FACTORS IN FLOODWAY SELECTION[1]

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INTRODUCTION

The increases in annual flood damages in spite of millions of dollars spent each year for flood control projects has resulted in a national effort to encourage management practices (zoning, subdivision, sanitary ordinances, etc.) to guide new developments away from flood prone areas. An essential part of flood plain management is the preservation of the floodway (the channel and those portions of the adjoining flood plain that are needed to effectively convey flood flows) as open space use, such as parks and agriculture. Accordingly, floodway regulations are more restrictive than flood proofing requirements applicable to buildings proposed in flood prone areas outside the floodway. Unless the delineation of the floodway is based on sound engineering principles and properly related to existing and proposed developments, floodway zoning districts could be construed to be a taking without due compensation.

Increases in flood stages due to encroachments on the floodway are one of fifteen (15) hydraulic and planning factors involved in the selection of the floodway that are discussed. On the basis of floodway encroachment studies done on various size streams, primarily in Iowa and Wisconsin, the writer considers one-half foot a reasonable upper limit for permitted increases in flood stages. Although the paper is based essentially on the experience gained in

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floodway selections for over 50 Wisconsin communities, the paper also reflects the response to a questionnaire directed to an engineering firm representing four Northeastern states; Papio Watershed Board, Omaha, Nebraska; and the states of Nebraska, Iowa, Michigan and Minnesota.

The purpose of this is not to discuss technical engineering aspects of floodway selection, but to acquaint the interested engineer with the planning, social, and political aspects involved in the selection of a floodway. Without the nonengineering considerations, it is unlikely that flood plain regulations can be successfully implemented, enforced or meet the necessary constitutional restraints.

The purpose of this paper also is to briefly convey the types of problems that have been experienced by the most states or organizatinns having active flood plain management programs.

NATURE AND OBJECTIVES OF FLOOD PLAIN MANAGEMENT

Flood plain management includes a full range of tools, programs and policies all working harmoniously together toward a common goal - - - flood damage prevention. These tools, programs, and policies include such things as (1) land use controls, (2) land acquisition or easement programs, (3) urban renewal, (4) tax adjustments, (5) financing controls for buildings by lending institutions where mortgage guarantees or funds to developers are not made available in flood prone areas or where flood protection measures are omitted from building proposals, (6) public policy guiding the construction and location of public facilities and services out of flood prone ares, (7) flood control measures and flood proofing of existing structures, (8) evacuation, (9) flood insurance and (10) flood warning systems.

Specific flood damage abatement objectives of flood plain management include the:

1) Prohibition of flood plain uses such as fill, dumping, storage of materials, structures, buildings and any other works which, acting alone or in combination with other existing or future uses, will increase potential flood heights and velocities by obstruction to flows and loss of valley storage.

2) Protection to human life and health.

3) Minimization of public and private property damage.

4) Minimization of surface and groundwater pollution which will affect human, animal or plant life.

5) Control of development which, acting alone or in combination with similar developments, will create an additional demand for public investment in flood control works.

6) Control of development which, acting alone or in combination with similar development, will create an additional burden to the public to pay the costs of rescue, relief, emergency preparedness measures, sandbagging, pumping, and temporary dikes or levees.

7) Control of development which acting alone or in combination with similar development, will create an additional burden to public for business interruptions, factory closing, disruption of transportation route, interference with utility services and other factors that result in loss of wages, sales, production and result in tax write-offs.

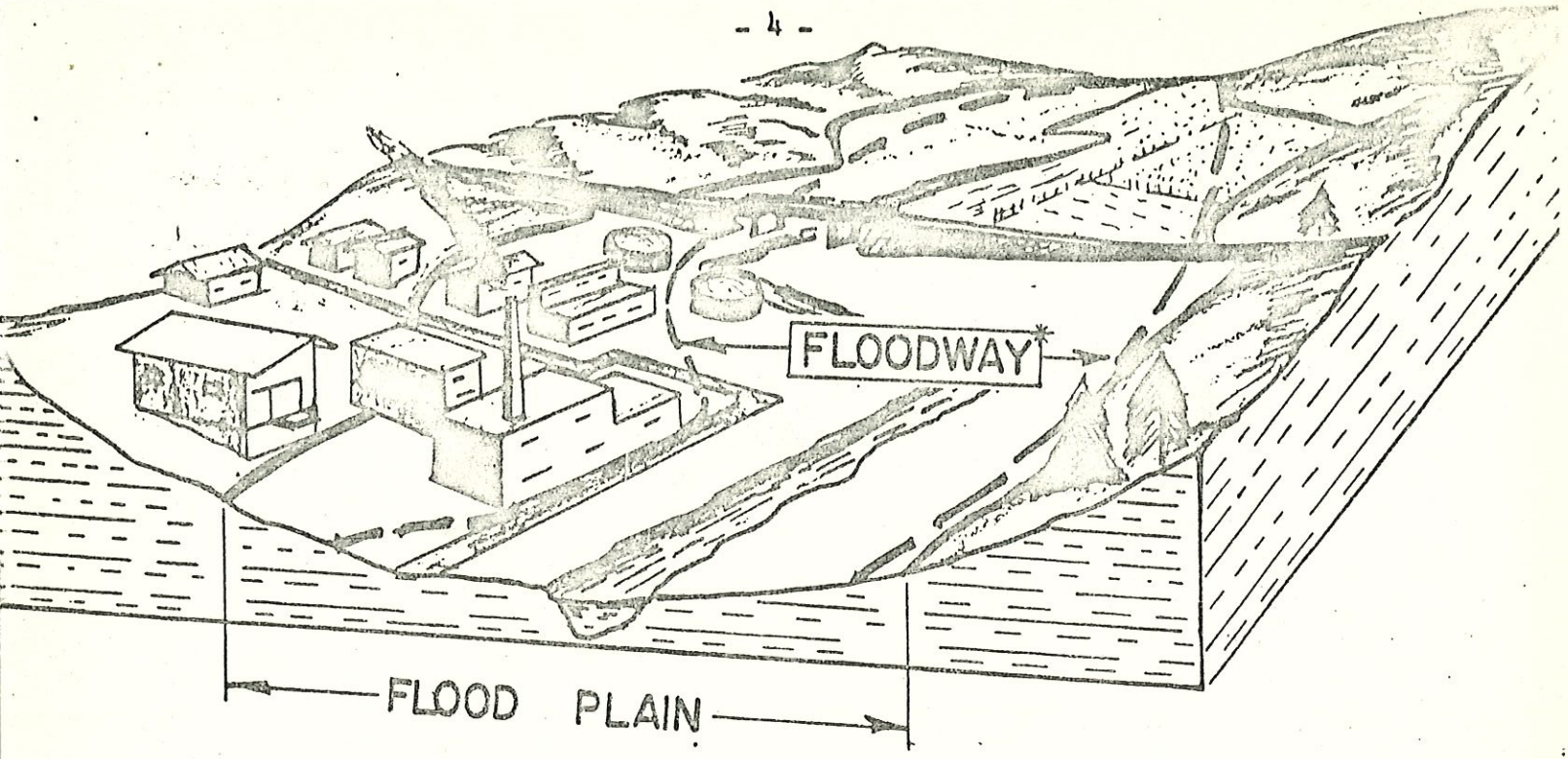
8) Provisions for public awareness of the flooding potential and to discourage the victimization of unwary land and home buyers.

