SECTION 4

DISCUSSION

GENERAL

4. This last section is written to highlight and summarize a number of aspects which might be developed further or researched into to make flood disaster prevention more efficient. Only hydrological aspects are considered. Other features, such as flood plain zoning, flood fighting, evacuation, etc., are not elaborated any further than their mention in previous sections. These are discussed in much greater detail in separate studies.

The section concentrates on some of the shortcomings of hydrological methodology associated with flood estimation and flood forecasting. Brief reference is also made to the importance of education and training of professional personnel. A final comment focusses attention on the general tendency for national hydrological institutions to view and incorporate the problems of river flooding within a much wider framework of water resources and environmental control.

PERMANENT CONTROLS

4.1 The point has already been made that estimation of floods can be one of the most difficult and imprecise processes of applied hydrology. Imprecision reflects in the planning of control measures; the greater the uncertainty, the greater the margin of safety allowed. Factors which cause or diminish uncertainty in estimation are worthy of research and investigation. Some of the more notable factors with regard to flood estimation are discussed briefly in an order which relates to methodology and an increasing sophistication and availability of data.

Morphology

4.1.1 The technique of using morphological features of river channels to estimate flood discharges and their frequency deserves much greater attention than it has received in the past. A major reason for this is that in principle morphological methods require little or no hydrological information, a problem that most regions face to some degree. Normal flow characteristics of the channel are established as required using hydraulic estimates or by sample gauging.

Much research, however, is required to make the concept more effective and useful. This research probably now needs to be more scientifically based than previously adopted empirical methods and must take into account all factors which are involved in the inter-relationship between flooding, its frequency and the geometric property of the river channel and the flood plain.

Another factor tied in with this type of approach is the general relationship between natural vegetation and frequency of inundation. Limited research on these features is being carried out but more concerted effort is required.

Meteorology

4.1.2 In many parts of the world (developed and developing regions) hydrologists are frequently requested to estimate flood discharges for rivers in which there are no discharge data. They resort to using precipitation data and a modelling technique which is usually a very simple one and makes use of various assumptions to determine peak discharges of specified frequency. A complete intercomparison study of these methods seems justifiable. It might take the form of comparing results of these simple methods, initially for different river systems and different regions where streamflow data are available, with frequency values obtained by using standard frequency analysis. Parochial research of this type has met with limited understanding so far.

Flood Maxima - Regional Flood

4.1.3 The most significant question to be answered in this context is just what is a "Maximum Flood"? Envelopes (the Regional Flood) tend to change in time as more hydrological data become available. They do not therefore provide an altogether clear picture of potential maximum flood discharges.

There is much to be said for the meteorological approach, which endeavours firstly to determine the maximum possible precipitation (PMP) by optimizing the causal factors. The runoff from PMP, the maximum possible flood (M.P.F.) is then determined by using simple rainfall runoff models. Estimates using this approach often lead to values several times larger than maximum observed peak discharges and currently lead hydrologists to doubt their validity in practical terms. Further work is needed on this type of estimation; it has already become appreciated for its systematic approach.

M.P.F. may of course be caused by other factors. For example, dam failures are just as improbable as P.M.P. and it seems justifiable therefore that estimation of flood surge caused by dam failure (where dams exist) could also be counted as M.P.F. Hydrologists tend to be insular in estimating floods from causes other than meteorological ones.

In this context there is need for an international survey of river flood disasters to determine the relative importance of non-meteorological factors, both in terms of the frequency of their occurrence and of their influence on peak discharges and river levels.

Frequency Analysis

4.1.4 A major problem in frequency analysis is extrapolation of the cumulative frequency line to estimate the magnitude of events with very rare occurrence. This is achieved usually by using one of several possible parametric representations of the cumulative frequency distribution. Opinions differ as to which one to use and unfortunately the various parametric representations generally lead to quite different estimates of more extreme events. This causes a great deal of indecision in estimating flood frequency for rare events when extrapolation is necessary. Research is being carried out to investigate this problem, but definitive solutions are not yet forthcoming and may not be for some time to come.

