification of river channel such as clearance of vegetation

5 Assuransie teen oorstromingskade
Insurance against flood damage

6 Noodmaatreëls soos ontruiming, gebruik van sandsakke, ens.
Emergency action such as evacuation, use of sand bags, etc.

7 Aanvaar maar die skade
Accept the loss

8 Ander (spesifiseer)
Other (specify)

APPENDIX C

Questionaire to urban residents

STEDELIKE VLOEDGEVAAR
URBAN FLOOD HAZARD

1. Dorp Adres
   Town .... Address ....

2. Ouderdomsklas: Geslag M / V
   Age class: 25 25 - 40 40 - 65 65+ Sex M / F

3. Hoe lank woon u reeds by u huidige adres?
   How long have you been living at your present address? ....

4. Is u die eienaar of huurder van bogenoemde eiendom? EIENAAR / HUURDER
   Do you own or rent the above property? OWN / RENT

5. Dink u dat die perseel wat u bewoon in die gevaar staan om periodiek oorstroom te word? JA / NEE
   Do you believe that the site on which you are living is subject to the hazard of periodic flooding? YES / NO

Indien u antwoord op vraag 4 JA was, beantwoord asb. ook die volgende vrae. As dit NEE was, is die orige vrae nie van toepassing nie. Stuur asseblief nogtans die vraelys terug.
If your answer to question 4 was YES, please also answer the following questions. If it was NO, the rest of the questions will not be applicable. Please still return the questionaire.

6. Het u al oorstroming van die perseel wat u bewoon ondervind? JA / NEE
   Indien JA, in watter jaar/jare? ....
   Have you ever experienced flooding of the site you now occupy? YES / NO
   If YES, in which year(s)? ....

7. Het u geweet dat die perseel aan oorstroming onderhewig was voordat u hier ingetrek het? JA / NEE
   Did you know that the site was subject to flooding before you occupied it? YES / NO

8. Hoe dikwels dink u sal u perseel oorstroom word? Een keer elke ......jaar?
   How often do you think your site will be flooded? Once every ......years?

9. In die geval van 'n oorstroming wat dink u word bedreig:
   1 U lewe
   2 U huis
   3 Buitegeboue
   4 Inhoud van huis
   5 Tuin

   In the event of a flood, what do you think is threatened:
   1 Your life
   2 Your house
   3 Outbuildings
   4 Contents of house
   5 Garden

10. Wat dink u sal die oorsprong van 'n oorstroming by u wees:

1 Baie swaar reënval in die gebied
2 Rivier wat sy walle oorstroom
3 Dam(me) wat breek
4 Ander (spesifiseer)

....

....

What do you think will be the source of the flooding of your property:

1 Very heavy downpours in the area
2 River bursting its banks
3 Dam(s) breaking
4 Other (specify)

....

....

11. Hoe beangs is u oor die moontlikheid van 'n oorstroming:

1 Lê soms in die nag wakker uit kommer daaroor
2 Bekommer my dikwels daaroor
3 Bekommer my somtyds daaroor
4 Bekommer my slegs daaroor as dit aanhoudend hard reën
5 Dit is soms 'n verbygaande gedagte
6 Ek is gladnie daaroor besorg nie

How anxious are you about the possibility of a flood:

1 Sometimes spend sleepess nights worrying about it
2 Often worry about it
3 Sometimes worry about it
4 Only worry about it when it rains hard continuously
5 I sometimes give it a passing thought
6 I am not at all concerned about it

12. Om watter rede(s) het u op hierdie perseel kom woon?

1 Dit was die enigste gepaste een beskikbaar
2 Die huis het aan my vereistes goed voldoen
3 Die buurt was aantreklik
4 Die eiendom was in my prysklas
5 Ek het die eiendom geërf
6 Dit was naby my werkplek
7 Ander redes: (spesifiseer in die ruimte hieronder)

For what reason(s) did you elect to live on this site?

1 It was the only suitable one available
2 The house was well suited to my requirements
3 The neighbourhood was attractive
4 The property fell within my price class
5 I inherited the property
6 It was near my place of work
7 Other (specify in the space below)

....

....

13. Is u van plan om weens die oorsrtomingsgevaar te verhuis? JA / NEE
Do you intend to move because of the flood hazard? YES / NO

APPENDIX D : Summary table of responses to the drought questionaire

Farm size (Question 3)

Tenancy	Number of farms Size classes (ha)					
	<5000	5000-10000	10000-15000	15000-20000	>20000	N
Owned	65	65	30	7	6	173
Leased	27	12	5	0	1	45
Total	56	58	31	18	9	173

Educational status (Question 4)

Number of respondents	<Matric.	Matric.	Degree/Diploma	Postgraduate
156	89	26	34	7

Length of farm occupation (years) (Question 5)

Number of respondents	Years <5	5 - 10	10 - 15	<15
177	10	21	16	130

Former residence (Question 6)

Number of Respondents	Place of former residence Inside the region	Outside the region
169	133	36

Income from a source outside the farm (Question 7)

Number of respondents	Percentage of income			
	0	1 - 25	25 - 50	>50
170	128	20	9	13

Income from various categories of farming (Question 9)

Respondents per category

Source of income	Categories (per cent)					
	0-24	25-49	50-74	75-99	100	N
Livestock	2	2	1	21	151	177
Fodder crops	9	2	1	0	0	12
Cereals	5	0	0	0	0	5
Other	7	1	3	1	0	12

Production of fodder (Question 10)

Number of respondents	Amount of fodder produced (tons)				
	<25	25 - 49	50 - 99	100 - 199	>200
44	16	9	7	7	5

Recording of rainfall (Question 11)

Number of respondents	Record rainfall	Do not record rainfall
174	116	58

Number of livestock kept (Question 12)

Number of respondents	Head of livestock (small stock units) <1000	1000-1999	2000-2999	3000-3999	4000-7999	>8000
175	48	74	30	13	8	2

Ability to estimate carrying capacity (Question 13)

Number of respondents	Accuracy of estimation Very accurate	Well	Poor
176	28	135	13

Perceived return periods of droughts (Question 14)
(Respondents per category)