9) Maintenance of a stable tax base through the preservation or enhancement of property values for future flood plain development. In addition, development of future flood blight areas on flood plains will be minimized and property values and the tax base adjacent to the flood plain will be preserved.

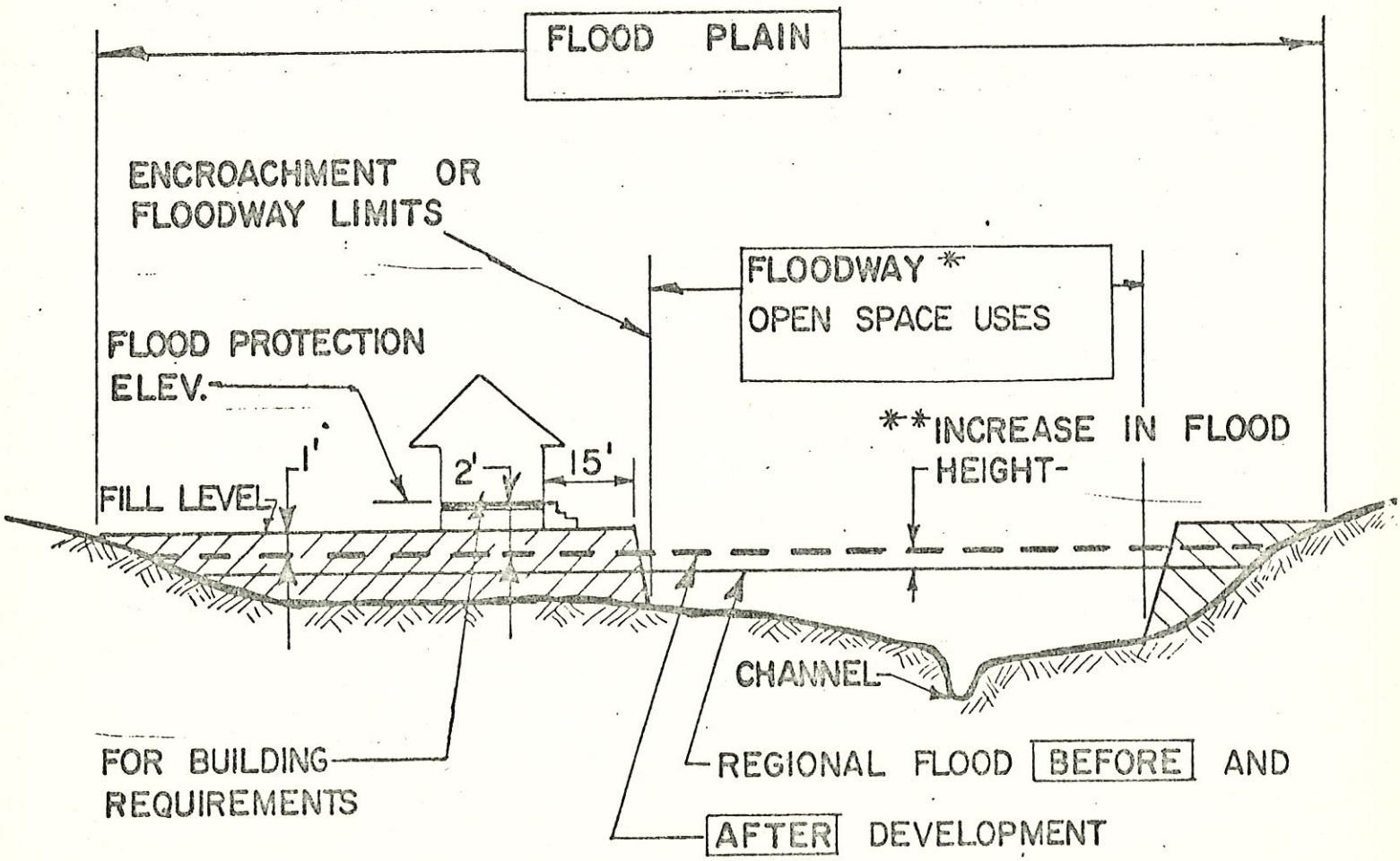
Flood plain management standards applicable to the delineated flood plains are simply related to two objectives -- the needs of nature and the needs of man. The first need is accommodated by retaining the channel of the stream and as much of the flood plain adjacent to the stream as is needed to convey the design

flood. This area is commonly called the "floodway" (see Figure 1). In some states the limits of the floodway are called encroachment lines. The standard permitted uses in these areas are "open space" uses that have a low flood damage potential. They include uses associated with agriculture, recreation, parking, sand and gravel operations and other related areas. Filling and structures not associated with open space use are not permitted in the floodway or between encroachment lines.

Fulfilling the needs of man and the community is achieved by requiring areas for flood protection outside the floodway, subject to inundation by flood waters. Such areas are generally contiguous to high ground. In times of flooding these areas are associated with lesser flooding depths and slow flood water movement. New buildings or additions to existing buildings, and areas used for storing materials that are buoyant, flammable, explosive or toxic must be elevated or floodproofed to the design flood elevation, in addition to appropriate amount of freeboard.



*That portion of the flood plain required to carry and discharge flood waters. The limits of the floodway are smooth lines that exclude areas associated with stagnant flood waters, intensive urban development and other areas not effective in conveying flood waters.



**Increases in flood heights result from filling and development on the flood plain.

FIGURE 1

Importance of and Need for Floodway:

Any filling or building on the floodplain will tend to increase flood heights. Although the effect on increasing flood heights of a single fill or building may be insignificant, the combined effect of a number of such projects over a long period of time could drastically increase the flood hazard. Ideal approaches to prevent obstructions on flood plains would be acquisition of the flood plain for open space use or establishment of land use controls to completely prohibit any filling, obstruction or structure on the flood plain. The first approach would generally be economically unfeasible for most communities to accomplish under present state and federal assistance programs, and the second approach undoubtedly would be adjudged unconstitutional.

Accordingly, land use controls reflecting the flood hazard must be developed in such a way that some reasonable uses are permitted on the flood plain without significantly increasing flood stages. This is usually accomplished by delineating a line (floodway) on each side of a stream which separates the effective hydraulic conveyance areas from the flood fringe areas or areas of intense urban development which are not greatly effective in conveying flood waters. Floodway lines must be established in such a manner that the loss of valley storage and hydraulic conveyance attributable to guiding future development outside the floodway will not increase flood heights more than applicable regulatory standards.

Tailoring Floodway to Local Needs:

Proper floodway selection, in addition to the hydraulic engineering considerations, reflect existing development and public facilities on or in the flood plain; local comprehensive land use plans; and local social and political concerns.

The following are some of the engineering and planning factors associated with floodway selection. These factors are portrayed in Figure 2. The engineering factors associated with the text herein have "E" prefixes and the planning factors are prefixed by the letter "P".

Obviously the character of flood plain development, types of flooding problems local concerns are unique for each community; therefore, factors controlling the selection of the floodway will necessarily vary for each community--even for adjoining communities along the same water course. Tailoring floodway selection to local conditions undoubtedly will result in many compromises, however, the increase in flood heights associated with any selection generally is inflexible under most state laws or rules..

