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DISASTER RELIEF CO-ORDINATOR
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Disaster Prevention and Mitigation

A Compendium of Current Knowledge

Volume 2

HYDROLOGICAL ASPECTS

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FOREWORD

The Office of the United Nations Disaster Relief Co-ordinator (UNDRO) presents the second volume in the series entitled "Disaster Prevention and Mitigation". The purpose of these publications is to provide the international community with a comprehensive review of existing knowledge of the causes and characteristics of natural phenomena and the preventive measures which may be taken to reduce or eliminate their impact on disaster-prone developing countries.

These volumes are being prepared in accordance with General Assembly resolution 2816 (XXVI), which calls upon the Office of the United Nations Disaster Relief Co-ordinator to promote the study, prevention, control and prediction of natural disasters, including the collection and dissemination of information on technological developments.

The aims of these studies are, first, to identify the existing knowledge and expertise which may be applied directly toward the prevention of natural disasters, particularly in developing countries and, secondly, to identify the gaps in current knowledge which require concerted action by the international community.

During the last two decades the international community has become increasingly alarmed by disasters, which have tended to be more destructive as they affect ever larger concentrations of population. While the response of the international community has been focussed primarily on relief action, it is now realized that the actual and potential consequences of disasters are becoming so serious and increasingly global in scale, that much greater emphasis will henceforth have to be given to planning and prevention. The effects of natural phenomena must be viewed not only in humanitarian and broad social terms, but also, and primarily, in economic terms. Natural disasters are a formidable obstacle to economic and social development. Moreover, in terms of percentage of gross national product, the losses caused by disasters in disaster-prone developing countries more than cancel out any real economic growth. There has thus been a growing awareness by Governments of the need to focus more attention on disaster preparedness and prevention, and a recognition of the fact that disaster prevention and pre-disaster planning should be an integral part of national development policy.

The "International Strategy for Disaster Prevention", proposed by UNDRO and approved by the General Assembly at its twenty-ninth and thirtieth sessions, will provide the conceptual framework for all national and international action in the prevention and mitigation of natural disasters. This strategy will harness the collective human and material resources of the world towards removing the scourge which natural disasters represent for many disister-prone developing countries. The present series on "Disaster Prevention and Mitigation" provides one of the inputs for the formulation of the strategy.

The intensification of flood plain occupation and its importance to the social and economic well-being of a region leads to increased demand for protection from floods, which usually becomes acute in the wake of a major flood disaster. Yet, despite a variety of efforts over the years to provide protection for flood-prone

areas, the loss of life and the economic losses continue to mount in industrialized as well as developing countries, largely as a result of expanded investment, continuing urbanization and the growth and concentration of population.

This volume, Hydrological Aspects, concentrates mainly on flood disaster prevention and preparedness. It reviews the causes, kinds and nature of flooding, the various types of controls, the current level of technology, evaluates the risks of flood plain occupation and describes temporary as well as permanent measures for the prevention of floods and their associated problems. Attention is given to methodology, data monitoring, warnings and flood fighting; areas needing further research and action are specified.

All the publications in the series "Disaster Prevention and Mitigation" are addressed to a broad range of users, including high-level government officials, administrators, technical experts in the field and specialists in the various areas of disaster prevention. They are also designed to guide officials at the national and regional level in the formulation of policies for preventive measures against the types of natural phenomena affecting their region.

The Office of the United Nations Disaster Relief Co-ordinator invites the readers of this volume, Hydrological Aspects, to provide the United Nations with their comments and suggestions.

This monograph was prepared by the Office of the United Nations Disaster Relief Co-ordinator with the active collaboration of the World Meteorological Organization. It was made possible through the co-operation and support of the United Nations Environment Programme (UNEP).

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SECTION 1

INTRODUCTION

GENERAL

1.1 For the major proportion of any one year the flow of water in the lower reaches of most rivers is constrained within well defined alluvial-channels. During these times alluvial plains through which the rivers flow are very attractive to inhabitation. They are agriculturally rich which encourages the development of farming, and the proximity of a river channel has in the past provided a readily accessible source of water supply, a suitable medium for effluent disposal, and has particularly in the past established an efficient means of communication and transport. In some regions the development of communities in areas other than alluvial plains is difficult. Japan, for instance, is a country consisting largely of high mountain ranges and inter montane alluvial plains. As a consequence approximately 52 percent of the people live in only 10 percent of its total area, the rich alluvial flood plains.