Climatic or other changes give rise to trends or cycles in which hydrological phenomena vary in time. Thus the probability of getting a certain peak discharge on a given river may be changing. Traditional frequency analysis does not recognize this fact but hydrologists are nowadays keenly aware of the possibility and of possible consequences in wrongly interpreting data analyses. A simple illustration of such a problem (not necessarily typical) is the increasing probability of the river Thames flooding the City of London due to tidal surge. This is the result of a general geological subsidence of the East and South regions of Great Britain. Continued research into the evidence and influence of climatic changes is considered important.

Regional Frequency

4.1.5 To a large extent, the above comments on frequency analysis produce corresponding problems in developing and interpreting regional frequency curves. A vast amount of research and development has gone into regional analyses; methodology and results are recognized in many regions. The general nature of the resulting parametric relationships of required frequency studies strongly suggests that an international study be established to determine if interregional interpolation of parametric values can be carried out particularly for those regions having few data. Results of such an investigation would be especially appreciated by engineers and hydrologists in developing regions.

Hazard Assessment

4.1.6 Hazard is estimated usually on the basis of a flood peak discharge having a given frequency of occurrence. The choice of frequency can be based on a cost-benefit analysis if subsequent control is to be developed; but in developing and some developed countries cost-benefit may not be the appropriate objectives to use. In its place cost-effectiveness is adopted. This raises the question, on what basis is the hazard estimation flood frequency and the design flood frequency chosen? Is this to be left to the intuitive feelings of the engineer or planner, or should a more natural approach be taken? If it should, then what is the approach to be?

Controls

4.1.7 The majority of hydrology in permanent control measures is contained within the problem of flood estimation. A remaining and significant portion, however, exists in the design of controls and their operation. In this, hydrological problems are well recognized and mostly reliable given sufficient data (estimated or measured) and suitable design personnel.

Land use changes promote changes in flood potential of natural catchments. Results of urbanization are predictable but the influence of rural patterns demands continued investigations before estimation can become sufficiently precise.

EMERGENCY MEASURES

4.2 The hydrological emphasis in emergency measures is in promoting more accurate forecasts of flood conditions as soon as is practicable or desirable. Methodology adopted is determined very often by the nature of flood flows.

River-Based Data Methods

4.2.1 Sufficient methodology exists for there to be no theoretical reasons why accurate forecasts of floods cannot be made, provided that unmeasured inflows in the river sections concerned are not too significant. The range of forecasts based on these methods however may not provide sufficient time for action.

Precipitation-Runoff Modelling

4.2.2 Forecasts based on reported precipitation provide additional time for action. Accuracy of rainfall-runoff modelling is variable and not always satisfactory. Inaccuracy is often due to poor and inadequate input data which can be rectified by intensification of monitoring if the situation demands. Imagination of the hydrologist still plays a large role in making a forecasting model function with the accuracy required but some further development is needed to reduce the complexity of some models and make them more suitable in a condensed form for handling during flood forecasting. Simplification is considered one of the key factors in future research.

Snow

4.2.3 Forecasting snowmelt floods entails problems similar to those experienced with rainfall. Methodology is well established; the major need is for better input data. Snow surveys provide suitable estimates of water equivalents in many regions but they necessitate regular and prolonged field excursions by personnel, often under adverse weather conditions. In some regions also pre-planned regular surveys at intervals of 1 week or more may not be suitable. There is real need for the further development of remote sensing devices which will work under very adverse weather conditions and will have the capability of measuring snow water equivalent data and transmitting them automatically to a central processing office. A number of instruments to do this exist but all generally measure only single site samples of water equivalent. Heterogeneity of snow cover demands alternative measures which give values for water equivalents averaged on areas of catchment. Progress in this is slow.

Quantitative Precipitation Forecasts

4.2.4 In certain circumstances giving forecasts of flooding even in advance of rainfall is necessary if the forecast is to be effective. This is often true of flash floods. To date Q.P.F. using meteorological modelling is largely experimental and forces the hydrologist to adopt simple empirical and extrapolation procedure to estimate the probable amounts of rainfall that will occur. The demand for more physically based meteorological models, however, grows and efforts are being made to satisfy the hydrologist's requirements. In the context of flood forecasting, Q.P.F. deserves a major research effort in most regions.