ENGINEERING FACTORS OF FLOODWAY SELECTION

E-1. Design Discharge and Hydraulic Capacity:

The same discharge used for the delineation of the regulatory flood plain should be used as the basis to determine the hydraulic capacity or waterway area needed for a particular floodway. If, for example, the regulatory flood plain is delineated by the 100-year recurrence interval flood and the intent is to provide flood protection to the same flood, then the floodway must be of significant size to convey the 100-year flood discharge.

Federal and most state standards for the determination of the floodway and the delineation of the flood plain are based on the 100-year recurrence interval flood. Federal guidelines (5)-(7)[3] and state laws in some states (Nebraska, Minnesota, Michigan and Wisconsin, for example) require that the flood frequency be determined by the statistical technique endorsed by the Federal Water Resources Council.(6)

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3. Numerals in parenthesis refer to corresponding items in Appendix I - References.

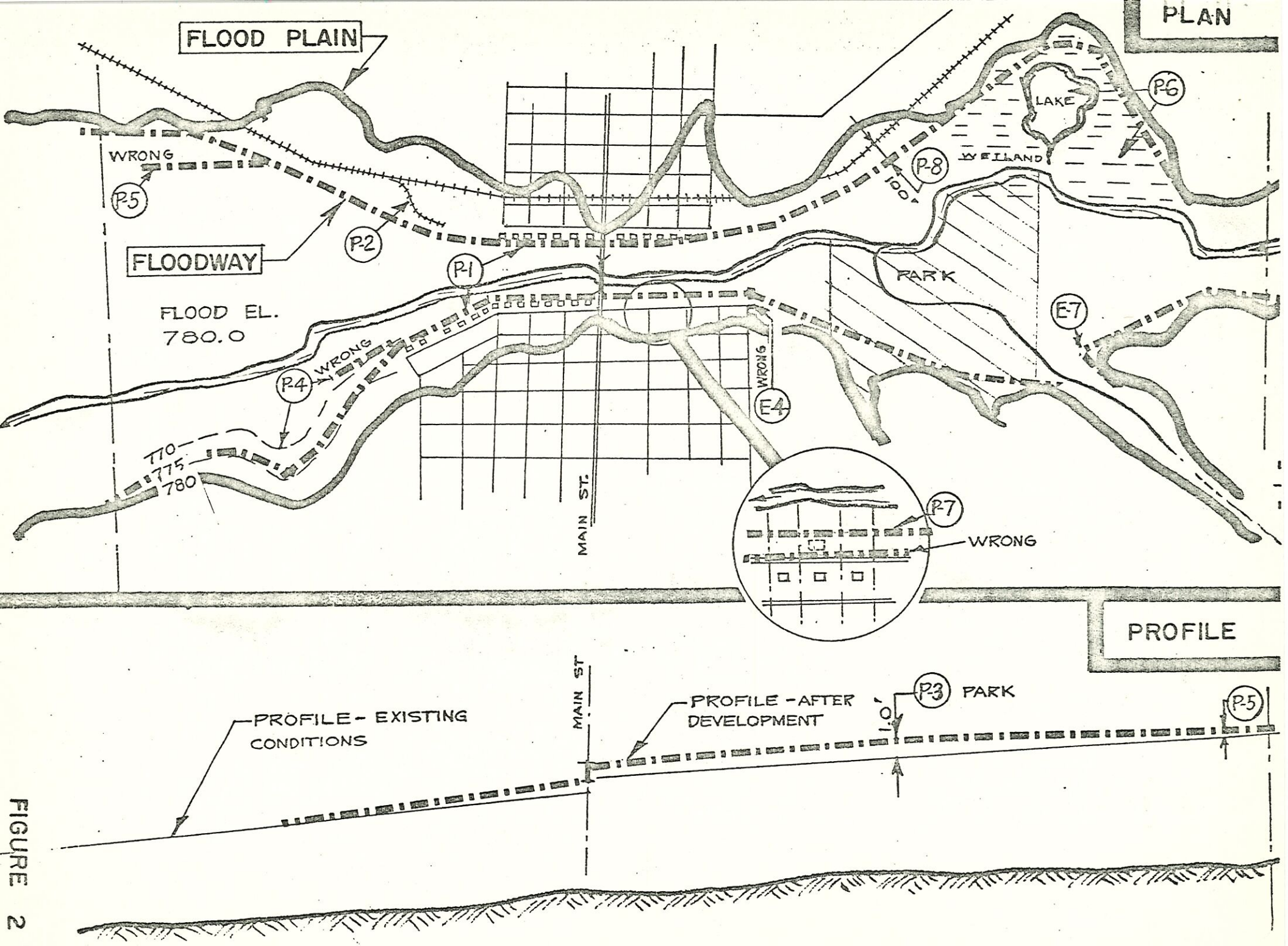

PLAN
FLOOD PLAIN
WRONG
P-5
FLOODWAY
P-2
P-1
FLOOD EL.
780.0
P-4
WRONG
770
775
780
MAIN ST.
E-4
WRONG
LAKE
P-6
WETLAND
P-8
100'
PARK
E-7
P-7
WRONG
PROFILE
MAIN ST
PROFILE - EXISTING CONDITIONS
PROFILE - AFTER DEVELOPMENT
P-3
PARK
10'
P-5

FIGURE 2

The natural floodway for a 100-year or any particular size flood is the by-product of the engineering judgements exercised in the calculation of the water surface profile for the 100-year flood or another selected flood under flood plain conditions at the time field surveys were done for valley cross sections.

Most agencies with the aid of a computer program (1) and other data and judgements use the standard step method for computing water surface profiles. The valley sections used for the computation are usually cut off near the flood plain limits to exclude the effects of areas not effective in conducting flow such as bays or inlets where expected water would be quiescent or eddying. The natural floodway is, therefore, determined by drawing smooth lines (deplicting uniform hydraulic flow patterns) connecting the cut-off points of the valley cross sections used for the original flood plain delineation. This procedure is representative of floodway delineation services provided for many years by the Tennessee Valley Authority.

Several of the Northeastern states use a multiple of the mean annual flood for the flood plain delineation and a lower multiple of the mean annual flood for the floodway delineation. The Southeastern Wisconsin Regional Planning Commission (SEWRPC), whose pioneering flood plain management efforts pre-date state flood plain management standards, have been used on the Root and Fox River Watersheds, the 100-year flood to delineate the flood plain and the 10-year flood plain for the floodway. Since the irregular 10-year flood plain limits never coincide with the smooth 100-year floodway lines, types of implementation problems frequently occur such as those shown in Figures 3 and 4.

