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UTILIZATION, PLANNING, AND PROBLEM EVALUATIONS OF URBAN ARTERIAL WATERWAYS AND CORRIDORS AS AN URBAN RESOURCE

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THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

UTILIZATION, PLANNING, AND PROBLEM EVALUATIONS OF URBAN ARTERIAL WATERWAYS AND CORRIDORS AS AN URBAN RESOURCE

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

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degree of

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BY

LAILA RASHEDI-ASHRAFI

Norman, Oklahoma

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UTILIZATION, PLANNING, AND PROBLEM EVALUATION
OF URBAN ARTERIAL WATERWAYS AND CORRIDORS
AS AN URBAN RESOURCE

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ABSTRACT

Widespread concern about flooding and possible use of the nation's urban river corridors has generated unprecedented interest in the potential for utilization of urban riverine corridors while simultaneously protecting the environment. This research effort is directed toward the development of a conceptualized plan to utilize the arterial waterways and intermittent streams as a resource and an asset to the community, so that existing problem areas can be economically transferred into useful and feasible activity centers. Flooding problems and methods of flood mitigation, both structural and non-structural are presented. Physical effects of certain practices, such as sand mining and its effect upon flooding, sedimentation, river regime changes, erosion and backwater are also presented. A river corridor plan is invoked on the basis of a study of the soil, topography, vegetation, hydrology and cultural features assembled and an array of potential benefits from reclaiming the corridors presented. A multi-purpose, multiple-approach river corridor plan strategy has been developed and general application to riverine corridor areas has been made.

ACKNOWLEDGEMENTS

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The author also would like to express her thanks to her husband, Karim, for his patience, understanding, encouragement and unyielding support which was needed to complete this work.

To My Brother

Ali

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CHAPTER I

INTRODUCTION

One of the basic problems facing the world is the pressure of an increasing population with aspirations for higher living standards and even more environmental demands upon already overburdened land resources. The quality of the environment is as much a major public concern as is the availability of land resources. People today, more than ever before, need areas where they can escape from the pressure and demands of everyday life and enjoy outdoor recreation activities. The number of people participating in recreational activities is increasing at an all time increasing rate. This is the result of urbanization, reduced working hours, increased leisure time, rapid modes of transportation and increased discretional income. Based on a National Park Survey report, [57]*, 68,000,000, and 268,000,000 people visited national parks in the United States in 1957 and 1976 respectively. This amounts to more than one annual visit for each American. Every weekend and holiday, millions of Americans flee the congestion of the city seeking refuge in the beauty and tranquility of the natural environment. In so doing, they are fulfilling a need which is basic in most people--the need to "get away from it all".

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*Numbers in brackets refer to References.

Urbanization has also resulted in an increased volume of storm runoff, resulting in localized flooding. Johnson [23] has estimated that storm runoff volumes may increase two to three times following the urbanization of small desert watersheds in the semiarid regions of the Southwestern United States. The volume of runoff can be anticipated and flooding in riverine corridors can be reduced by means of proper storm water management techniques and appropriate corridor planning.

Historical evidence indicates that most cities are of necessity usually situated on or near a river or some other body of water. River flood plain areas and riverine corridors are a bonus urban commodity. These areas can serve a variety of purposes; the adjacent river channels can be used as a water supply source as well as a multipurpose drainage conduit; the riverine bank itself can be used as a petrographical aggregate source, and the stream bed can be used as a source of sand, gravel or other mineral extraction.

Stream beds and riverine corridors are an important, but as yet mostly a nonutilized resource of the urban community, with high potential value and special functions in the urban scheme of economics, social, cultural, recreational, educational and commercial development. They offer sites where recreational facilities would serve as buffers for developed areas, provide linkage to adjacent neighborhoods and public facilities, provide wildlife habitates, protect areas of scenic importance to the community, provide vista access to areas of beauty, and would serve a need for areas of solitude where people could enjoy outdoor recreation facilities.

Up to the present this important community resource has not been fully utilized. Most urban stream corridors have been used as promiscuous dumps and general disposal areas for all types of refuse and cast-off materials. Many people do not view the stream corridors as places of beauty along which one can commune with nature, picnic, play or relax. Most municipalities have not seriously considered the use of stream or riverine corridors as a resource. During past decades municipal responsibility in the corridor area has been generally limited to flood control structures and other hydromechanic measures to reduce damages resulting from high waters.

Most professionals with a vision to the future recognize that urban stream corridors, their beds and adjacent riverine environments are an integral part of the community's historical, cultural, and recreational heritage. The maintenance, enhancement, restoration, protection, and well-being of the corridor, its banks and tributaries in a natural or near-natural state should be a goal or policy of urban municipalities.

It can be advantageous to modify these areas from existing uses or nonuses to recreational or other beneficial uses, such as camp-sites, jogging trails, dune buggie areas, children's parks, open spaces, fishing areas, rookeries, and a maze of other sites of recreational activity. However, the water quality and ecological state of the specified and designated corridor areas must be preserved and maintained at its natural environmental state and not be permitted to deteriorate as the result of corridor planning and activity.