Nature of the drought	Return period (years) <5	5-9	10-14	15-19	20	30	40	50	N
Severe	20	43	49	5	6	3	1	1	128
Moderate	61	58	5	0	1	1	0	0	126
Light	95	2	2	0	0	0	0	0	99

Date of previous drought (Question 15)

Number of respondents	Date of drought (year)
1	1947
31	1960
3	1961
2	1962
3	1963
2	1965
18	1966
6	1967
11	1968
8	1969
17	1970
9	1971
8	1972
11	1973
1	1974
1	1975
1	1976
2	1977
7	1978
7	1979
3	1980
4	1981
2	1982
2	1983
N = 160	

Perceived severity of previous drought (Question 16.1)

Number of respondents	Nature of previous drought (perceived) Severe	Moderate	Light
166	103	60	3

Duration of previous drought (Question 16.2)

Number of respondents	Duration (years) <1	1 - 2	2 - 4	>4
162	27	56	50	29

Responses to previous drought (Question 16.3)
(Number of respondents)

Response	Adoption of response Yes	NO	N
Reduce livestock	147	16	163
Artificial feeding	144	17	161
Sink more boreholes	53	88	141

Reduction of livestock : Previous drought (Question 16.3.1)

Number of respondents	Number of livestock <250	250-499	500-749	750-999	1000-1999	>2000
129	26	48	24	7	20	4

Losses experienced : Previous drought (Question 16.4)
(Number of respondents)

Loss	Loss experienced Yes	No	N
Livestock deaths	98	56	156
Income reduced	147	7	154

Livestock losses : Previous drought (Question 16.4)

Number of respondents	Number of livestock lost <100	100-199	200-299	300-399	400-499	>500
79	31	23	9	8	2	8

Reduction of income : Previous drought (Question 16.4)

Number of respondents	Percentage reduction of income
1	2
1	5
10	10
1	12
3	15
15	20
1	21
8	25
22	30
3	33
1	35
12	40
1	45
34	50
1	56
6	60
5	70
1	75
3	80
8	99
N = 137	

Perceived severity of present drought (Question 17.1)

Number of respondents	Nature of drought (perceived)		
	Severe	Moderate	Light
176	155	18	3

Duration of present drought (Question 17.2)

Number of respondents	Duration (years)			
	1	1 - 2	2 - 4	>4
171	19	18	28	106

Responses to present drought (Question 17.3)
(Number of respondents)

Response	Adoption of response		
	Yes	NO	N
Reduce livestock	156	16	172
Artificial feeding	159	11	170
Sink more boreholes	51	96	147

Reduction of livestock : Present drought (Question 17.3.1)

Number of respondents	Number of livestock					
	<250	250-499	500-749	750-999	1000-1999	>2000
138	26	41	28	10	25	8

Losses experienced : Present drought (Question 17.4)
(Number of respondents)

Loss	Loss experienced Yes	No	N
Livestock deaths	101	56	157
Income reduced	145	16	161

Livestock losses : Present drought (Question 17.4)

Number of respondents	Number of livestock lost <100	100-199	200-299	300-399	400-499	>500
83	36	20	10	7	4	6

Reduction of income : Present drought (Question 17.4)

Number of respondents	Percentage reduction of income
1	4
2	5
4	10
5	15
1	17
13	20
6	25
1	26
21	30
4	33
1	35
7	40
2	45
28	50
2	55
8	60
4	70
6	75
6	80
1	85
1	90
1	95
6	99
N = 131	

Consideration of drought hazard in planning (Question 18)

Number of respondents	Degree of consideration		
	Not at all	Partly	Thoroughly
169	0	33	136

Feasibility of planning for drought (Question 19)

Number of respondents	Feasibility of planning for drought Yes	No
167	121	46

Options adopted to reduce the hazard of drought (Question 20)

Number of respondents (N = 180)	Option
160	Stocking at below veld carrying capacity
57	Producing own stock feed
67	Building up a fodder bank
104	Saving up reserve capital
36	Veld improvement schemes
43	Planting "old man salt bush"
23	Planting spineless cactus
8	Planting agave
42	Building more farm dams
153	Upgrading livestock quality
42	Diversification of farming
55	Enlarging farming operation
20	Other

Application of official drought management principles (Ques. 21)

Number of respondents	Application of principles Fully	Partly	Not at all
165	72	90	3

General condition of the veld (Question 22)

Number of respondents	Condition of the veld		
	Worse	Better	The same
162	56	47	59

APPENDIX E : Summary table of farmers' responses to the flood questionaire

Respondent	Farm size (ha)	Educational status				Years on farm
		Below matric.	Matric.	Degree/ diploma	Postgrad.	
1	8930			X		17
2	1100		X			28
3	7			X		8
4	107	X				3
5	3600		X			20
6	5000		X			38
7	6000			X		31
8	2252		X			38
9	–		X			9
10	3854		X			69
11	4860		X			52
12	683	X				8
13	7410		X			28
14	1400			X		12
15	650			X		5
16	93		X			11
17	59	X				11
18	282			X		13
19	129			X		28
20	950	X				12
21	1300		X			30
22	229			X		10
23	3180			X		34
24	1271			X		7
25	1123		X			40
26	1835	X				38
27	678		X			37
28	1200		X			13
29	443		X			23
30	155			X		11
31	1181		X			42
32	424			X		42
33	1200				X	17
34	2587		X			45
35	343				X	72
36	1467		X			78
37	1280	X				65
38	3974		X			11

APPENDIX E (continued)