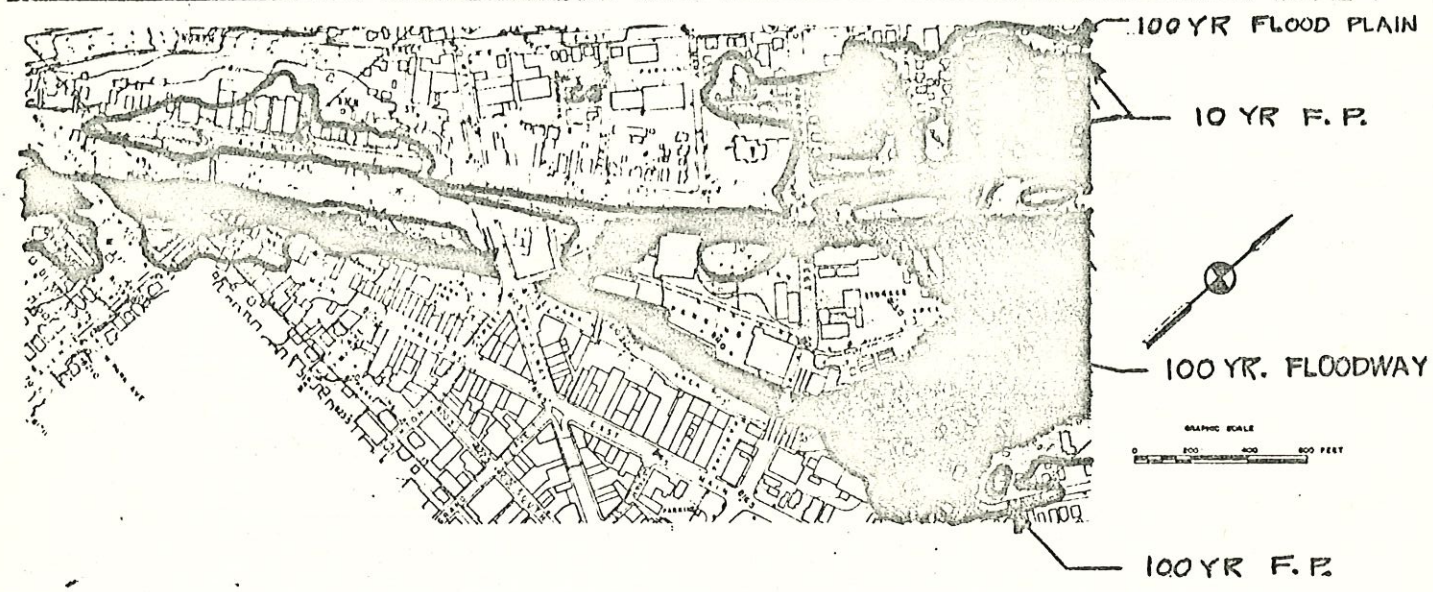


FIGURE 3

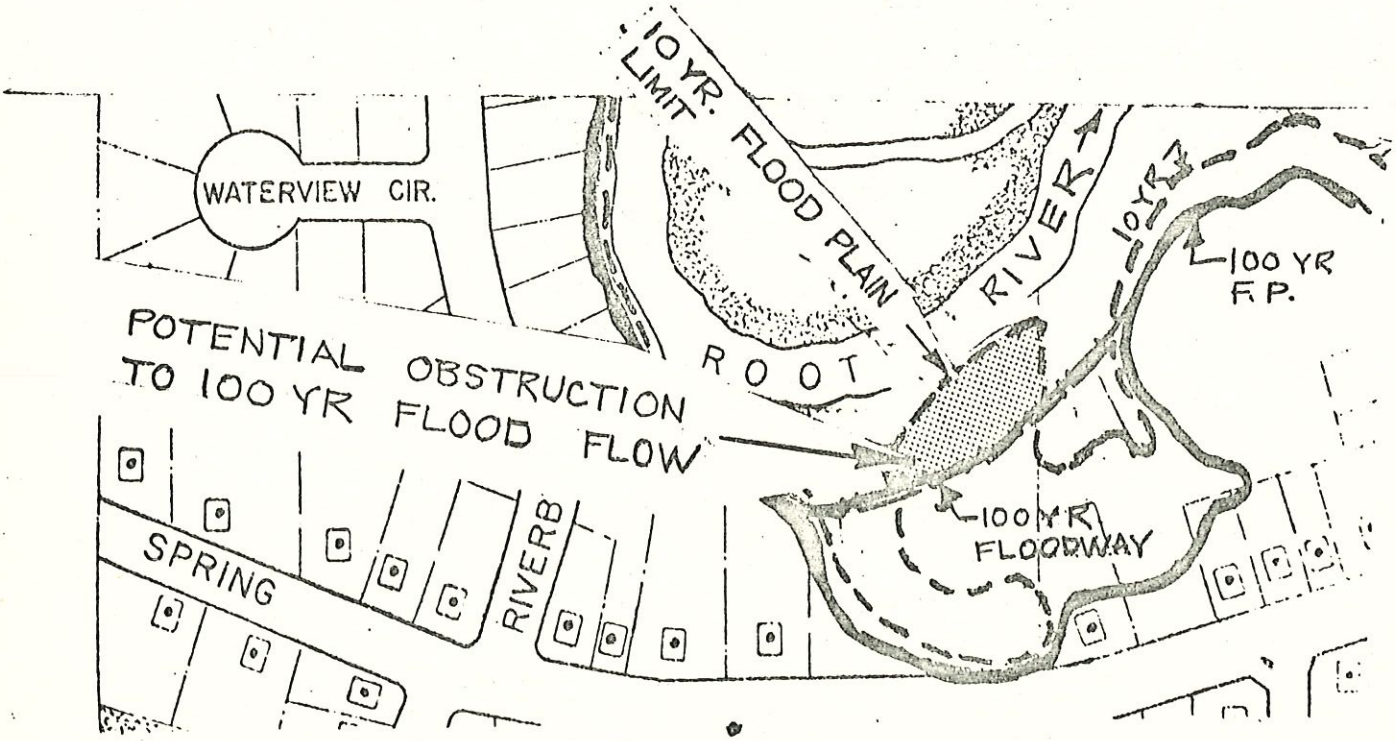


FIGURE 4

Figure 3 indicates that a large portion of the 10-year flood plain lies outside the 100-year floodway. Under the terms of the SEWRPC ordinance, fill and structures are prohibited in this area on the basis that this area is needed to convey flood flows. If, for example, a building permit was denied for a vacant lot in this area, the legality of such regulation would be questionable since the legal test of restricting development (the means) to preserve the carry capacity (the objective) is not valid outside the 100-year floodway. Although this area may serve as valley storage, courts have not sustained regulations solely for the preservation of valley storage(8).

Under the terms of the SEWRPC ordinances, fill and structures are permitted as conditinnal uses outside the 10-year flood plain. Figure 4 illustrates another potential conflict where such projects could be permitted in an area which would be within the 100 year flood floodway and tend to increase flood heights.

E-2. Increase in Flood Heights:

As previously stated, any filling or building on the flood plain will increase flood heights. However, if such development is limited to areas outside the natural floodway the increases in flood heights are generally incalculable. Exceptions to this rule are areas where potential loss of valley storage will be significant. The State of Michigan's flood plain, management program limits development to the natural floodway limit. The practice in the states of Wisconsin and Minnesota is in as much as possible to initially guide development outside the natural floodway.