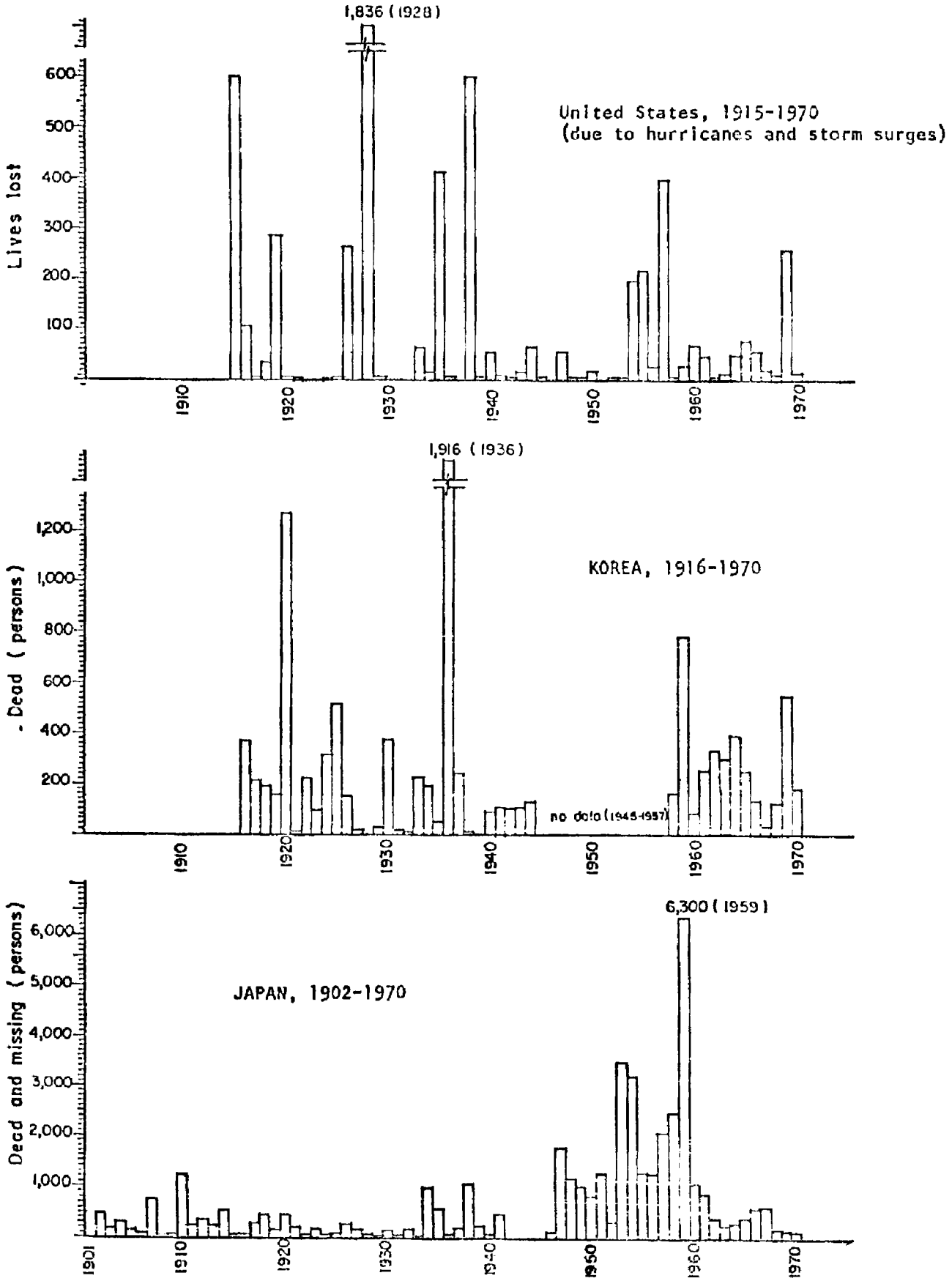
At infrequent intervals, in times of high river flow, alluvial plains serve to absorb, and in some measure to pass, flood waters in excess of river channel capacity. Despite the attractions therefore, occupation of flood plains involves risk. With extreme flooding, this risk becomes a hazard and disasters occur creating widespread damage to property and agriculture, disruption of communication systems, commerce and industry, and hardship and suffering for those affected, including loss of life, In terms of deaths alone, the horrific proportions a flood disaster can attain is illustrated by Fig. 1 which demonstrates that death from flooding in the USA, Korea and Japan occurs almost every year and that on infrequent but highly significant occasions the number of deaths can rise alarmingly. This is frequently due to one extreme event only. Of all the natural phenomena capable of producing disaster, flooding is by far the most significant in causing loss of human life. The severity of such disasters is often increased several fold by the after effects: disease and starvation.