Respondent	Serious floods experienced	Floodprone land		Perceived hazard level			Cultivated land	
		Yes	No	Low	Mod.	High	Total (ha)	Floodprone (ha)
1	2	X			X		120	30
2	1	X		X			82	8
3	1	X				X	7	7
4	0	X			X		33	10
5	2	X				X	160	128
6	5	X				X	120	20
7	1		X	X			55	0
8	2	X			X		160	100
9	1	X	X				100	0
10	2		X		X		34	34
11	2		X			X	300	0
12	1		X		–		28	400
13	0	X		X			50	30
14	0		X	X			160	20
15	0		X		X		150	100
16	2	X				X	72	20
17	0		X	X			55	25
18	0	X		X			70	70
19	3	X			X		129	129
20	0		X		–		70	30
21	2	X			X		76	40
22	0	X			X		50	38
23	0		X		–		225	0
24	0		X	X			120	45
25	1		X	X			35	3
26	2		X	X			50	5
27	3	X				X	40	18
28	1		X		X		45	35
29	3	X				X	55	15
30	0		X		X		64	10
31	1		X		X		92	21
32	1		X	X			79	0
33	2	X			X		60	8
34	2	X		X			26	5
35	–	X				X	30	30
36	7	X				X	60	50
37	5	X			X		80	50
38	0	X		X			80	40

APPENDIX E (continued)

Respondent	Source of income (%) Sheep/ goats	Cattle	Fodder	Cereal	Fruit	Other	Expected flood return period (years) Ser.	Mod.	Light
1	70	20	10	0	0	0	100	50	15
2	60	8	15	3	4	10	–	–	–
3	0	50	0	0	0	50	50	10	3
4	0	0	80	20	0	0	10	–	–
5	95	0	5	0	0	0	20	15	10
6	80	20	0	0	0	0	–	5	–
7	85	10	5	0	0	0	–	20	–
8	55	0	15	0	0	30	13	–	–
9	40	40	10	0	0	10	25	10	5
10	90	10	0	0	0	0	100	50	10
11	70	30	0	0	0	0	–	–	20
12	25	30	30	0	0	15	–	4	–
13	70	20	0	0	0	10	–	10	3
14	30	0	10	60	0	0	–	100	–
15	50	0	50	0	0	0	30	10	5
16	0	0	100	0	0	0	100	–	–
17	0	0	60	35	0	5	100	–	–
18	5	0	60	35	0	0	50	20	20
19	0	0	60	40	0	0	–	10	–
20	35	10	50	5	0	0	–	–	–
21	35	15	50	0	0	0	100	50	10
22	0	60	40	0	0	2	50	20	10
23	40	60	0	0	0	0	–	–	5
24	50	50	0	0	0	0	100	50	10
25	40	40	20	0	0	0	100	20	10
26	55	45	0	0	0	0	–	–	30
27	30	50	20	0	0	0	20	10	5
28	0	100	0	0	0	0	10	5	2
29	70	15	0	0	0	15	8	3	–
30	10	90	0	0	0	0	–	–	–
31	91	0	9	0	0	0	–	–	–
32	20	30	0	0	20	30	50	30	20
33	0	10	0	0	90	0	–	20	–
34	0	60	0	0	40	0	25	10	5
35	90	5	5	0	0	0	20	10	–
36	75	5	15	0	0	0	*	*	*
37	70	5	25	0	0	0	10	–	5
38	95	3	1	1	0	0	–	12	–

* The years in which floods occurred are given:
Serious floods - 1928, 1941; moderate floods: 1932, 1971, 1984; light floods: 1961, 1977.

APPENDIX E (continued)

Respondent	% of income from crops threatened by flood	Property threatened by flood			Last flood	
		Yes	No	Value (R'000)	Date	Value of damage (R'000)
1	5	X		300	1974	150
2	10		X	0	1974	8
3	100		X	0	1974	0
4	80		X	0	1974	0
5	60	X		130	1976	25
6	5	X		1500	1986	5
7	0		X	0	1961	10
8	10	X		100	1974	50
9	10		X	0	1983	4
10	10	X		50	1974	80
11	0	X		300	1974	100
12	0	X		12	1988	1
13	0		X	0	1985	2
14	80		X	0	1974	0
15	50	X		10	1974	30
16	100		X	0	1974	80
17	45		X	0	1974	0
18	100		X	0	1974	0
19	40		X	0	1983	20
20	30		X	0	1974	0
21	50		X	0	1974	50
22	85	X		80	1974	5
23	0		X	0	–	0
24	20		X	0	1976	0
25	3		X	0	1974	2
26	0		X	X	1976	0
27	20	X		150	1974	80
28	50	X		10	1974	30
29	5	X		70	1984	4
30	20		X	0	–	0
31	33		X	0	1974	3
32	20	X		200	1974	200
33	8	X		8	1976	2
34	5	X		0,5	1976	10
35	50	X		5	–	5
36	–		X	0	1977	6
37	20	X		10	1977	25
38	2		X	0	1974	–

APPENDIX E (continued)

Respondent	Hazard reducing measures							
	Avoid floodprone locations	Earth-works	Dams	Modify river channel	Insur-ance	Emer-gency action	Accept loss	Other
1	–	X	–	–	X	X	–	–
2	–	–	–	–	–	–	X	–
3	–	–	–	X	–	–	–	X
4	X	X	–	–	X	–	X	X
5	X	X	X	–	–	–	–	–
6	X	X	X	–	–	–	X	–
7	–	X	–	–	–	–	–	–
8	–	X	–	–	–	X	–	–
9	–	–	X	–	–	–	X	–
10	–	–	–	X	–	–	X	–
11	–	X	–	X	–	–	X	X
12	–	–	X	–	–	–	–	–
13	–	–	–	–	–	–	X	–
14	–	–	–	–	–	–	X	–
15	–	X	–	–	–	–	–	–
16	–	–	–	X	–	–	–	–
17	–	–	–	–	–	–	X	–
18	–	–	–	–	–	–	X	–
19	–	–	–	–	–	–	X	–
20	X	X	–	–	–	–	–	–
21	–	–	–	–	–	X	X	–
22	X	–	–	–	X	–	X	–
23	X	X	–	–	–	–	X	–
24	–	–	X	X	X	–	–	–
25	X	–	X	–	X	–	X	–
26	–	–	X	–	–	–	–	X
27	–	–	–	X	X	X	X	–
28	X	–	–	–	–	–	X	–
29	X	–	–	X	–	–	–	–
30	–	X	–	–	–	–	X	–
31	–	–	–	–	–	–	X	–
32	X	X	X	X	–	X	X	–
33	–	–	–	–	–	–	X	–
34	X	–	–	–	–	X	X	–
35	–	X	–	X	–	X	–	–
36	–	–	–	–	–	–	X	–
37	–	–	–	–	–	–	X	–
38	–	X	–	X	X	–	–	–