Flash Floods

4.2.5 By their very nature flash floods often make early warnings difficult to achieve. Q.P.F. is one possible solution to the problem when it can be developed. Another way is the reduction of time in giving forecasts by condensing procedure. Many and original condensed procedures exist and it seems a worthwhile task for reference purposes to undertake a complete survey of them. Such a survey would constitute a useful guide. Speeding information transfer is another way of advancing warnings, an illustration of one method was previously shown. Other fully integrated data sensing-flood warning systems are worthwhile developing and would probably need to incorporate the sensing of rainfall (or streamflow), data processing and a condensed forecasting procedure, and warning transmission. Radar would play an important part in this system. The possibilities of fully integrated systems of this sort are worth full investigation, particularly where irregular and flash floods are concerned.

Ice Jams

4.2.6 The probable occurrence of an ice jam and the quantitative surcharge effect it produces after it has formed are both parts of some forecasting routines when ice is involved. The difficulty in all cases seems to be the inability to estimate with accuracy future surcharge before the ice jam forms and thus provide early quantitative forecasts. For those regions affected, there is an obvious need to promote investigations into the forecasting of the occurrence of ice jams, and the probable river discharge in advance of their occurrence.

Hydrometric Networks

4.2.7 New and quite sophisticated technique and instrumentation for data sensing seems to develop each year (e.g. the ultrasonic river gauge). Sufficient variety exists to cope with most river level and rain gauging demands, though this does not mean, of course, that instruments are always used in a correct manner.

A significant problem persists relating to the number of sensors required and their positioning. In terms of data acquisition, networks appropriate for flood estimation and for hydrological design, certain principles have been laid down as guidelines for network design, but a great deal more yet needs to be achieved. Flood forecasting networks seem best to be developed in a progressive manner especially if large expenditures on data transmission systems are to be incurred. Development is continuously checked against forecast efficiency, and supplementary sensors placed if analysis shows this to be required. Conditions of network design can be used in the initial setting out of sensors but much depends on the hydrologist's intuitive understanding of the problem and his knowledge of the region.

Radar

4.2.8 Over the last decade progress in the use of radar to give quantifiable estimation of rainfall and snowfall intensities has been marked. This has been the result of investigation into, and improvements of, the calibration of the reflected radar signal with precipitation intensity. Further investigations are required and are being carried out to improve an accuracy of estimate. This is important, for radar offers several important advantages including

(1) an instantaneous indication of areal distribution of precipitation,

(2) the potential of measuring snowfall as well as rainfall,

(3) an areal measuring technique integrated with a central processing unit which produces quick information turnover,

(4) the measurement of precipitation in remote and inaccessible regions, and

(5) the ability to track storms, notably tropical cyclones.

Disadvantages are the high installation and running costs and the limitation of range due to topographic barriers (screening).

Other technology may develop to compete with radar in these advantages, but currently radar offers most hope in overcoming many of the difficulties encountered in traditional networks.

Satellites

4.2.9 Satellites must be mentioned in this final section, not because there is much to add to what has already been written in a previous section (pages 59 and 63), but merely to focus attention on the fact that this relatively new and remote device could eventually provide the solution to many of the problems presently encountered in data monitoring and transmission. They are for instance, presently used to provide valuable information on such matters as ecological changes over wide areas, the potential benefits of agriculture, the variability of water resources within a region, large-scale tectonics and potential earthquakes, land use and soil erosion, the availability of soil water for vegetal consumptive use and planned irrigation, and so on. Their use in flood disaster prevention is therefore not to be considered in isolation from other benefits. It is important that the potential applications of satellites be kept under constant study and review.

HYDROLOGICAL PERSONNEL

4.3 Essential to the successful mitigation of flood disaster is the availability of suitably qualified personnel. Hydrologists involved in flood problems need also to possess an aptitude for solving problems which do not align themselves to classical textbook solutions. Such types of problem are typically encountered particularly during the early development of a forecasting procedure and in estimating flood flows when data are scarce. It should be appreciated that the availability of suitable personnel is not necessarily related to the number of 'qualified' hydrologists. It is important that a correct training programme be maintained.