Major flood disasters have occurred throughout the history of social development but despite inconvenience and tragedy, people continue to inhabit flood plains and, what is more, are occupying such areas with increasing intensity. It might be inferred that to do so is worth the risk involved. Economic cost-benefit arguments are often used to explain this social phenomenon, but in many regions, and particularly the developing ones, these arguments are most difficult to apply because of the many intangible benefits and various uneconomic constraints involved. Local tradition and experience in occupancy are probably sufficient justification in many cases to indicate that all benefits outweigh all costs, economic or otherwise.

In certain circumstances this thesis may be misleading, particularly in view of the high degree of forgetfulness and naivité often exhibited by people. Much overcrowding of flood plains occurs and this is doubtless the result of these characteristics.

To investigate the merit and demerit of flood plain occupation, a detailed analysis of flooding and its associated problems is always justifiable.

Figure 1.1 Trends of lives lost due to flood



STORMS AND FLOOD CAUSES

1.2 The basic causes of most river flooding are the incidence of heavy rainfall, the occurrence of a strong and protracted snow-melt, or a combination of the two: not all serious inundation of flood land or damage from floods however is due to these hydro-meteorological phenomena. On many occasions other factors operate either to exacerbate an already occurring flood problem or to create a flood problem entirely of their own manufacture. These factors are associated most often with the promotion of a hydraulic surcharge in water levels. They include the presence of natural or man-made obstructions in the flood way such as ice jams (Fig. 1.2) bridge piers, floating debris, weirs, etc., and the often critical factor of tidal surge or wind set-up in estuaries. Also included are the generally unforeseen river surge events caused by sudden dam failure, land slip or mud-flow.

In many cases the most devastating flood producing rainfall event is that associated with the typhoon, hurricane, or other tropical cyclone, the name given to this meteorological phenomenon being dependent on the region in which it occurs. The Indian sub-continent, countries of Asia, the Pacific, Caribbean and Atlantic seaboard of the USA are all regions typically subject to such events. Catastrophic flooding from rainfall is often aggravated by wind induced surcharge along the coastline. Rainfall intensities are high and the area of the storm is broad-based; these two factors together are capable of producing extreme flood discharges in both small and large river basins.

Size of catchment usually governs the character of flooding and therefore the type of meteorological event, or events, which are capable of inducing extreme floods. On very large rivers for instance, such as the Nile and the Mekong, river flow is relatively slow to change in the downstream reaches. Flood waters are therefore most often an amalgam of numerous and widespread rainfall events, possibly with considerable snowmelt contribution. In large river basins flooding is usually seasonal, the hydrograph is long based and, of major significance, peak discharges are achieved and sensibly maintained over what can prove to be an uncomfortably long period of days or even weeks.

Flood producing rainfall, with or without snowmelt, can also be of extratropical or frontal character. It may alternatively be the result of a large atmospheric depression with moisture laden winds, moving from a marine environment onto and over a land mass. Typical of the latter type of phenomenon are the characteristically seasonal Monsoons in Asia, and the line squalls which frequent the west coast of Africa. Rainfall in these events is generally widespread and can be heavy. Intensity can be high and is generally influenced by topographic relief.