It is the purpose of this study to focus on adaptation of the appropriate and available corridors for the manifold purposes for which they can be used. Further, it is an important goal to formulate and evaluate all of the existing alternatives in planning and management of stream corridors.

CHAPTER II

OBJECTIVES OF THE STUDY

The general objective of this study is to compile a plan, or strategy, to utilize the arterial waterways and intermittent streams as a resource and an asset to the community rather than a detriment or an unwanted responsibility.

The specific objectives of this study are:

1) To provide the most economically feasible methodology to elucidate the mitigation strategies of urban flooding, channelization, detention, diversion, land treatment or combination of these practices.
2) To study sand mining or other mineral removal practices in order to assess the benefits, detrimental factors, and potentially useful effects of permitted mineral removal, and subsequently to set forth or prepare a set of guidelines to minimize the hydrologic, hydraulic, and other physical impacts of sand mining activities.
3) To develop a general plan for stream channel corridors so that existing problem areas can be economically transformed into useful and feasible activity centers. And to preserve, or reserve the appropriate areas of ecological sanctity.

4) To predict and qualitatively assess the impact of each alternative on the physical, chemical, biological, cultural, and socioeconomic environment.

5) To present the great potential benefits from using the corridors for recreational, nature trails, etc. for the general public good while promoting ecology.

The problem areas that merit attention and research in this water-related study are as follows:

I. Flood Flow Abatement Practices

1. Channelization
2. Detention
3. Diversion
4. Land Treatment

II. Sand Mining Activities

1. Current Practices
2. Detrimental Effects
3. Beneficial Effects
4. Legal Aspects
5. Hydrologic and Hydraulic Response to Sand Mining

III. Recreational Use of the Flood Plain Corridors

1. Sports, Pathways, etc.
2. Dune buggie and rough terrain environmental activities
3. Bank stabilization - conjunctive use

IV. A Riverine Corridor Plan

1. Economic Viability and Value
2. Community affectation
3. Easement and Probable Condemnation as requisites
4. Community responsibility
5. Integrated Flood Plain Management Program

CHAPTER III

COMPUTERIZED LITERARY SEARCH

A formal literary search and information acquisition can best be accomplished at this time by means of computerized data bases. The great speed and depth of coverage using this technique obsoletes the archaic search procedures that were used only a decade ago. The results of any computerized literary search/survey will depend upon the key words selected by the searcher, and how thorough and complete the computerized information was described. There are many computerized data bases that may be used. The appropriate base or bases selected are determined by the nature of the problem at hand.

For the purpose of this study a literary survey was performed by an extensive computer search of several pertinent available data bases, namely: NTIS (National Technical Information Service), Compendex, SSIE (Smithsonian Science Information Exchange), C.D.A. (Comprehensive Dissertation Abstracts), CRIS (Current Research Information System), SCI (SciSearch), Enviroline, WRSIC (Water Resources Scientific Information Center), and the National Newspaper Index information retrieval systems. The search was performed to provide the historical literature applicable and pertinent to problem under consideration.

The search has indicated that few similar studies have been performed in the past, however, there are some marginal studies that are related to the topic addressed in this project.

The initial and, ultimately the most fruitful information was obtained from the NTIS computerized data base. Initially the NTIS output provided about sixty pertinent references, however, only about twenty of these were actually relatively very close to the subject at hand. In addition to NTIS results, two papers were discovered in the journal of the Urban Planning Development Division and Civil Engineering respectively, namely "An Unusual Challenge - American River Parkways", [28] and "Regional Flood Plain Management" [29] which were discovered in the query of the Compendex data base. The other databases provided essentially nothing that was not found by the NTIS or the Compendex system.

The carefully selected final list of key words used in the computerized search are listed in the Appendix.

A general description of the data bases that have been used in the computer search, will be described alphabetically in the following paragraphs:

C.D.A.

Comprehensive Dissertation Abstracts is produced by University Microfilms International (UMI). It is a subject, title, and author guide to almost every American dissertation accepted at an accredited institution since 1861. It contains approximately 99 percent of all American dissertations, thousands of Canadian dissertation, and an increasing number of papers accepted in institutions abroad. This data base has monthly updating activity with about 3500 new citations each month.

Compendex

The Compendex data Bases is the machine readable version of the Engineering Index which provides worldwide coverage of the journals, literature, publications of engineering societies and organization, government reports and books. It is an interdisciplinary index to the world's engineering developments which provides about 7000 citations per month.

CRIS

Current Research Information System provides access to agriculturally related research information. It covers current research projects in agriculture and allied Sciences, conducted by USDA research agencies and other cooperating state institutions. The subject coverage of CRIS covers biological, physical, social and behavioral science related to agriculture including natural resource conservation and management, rural development, environmental protection, regional development, forestry, outdoor recreation, housing, etc.

Enviroline

Enviroline is produced by the Environmental Information Center. It consists of abstracts and citations (79000 citations since 1971), which provides interdisciplinary, scientific, technical, and socio-economic coverage of the major English-Language and more important non-English Language environmental and resources literature.