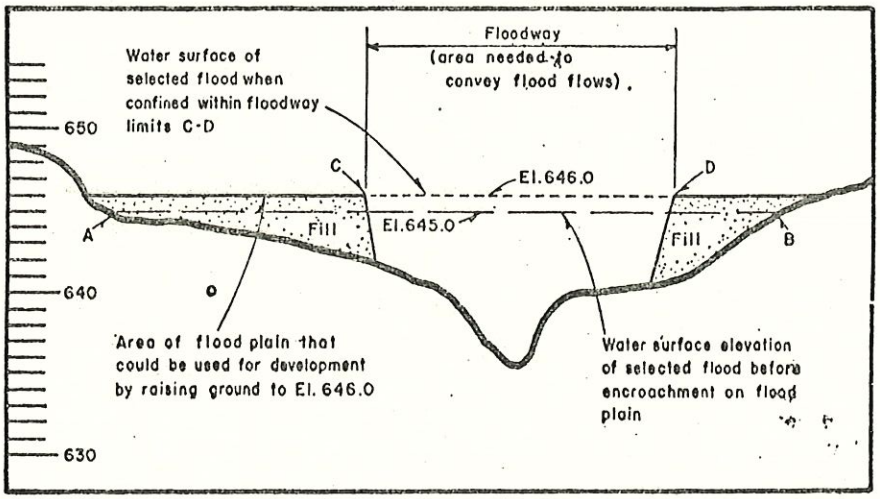
When existing development, comprehensive land use plans, and social and political considerations require use of the flood plains within the natural floodway, it is necessary to determine the changes in flood heights which will be attributable to the planned encroachment.

Increases in flood heights resulting from the adjustment of the floodway(encroachment) line riverward of the natural floodway are reflected in most state standards or federal guidelines[5]. These standards limit theoretical increases between 0.5 and 1.0 foot and vary in different states.

Iowa and Nebraska both have maximum backwater amounts of 1.0 feet. In Iowa's program, backwater is the controlling factor in floodway selection. On more or less a trial and error basis the floodway lines are adjusted until the increases for a hydraulic reach of a stream are uniformly one foot.

In the states of Minnesota and Wisconsin increase in flood heights in urban areas generally should not exceed 0.5 foot in any one reach or for the cumulative effect of several reaches of a stream. Heights greater than 0.5 foot may be permitted if existing uses and the community's comprehensive plan indicate that the affected area is and will remain under open space use. However, in areas where the flood plain is intensively developed, no increase in flood heights may be permitted. Where the fulfillment of community land use needs would increase flood heights above permitted levels, it may be necessary to consider channel enlargements or other factors to lower flood heights.

Figure 5, a drawing from the Public Works Magazine,[2] illustrates how the increases in flood stages are implemented in land use controls. In this drawing the horizontal long-dashed line between points A and B represents a flood level at elevation 645.0 in a valley cross-sectional view. In studying the effect of encroachments (a community development plan) on the flood plain, it is assumed that the channel and the portion of the flood plains between the encroachment line points C and D convey the selected flood. It is further



Valley cross-section shows the effect of fill on flood flow elevations.

FIGURE 5

assumed that the entire area outside the encroachment limits (but within the limits of flood inundation) will be filled.

By confining the same flood between encroachment limits C and D, the effective waterway area or floodway is reduced and the water surface elevation increases 1.0 foot in this example, or to elevation 646.0. This new elevation reflects the flood stage that would be created by the same flood under future flood plain developments.

Although the engineering studies assume that all of the land outside of the floodway encroachment line will be lost for hydraulic conveyance, it is unlikely in practice that all of this area would be lost for valley storage purposes unless the area was protected by a temporary or permanent levee. Most state programs, including Wisconsin, do not as a general practice study the loss of valley storage due to potential development outside the selected floodway. Exceptions are made where particular circumstances indicate that existing development patterns and land use plans will have a significant effect on valley storage. Some of the practical and economical reasons why valley storage is not calculated routinely in floodway selections in Wisconsin's program are as follows:

1. In practice, restrictive floodway encroachments are generally only applicable to short reaches of a water course in developed urban areas. The increased discharges associated with loss of valley storage for such encroachment generally result with a negligible increase in flood stages for the 100-year flood. In a typical stage-discharge rating curve for a stream, a significant increase in discharge will generally result with an insignificant increase in flood stages (the primary factor in land use controls) for large discharges in the range of the 100-year flood.

Where wetlands and other natural storage areas upstream from a community appear significant, these areas if adjoining the natural hydraulic floodway are reflected in the selected floodway as described planning consideration P-6.

2. Present open-channel flood routing methodology and computer application thereof have not developed to a stage for economical application for a state level program. It is unlikely the costs for additional field data and engineering studies could be justified since under present practice as previously described increases in flood stages attributed to loss of valley storage are minor.

3. Present case law makes the legality of regulations for the purpose of preservation of valley storage questionable (8).

4. State standards for flood plain regulations require one to two feet of freeboard above the 100-year flood level for flood proofing measures. Freeboard is a factor of safety that, among other things, tends to compensate for loss of valley storage.

5. Increase in flood heights due to valley storage is somewhat theoretical and unpredictable. The loss of valley storage under characteristics of some flooding events could lower flood heights by eliminating normal coincident peak flows from one or more tributaries. Additionaly, filling along smooth hydraulic flow lines represented by floodway limits could, particularly near bridge approaches, improve the hydraulic efficiency and lower flood heights by eliminating eddy losses from floodway fringe areas.

In most states, the calculation of backwater for floodway selections is done by modifying the field survey cross sections used for the initial flood plain

delineation. The calculation of the water surface profiles are based on confining the flow between the cross sections modified to reflect the floodway encroachment limits by the standard-step method (1) utilizing digital computers. Most states indicate the Corps of Engineers is the principal source of technical assistance in flood plain-flooding assistance. The U. S. Geological Survey, U.S. Soil Conservation Service and private consultants have also assisted some states in these studies. The states of Wisconsin, Minnesota and Iowa undertake state level flood plain-floodway delineation studies in addition to floodway studies using data derived from federal flood plain information reports.

The types and magnitude of problems increase with greater floodway encroachments. Because of varying topography it is difficult to generalize particular problems. However, of the studies done by the writer and information obtained from states previously described, it appears that the depths of water for the 100-year flood-one foot encroachment vary from 5 to 9 feet just outside of the floodway encroachment line. This also has the effect of leaving 50-75% of the flood plain outside the floodway for future development. Considerable lower depths of water are associated with the 100-year flood - 0.5 foot encroachment and accordingly less flood plain land is available for development. The floodway encroachment causing a one foot increase in the water surface profile tends to maximize and encourage the use of flood plains. This in turn creates implementation problems and adverse environmental effects such as the following:

1. The high flood depths for the 100-year flood near the selected floodway make flood proofing of structures impractical or unrealistic. This

could result with corresponding regulations being adjudged as unreasonable or a basis for variance in standards resulting with inadequate flood protection. Planning factor P-4 herein further discusses this problem.

2. In broad flood plains under different ownerships, new structures and development patterns built on fill above the flood level initially near the floodway before the land near high ground is developed create "island" type of development. This results in uncontrolled interior drainage problems. In addition, there are difficulties in the extension of public roads, sewer and other facilities at proper elevations when such facilities must extend from high ground across undeveloped land for a sizeable distance of the flood plain. Generally, this problem results with improper protection to these facilities, thus a primary objective of flood plain management is not achieved. Potentially large depths of water surrounding the "island" type of development could endanger life and cause public burdens for rescue and relief measures -- another objective of management.

3. Flood velocities increase near the floodway limits with greater degrees of floodway encroachment. Therefore, fill material placed outside the floodway is susceptable to erosion and a potential for water pollution. Initial development could also cause an alteration of flow distribution resulting in local scouring and deposition of stream sediment load.