The slow developing characteristic of flood flows in many large rivers is in sharp contrast with the "flash flood" more commonly but not exclusively associated with small catchments. As the name suggests, flash floods are events with very little time occurring between the start of the flood and the peak discharge. They are often associated with a short time between storm incidence and the arrival of the flood wave, but this is not always true. Floods of this type are particularly dangerous because of the suddenness and speed with which they occur. They develop in a basin following the occurrence of one or more of the previously mentioned storm types and especially if catchment slope is conducive to acceleration of runoff rather than its attenuation. Flash floods are more commonly associated with isolated and localised intense rainfall originating from a convection cell in the form of a thunderstorm event or, in the extreme case, as a tornado with its

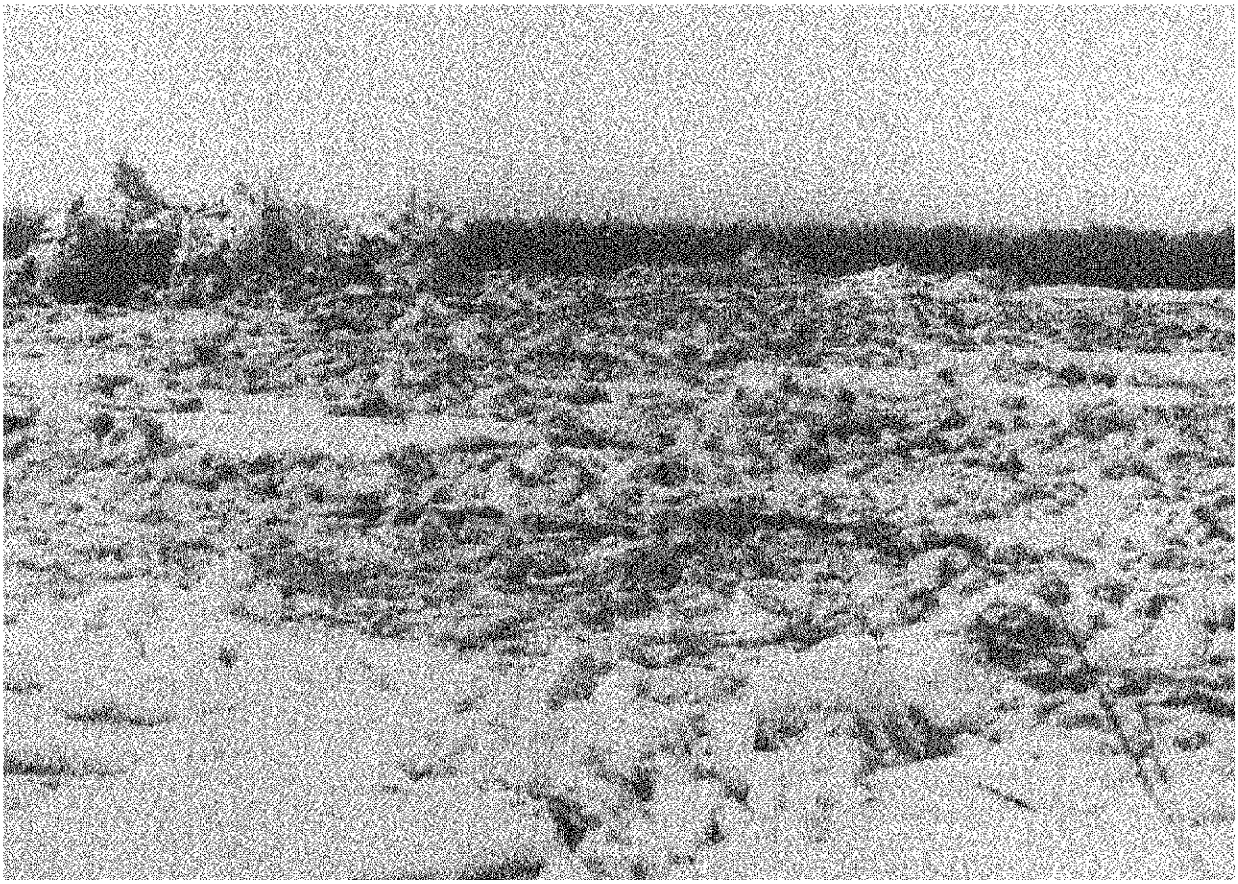


Figure 1.2 - ICE JAM IN THE RIVER DANUBE

destructive winds. Few countries are spared the problems associated with this type of event. In some regions severe and disastrous flash floods occur so infrequently on any particular small catchment, and there are so many small catchments within a given region, that efficient surveillance, warning and protection against the eventuality proves difficult. In other regions, flash floods occur each year on the same river, warning in these cases is more a problem of timeliness.