Environmental abstracts include approximately 10,000 unique abstracts per year drawn from over 5000 periodicals, symposia, governmental and institutional reports, and other primary and secondary sources.

National Newspaper Index

The National newspaper index provides a valuable adjunct in the areas of market research, journalism, public relations, government relations, and the social sciences.

It provides a complete indexing of the Christian Science Monitor, The Wall Street Journal, and The New York Times. All articles, news reports, letters to the editor, editorials, product evaluations, biographical peices, etc. are included in the National Newspaper Index.

NTIS

The National Technical Information Services (NTIS) data base consists of government conducted research, engineerig reports, journal articles, and translations prepared by Federal agency contractors. (It represents the reports of over 300 federal government agencies.)

The NTIS data base includes topics of immediate, broad interest such as environmental pollution and control, social problems, energy conservation, technological transfer, urban and regional development and planning. It provides about 5000 new unclassified, unlimited distribution reports available to the public per month.

SciSearch

SciSearch is produced by the Institue for Scientific Information

(ISI). It contains records published in Science Citation Index (SCI) and records from a series of current contents of Publications which are not included in the printed version of SCI. SciSearch is a multidisciplinary index to the literature of Science and Technology which covers every area of the pure and applied sciences.

SSIE Current Research

The Smithsonian Science Information Exchange (SSIE) data base includes summary of research either in progress or completed in the past two years. It consists of all fields of basic and applied research in the engineering, physical, social and life sciences. Project's summaries are indexed in depth by professional Scientists and engineers. Project descriptions are received from over 1,300 organizations. Approximately 90% of the information is provided by agencies of the federal government. SSIE provides about 9,000 projects per month and contains about 170,000 citations as of June, 1978.

A brief review of the available literature is presented as follows:

In 1968, [28] a parkway planning effort along the American River through the Sacramento urban area was adopted in order to provide a viable facility that could serve many interests of the community and to preserve and protect the parkway for future generations (Don H. Nanle, F. ASCE and Walt S. Veda, 1977), [28]. The plan contained two broad categories of uses, natural and recreational areas. Types of development, and where it could take place, the type of recreational activities, boundary of the parkway and existing and future access location were spelled out by the Plan. Recreational activities recommended for the Parkway varies from water-oriented activities such as swimming, fishing, boating and rafting, to hiking, horseback riding, bicycling and picnicking. Continued urban development adjacent to the Parkway and increased recreational use of the Parkway presented unexpected problems. In order to protect the parkway and provide guidelines for future use and development, five land use categories were designated based on topography, geology, type of soil and vegetation, wildlife, drainage, existing patterns of use and accessibility. The recommended land use categories are: 1) open space preserves; 2) nature study areas; 3) protected areas; 4) limited development areas; and 5) developed recreational areas.

In May 1971, [16] a Greenbelt planning program was proposed by the Stillwater, Oklaoma Greenbelt Committee and city officials in order to establish and develop a greenbelt as a part of recreational areas and other open spaces serving the Stillwater urban area. The plan envisions a greenbelt along the Boomer and Stillwater creeks, with areas of concentrated development ("nodal areas") connected by linear open space elements along the two streams. The purpose of the Greenbelt was to: preserve and enhance scenic natural areas; provide recreational and cultural facilities and other attractive open spaces for the enjoyment and benefit of the community; maximize benefits and minimize adverse effects of the flood control measures; and to include in the greenbelt, lands that can be used for at least two of the five major open space functions, such as amenity, conservation, protection, production and recreation. Type of facilities proposed to be located in the nodal areas and in the linkages connecting the nodal areas are: bicycle trails, nature trails and pedestrian paths, equestrian trails, picnic areas, parkways, playfields, neighborhood playground and recreation centers. The priorities given each recreational use were derived from a recreational demand survey conducted by the students of Oklahoma State University.

Pursuant to earlier plans for using the Potomac and Anacostia River Banks (District of Columbia) H. Conard et al. (1972) (29) prepared a proposal for waterfront development along the two rivers to preserve amenities as well as respond to the demand for growth and change. In order to provide increased opportunities for recreation and to meet the needs of a growing population, a wide variety of activities and land uses were proposed based on different locations and existing conditions. Among the recommendations are: use of river for swimming, fishing and boating; aquatic gardens, different types of park and playground such as open parks, overlook parks, natural and screen parks, promenades and bicycle paths, etc. Protection and preservation of the natural river environments also have been emphasized.

Robert Chester Johnson, (1973), [23] developed a water based linear parkplanning model to utilize stream channels and flood plains within small watersheds in semiarid urban regions for recreation and flood control purposes. Factors such as climate, geology, soils, slope, hydrology, mature vegetation, and wildlife were examined in order to determine the suitability of the land to support a water-based linear park system. Dry stream channels were recommended to be utilized as the core of a linear park system which would include horse trails, bicycle and hiking trails; picnic and play areas; nature vistas and desert buffer strips; and also be part of a larger continous integrated metropolitan recreation system. For localized flood damage reduction, diversion of portions of storm runoff from main washes into off-channel basins and use of the impounded waters for conservational and recreation purposes or for release into the main channel after designed value peak flows were achieved.