The above problems can be minimized if the initial floodway selection is based on smaller increases in the water surface profile. Development can be easier guided from high ground toward the floodway limit. Since flood plain zoning regulations, like any type of land use controls, must be flexible to meet changing conditions and needs, future adjustments of the floodway line riverward consistent within the limits of applicable backwater criteria are possible.

E-3. Equal Degree of Encroachment:

When adjustments of the natural floodway lines are made riverward, legally sound flood plain regulations require, in as much as possible, the floodway lines be established such that the development rights on both sides of a stream are reflected. This is not determined by equal distance measured from the channel of both sides of the stream, but is determined by the loss of hydraulic conveyance due to planned development outside the selected floodway line on each side of the stream.

Through a water surface profile computer program designed for floodway encroachment (4) used by Iowa and Wisconsin equal hydraulic conveyance on both sides of the stream is determined. The computer prints out hydraulic characteristics for each valley cross section. At each subsection (determined by a change in Manning's roughness value) along a given valley cross section the incremental hydraulic conveyance is given. Thus, the limits of the floodway for a particular valley cross section can easily be set such that the total incremental hydraulic conveyance loss on one side of the selected floodway limit on the cross section equals the same total on the other side. This procedure is done for each cross section. The floodway is drawn by plotting on plan view the calculated floodway intercepts on each valley cross section and drawing a smooth line deplicting hydraulic behavior between similar intercepts.

Equal degree of encroachment is often not possible where other floodway selection factors govern such as the existing development, unusual topography or meandering stream conditions.

E-4. Hydraulic Transition:

Obviously flood flows ignore property lines and political boundaries. Therefore, the floodway lines should follow proper hydraulic flow configuration from one type of development pattern to another. Abrupt changes in the floodway line should be avoided.

E - 5. Effects Transportation Systems (3):

The location of the floodway lines are influenced by the location of a transportation system paralleling a stream and the amount of flow through bridge openings over the approach grades for the regulatory flood. Figure 6 illustrates, among other things, a railroad paralleling a stream. The railroad acts as the floodway limit or the dividing line between moving and stagnant water. Transportation systems paralleling the stream that encroach on the natural floodway have an appreciable effect on increasing flood heights. In general, this reach restriction of the floodway will have a greater effect on increasing flood heights than a point restriction associated with a bridge crossing.

Where the regulatory flood passes through the bridge opening without any overtopping of the overgrade, the floodway lines are transitioned into and out of the bridge opening as also illustrated in Figure 6. If the regulatory flood overtops the roadway, the floodway lines are positioned so the portion of the roadway that is overtopped by floods will be included in the floodway as shown in Figure 6. Under these conditions flood plain management would prohibit any filling and building that would make the overflow area ineffective.

E - 6. Location of Permanent or Temporary Flood Control Measures :

Flood plain regulations such as zoning, do not solve existing flood problems. Structural or flood control measures are effective in protecting existing developments on the flood plain if such measures are properly related to a flood plain management plan. Where applicable, the location of permanent or temporary flood control measures should influence the location of the floodway.

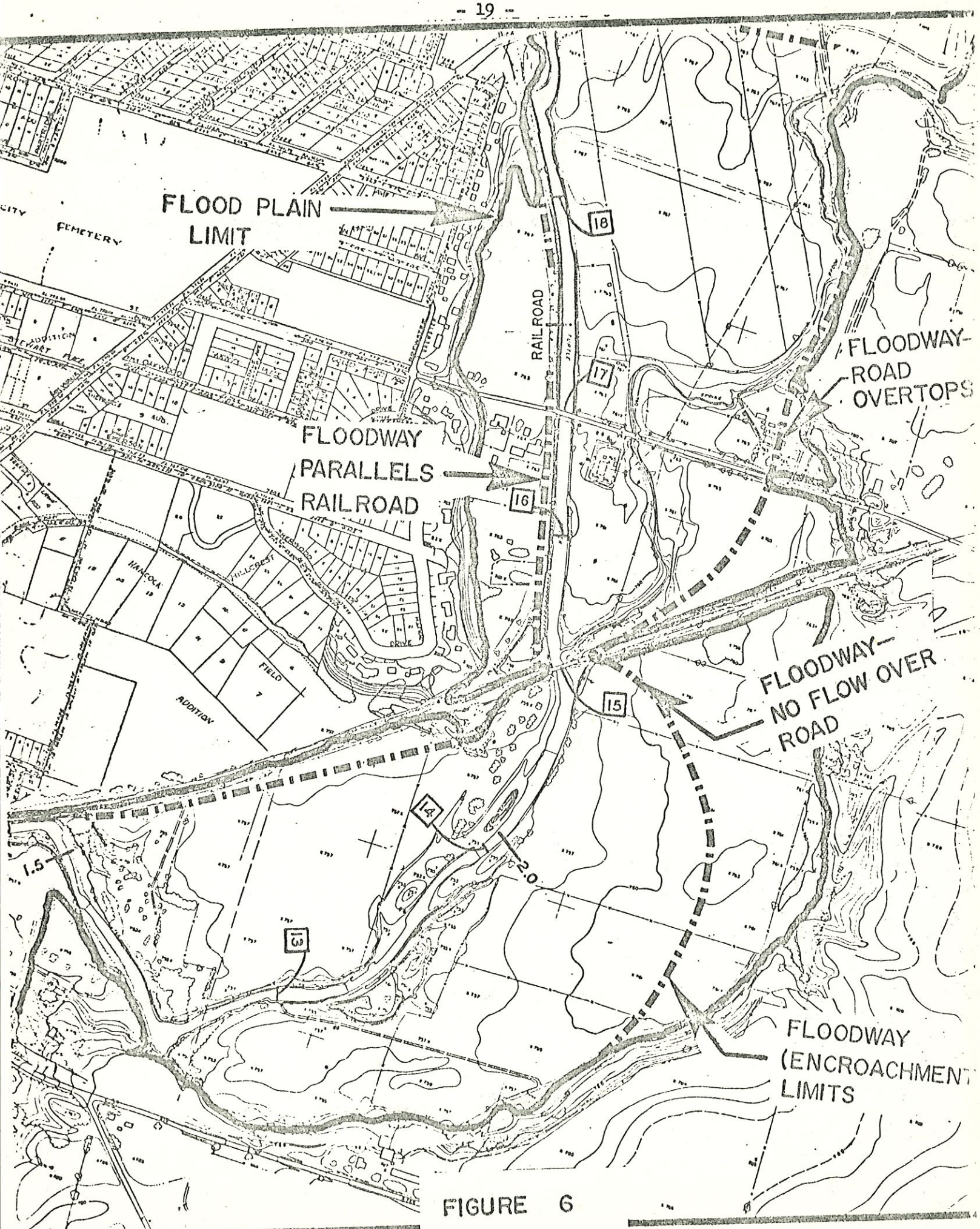

FLOOD PLAIN LIMIT
CEMETERY
RAILROAD
FLOODWAY-ROAD OVERTOPS
FLOODWAY PARALLELS RAILROAD
FLOODWAY-NO FLOW OVER ROAD
FLOODWAY (ENCROACHMENT LIMITS
ADDITION
HANCOCK
HILLCREST
DRIVE
FIELD
18
17
16
15
14
13
1.5
2.0

FIGURE 6

E - 7. Interior Drainage Considerations:

Frequently, the effects of tributaries, ditches and other lateral water courses are ignored in the delineation of the floodway for the main river or stream. When the floodway line cuts across tributaries this generally implies to the non-technician that fill or development is permitted outside the floodway of the main stream. Therefore, this could result with obstructions on watercourses that contribute run-off to the main stream. Lateral drainage patterns or watercourses should be reflected in the delineation of the floodway on the main stream as substantial damage can occur along these tributary streams.