The ultimate potential and extent of river flooding can be due to two or more superimposed phenomena, not altogether of a hydrometeorological nature. Anticipating and predicting the severity of future flooding can therefore be a difficult and hazardous task.

DISASTER PREVENTION

1.3 To a limited extent, a community is willing to tolerate an amount of flooding, and over a period of years community life comes to terms with this eventuality. Nevertheless, intensification of flood plain occupation and its growing importance to the social and economic welfare of a region leads to increased demand for flood protection. The demand becomes acute when a major disaster occurs. For many centuries demand in all regions has led primarily to the development of engineering measures to control the movement of flood waters and as a result we now recognize well-established engineering techniques in combatting river floods. This consists of one or more of the following methods:

Storage Methods

(a) Construction of a dam or dams to attenuate peak discharges by flood storage;

(b) Development of controlled and temporary storage in an unoccupied flood plain area upstream of an occupied zone;

Conveyance Methods

(c) River bank levee construction to prevent inundation of flood plain by water levels greater than river bank top;

(d) Cutting a by-pass channel to relieve the normal river channel of flood surcharge;

(e) River channel improvement by re-aligning, enlarging cross-sectional area, or increasing bed slope, to increase its conveyance and hence its discharge capacity.

Numerous examples of engineering control exist in both developed and developing countries. With the exception perhaps of major dams, constructed very often for water conservation as well as flood control purposes, all schemes are of limited flood capacity. In time events do occur which exceed the design capacity causing inundation of the protected area. By itself this would not necessarily be of major consequence were it not for the fact that construction of flood protection schemes often leads to intensification of flood plain occupancy due to an exaggerated sense of security induced in the people protected. It is not easy to maintain a public understanding of the limitations of flood protection and even when it is maintained certain people may still disregard warnings and continue to build on and occupy more of the flood plain, hoping of course that should extreme floods occur, the state will undertake to evacuate people and property and will

then accept responsibility and give financial aid for reinstatement. To compound this danger, there is also the possibility of a scheme's failure, in which case the disaster may be more serious than it would have been without the presence of engineering controls.

Since it is often impractical to protect all areas against all flooding, there is clearly a need for other measures to be taken to avoid flood disaster. This need usually becomes very obvious when a major disaster occurs and has often led from the use of ad hoc emergency measures to a more institutionalized system of disaster prevention. Experts in flood prevention have come to recognize the importance of these other measures and particularly the importance of their systematic application. They realise that to overcome flood disaster it is necessary to consider the combined influence of structural and non-structural measures. Non-structural methods of disaster prevention include flood plain zoning, flood proofing, insurance and limited acceptance of damage, land use, evacuation, and flood fighting.

The importance of these various non-structural measures and of the planning, organizational and operational aspects associated with developing and implementing them has been highlighted in a number of recent publications. Two in particular are the Report of the United Nations Interregional Seminar on Flood Damage Prevention Measures and Management held in Tbilisi, U.S.S.R. in 1969, and Guideline for Flood Loss Management in Developing Countries prepared by the Department of Economic and Social Affairs, United Nations, New York, in 1974. Both give comprehensive accounts of the problems involved.

CONTENT AND STRUCTURE

1.4 A review of current thinking indicates that for any cause of flooding, disaster prevention may be accomplished using two fundamental approaches. (See Fig. 1.3) Firstly, it may be achieved by using permanent controls, structural or non-structural, designed and developed in advance of flooding. Secondly, it may be obtained by employing temporary measures, planned in advance, but carried out during the emergency. In both approaches, the significance of hydrology is clearly seen. It involves data monitoring, data processing and analysis, flood estimation, flood forecasting, flood warning and the preparation of control rules. Final emergency actions are collectively referred to as preparedness; permanent controls are referred to as prevention.

This volume concentrates mainly on the hydrological aspects of flood disaster prevention and preparedness and is written broadly along the lines of Figure 1.3. Description is contained within two main sections which follow. Section 2 deals with permanent control methods; Section 3 with emergency measures.