APPENDIX F : Summary of urban residents' responses to the flood hazard

Respondent	Age class <25	25-40	40-65	>65	Sex M	F	Length of residence (years)	Tenancy Own	Rent	Site subject to flooding Yes	No
1				X		X	40	X		X	
2				X		X	16	X			X
3				X	X		16	X			X
4				X		X	39	X			X
5				X	X		15	X			X
6			X			X	11	X			X
7				X	X		31	X			X
8				X		X	18	X		X	
9			X		X		9	X			X
10			X		X		30	X			X
11				X	X		8	X			X
12			X		X		24	X			X
13		X				X	2		X	X	
14			X			X	13	X			X
15			X		X		8	X		X	
16			X		–		9	X			X

APPENDIX F (continued)

Respondent	Site previously flooded Yes	Site previously flooded No	Prior knowledge of hazard Yes	Prior knowledge of hazard No	Perceived flood frequency (years)	Threatened by flooding: Life	House	Out bldgs.	Content of house	Garden
1	–	X	X	–	5	–	X	–	X	–
2	–	X		X	–	–	–	–	–	–
3	–	X		X	–	X	X	X	X	X
4	–	X		X	–	X	X	X	X	X
5	–	X	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–	–	–	–
7	–	X	–	–	–	–	–	–	–	–
8	–	X		X	–	–	–	–	–	–
9	–	–	–	–	–	–	–	–	–	–
10	–	–	–	–	–	–	–	–	–	–
11	–	X	–	–	–	–	–	–	–	–
12	–	X	–	–	–	–	X	–	–	–
13	X		X		50	X	X	X	X	X
14	–	X	–	–	–	–	–	–	–	–
15	–	X	X		100	X	X	X	X	X
16	–	X	X		100	–	X	X	X	X

APPENDIX F (continued)

Respondent	Source of flooding: Heavy rain	River bank over-flow	Dam break	Other	Anxiety level	Reasons for chosing site	Move due to hazard: Yes	No
1	-	-	X	-	2	5	-	X
2	-	-	-	-	-	-	-	-
3	X	-	X	-	1	2	-	X
4	X	-	X	-	4	2/3	-	X
5	-	-	-	-	-	2/3/4	-	X
6	-	-	-	-	-	-	-	-
7	-	-	X	-	6	1/2/3/4/6	-	X
8	-	X	X	-	3	1/2/3/4	-	X
9	-	-	-	-	-	-	-	-
10	-	-	X	-	1	5	-	X
11	-	-	-	-	-	-	-	X
12	-	-	X	-	2	3	-	X
13	-	X	X	-	3	5	-	X
14	-	-	-	-	-	-	-	-
15	-	X	-	-	3	2	-	X
16	-	-	-	-	-	-	-	X

REFERENCES

Acocks J P H 1975: Veld Types of South Africa. *Memoirs of the Botanical Survey of South Africa*, No. 40. Botanical Research Institute, Department of Agricultural Technical Services. Republic of S.A.

Alexander W J R & C P R Roberts 1981: *Report on the Buffels River Flood*. Department of Water Affairs, Forestry and Environmental Conservation. Pretoria.

Allanson B R & M A Rabie 1983: Freshwater Systems. In Fuggle R F & M A Rabie : *Environmental Concerns in South Africa*, Chapter 11. Cape Town, Juta & Co. Ltd.

Askew A J & D J Pilgrim 1979: Identifying Flood-Plain Hazards : A National Programme of Flood-Plain Mapping. In R L Heathcote and B G Thorn (eds.): *Natural Hazards in Australia*. Proceedings of a Symposium sponsored by Australian Academy of Science, Institute of Australian Geographers and Academy of Social Sciences in Australia. Australian Academy of Science, Canberra.

Beyer J L 1974: Global Summary of Human Response to Natural Hazards : Floods. In: F G White (ed) : *Natural Hazards : Local, National, Global*. New York, Oxford University Press.

Barnard W S, P S Smit & J A van Zyl 1972: *Suid-Afrika : Die land en sy streke*. Cape Town, Nasou.

Blanford H F 1884: On the connection of the Himalaya snowfall and seasons of drought in India. *Proceedings of the Royal Society of London*. 37: 3.

Burton I 1962: *Types of Agricultural Occupance of Flood Plains in the United States*. Chicago, University of Chicago, Department of Geography Research Paper No. 75.

Burton I & R W Kates 1964: The flood plain and the seashore : A comparative analysis of hazard zone occupance. *Geographical Review*, 54: 366-385.

Burton I & R W Kates 1964b: The perception of natural hazards in resource management. *Natural Resources Journal*, 3: 412-441.

Burton I, R W Kates & G F White 1968: *The Human Ecology of Extreme Geophysical Events*. Working Paper No. 1, Natural Hazard Research, Department of Geography, University of Toronto.

Burton I & R W Kates 1972: The perception of natural hazards in resource management. In R W English & R C Mayfield: *Man, Space and Environment*: New York, Oxford University Press.

Burton I, R W Kates & G F White 1978: *The Environment as Hazard.* New York, Oxford University Press.

Cape Provincial Administration 1987: *Department of Roads : Bridge design manual.* Office of the Provincial Roads Engineer, Cape Town.

Carter C A & A J Ritchie 1985: Stormwater master planning. *Municipal Engineer*: 30-32.

Christopher A J 1982: *South Africa.* London, Longman.

Chung J C 1982: Correlation between the tropical Atlantic trade winds and precipitation in north-eastern Brazil. *Journal of Climatology*, 2: 35-46.

Chutter J 1973: An ecological account of the past and future of South African rivers. *Newsletter of the Limnological Society of South Africa*, 21: 22-34.

Clark, C 1987: Deforestation and Floods. *Environmental Conservation*, 14(1).

Coetzee M J A 1983: Verslag oor die voorligtingstaak in Middelburg Kaap Wyk. Unpublished report by the Agricultural Extension Officer, Middelburg, Cape.