PLANNING, SOCIAL, POLITICAL ASPECTS OF FLOODWAY SELECTION

P-1. Existing Development:

Floodway lines should generally follow the riverward side of existing building patterns. The character of existing development and plans for permanent evacuation and urban renewal are also considered in the location of the floodway line in developed areas. In conventional zoning, the establishment of a residential district does not bisect areas presently used for industrial purposes. The floodway, characterized by open space use, likewise should exclude areas of intense development to minimize the extreme hardships associated with non-conforming structures in the floodway.

In designing a levee system to protect an urban area, it is not always possible to protect all developments due to such things as topography, physical location of a particular development with respect to the main area to be protected and economics. Because of these and other engineering and planning factors for floodway selection, it is not always possible to exclude all dwellings from the selected floodway. In these cases, to prevent unnecessary

legal attack and individual hardships, these properties should be given first priority for land acquisition. Additionally, these areas are associated with large depths of water and velocities where the greatest danger to life and property is expected.

The availability of existing streets, rail transportation, ports or harbors, water, sewer and other public services or facilities must also be considered in floodway selections. It is unlikely that zoning, for example, prohibiting residential buildings where there has been prior investment of public funds for these services would be upheld as reasonable.

P-2. Community Comprehensive Plans:

Flood plain regulations as well as any land use controls must be related to and made part of applicable regional and local comprehensive land use plans. The floodway selection should reflect planned areas for residential, commercial, industrial, park, and other areas including plans for extension of streets, water and sewer. Recently approved subdivision plats or similar decisions governing land use made by the community are also important elements in floodway selection.

In some communities steep bluffs or unique topographic features and political boundaries preclude future community growth outside the flood plain. Therefore, the floodway must be selected to provide for some reasonable community growth, such as establishing a floodway line that represents the extension of existing development paralleling the watercourse. The actual set-back of the floodway line in this example would be governed by the permissable increases in the water surface profile as discussed in Engineering Factor E-2 of this paper.

P-3. Increase in Flood Heights:

The engineering factors (E-2) associated with increases in the water surface profile have been previously discussed. Also discussed were the uncontrolled development and environmental problems associated with severe floodway encroachments, particularly in undeveloped flood plain areas. However, to accommodate existing development factors discussed in P-1, large increases (around 1.0 feet) in the water surface profile can be expected. Generally, these increases can be tolerated where the affected area is in open space use (for example, a golf course or municipal park) and where there are assurances that local land use plans and controls will be implemented in such a way that the land will remain open space. On the other hand, where the affected areas are highly urbanized, no increases in flood heights should be permitted. This is of particular importance in broad flood plains where any increase in flood heights could affect large areas of existing urban development and where the expected increase in flood heights is attributable to future or planned developments downstream from the urban development.

P-4. Flood Depths and Velocities:

Flood depths and velocities in flood prone areas excluded from the floodway should be small and reasonably compatible with the regulations and degree of safety for permitted uses outside of the floodway. For example, if the depth of the regulatory flood level was 10 to 12 feet for a sizeable area, regulations requiring residential buildings to be placed on fill above the flood level or structurally flood proofed to the flood level could be construed to be unreasonable and may not provide the required safety to the building or to human life. Under this example, such potential problems could be eliminated by shifting the floodway line away from the river until the depths and velocities outside of the floodway are consistent with the permitted zoning uses such as residential, commercial and industrial.

Although there is no rule of thumb on practical fill heights (especially where proposed fill will be done by and for a grading contractor or where a waste site is needed for a nearby construction project), the economical or practical upper limits to structurally floodproof a residential dwelling to withstand hydrostatic pressures is about four to five feet. Commercial areas can generally be floodproofed to greater depths (5 to 6 feet) except where danger to life and inadequate flood warning time, for example, would require lower flood depths such as for a large shopping center. Because of the many floodproofing structural alternatives for industrial areas, flood depths in excess of 10 feet may be exceptable for certain industrial areas. A warehouse for storage of steel beams, for example, could be placed at natural ground level and designed in such a way to provide for passage of floodwaters through the structure without increasing the flood damage potential and not conflicting with other flood plain management objectives.

Flood velocities for the regulatory flood should not exceed 2 or 3 feet in residential areas or areas designed predominately for human occupancy. A rule of thumb frequently used in practice is that the product of the depth of water and the velocity should not exceed 7 for areas associated with human occupancy or habitation. Higher velocities may be permitted in other areas.

The most frequent problem of floodway selections encountered in the administration of adopted flood plain regulations in Wisconsin is the unreasonably large regulatory depths attributed to the manner in which the initial floodway was delineated.

P-5. Plans of Adjoining Communities:

As previously mentioned (E-4), floods ignore political boundaries or abrupt changes in direction. Therefore, there must be proper hydraulic transitions between the floodway and flood plain development plans established by adjoining

communities. In addition, any increases in flood heights attributable to a floodway selection of one community should have negligible affects on adjoining communities or, in any case, not more than 0.5 feet. For acceptable floodway selection affecting more than one community, it is essential that representatives from these communities actively participate in the selection.

P-6. Wetlands, Existing Bodies of Water, Unique Environmental Features:

As stated previously, the establishment of a floodway line implies to non-technicians that areas outside the floodway can be filled or developed. In many cases, adjoining but outside the "hydraulic" floodway there will be areas where non-hydraulic principles will dictate an adjustment of the floodway lines so that the floodway will include such things as wetlands, existing bodies of water and unique environmental features in order to minimize the following types of common problems:

1) The development of land unsuitable for building sites as delineated on detailed soil maps. This concern is especially important for areas not served by public sewers. On site waste disposal systems (for example, septic tank soil absorption systems) can cause pollution problems in soils that are too dense or tight to allow adequate percolation of effluent. (The soil becomes clogged and the system ceases to operate.) Other soils are too porous and allow the effluent to percolate too quickly. In addition, it is obvious that effluent cannot be adequately treated where there is high ground water. Under Wisconsin law, there must be at least three feet of soil between the bottom of the soil absorption system and high ground water or bedrock. Another three feet above the system is also required. The percolation rate must not exceed 60 minutes for the water to fall one inch in a prescribed test hole.

Also under Wisconsin law, no septic tank-soil absorption systems are permitted in the flood plain. Therefore, in rural areas where there are no public sewer

facilities, no floodway is initially delineated to avoid conflicts with other applicable health laws.

2) Filling of wetlands. Wetlands are areas where groundwater is at or near the surface much of the year. Tamaracks, sphagnum moss, sedges, cattails, reed and bulrushes are typical wetland vegetation types. Wetlands are seldom suitable for building for the following reasons:

a) as stated above, septic tank systems will not function because of high groundwater.

b) private water supplies are often polluted by septic tank wastes that have not been adequately absorbed by the soil.

c) transported fill may not have the absorption qualities needed to treat septic tank wastes.

d) foundations of buildings and roads develop structural problems due to frost action and the settling or stabilization of the ground over a period of years.

