behavior. They also often impact adversely on the rather unique resources that are present in flood plains. Of particular concern here are the generally fragile and very susceptible resources that society values highly, which occur in the interface zone between land and water. Generally this would be in areas involved in flooding relatively frequently; say at least every 5 years.

Planning for flood plain use for whatever purpose, must view this territory in relation to the larger area of which it is part. The future use role of the flood plain must be tuned to the region's future. Land use decisions including transportation and other adjustments must be made only with an awareness of the consequence of flooding, the threat of loss to property and life, and the cost shifted to neighbors, the community, and the nation as a whole. The most appropriate future role or roles, including the use of the space and environmental resources of the flood plain, must be conceptualized before adjustments to flooding or to its effects can be meaningfully identified or evaluated.

HYDROLOGICAL VIEWPOINT OF FLOOD-PLAIN USE

Edward J. Kennedy, Hydrologist, U. S. Geological Survey, National Center, Reston, VA

Flood-plain hydrology is primarily concerned with floodflow rates and extent of inundation. The U. S. Geological Survey network of about 10,000 gaging stations and records for other sites furnish the basic data for most frequency analyses. Records for large streams are long but those for small tributaries are short or non-existent. Rainfall-runoff modeling, regression analysis, and unit hydrographs are the most used analytical techniques. Floodway delineation, a straightforward hydraulic computation, has legal and social complications. Differences in the position and shape of the 100-year water-surface profiles as computed by different agencies present a problem that may be reconciled at local, State, or national level, or, as a last resort, by a National Academy of Sciences panel.

The hydrologic viewpoint of flood-plain use is broad and involves some interesting techniques and challenging problems. Flood-plain hydrology is primarily concerned with flow rates and with the depths and areal extent of inundation associated with floods of specific recurrence intervals. Factors that may cause the flood characteristics to change are also important. The technical procedures used to calculate flood frequency and magnitude depend on basic data, principally records of stream flow.

The main source of observed field data is the U. S. Geological Survey's gaging-station network. About 10,000 continuous record streamflow gages are in operation today and records are available for about 17,000 additional sites throughout the fifty states and territories. A typical gaging station is a stilling well beside a stream. The structure itself, without the recorder, is not very different from gages built hundreds or even thousands of years ago. Modern gages contain instruments that record water level (stage) in the stream generally by punching stage on a 16-channel paper tape at intervals that range from 5 minutes to an hour, depending on the expected rate of rise and decline of the water level. Special gages for highway-design-oriented small stream studies record flood-stage hydrographs and rainfall simultaneously. Others record only peak stages. State and Federal Highway agencies provide financial support for about 5,000 of these small-area gages. Measurements of discharge, especially during floods, define the relationship between stage and discharge, and recorded stage values are converted to discharge by digital computer using the relationship. Daily mean discharge values and annual peak discharges are stored in a computer for rapid retrieval in any one of many convenient formats. For instance, a log-Pearson III flood-frequency curve can be obtained for any gage with more than 10 years of record.

Length of record is a prime factor in flood-frequency analysis. Most hydrologists recognize the inadequacies of estimates of the magnitude of a flood whose recurrence interval is more than twice the length of the streamflow record. Some U.S. streams have historic records of major floods that go back 300 years. A few streams have continuous records for periods exceeding 100 years. These and the many with more than 50 years of record are generally for large rivers. Few streams with drainage area less than five square miles have records as long as 20 years. The smaller tributaries that relate to flood-plain land-use regulation typically have short records or no records at all.

The long-term flood-frequency characteristics of a small stream can be estimated after a few years of gaging by using a rainfall-runoff model. Flood hydrographs and the corresponding basin rainfall data are collected at the site for calibration. A long-term record of flood peaks is then generated from a long-term precipitation record.

Two approaches to flood magnitude and frequency computation for ungaged or inadequately gaged sites are used. One is regression analysis in which the magnitude of the 100-year flood (Q_{100}) at each gaging station in the general area is related to such parameters as drainage area (A), stream slope (S), areas of lakes and ponds upstream (L), basin width (W), and annual precipitation(P). The resulting equation, in the form, $Q_{100} = a A^b S^c L^d W^e P^f$, is used to estimate the 100-year flood at ungaged sites; the basin parameters are measured from maps. The other method uses unit hydrographs and statistically derived design rainstorms. Each method has advantages and disadvantages, supporters and detractors.

Flood characteristics are substantially modified by works of man. Flood-control reservoirs, retention basins, and certain land treatments generally reduce the magnitudes of floods and may have a major impact on flood-plain use. Development of an urban basin with pavement and sewers generally increases flooding, especially the magnitudes of the more frequent floods on small streams. The Geological Survey and others are investigating the "urbanization effect" by operating special urban-area gaging stations and calibrating rainfall-runoff models.

With regard to flood-plain use, a floodway is the main channel of a stream plus portions of the adjacent flood plain that in the future, are to be kept free of all structures. The floodway fringes are the remaining portions of the flood plain and building and filling are permitted there with certain restrictions. The floodway fringes are so located that their complete filling or obstruction would raise the 100-year flood profile by no more than a specified amount ordinarily less than a foot. The hydraulic computations are fairly straightforward but economic, legal, political, and ecologic factors make the matter of floodway use somewhat controversial. Transportation is involved as railroad rights of way are often in the floodway and the right to maintain and modify embankments and structures located there is not yet clear. Hydraulic design of bridges, especially those on secondary roads, could raise problems. In densely populated areas with flat-gradient streams, even minor additional flooding may be intolerable. Extremely wide flood plains provide natural reservoirs for floodflow storage and widespread filling of them may increase floodflow downstream. Problems are plentiful in floodway design, but few of them are technical.

Water-surface profiles of 100-year flood events, computed by different agencies, often disagree substantially even when identical values of discharge are used. A great deal of judgment in data interpretation is involved and there is no universally applicable procedure. The Water Resources Council's Bulletin 15 (an updated version is being prepared) was designed to help unify procedures at gaged sites. Most differences are resolved locally by the agencies involved. Some States coordinate the various values submitted before adopting an official regulatory flood value for zoning purposes. A National Academy of Sciences panel studies both sides of the very few unreconcilable differences. The value accepted by the panel is official for virtually any purpose.

Hydrologic techniques, though far from perfect, provide a technical basis for flood-plain management decisions that can dramatically reduce the horrendous damages resulting from past encroachments on flood plains.

IMPACT OF FLOOD PLAIN REGULATION ON RAIL TRANSPORTATION

D. S. Bechly, Engineer-Structures, Illinois Central Gulf Railroad

In the remarks that I am about to make, I would like to bring to you some thoughts, based upon my experience, as to the impact that proposed flood plain regulation may have upon the railroad segment of the transportation industry. In making these remarks I am speaking as an engineering officer of the Illinois Central Gulf Railroad and my data base, so to speak, is confined to the impact on that particular railroad. However, as it is one of the principal railroads of the country and operates throughout the length of the Mississippi River Valley, I would believe that these remarks would be typical for the railroad industry.

The purpose of the presentation this afternoon is to attempt to make you aware of the topic of flood plain regulation. The widespread formulization of such regulation is a current and ongoing thing, and most of us in the railroad industry have not yet had to come to grips with it. As the previous speakers have indicated, the current concept was developed primarily in connection with the underwriting of Flood Protection Insurance Programs which, in my understanding, have been developed primarily for the housing industry. Nevertheless, the present and forthcoming regulations will definitely affect the railroads of the country. This effect will not necessarily be bad, but it could be