For the purpose of flood damage mitigation, the study team of the Insitute of Environmental Science of Miami University 1976 (20) made a detailed study of the Great Miami River Corridor lands and existing facilities and suggested three land uses which are compatible with seasonal, or occasional flooding--agriculture, open space, and recreation. This type of land use will reduce the cost of flood control and at the same time will make possible maximum public use of the land. It will also contribute to the cultural and economic vialility and vitality of the area. The study team also have specified areas or nodes that can be modified for recreational use and have suggested the kinds of activities that can be developed along the Great Miami River Corridor. Recommended facilities cover a wide variety of types, such as camping, boating, fishing, gardening, hiking trails, bikeways, horsetrails, and fun-fitness trails, which in turn indicate great possible benefits of the river corridor plan to the community. The area between recreational nodes are recommended for use in either agriculture or open space. Trails through these areas will connect the nodes.

In 1980, Smith, Biffle and Dittrich [39] conducted an extensive study within the Mingo Creek watershed in Tulsa, Oklahoma in order to reduce flooding problems by investigation of the multi-use potential of flood plain lands. To reduce flooding some options such as: "no action, flood plain acquisition, flood plain management, channel improvement, levees, regional detention, flood-proofing, and reservoir" have been analyzed on a small scale by the Tulsa Corps of Engineers. A combination of channelization and detention are generally recommended to provide 100-year flood protection on 2,200 acres of Mingo's flood mitigation sites, providing a project benefit to cost ratio of about 3 to 1, [40]. Because of the sensitivity of the Corp's plan to open space and recreational opportunities and needs, Smith et al (1980), have suggested the concept of Regional Detention. To prevent further losses from flooding they have recommended the incorporation of recreation and conservation of open space uses within the flood control program. Recreational activities suggested by Smith et. al., vary from very high intensity type sports, such as baseball or camping, to the most passive type such as nature study or bird watching.

CHAPTER IV

RESULT OF THE STUDY

Successful implementation of any plan to utilize stream channel corridors for recreational purposes requires a good understanding of potential problems, beneficial or detrimental effects of any proposed plan, and the technique by which detrimental environmental effects need answers can be eliminated. In this chapter, the problem areas will be identified, the solution methodology of the problems will be discussed and finally a general plan presented for river corridors whereby present massive problem areas can be transformed economically into useful, ecologically protected, and totally feasible activity centers.

The case study results are presented in three sections. The first section presents flooding problems and forcasts, and measures to control flooding with reference to traditional methodology. The second section discusses sand mining activities-beneficial and detrimental effects-and hydrologic and hydraulic response to these activities. The third section presents recreational use of the flood plain corridors and offers a riverine corridor plan format strategy.

Section 1

Flooding

Flooding is one of the main problems for planning recreational centers in stream corridor areas. Hydrologic characteristics of the watershed producing the flood response and the impact of urbanization on plain areas should be carefully examined in the development of a recreational system to determine the optimal size and feasibility of flood control systems. Urban flooding is a natural hazard to which most communities are exposed. Every year flood waters inundate areas inhabitated and used by man. About 90 percent of the natural disasters in the U.S. are flood-related [35] and account for greater average annual property losses than any other natural hazard [62]. Any improvements which increase the amount of impervious areas, such as replacing open space with residential development will increase the peak of storm flow, shorten the concentration time and subsequently increase the volume of storm runoff from the area under consideration. Actually increases in flooding have basically occured because of development on these contigious areas [62]. The relatively new subject of "Stormwater Management" has been born as a direct result of the flooding effects of urbanization.

Floods usually occur when the amount of water in a stream channel exceeds the capacity of the channel, or when storm sewers and drainage channels are too small to carry away the excess water resulting from an abnormally heavy rainfall during a short period of time. This problem frequently occurs in urban areas. Conditions contributing to floods are amount of percipitation, type of soil, geological property, width of flood plain, ground cover, and topography. Urbanization also intensifies problems in areas where run-off was previously impeded by vegetated or forested lands. An agricultural watershed with good conservation treatment will produce less runoff and resulting smaller peak flows. Urban watersheds with parks, greenbelt areas and properly designed drainage systems will produce less runoff and lower peak discharges than those with little vegetation and poorly designed floodwater removal systems. The intensity, distribution, duration and time of occurence of rainfall are all significant factors concerning flooding. For this reason a good knowledge of the hydrologic factors is required in any future flood study.

Geology is another important factor affecting flooding in a watershed. Storm runoff is affected by both subsurface and surface geologic characteristics. A watershed having rock exposed on the ground surface will produce much more runoff than a watershed that has a deep sand underlain by rock, [26].

The slope of the ground surface is a factor in overland flow process and a parameter of hydrologic interest, especially on small watersheds where the overland flow process may be a dominant factor in determining hydrograph shape. (The distribution of land surface slopes can be determined by establishing a grid of a set of randomly located points over a map of the watershed. The slope of a short segment of line normal to the contours is determined at each grid intersection of random point. The mean, median, and variance of the resulting distribution can be calculated.)