In both sections, early paragraphs concentrate on the hydrological methodology associated with data analyses since these govern completely the requirements of data monitoring, planning and operational aspects which are explained in later paragraphs. With one or two notable exceptions, technique and problems of data monitoring are common to permanent control and emergency measures. For this reason data acquisition is not described in Section 2. The fourth section attempts to highlight some hydrological features which could be developed further to improve the efficiency of disaster prevention. A bibliography is presented in acknowledgement of the many references made in preparing this volume.

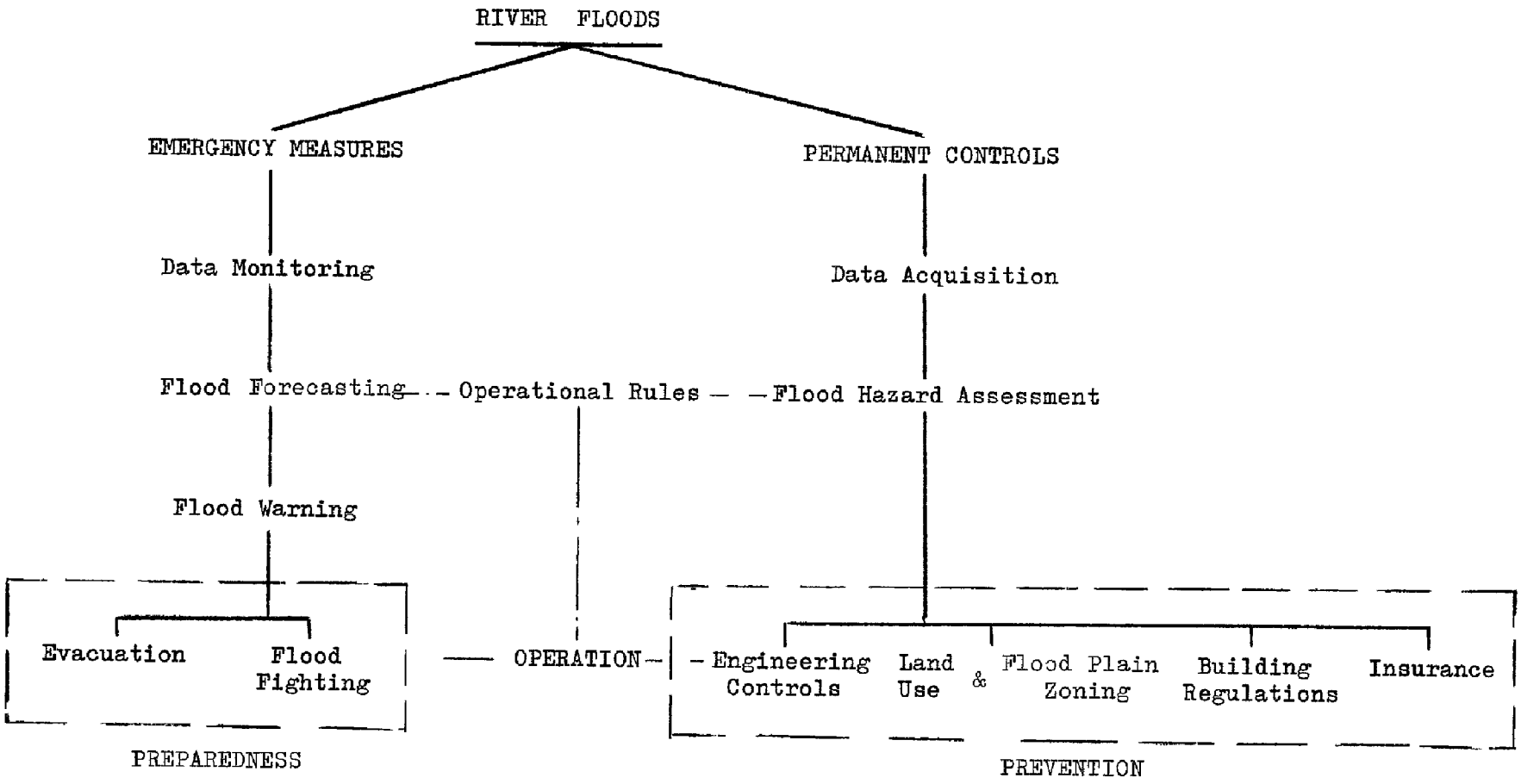


FIG.1.3 - ASPECTS OF FLOOD DISASTER PREVENTION AND PREPAREDNESS