Coetzee M J A 1984: Personal interview with Mr M J A Coetzee. Agricultural Extension Officer, Middelburg, Cape.

Craig I J 1910: England-Abyssinia - The South Atlantic : a meteorological triangle. *Quarterly Journal of the Royal Meteorological Society*, 36: 341-351.

Critchfield H J 1961: *General Climatology*. Englewood Cliffs, Prentice-Hall Inc.

De Swardt S J & O E Burger 1941: National Provision against Drought. I. The Extent of the Drought Problem. *Farming in South Africa*, XVI(183): 193-196; 237-239.

De Swardt S J & O E Burger 1941: National Provision against Drought. II. Present Measures to Relieve Drought and an Examination of a "Fodder Bank" Scheme. *Farming in South Africa*, XVI(184): 237-239.

De Kock G C : Droogtevoergewasse. Unpublished cyclostyled report. Grootfontein Agricultural College, Middelburg, Cape.

Departement van Landbou 1926: Die Groot Droogtevraagstuk van Suid-Afrika. *Government Printer.*

Dewar N 1981: Planning in High Risk Areas. The Laingsburg Flood Disaster. *Swaplan*, No. 15.

Dey B 1982: Nature and possible causes of droughts in the Canadian priaries - case studies. *Journal of Climatology*, 2: 233-249.

Douglas I 1979: Flooding in Australia : A Review. In Heathcote R L & B D Thom (eds.): *Natural Hazards in Australia*. Proceedings of a Symposium sponsored by Australian Academy of Science, Institute of Australian Geographers, Academy of the Social Sciences in Australia. Canberra, Australian Academy of Science.

Dyer T G J 1975: Solar activity and rainfall variation over Southern Africa. *South African Journal of Science*, 71: 369-372.

Dyer T G J 1976: Expected future rainfall over selected parts of South Africa. *South African Journal of Science*, 72: 237-239.

Dyer T G J & P D Tyson 1977: Extended forecasts of above and below normal rainfall over South Africa. *Journal of Applied Meteorology*, 16: 145-147.

Esterhuse C 1984: Personal communication. Land Bank Assessor, Sutherland.

Estie K E 1981: The Laingsburg Flood Disaster of 25 January 1981. *Newsletter* 385. Pretoria, Weather Bureau.

Eysenck H & G Wilson 1976: *Know you own Personality*. Harmondsworth, Penguin Books.

Fisher R C 1983: Land and land tenure. In Fuggle R F & M A Rabie : *Environmental Concerns in South Africa*. Cape Town, Juta & Co. Ltd.

Fiske E 1975: A radical new way to select rams. *Farmers Weekly*, 28 May 1975: 6-10.

Flemming G 1973: Flood frequency and the effects of catchment changes. Water and Water Engineering, 77: 127-131. Quoted in Smith K & G A Tobin 1979: *Human adjustment to the flood hazard*: 18. London, Longman.

Fuggle R F 1983: Nature and ethics of environmental concerns. In Fuggle R F & M A Rabie : *Environmental concerns in South Africa*. Chapter 1. Cape Town, Juta & Co. Ltd.

Garstang M, G D Emmitt & B Kelbe 1981: *Rain augmentation in Nelspruit*. Final report to the Water Research Commission, Pretoria. Virginia, Charlottesville, Simpson Weather Associates Inc.

Gerasimov I P & T V Zvonkova 1974: Natural hazards in the territory of the USSR : study, control and warming. In G F White (ed.) : *Natural Hazards : Local, National, Global*.

Oxford, Oxford University Press.

Golant S & I Burton 1970: A semantic differential experiment in the interpretation and grouping of environmental hazards. *Geographical Analysis*, 2: 120-134.

Gold J R 1980: *An Introduction to Behavioural Geography*. Oxford, Oxford University Press.

Golledge R G, L A Brown & F Williamson 1972: Behavioural approaches in geography : An overview. *The Australian Geographer*, XII(1): 59-79.

Golledge G R & H Timmermans 1990: Applications of behavioural research on spatial problems I : cognition. *Progress in Human Geography*.

Gouws V C 1963: Heavy rains over the Eastern Cape during March 1963. *Newsletter* 1969. Weather Bureau.

Gregory S 1986: The Climatology of drought. *Geography* 71: 97-104.

Grosskopf J F W 1932: *Plattelandsverarming en Plaasverlating*. Part 1. Economic Report. Carnegie Commission of Inquiry into the Poor-White problem in South Africa. Stellenbosch, Pro Ecclesia Printers.

Hallward J (ed.) 1986: The Laingsburg Flood : An Analysis and Evaluation of the Higher Order Impacts and Redevelopment Process. Cape Town, Department of Environmental and Geographical Science, University of Cape Town.

Harmse J T & H W A Ellman 1981: *Natuurkundige faktore wat aanleiding gegee het tot die Laingsburg-vloedrampimplikasies vir beplanning*. Eenheid vir Toekomsnavorsing, Geleentheidspublikasie 81(2).

Hastenrath S 1976: Variations in low-altitude circulation and extreme climatic events in the Tropical Americas. *Journal of Atmospheric Sciences*, 33: 202-215.

Hastenrath S & L Heller 1977: Dynamics of climatic hazards in northeast Brazil. *Quarterly Journal of the Royal Meteorological Society*, 103: 77-92.

Hattingh H S 1979: *Relatiewe doeltreffendheid van groot en klein boerderyeenhede*. Paper presented to the "Symposium on the future farming pattern in South Africa" under the auspices of "The Centre for Agricultural Management Studies", University of South Africa, at the Holiday Inn, Vanderbylpark, 15 February 1979.

Hayward F C & G A Jacobs 1979: Woolled Sheep : Utilization of Drought Resistant Fodder Crops. *Wool Production* D.3.3. Pretoria, Department of Agriculture.

Hayward L Q & J J Taljaard 1953: The Southern and South-Eastern Cape Floods. *Newsletter* WB 55: 2-3. Pretoria.

Hayward L Q & H J C van den Berg 1970: The Eastern Cape Floods of 24 to 28 August 1970. *Newsletter* 129. Pretoria, Weather Bureau.