When problems demand special knowledge and ability, and appropriate expertise is not available within a region, there is little reason why specialists from outside the region should not be employed over a limited period of time. This serves at least two useful purposes. Firstly, correct methodology will be employed and problems will be solved in an efficient and expeditious manner (N.B. A good expert will always avoid over-elaboration). Secondly, regional personnel may learn from the methods employed and from the expert using them.

Education should in part extend also to the general public. A reasonable understanding of the problems involved and the general consequences of flooding is important if people are to accept and appreciate permanent control measures, and to respond efficiently to emergency warnings. Good public relations between the communities affected and professional personnel should be maintained. This is greatly helped if programmes of relevant lectures, films and visits are held at suitable intervals.

ORGANIZATION

4.4 Organizations dealing with the varied problems of river flood disaster prevention have usually in the past gone through several stages of evolutionary development. Their evolution helps to emphasize that control of large and extreme river discharges should not, in general, be considered in isolation. For example, decisions in flood prevention may be constrained by their effect on the conservation of water resources, and decision in water resource development may be influenced by the degree of flood control required. For these and other reasons, national and regional organizations which have often been set up initially to deal exclusively with river flooding (and land drainage) are found to be incorporated eventually within larger organizations having much wider terms of reference.

The scope of these organizations varies between regions. Where for instance, density of population is not high and/or social development is not advanced, organizations may be found to be mainly concerned with volume control of water. In highly developed regions, control and maintenance of water quality may become a dominating factor. It is usually determined that when it is necessary to influence the variation of quality and quantity of river water (and water from other sources) many more problems emerge, most of which reflect on the environment in which we live. In the broad sense therefore, concern for the problems of river flooding is to be viewed as part of a much wider problem altogether, a concern for the environment and the ways in which human interference affects it.

The above discussion is not intended to imply that all aspects of the flood problem should necessarily be organized under a single ministry, or agency, responsible for all environmental matters. Nevertheless, there are sound reasons for close affiliation of forecasts and warnings of the various types of natural disasters.

From the scientific point of view, hydrology is a geophysical or earth science. It is one of the three frequently grouped as the fluid-earth sciences, including also meteorology and oceanography. Physically they are divided by the earth's surface and the sea-coasts, but the interface problems are numerous. Prediction in the three fields are inseparable. Air-sea interaction is decisive in weather phenomena. A tropical storm is formed and the state of the sea becomes critical. The storm moves toward the coast where warnings of wind and storm surge become the primary concern. If the storm then moves inland producing heavy rainfall, devastating floods may result. The extent of flooding in estuaries depends on rainfall, numerous hydrological factors, wind, configuration of the continental shelf, astronomical tides, and so on.

It is rather common practice for the national Meteorological Service to meet water management needs with respect to weather forecasts and basic meteorological data. In those countries where hydrological forecasting and warning is undertaken as a public service on a national scale, the activity is often assigned to the same agency which is responsible for weather forecasts and warnings - a practice which is becoming more widespread. It is not unusual under these arrangements, however, for water agencies to assume the responsibility for preparing those forecasts required for operating water control structures under their management. Many countries have no national hydrological forecasting service as yet and, in this case, water management agencies (public works, flood control, irrigation, hydro-power, etc.) are obliged to make their own forecasts for operational purposes.

Economic and other considerations are believed to weigh heavily in favour of a combined national Meteorological and Hydrological Service, possibly including some oceanographic functions. The principal problem with this organizational structure is the interface between river forecasting and river control operations. Secure communications and close co-ordination between forecaster and operator(s) is a necessity. If all inter-related operations are under a single authority, natural-flow forecasts can be provided to the operator in which case planned operations would then be communicated to the forecaster. In a highly developed river system and with a modern forecast service, the basis for operations can be programmed into the computer-storage facility used for preparing forecasts. It should be stressed, however, that this inter-face problem is not yet of particular importance in most parts of the World.

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