Preservation of wetlands are necessary for many ecological, water pollution, and environmental reasons. Wetlands act as a natural filter for sedimentation and nutrients that contribute to water pollution. Wetlands provide for storage of flood waters. Although the storage areas may be of less importance for floods in the magnitude of the 100-year discharge, these storage areas generally have a significant effect on reducing adverse flooding for the more frequently occurring floods. In addition, wetlands provide prime spawning grounds for fish and necessary nesting sites for waterfowl. The natural plant and animal communities found here provide ecological balance to a watercourse.

To minimize possible legal attack on land use controls reflecting the foregoing in that the means (preservation of fish spawning grounds for

example) do not accomplish the objective (flood damage prevention) the following considerations are suggested where there is a significant deviation from the "hydraulic" floodway:

a) The areas previously described as unsuitable for building sites must be contiguous to the "hydraulic" floodway.

b) The purpose of the floodway district in the text of a zoning ordinance for example, must clearly state that in addition to preserving the hydraulic capacity of the stream, the floodway has been delineated to protect prime wetland areas, valley storage, etc., for specific objectives applicable to the particular area. It may also be necessary to name the zoning district to coincide more specifically with the objective of the floodway selection such as "Floodway-Storage District".

P-7. General Legal Considerations (8):

Because floodway regulations stringently restrict development, it is particularly essential that they be carefully conceived and delineated to meet constitutional arguments such as:

(a) Equal degree of protection - so far as possible, the floodway lines should be located to provide for the same degree of hydraulic conveyance on each side of the stream. As described in E-3, this does not mean that lines should be located at equal distance from the outer of the stream since ability to pass a proportional amount of flows depends upon many other factors.

(b) Permit reasonable uses - Arguments that floodway regulations "take" property are likely since most uses are prohibited in this area. Courts have sustained severe restrictions for development which, like floodway development, will have nuisance-like effects upon other lands. Likewise, Constitutional attacks may also be averted if some consideration is made in location of the lines not to prevent all economic uses for individual

properties. In some instances, it may be sound from a hydraulic standpoint to include one whole property in the floodway or to shift the area slightly to include only portion of that property and a portion of another. The latter approach to permit some limited development on both properties would be more likely to meet the equal protection argument.

P-8. Identifiable Land Features:

Although the hydraulic flow limits of the floodway ignore property lines, political boundaries, and abrupt changes in direction, there are times when it may be possible to select the floodway to coincide or parallel some identifiable land feature such as a street or railroad, fence or power line, old levees and property lines. Where the floodway parallels such features for a significant distance,it is desirable to dimension on the floodway map the appropriate separating distance. The inability of officials and affected landowners to accurately locate the floodway on the ground is a major problem in implementation and administration of flood plain regulations.

TYPICAL PROBLEMS IN FLOODWAY SELECTION

The following is a summary of typical problems described by the states and organizations that responded to the questionnaire, excluding Wisconsin: The comments are listed in their entirety without listing the source or without regard to duplication.

1. (a) It is difficult to limit the increase in flood stage to exactly 1.0 feet for the length of a study reach.

(b) Several computer runs have to be made before a final degree of encroachment can be accepted.

(c) It is often difficult to locate precisely the encroachment limits such that they can readily be identified in legal documents needed for appropriate local flood plain regulations.

(d) The encroachment studies are often quite time consuming.

2. (a) Our major problem associated with floodway delineations is obtaining adequate valley cross sections from the consulting engineers.

3. (a) Lack of current mapping of sufficient detail to adequately delineate the flood plain.

(b) Lack of gauge records and length of records to properly develop frequency curves.

(c) Lack of funding of the program by the State Legislature.

(d) Shortage of qualified technical staff.

(e) Lack of public understanding of flood plain regulation as a worthwhile supplement or alternative to flood control.

4. One of the main problems which we have encountered in the use of floodway delineation materials both for flood plain delineation and floodway delineation is the accuracy which the public assumes in connection with these studies. The location of lines are based on either the measured distances from a known landmark or centerline of the stream or from photo interpretations of aerial photography. Particularly, the location of a line at the edge of the flood plain is very hard to delineate and can only be accurately determined after a close interval topographic map has been obtained.

In general, we have found the delineations have been accurate but that problems do exist when they are not checked against field surveys for particular individual locations. In general, the information contained in our Selected Floodway Studies has been well accepted and well received by developers, and

the regulatory agencies. The need for a local agency with personnel trained in the interpretation of this type of information and who can work with developers and landowners in the floodway is of great need to make any flood plain management program successful. It is generally impossible for State agencies to adequately provide this information to all who seek it. I say this because of the numerous daily inquiries which are fielded by this office.

5. (a) Inadequate documentation of engineering judgments used in developing flood plain information study.

(b) Use of different computer program by agency doing floodway analysis.

(c) Lack of field survey data at "key" locations in study reach where the effects of various development patterns should be studied. Often this may be avoided by pre-planning for flood analysis before the delineation study is ever started.

(d) To what extent would "equal degree of encroachment" concept be used in selecting floodway.

6. (a) Costs per mile.

(b) Difficulty in relating allowable increase in water surface profile to length of reach (i.e., 1'/mile, etc.)

(c) Estimating extent of topographic coverage required before design water surface profile is computed.

(d) Number and spacing of cross-sections.

(e) Effective communication with the public.

(f) Incompatability of techniques and methodologies between state and federal agencies. (C of E, USGS, S.C.S. & HUD).

(g) Underfunding of State programs which limits application of delineation studies to comprehensive flood plain management.

CONCLUSIONS

Successful floodway selection goes beyond the scope of the single purpose factor-open channel hydraulics. The selection not only involves the assistance of engineers familiar with the hydraulic characteristics of flood flows, but equally important, local officials, attorneys, planners, engineers, private developers and real estate interests that are familiar with present and future community needs for parks; residential; commercial and industrial areas; public utilities and land acquisition programs.

Since any decision for planned flood plain development will influence flood flows, it is essential that the hydraulic engineer act as a leader in coordinating the team approach to floodway selections. He should guide local decisions properly where, in his judgment, their selections would cause adverse flow conditions. When the selection of the floodway can be initially worked out within the scope of governing criteria for increases in the water surface profile, duplication and costs for engineering studies will be minimized.

Floodway studies can also be done more economically if at the time of selecting valley cross sections for basic flood plain delineation, survey data is obtained for anticipated floodway studies. In most cases, this can be accomplished at no additional expense.

Many problems in the implementation of floodway regulations can be avoided if the selected floodway in as much as possible conforms to the natural floodway for the regulatory flood or where backwater amounts are under 0.5 feet. When adjustments are made to accommodate existing and proposed developments, the flood depths outside should be in agreement with practical floodproofing limitation for the affected land use districts such as residential, commercial, industrial and parks. When both the engineer and

the community gain experience implementing floodway regulations or when political or development pressures arise, the floodway lines can be amended to provide for greater flood plain use within governing backwater criteria.

APPENDIX 1 - REFERENCES

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