The width of the flood plain usually determines the depth to which waters will rise for a given flood. A watershed with narrow flood plain will tend to have greater water depths from a given flood than a watershed with wide flood plains.

Floods can be classified into several categories as follows:

1. The maximum known flood or the greatest flood of record, which can be of great magnitude or slightly greater than those which occur frequently. Hydrological studies are necessary to determine which category it should be placed.

2. The maximum probable flood or the largest flood for which there is any reasonable expectancy with respect to a particular climatic area. Its magnitude is about twice the standard project flood. This flood has been considered the 1000-year flood, and can be used for the design of spillways in which failure would result in high damage, [24].

3. The Standard Project Flood is the greatest flood which can be expected to occur with the coincidence of the most critical conditions [7]. This flood is defined as the "discharges that may be expected from the most severe combination of meteorologic and hydrologic conditions that are considered reasonably characteristic of the geographical region involved, excluding extremely rare combinations". This type of flood has variable frequency with a recurring interval of 100 to 500. The U.S. Army Corps of Engineers uses the Standard Project Flood as a design criterion of its studies. This flood is usually about 50 percent of the probable maximum flood for the area. The Standard project flood best can be determined by transposing the greatest rainstorm in the region surrounding the project and converting the rainfall to flow by use of rainfall-runoff relation and the unit hydrograph procedure.

4. The Regional Flood is the largest historical flood in the same or similar watershed which has a distinct danger of occuring again. The Regional flood provides a good basis for determining flood plain regulations, [24].

The volume of runoff causing a flood depends on the previously mentioned independent and interrelated variables. For most flood control practices records of these variables should be gathered in order to predict the flood peak. Such data are available from the U.S. Weather Bureau, the U.S. Soil Conservation Service, the U.S. Geological Survey, and information from long time residents of the appropriate area.

The U.S. Geological Survey maintains a vast stream gaging network which provides basic data for flood studies. The U.S.G.S. annual climatological data reports, including summaries of flood losses, are also of value in providing needed information.

The U.S. Soil Conservation Service of the U.S. Department of Agriculture undertakes soil studies and surveys which offer some generalized assistance in mapping flood problems. The U.S.S.C.S., upon identifying the types of soils, can interpret them for urban needs. This operational soil study gives detailed soil characteristics down to areas as small as one-half acre and indicates areas of poor drainage, high water tables, and deposits of alluvial soil. While these maps do not show the flood plain in detail, they are useful in indicating areas unsuitable for development and would be of great value to planning commissions in the preparation of a comprehensive urban corridor plan. The U.S. Geological Survey, Department of the Interior has been preparing flood hazards maps since 1903. These maps show the approximate areas inundated by the greatest flood on record, flood profiles, frequencies and history. Besides use in the establishment of flood-plain regulations, these maps have been used by public officials in the purchase of open spaces and selection of reservoir sites.

Estimation of Runoff

The storm runoff from a drainage basin is an important component in the formation of flood peaks. A number of techniques can be used to estimate the amount of runoff from a drainage basin. The selected method should be based on the size of drainage areas and available data. The most common methods for predicting flood flows are as follows:

Flooding Caused by Backwater

Channel constrictions as a result of natural and modified conditions cause backwater above the normal flow depth. As a result channel capacity to drain storm water at a particular location would be decreased as a part of the flow moves along the banks and flood plains to create flooding problems during high flow periods. Before implementation of any plan in the river corridor areas, the extent of backwater should be determined. There are several methods to calculate backwater, and as a result, to determine the temporary flood zone. The many available design manuals similar to "Hydraulics of Bridge Waterways," published by the U.S. Department of Transportation/Federal Highway Administration in 1973, gives enough information to calculate backwater magnitudes.

Today computerized backwater programs are strong and powerful efforts to improve the accuracy and ease of computation of backwater problems. Among these the U.S.G.S. step-backwater computer programs No. E 431 and HEC-2 are the most applicable. The HEC-2 program which was developed by the Hydraulic Engineering Center of the U.S. Army

Corps of Engineers, is particularly useful to solve backwater problems with great speed and accuracy. It computes and plots the water surface profile for river channels of any corss section for either sub or super critical flow and computes backwater curves in river channels. The effects of hydraulic structures such as culverts, bridges and embankments are also inputted into the computations.

In order to calculate backwater curves using HEC-2, the user must select one of the two available methods the special bridge routine or the normal bridge routine. The Special Bridge Routine computes losses through the structures for low flow, weir and pressure flow, or for any intermediate flow condition. The Normal Bridge Routine treats the cross section at the bridge or culvert just as any river cross sections with the exception that the area of the bridge or culvert piers below the water surface is subtracted from the total flow area and the wetted perimeter adjusted accordingly. This option is used for applications where the special bridge routine does not easily accept the data from complicated configurations.

