Journal of Energy Research and Environmental Technology (JERET)
Print ISSN: 2394-1561; Online ISSN: 2394-157X; Volume 2, Number 3; April-June, 2015; pp. 248-250

http://www.krishisanskriti.org/jeret.html

Flood Forecasting by Remote Sensing and GIS

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Abstract—*Flood causes considerable damage to human lives and property almost every year. About one third of total flood prone area (40 mha assessed by the Rashtriya Barh Ayog) of the country has been provided with reasonable Protection against flood of a low magnitude due to technological and Economical constraints but there is no protection from floods of higher Magnitude. Since adoption of National Flood Policy by Government of India in 1954, it was realized that a total protection against flood by structural means alone is not possible and that optimum solution would consist of a mixture of structural and nonstructural measures. Therefore, stress has been laid on non-structural measures like flood forecasting and warning, which is most important among such means to minimize the damage potential from floods. Accurate and timely flood forecasts and advance warning have, therefore, to be aimed for providing valuable time to the people and to civil authorities in taking preventive measures like evacuation, relief and rehabilitation measures, preparedness for flood fighting by engineering authorities etc. and thus mitigating such losses from floods.*

1. FLOOD FORECASTING AND WARNING SYSTEM

To form an effective real-time flood forecasting system, the basic structures need to be linked in an organized manner. This essentially requires:

(a) Provision of specific forecasts relating to rainfall for both quantity and timing, for which numerical weather-prediction models are necessary;
(b) Establishment of a network of manual or automatic hydrometric stations, linked to a central control by some form of telemetry;
(c) Flood forecasting model software, linked to the observing network and operating in real time.

Flood warnings are distinct from forecasts, as they are issued when an event is occurring, or is imminent.

Flood warnings must be issued to a range of users, for various purposes. These purposes include:

(a) To bring operational teams and emergency personnel to a state of readiness;
(b) To warn the public of the timing and location of the event;
(c) To warn as to the likely impacts on, for example roads, dwellings and flood defence structures;
(d) To give individuals and organizations time to take preparatory action;
(e) In extreme cases, to give warning to prepare for evacuation and emergency procedures.

Early warning of a flood may save lives, livestock and property and will invariably contribute to lessening of the overall impact. Flood warnings need to be understood quickly and clearly and so considerable attention has to be given to how technical information is conveyed to non-specialists from organizations, the public, the media and in some cases illiterate population groups. There are a number of features common to all flood forecasting and warning systems, which are related to causes, impacts and risks.

Understanding flood hydrology

When developing models and systems for flood warning, it is fundamental to understand the causes of flooding in any given catchment or river basin. The size, shape and topographical structure of the catchment control the basic response to the key driver of flooding, which is the input of precipitation. Land use, geology, soils and vegetation affect the speed of response of the catchment to rainfall, and the losses to soil and deeper recharge are also major features of flood response. The extent of urbanization is also important, not only through the introduction of impermeable areas, but also through the modifications to urban drainage through sewers, culverts and engineered river reaches, which act to increase the rapidity of response of flood flow in the catchment. The influence of river and drainage controls can also introduce elements of uncertainty, through blockage, overflow of structures and the elimination of detention storage. All of the above features can be parameterized to a greater or lesser extent by hydrological and hydraulic models of varying complexity. Simpler forms of flood estimation can be carried out using multivariate equations, which require estimates of the key components to be extracted from mapped information or other spatial data. It is essential as a preliminary to more detailed modeling for flood hydrologists to have a thorough understanding of the nature of the catchments involved. Information on catchment size and shape can be obtained from basic topographic mapping. Natural characteristics can be obtained from geological, land-use, soil and vegetation mapping.

In more detailed models, man-made features and structures need to be identified and their operational characteristics detailed from design reports and operation manuals. In more detailed models, man-made features and structures need to be identified and their operational characteristics detailed from design reports and operation manuals. The nature of the precipitation that causes flooding needs to be fully understood both in the context of events and seasonal climatology. Significant types of precipitation leading to flooding are:

(a) Short-duration, high-intensity rainfall (often localized);

(b) Long-duration, widespread rainfall;

(c) Snowfall and snowmelt;

(d) Extended seasonal rainfall.

The different types of precipitation will cause varying responses in a given catchment, and the relative importance of the impact of different types of events need to be evaluated in order to define the most appropriate approach to developing flood warning. In areas where there is a regular and significant pattern of seasonal rainfall, a fixed observation network for rainfall and river levels can be established as the basis for the flood warning system. These can be distributed in such a way as to provide regular, spatial representation or located at key points with regard to flood risk. Where rainfall is more infrequent, and often inherently more variable both in quantity and spatial distribution, the fixed, representative network Approach is less suitable. These conditions, which are typical of more arid climates, are also more difficult to model by the commonly available hydrological and hydraulic models. Typical problems encountered in arid or semi-arid areas are:

(a) Highly localized rainfall, which may not be captured by rain gauges, particularly if these are sparsely distributed;
(b) Highly seasonal rivers, with a large range of discharge and level. These are difficult to measure with both structures or at rated sections by current meter, as channel conditions change during and after each flood event;
(c) Ephemeral rivers, which exhibit considerable losses through the channel bed along lower reaches;
(d) Major changes in the course of rivers and destruction of measuring devices by flood flows;
(e) Problems of maintenance and performance of monitoring equipment in harsh conditions especially dust and heat. Under these conditions, modern techniques of remote-sensing can prove more useful did not guarantee the correct representation of physical processes, especially across scales. A well-known example of a lumped model is The than conventional instrumentation. It may be possible to use satellite or radar-based monitoring for the observation of rainfall. River conditions will need to be observed at suitable places for locations at risk, but it is imperative that these provide adequate lead time, as the high speed of flooding is also a common feature of arid and semi-arid regions.