Heathcote R L & B G Thom 1979: *Natural Hazards in Australia*. Canberra, Australian Academy of Science.

Henderson-Sellers A & P J Robinson 1986: *Contemporary Climatology*. New York, Longman with John Wiley and Sons.

Hewitt K & I Burton 1971: The hazardousness of a place : a regional ecology of damaging events. Working Paper 6, Toronto: Natural Hazard Research Unit, Department of Geography, University of Toronto.

Hewitt K 1983: *Interpretations of Calamity*. Boston, Allen & Unwin Inc.

Hewlett J D & W L Nutter 1969: An outline of forest hydrology. Athens, Ga. University of Georgia Press. Quoted in Smith K & G A Tobin 1979: *Human adjustment to the flood hazard*. London, Longman.

Hinchey M T 1979: Proceeding of the Symposium on Drought in Botswana. Gaberone, Botswana Society.

Hoyt W G & W B Langbein 1955: Floods. Princeton, Princeton University Press. Quoted in Smith K & G A Tobin 1979: *Human adjustment to the flood hazard*: 18. London, Longman.

Institute of Hydrology 1981: Research Report 1978-81. Natural Environment Research Council, Wallingford, England.

Jackson E L & T Mukerjee 1974: Human adjustment to the earthquake hazard of San Francisco, California. In: G F White (ed.): *Natural Hazards: Local, National, Global*: 160-166. New York, Oxford University Press.

Jacobs G A & F C Hayward 1981: Utilization of Drought-Resistant Fodder Crops by Sheep. *Mutton Production* C.2.1. Pretoria, Department of Agriculture.

Jacobs G A & F C Hayward 1981: Feeding of Sheep during Droughts. *Mutton Production* C.2.2. Pretoria, Department of Agriculture.

Kates R W 1962: Hazard and Choice Perception in Flood Plain Management. Research Paper No. 78. Chicago, University of Chicago, Department of Geography.

Kates R W 1965: Industrial Flood Losses: Damage Estimation in the Lehigh Valley. Research Paper No. 98. Chicago, University of Chicago, Department of Geography.

Kates R W 1971: Natural Hazard in Human Ecological Perspective: Hypotheses and Models. *Economic Geography*, 47: 438-451.

Kidson J W 1977: African rainfall and its relation to the upper air circulation. *Quarterly Journal of the Royal Meteorological Society*, 103: 441-456.

King J W 1973: Solar radiation changes and weather. *Nature*, 245: 443-446.

Kunreuther H 1974: Economic analysis of natural hazards : an ordered choice approach. In G F White (ed.): *Natural Hazards: Local, National, Global*: 206-214. New York, Oxford University Press.

Lamb P J 1978: Large scale Tropical Atlantic circulation patterns associated with Subsaharan weather anomalies. *Tellus*, 30: 240-251.

Lamb P J 1983: West African water vapour variations between recent contrasting Subsaharan rauny seasons. *Tellus*, 35A: 198-212.

Lamiell J T 1981: Toward an idiothetic psychology of personality. *American Psychology*, 36: 276-289.

Lichtenstein H 1812: *Travels in Southern Africa in the Years 1803, 1804, 1805 and 1806*. London.

Linsley R K, M A Kohler & J L H Paulus 1949: Applied hydrology. In Chorley R J 1969: *Water, Earth and Man*. London, Methuen.

Lippe E C A 1962: Gales and floods over the south-western and southern Cape coasts during the period 19-22 August 1962. *Newsletter* 234: 157-169. Pretoria, Weather Bureau.

Lloyd P E & P Dicken 1972: *Location in Space*. London, Harper and Row.

Lockwood L G 1981: Carbon dioxide and climate. *Progress in Physical Geography*, 5: 99-106.

London H & J Exner 1978: *Dimensions of Personality*. New York, Wiley.

Louw W J 1982: Rawson se siklus. *Newsletter* No. 400: 103-105. Pretoria, Weather Bureau.

Louw W J 1983: Nat en droë periodes in Suid-Afrika 1921-1983. *Newsletter* 414. Pretoria, Weather Bureau.

MacVicar C W, R F Loxton, J J N Lambrechts, J Le Roux, J M de Villiers, E Verster, F R Merryweather, T M van Rooyen & H J von M Harmse 1977: Grondklassifikasie - 'n Binomiese

Sisteem vir Suid-Afrika. Pretoria, Department of Agricultural Technical Services.

Meadows M E 1985: *Biogeography and Ecosystems of South Africa*. Cape Town, Juta & Co. Ltd.

Midgley D C 1972: Design Flood Determination in South Africa. Hydrological Research Unit. Report No. 1/72. Witwatersrand, University of the Witwatersrand, Department of Civil Engineering.

Miller G T 1988: *Living in the Environment*. California: Wadsworth Publishing Company, Fifth Edition.

Mitchell J F B 1983: The seasonal response of a general circulation model to changes in CO_2 and sea temperatures. *Quarterly Journal of the Royal Meteorological Society*, 109: 113-153.

Mol A 1984: Personal communication with A Mol, Associate Professor of Business Economics, University of South Africa, Pretoria.

Moline N T 1974: Perception research and local planning : floods on the Rock River, Illinois. In G F White (ed.) 1974: *Natural Hazards: Local, National, Global*: 52-59. New York, Oxford University Press.

Morren G E B Jr 1983: A general approach to the identification of hazards and responses. In: K Hewitt (ed) 1983: *Interpretations of Calamity*. Boston, allen and Unwin Inc.

Murphy F C 1958: Regulating Flood-Plain Development. Research Paper 56. Chicago, University of Chicago, Department of Geography.

Myburgh D W 1976: Evolution of urban centres in the Eastern Cape Midlands. Unpublished Masters degree thesis. Stellenbosch, University of Stellenbosch, Department of Geography.

Nieman W A, J T Harmse & H W A Ellman 1981: Natuurkundige faktore wat aanleiding gegee het tot die Laingsburg vloedramp: implikasies vir beplanning. Buro vir Ekonomiese Ondersoek. Stellenbosch, Universiteit van Stellenbosch.