Flood Control

Absolute control over floods is rarely feasible either physically or economically. Man can do little to prevent a major flood, but he may be able to minimize damage to the crops and property within the flood plain of the river. Measures to reduce or prevent flood losses are either structural, non-structural, or a combination of both. The commonly accepted measures for reducing flood damages are:

1. Dams and reservoirs to reduce the peak of flow.
2. Levees and floodwalls to confine the flow within a predetermined channel.
3. Channel improvements to increase velocity by reducing the peak stage.
4. Channel diversion to divert flood waters through bypasses or floodways to other channels or even other watersheds.
5. Reduction of flood runoff by appropriate stormwater management techniques.
6. Flood proofing of specific property.
7. Flood plain management by proper zoning and control.

Structural Urban Flood Control

Levees, Floodwalls, Dikes and Berms

Levees and floodwalls are one of the oldest and most common types of structural measures which serve to protect properties from overflow. Their presence tends to confine and contain flood flow and thereby incerase the height of flood stages. They are essentially longitudinal dams built parallel to a river rather than across its channel. Their purpose is to provide protection rather than to control floods.

A levee is an earth dike usually built of materials excavated from borrow pits paralleling the levee line while floodwalls are usually masonry constructions designed to withstand the hydrostatic pressure (including uplift) exerted by the flood waters. Details of a typical levee and floodwall sections are shown in figures (4-1) and (4-2).

Although these structures provide considerable protection, the problem of interior drainage (the disposal of waters which collects behind a levee) is present in almost all levee designs as in the case of Louisville, Kentucky, where there is continued concern with the ponding areas behind the levees. The best solution to this type problem depends on the local topography and the stream characteristics. General solutions to the problem of interior drainage is to collect the water at some low point or in the storage basin and to pump it over the levee during floods when gravity flow through outlet gates is impossible. A disadvantage of levees or floodwalls shows that they sometimes have a tendency to reduce the channel capacity, thus heightening the crest of flood waters in unprotected areas. Channel improvements, which usually accompany levee construction, increase velocity and may offset some or all of this increase.

<u>Channel Improvements</u>

Channel improvements offer another method of flood mitigation which provide greater capacity for handling floodwaters within the channel itself. This can be accompanied by removal of brush and snags, dredging of bars, changing the channel cross section by