2. LITERATURE REVIEW

2.1 Flood forecasting methods and models

2.1.1 State-of-the-art hydrological modeling

Burnash et al, 1973

The development of hydrological models started in the 60s and was enhanced by the advance of high-speed computers and by the demand imposed by advanced water management engineering projects. Due to computer limitations and lack of spatial information, lumped models were initially applied. Spatial variability of the characterization of the landscape, hydro-meteorological forcing, or initial conditions were not explicitly accounted for in this type of formulation. To overcome these weaknesses, effective parameters were calibrated based on the hydrograph at the outlet of the basin. Parameter calibration guaranteed good fit and a correct overall mass balance but Sacramento Soil Moisture Accounting Model which is the main model used for river forecasting by the National Weather Service River Forecast Centers across the United States.

2.1.2 Stochastic models for real time flood forecasting

Box and Jenkins, 1970; Salas et .al., 1980.

Several stochastic/time series models have been proposed for modeling hydrological time series and generating synthetic stream flows. The time series models are considered to be most suited for real time forecasting as on-line updating of model forecasts and parameters can be achieved using various updating algorithm. It has been observed that the dynamic stochastic time series models are most suitable for online forecasting of floods

(Kalman, 1960; Sage and Husa, 1969; Eykhoff, 1974; Kashyap and Rao, 1975; Kumar, 1980; O’Connell, 1980; Chander et al., 1980, 81, 84).

These models also provide a means for the quantification of the forecast error, which may be used to calculate the risks involved in the decisions based upon these forecasts. Further ,these models can be operated even with interrupted sequences of data and easy to implement on computer and other computing devices.

2.1.3 Artificial nueral network models for real time flood forecasting

Xiong and O’Connor (2002)

The formulation of real time flood forecasting using statistical & stochastic models is based upon the assumption of linearity whereas the quantity of runoff resulting from a given rainfall event depends upon a number of factors and is dominantly nonlinear.

Recently, another class of black box models in the form of Artificial Neural Network (ANN) has been introduced in modelling real time problems wherein the nonlinear relationship between the rainfall and runoff process is modelled. The ANN model has wide applicability in Civil Engineering applications and many research papers have been published on its application. The use of ANN in real time flood forecasting is of very recent origin and is still in the evolution stage. Recently Xiong and O'Connor (2002) studied four updating models for real time flood forecasting, in which the authors have shown that the use of ANN model as forecast error update model has infact not improved the real time flow forecasting efficiencies over that of the standard AR model.

2.1.4.Fuzzy logic techniques for real time flood forecasting

Zadeh, 1965

The emergence of a flood and thus its forecast depend elementarily on the discharge process in the natural catchment area of the river. This process is rather complex and its mapping into a suitable process model for an automated flood forecast is accordingly difficult. Hydrologic models are useful only to the degree that they represent processes in the world. Mathematical models have been developed based either on physical considerations or on a statistical analysis to estimate floods from small as well as large size catchments. Existing flood forecasting models are highly data specific and complex. Unlike mathematical models that require precise knowledge of all the contributing variables, fuzzy logic, on the other hand, offers a more flexible, less assumption dependent and self-adaptive approach to modelling flood processes, which by their nature are inherently complex, non-linear and dynamic. Fuzzy Logic based model

can be used to model process behaviour even with incomplete information. Fuzzy logic is widely regarded as a potentially effective approach for effectively handling non-linearity inherently present in the hydrological processes

2.1.5 Use of remote sensing and gis in flood forecasting

Ranaee et al. (2009)

He had done flood routing in a two branches of ZOSHK river using HECGeoHMS,HEC-HMS and MIKE 11 software. They used HEC-GeoHMS software to prepare required statistics for rainfall-runoff modelling in HEC-HMS. Later on, they used the output information of HEC-HMS model as input data for flood routing modeling in MIKE11 software.Finally, they calibrated computed statistics of MIKE 11 software in compare with observed data in hydrometric station which was located in that river outlet. They suggested a suitable procedure for flood routing in rivers with uncompleted initial and boundary condition.

3. OBJECTIVES

The broad motives of this study are to contribute:

- To the evaluation of the value of remote sensing data for flood prediction across multiple scales and to provide a rational basis for future data requirements.
- Floods are the result of the complex interaction of meteorological processes, land surface and soil properties, and antecedent moisture conditions. On one side, remote sensing information provides insights about all of the variables that should be accounted for in a flood prediction system, with near global coverage and relatively low costs.
- On the other, coarse spatial and temporal resolution, sampling frequency, and retrieval errors limit its applicability for flood prediction at small scales. Therefore remote sensing information can be used to predict floods with an acceptable level of accuracy.

4. METHODOLOGY

The modelling system developed in the project will consists of:

i) A hydrological model (Rainfall-Runoff Model) for generating runoff from a number of catchments schematized in the basins.

ii) A Hydrodynamic Model for routing flows through the river and reservoir system to compute flows, water levels and flood maps.

iii)A real time flood forecast module for computing stream flow and flood forecast for period of 3 days from the time of forecast.

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