Nieman W A, J T Harmse & H W A Ellman 1981: Klimatologiese en Geomorfologiese Aspekte van Oorstromings in Suid-Afrika met spesiale verwysing na die Laingsburg-ramp. Stellenbosch, Universiteit van Stellenbosch, Departement van Geografie.

Nurse G T, J S Weiner & T Jenkins 1985: The Peoples of Southern Africa and their affinities. *Research monographer on human population biology* No. 3. Oxford, Claredon Press.

Oliver J 1975: The significance of natural hazards in a developing area : A case study from North Queensland.

Geography, 60: 99-110.

O'Riordan T 1986: Coping with environmental hazards. In: R W Kates and I Burton (eds) : *Geography, Resources and Environment*. Vol II. Chicago, Chicago University Press.

Parker D J & E C Penning-Rowell 1983: Flood hazard research in Britain. *Progress in Human Geography*, 7(2): 182-202.

Pecsi M & F Probald 1974: *Man and Environment*. Budapest, Research Institute of Geography, Hungarian Academy of Sciences.

Peet, R 1977: The development of radical geography in the United States. *Progress in Human Geography*, 1: 258. London, Edward Arnold.

Perry A H 1981: *Environmental Hazards in the British Isles*. London, George Allen & Unwin.

Pitman W V & D C Midgley 1967: Flood studies in South Africa : Frequency analysis of peak discharges. *Trans. S.Afr. Inst. Civ. Engrs*.

Pittock A B 1975: Climatic change and the pattern of variation in Australian rainfall. *Search*, 6: 498-504.

Preston V, S M Taylor & D C Hodge 1983: Adjustment to natural and technological hazards : a study of an urban residential community. *Environment and Behaviour*, 15(2): 143-164.

Preston-Whyte R A & P D Tyson 1988: *The Atmosphere and Weather of Southern Africa*. Cape Town, Oxford University Press.

R S A 1962: *Report on the Orange River Development Project*. White Paper X-'62. Secretary of Water Affairs.

R S A 1972: *Commission of enquiry into agriculture. Third (final) report*. RP 19/1972. Pretoria, Government Printer.

R S A 1979: *Department of Agricultural Technical Services*. Annual Report: 73.

R S A 1980: *Religion by Statistical Region and District*. Report No. 02-80-06. Pretoria, Government Printer.

R S A 1982: *Department of Agriculture & Sea Fisheries*. Annual Report. 1 April 1981 to 31 March 1982.

R S A 1983: *Droogte Bestuurspraktyke : Karoostreek*. Middelburg, Cape, Department of Agriculture.

R S A 1983: *Guidelines for the provision of engineering services in residential townships*. Pretoria, Department of community Development.

R S A 1986: National Transport Commission : *Road drainage manual.* Pretoria, Chief Directorate : National Roads. Third Revised Edition.

R S A 1988: Department of Agriculture and Water Supply. Circular letter A of 1988 (in substitution of circular letter no. 1 of 1986 as ammended). *Drought Aid Scheme for Stock Farmers in the Republic of South Africa.* Pretoria.

R S A 1990: S A Transport Services. Water engineering department. (Personal communication)

Rabie M A & C H B Theron 1983: Soil. In Fuggle R F & M A Rabie: *Environmental Concerns in South Africa.* Chapter 8. Cape Town, Juta & Co. Ltd.

Ramage C S 1983: Teleconnections and the siege of time. *Journal of Climatology, 3: 223-231.*

Ratcliffe R A S 1978: Meteorological aspects of the 1975-76 drought. Proceedings of the Royal Society of London A. 363: 3-20.

Rawson H E 1908: The anticyclonic belt of the Southern Hemisphere. *Quarterly Journal of the Royal Meteorological Society*, 34: 165-185.

Reynolds M G 1986: Veld se Agteruitgang. *Landbouweekblad*, 25 Julie: 16-17; 1 Augustus: 24-25.

Roberts C P R & W J R Alexander 1982: Lessons learnt from the 1981 Laingsburg flood. *The Civil Engineer in South Africa*, 24(1): 17-27.

Rorer L G & T A Widiger 1983: Personal structure and assessment. *Annual Review of Psychology*, 34: 431-463.

S A Transport Services 1990: Water Engineer's Department. (Personal communication).

Saarinen T F 1966: Perception of the Drought Hazard on the Great Plains. Chicago, University of Chicago, Department of Geography.

Scheaffer J R 1960: Flood Proofing : An Element in a Flood Damage Reduction Program. Research Paper 65. Chicago, University of Chicago, Department of Geography.

Schulze G C 1983: Sinoptiese Aspekte van die 1982/83 Droogte en die Invloed van die Suidelike Ossilasie/El Nino-Verskynsel op Reënval oor Suid-Afrika. Paper presented at the Symposium on Atmospheric Sciences in South Africa. Pretoria, CSIR.

Senate SC-2 1914: Report of the Select committee on Droughts, Rainfall and Soil Erosion.

Sentraoes 1986: Personal communication with J Haak on behalf of Sentraoes Korporasie, Johannesburg.

Sewell W R D 1965: Water Management and Floods in the Frazer River Basin. Research Paper 100. Chicago, University of Chicago, Department of Geography.

Simon H A 1952: A behavioural model of rational choice. *Quarterly Journal of Economics*, 69: 99-118.

Simpson-Housley, P & P Bradshaw 1978: Personality and the perception of earthquake hazard. *Australian Geographical Studies*, 16: 65-72.

Slovic P, H Kunreuther & G F White 1974: Decision processes, rationality and adjustment to natural hazards. In G F White (ed.): *Natural Hazards : Local, National, Global*. New York, Oxford University Press.

Smith D J G, M F Viljoen & P H Spies 1980: Guidelines for Assessing Flood Damage in South Africa. Institute for Social and Economic Research. Bloemfontein, University of the Orange Free State.

Smith K & G A Tobin 1979: *Human Adjustment to the Flood Hazard*. London, Longman.

Spies P H 1977: Vloedskades in sekere riviertrajekte van die Republiek van Suid-Afrika. Part II. BEO, Stellenbosch.

Steenkamp C W P & F C Hayward 1975: Drought Feeding on Merinos. *Wool Production* D.3.1. Pretoria, Department of Agriculture.