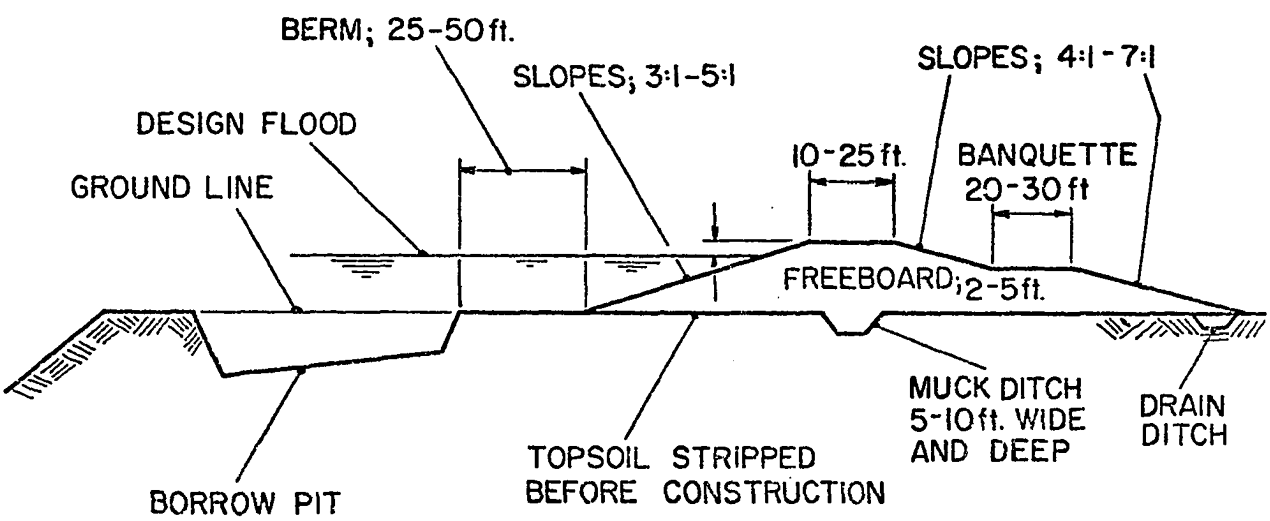

Figure 4-1 Typical levee cross section

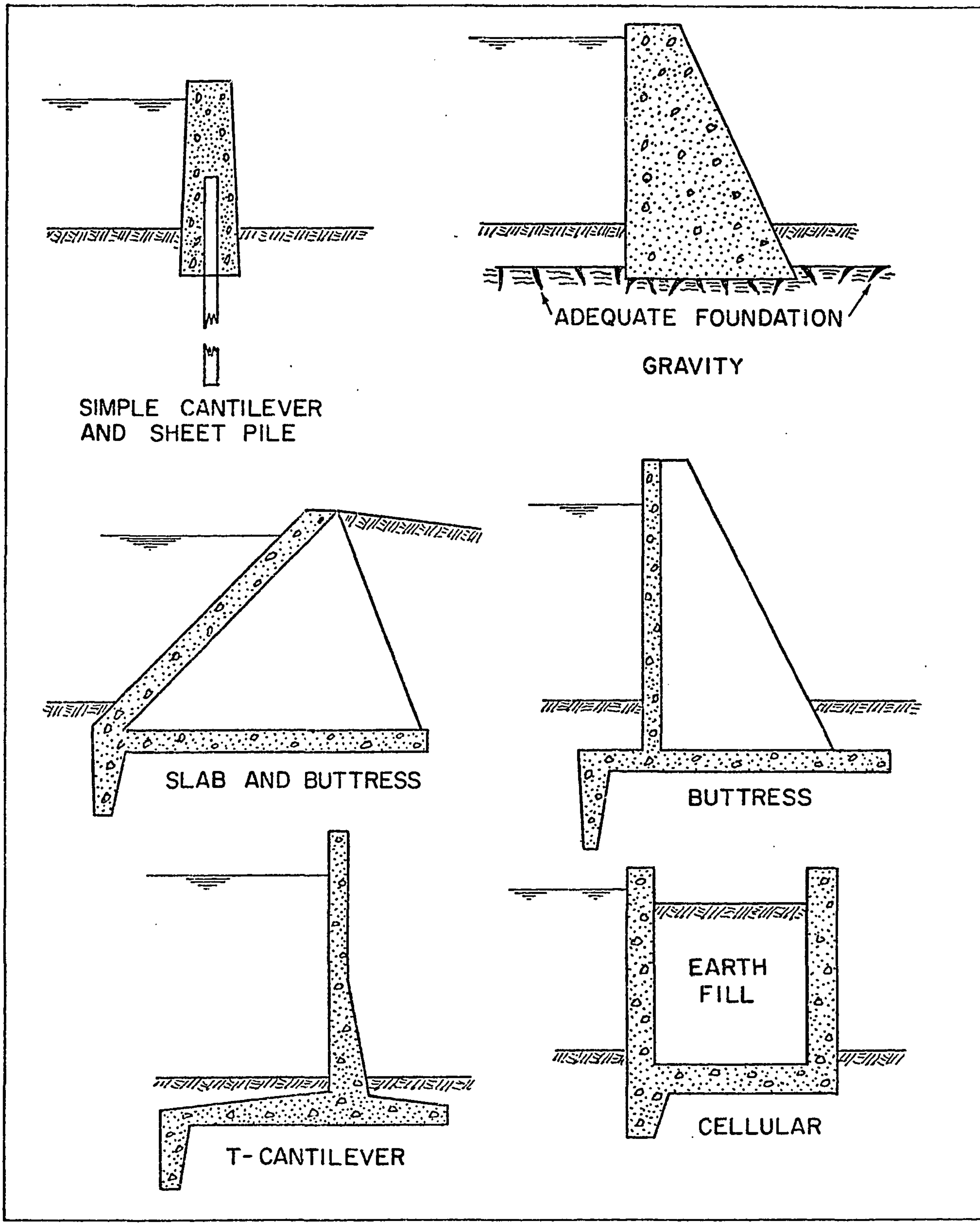

Figure 4-2 Some typical floodwall sections

widening and deepening, straightening of bends, and lining channel beds and walls. These methods achieve their purpose by decreasing manning's n for the reach, increasing hydraulic radius by increasing depth and increasing the channel slope by shortening the channel length. The effect of such improvements on flood height can be computed by applicable hydraulic procedures.

Channelization is associated with, or causes, environmental disruption that is unacceptable to many people. The possible adverse environmental impacts due to channelization fall into one of the following categories: 1) damage to the stream channel and/or flood plain; 2) damage to fish and wildlife, benthos and benthic materials; 3) aesthetic degradation and 4) downstream effects. Generally the best channelization is the one which is absolutely necessary and involves the minimum modification of the natural channel. Measures for improving channel capacity are essentially local protection measures which may increase flood magnitudes at downstream points.

Channel Diversion

Channel diversion is another method whereby communities can attenuate flood problems. Channel diversion permits excess flood waters to flow around an area through bypasses to other channels or even into another watershed, or it may shorten the distance the waters must flow.

Diversion channels serve two functions in flood alleviation. First, they store a portion of the flood water by creating a large, shallow reservoir and decreasing the flow in the main channel below the diversion. Second, they provide an additional outlet for water from upstream and hence increase velocity and decrease stage for some distance above the diversion point.

Opportunities for the construction of diversion channels are limited by topography of the valley and the availability of low-value land which can be used for the flood ways. Sediment deposits in river channels during low flows causes channel buildup problems. So they should be used only when absolutely necessary. This type of improvement is used in the Mississippi and Sacramento River Basin, Boggy Creek near Enid, Oklahoma is another example of channel diversion conducted by the Corps of Engineers [24].

Flood Mitigation Reservoirs

Reservoirs or hydraulic impoundments are a more positive means of flood control than levees and floodwalls, because they remove or detain a definite amount of water from the flood. The function of a flood mitigation reservoir is to store a portion of the floodwater in such a way as to minimize the flood peak at the point to be protected. In an ideal case the reservoir is located immediately upstream from the protected area and is operated to "cut off" or alter the flood peak. This is accomplished by slowly discharging all reservoir inflow until the outflow reaches the safe capacity of the channel downstream. All flow above this rate is stored until inflow drops below the safe channel capacity and the stored water is released to recover storage capacity for the next flood. Figure (4-3) illustrates the relationship between inflow and outflow hydrographs for a reservoir used for detention.

