offered relatively little resistance to the flow of flood waters.

The program regulations are designed so that any encroachment on the floodway should not result in an increase of backwater by more than one foot. Hydraulically, that means a head loss of no more than one foot through the bridge. The regulations are based on the 100 year flood. Highway designers generally resist building for the 100 year flood. In rural areas, with no flood plain development, design for a more frequent flood might be appropriate. However, the design should be tested for the 100 year flood. Economics may dictate a small bridge, and hence the encroachment and backwater are overlooked. Then someone comes along and builds just upstream from the bridge. This structure is wiped out in the next ten year flood because that person did not know the hydraulic limitations of the bridge.

Regulations are designed for two situations; encroachment in crossing a stream; and highway or railroad grades parallel to a stream where extensive fill is needed to achieve the grade. That fill should be evaluated because valley storage is quite critical to downstream losses and damages. In any environmental impact statement, valley storage loss should be evaluated and an attempt made to put a value on it.

ENGINEERING VIEWPOINT OF FLOOD PLAIN USE

G. R. Phippen, U. S. Army Corps of Engineers

What is our concern with Flood Plains? A flood plain is a piece of territory of varying size and conditions. Characteristics vary from the upper to lower reaches and from river system to river system. For our purposes they have one thing in common. They are defined by flood.

To handle the topic of the engineering viewpoint, or for that matter for any other related topic, it is important to ask why are we interested: Is it because of floods themselves? Is it because the flood plain offers at least in part unique resources of the land and water interface? Is it because the flood plain and its use present special challenges to a developer? Is it because as a land space resource it is subject to development pressures from outside it? Are we interested because it offers a relatively level space in an otherwise sloping terrain for railroads, buildings?

It is all of these and more. To properly treat the subject of Flood Plain use, it is necessary to view the flood plain as part of some larger encompassing territory. Questions must be answered. What role, or roles, is the Flood Plain playing? What role should it be playing? A more intensive use role, i.e., more buildings on it? A less intensive use, i.e., fewer buildings on it? The latter would likely be true much more frequently than the former, but this must be evaluated. Generally, we are especially concerned with part, not all, of the flood plain. So we can say our concern is with greater or lesser intensity of development in those portions of the flood plain which costs everyone concerned--the user, his neighbors, the community and the Nation--are highest.

It is only in this context that we can judge what patterns and modes of development make sense. It is only in this context that we can say what kinds of adjustments in existing development--or modifications of future development and/or of flood behavior - make sense.

The insurance program in its land use control aspects has a potential of making communities and states, and even Federal agencies, face the problem in a more direct fashion than has been true in the past. Like the Executive Order 11296 written in 1966 that said all Federal agencies must evaluate the flood hazard in decisions to build, fund, support, and/or transfer lands in flood plains, the National Flood Insurance Program reinforces the idea that uneconomic, hazardous, and unnecessary use of flood plains should be avoided. Much more in the way of appropriate planning and related implementation in this Flood Plain Management context is needed and will be needed as the National Flood Insurance Program and other flood-related programs--such as those of the Corps of Engineers--go forward. A program which manages flood losses by seeking to achieve optimal use of the flood plain, i.e., Flood Plain Management is the key. But let's look more specifically at my topic: "An Engineering Viewpoint." It seems relatively safe to say that at least the following types of considerations would fall logically to an engineer, or at least include those topics which engineers have chosen to solve within the general subject of Flood Plain Use:

1. Delineation of Flood Plains and Related Aspects of the Flood Problem.
2. The Nature and Characteristics of Flooding which bear on the matter of flood

plain use, such as the depths of flooding at various volumes, the rates of flood rise to peak, the duration of the flood, the velocities of water in the stream and in the overbank areas, and the nature of pollution and debris the flood is likely to carry.

3. The problems of structural integrity with flooding: wall loading, both water and soil; buoyancy, or uplift pressures; deterioration of the materials; and the design of measures to modify the flood, e.g., flood control; or to modify the consequences of flooding, e.g., flood proofing.

4. The Problems of Loss Evaluation: How much loss can be accepted as residual after implementation? Physical Losses, that is material losses; loss of life, loss of productivity, etc.

5. The problems of identifying those costs shifted by flood plain users to their neighbors and to the general public. These would be losses created by the impedance of flood flows and hence an increase in flood height; losses related to the creation of hazardous debris and pollution in the areas flooded; losses as the cost of relief and rehabilitation by the public, and costs of protective works.

6. The problems of changing flood plain conditions in response to changes of the flood plain by reason of development which increases runoff and sedimentation rates. (Note here rate, and also that the increase in quantity and not necessarily the peak is a regular outcome of changed infiltration and runoff.)

7. And finally an interest in all of the possible adjustments, e.g., flood control, evacuation, and regulation needed for appropriate use depending on the future role or roles of the flood plain.

It is safe to say, that all forms of transportation are in some way or another affected or could be affected by flooding. Waterborne transport, for example, protection of which was one of the motives for the Federal Government getting into flood control in the first place, is particularly prone to the vagaries of streamflow, hence both high flows and low flows are of concern. Highways are clearly involved both in terms of losses and in terms of their effects on floods. One report of statistics on highways that may be of interest is the Congressional Record (February 1974).

In this account, it was stated that emergency relief funds for repairs and reconstruction of damaged Federal Aid Highways alone between 1953 and 1973 amounted to nearly $500 million. The high year was $134 million, the low $1 million.

Railroads likewise are involved. I don't have damage dollars to relate, but listen to some of the statistics on the extent of physical damage from the Agnes Floods of 1972: 4400 freight cars destroyed; 1400 locomotives destroyed; Erie Lackawana Railroad -- 395 miles of track and 186 miles of mainline roadbed lost. Estimates place complete restoration at 2 to 3 years. The idea of lost use is an important one and one that must be recognized in decisions to utilize flood plain areas for transportation routes. In the case of railroads, it has been estimated that the business losses are often 25 to 50 percent as large as the physical losses in the large flood.

Road fills and railroad beds often function much like dikes and levees. They cut off flood plain and thereby increase the volume of water passing through one valley cross-section in a given time, and usually force the flood surface to rise locally and upstream. This also shifts the flood to the opposite side of the flood plain. It is this kind of shifting of floods and hence the cost of flooding that supports the basis for suit under common law when it can be shown that a significant damage is caused. One aspect of this problem may resolve itself in that the road and railroad embankments are often either submerged or breached in the large flood. This relieves some of the problem as the waters expand into the natural flood plain use.

Bridges, both rail and highway, are quite often culprits during flood periods. They regularly produce a constriction in the overflow area and perhaps more important, but less obvious, is that they function as debris collectors with damming and possible serious consequence of bridge-dam failure. It should be recalled though that bridge removal or reconstruction is not necessarily an answer to the problem. This action may merely shift the problem from one bridge to the next one downstream as is quite common in urban and urbanizing areas. In some physical situations encountered in flood plains, the practice is to not only provide for under-bridge flood capacity, but also for capacity in low overflow areas at bridge approaches.

At some time in all flood plains, a really big flood must be contended with. The flood of the hundred-year magnitude is a reasonable one for planning purposes. In some cases the much larger flood must also be a very conscious concern in the planning for the flood plain use. Knowledge of these "great" floods may be important in relation to transportation planning. It certainly is with others.

Engineering works designed specifically to modify floods, as is true in flood control, or in the form of roads and railroads can have a major impact on flood 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

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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.