Steila D 1983: Quantitative versus qualitative drought assessment. *Professional Geographer*, 35: 192-194.

Susman P, P O'Keefe & B Wisner 1983: Global disasters, a radical interpretation. In: K Hewitt (ed) 1983: *Interpretations of Calamity*. Boston, Allen & Unwin Inc.

Taljaard J J 1952: Swaar Neerslae langs die Suidkus. *Newsletter* 42: 2-4. Pretoria, Weather Bureau.

Taljaard J J 1961: Maart se Reënval en Oorstromings in die Karoo. *Newsletter*. Pretoria, Weather Bureau.

Tannehill I R 1947: *Drought : Its Causes and Effects*. Princeton, Princeton University Press.

Thompson G 1827: *Travels and Adventures in Southern Africa*. London, Henry Colburn.

Torry W I 1979: Hazards, hazes and holes : A critique of the environment as hazard and general reflections on disaster research. *Canadian Geographer*, 23(4): 368-383.

Triegaardt D O 1961: Flood rains in the Karoo, South Africa. W B Notos, 10.

Trudgill S 1990: Environmental issues. *Progress in Physical Geography*, 14/1: 80-88.

Tuan V F 1974: Tropophilia : A Study of Environmental Perception, Attitudes and Values. Englewood Cliffs, N J, Prentice Hall.

Tyson P D 1986: *Climatic Change and Variability in Southern Africa*. Cape Town, Oxford University Press.

Tyson P D, T G D Dyer & M Mametse 1975: Secular changes in South African Rainfall 1880-1972. *Quarterly Journal of the Royal Meteorological Society*, 101: 817-834.

U.G. 49 - '23 1923: Report of the drought investigation Commission. Pretoria, Government Printer.

UNISA 1984: Business and the drought. Conference sponsored jointly by Financial Mail and Unisa. Pretoria.

Van der Walt A J H, J A Wiid & A L Geyer 1966: *Geskiedenis van Suid-Afrika*. Adapted and updated by D W Kruger. Cape Town, Nasou.

Van Riebeeck Society (ed) 1961: T Baines : Journal of Residence in Africa 1842 - 1853. Cape Town, Van Riebeeck Society.

Van Riebeeck Society (ed) 1979: William Somerville's narrative of his journeys to the Eastern Cape frontier and Lattakoe 1799 - 1802. Second series No. 10. Cape Town, Van Riebeeck Society.

Van Zyl J A 1981: A Geomorphological Perspective on the Laingsburg Flood Disaster. Paper delivered at the Conference of the Society for Geography. Johannesburg, RAU.

Van Zyl J A 1985: 'n Kaart van die landvormstreke van Suid-Afrika. *The South African Geographer*, 13: 105-108.

Verbeek W J 1966: Toekomstige vleisproduksie in verband met droogtevraagstukke. *Journal of South African Veterinary Medicine Association*, 4(35).

Viljoen M F, J A Vos, D J D Smith & J W Prinsloo 1980: Die 1975-Vloedskades vir Verskillende Trajekte van die Vaalrivier. Volumes 1 & 2. Bloemfontein, Institute for Social and Economic Research, University of the Orange Free State.

Vines R G & A I Tomlinson 1985: The Southern Oscilation and rainfall patterns in the southern hemisphere. *South African Journal of Science*, 81(3): 151-155.

Viviers W G H & S Viviers 1969: *Hooy Vlakte : Die Verhaal van Beaufort-Wes, 1818 tot 1968.* Cape Town, Nasionale Boekhandel.

Vogel C H 1986: Documentary Evidence: a means of determining the climate of the Cape Colony. Unpublished M A Thesis. Johannesburg, University of the Witwatersrand.

Vos J A 1982: Die Bepaling van Vloedskades Binne Stedelike Nedersettings na Aanleiding van die 1975-Oorstromings in die Vaalrivier asook Riglyne vir die Vermindering van Vloedskades. Parts 1 & 2. Bloemfontein, Institute for Social and Economic Research, University of the Orange Free State.

Waddell E 1983: Coping with frosts, governments and disaster experts : Some reflections based on a New Guinea experience and a perusal of the relevant literature. In K Hewett (ed): *Interpretations of Calamity*, 33-43. Boston, Allen & Unwin.

Walker G 1928: World weather. *Quarterly Journal of the Royal Meteorological Society, 54: 79-87.*

Weather Bureau 1956: Climate of South Africa Part 3. Maximum 24-Hour Rainfall. W B 21. Pretoria, Government Printer.

Weather Bureau 1957: *Climate of South Africa* Part 4. Rainfall maps. W B 22. Pretoria, Government Printer.

Weaver J C 1954: Crop combination regions in tne Middle West. *Geographical Review*, 44: 175-200.

Wellington J H 1955: *South Africa. Part 2.* Cambridge, Cambridge University Press.

Weyman D R 1975: *Runoff Processes and Streamflow Modelling.* London, Oxford University Press.

Whillet H C 1965: Solar-climatic relationships in the light of standardised climatic data. *Journal of Atmospheric Sciences*, 2(22): 120-126.

White G F 1964: Choice of Adjustment to Floods. Research Paper 93. Chicago, University of Chicago, Department of Geography.

White G F 1973: Natural hazards research. In R J Chorley (ed): *Directions in Geography*: 193-216. London, Methuen.

White G F 1974: *Natural Hazards : Local, National, Global.* New York, Oxford University Press.

Whittow J 1980: *Disasters : The Anatomy of Environmental Hazards.* Pelican Books.

Wolpert J 1964: The decision process in spatial perspective. *Annals, Association of American Geographers*, 54: 537-558.

Worley D P & J H Patric 1971: Economic evaluation of some watershed management alternatives on forest land in West Virginia. Water Resources Research 7: 812-818. Quoted in K Smith & G A Tobin 1979: *Human Adjustment to the Flood Hazard*: 18. London, Longman.

Young E G 1957: Moisture profiles during vertical infiltration. *Soil Science*, 84: 283-290.

Young E G 1958: Redistribution of moisture in porous materials after infiltration. *Soil Science*, 86: 117-125.