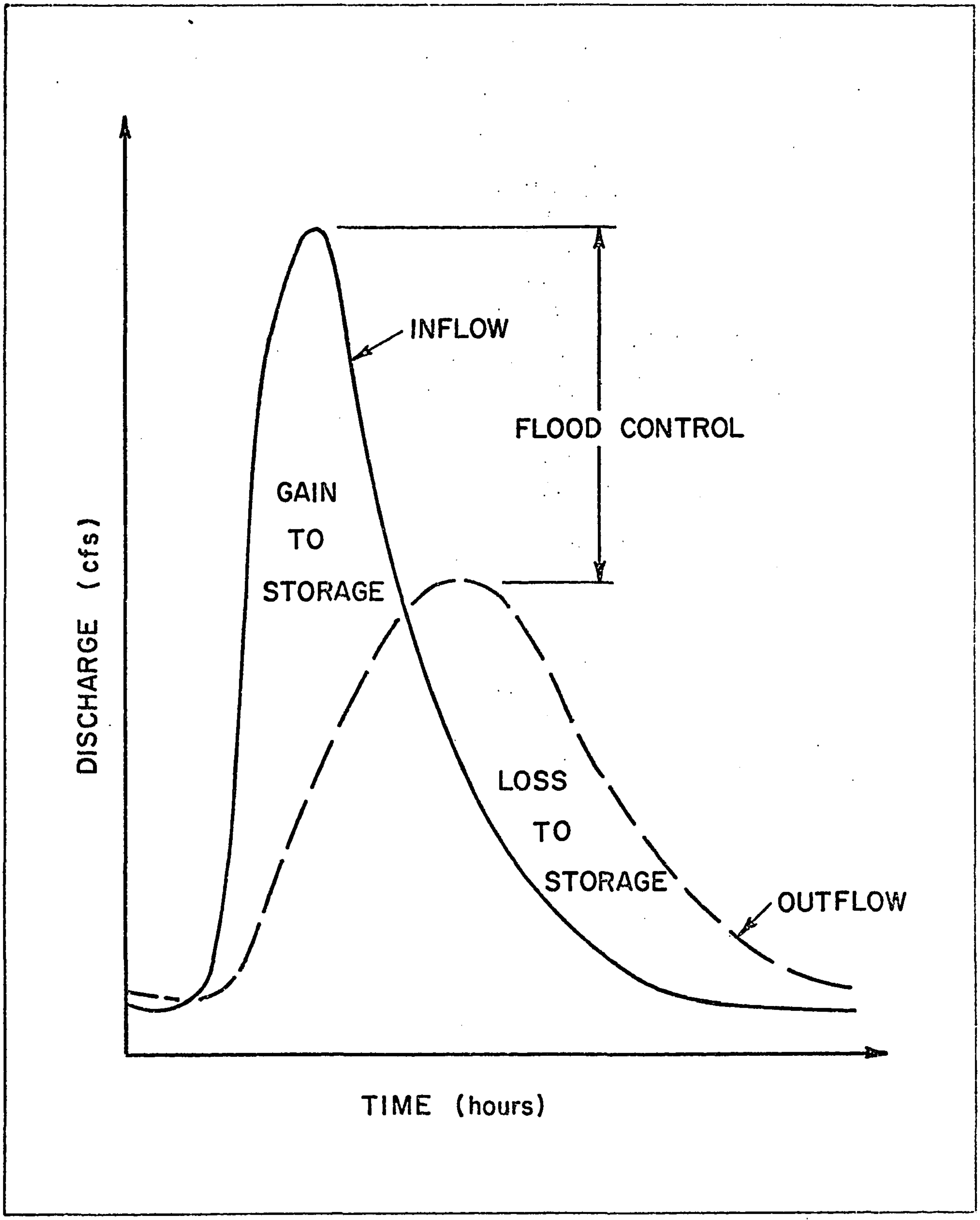

Figure 4-3 Inflow and outflow hydrograph relationship

The potential reduction in peak flow by reservoir operation increases as reservoir capacity increases, since a greater portion of the flood water can be stored. For this reason, storage capacity, usually expressed in inches or millimeters of runoff from tributary drainage area is a criterion for evaluation of a flood mitigation reservoir. The maximum capacity required is the difference in volume between the safe release from the reservoir and the design-flood inflow. As the reservoir size is increased, the law of diminshing returns may come into play. Because at low flow the hydrograph is wider, more water must be stored to reduce the peak a given amount as the total peak reduction is increased.

A flood mitigation reservoir has its maximum potential for flood reduction when it is empty. After a flood has occurred, a portion of the flood mitigation storage is occupied by the collected flood waters and is not available for use until this water can be released. A second storm may occur before the drawndown is completed. Consequently, it is often necessary to reserve a portion of storage capacity as protection against a second flood.

The common method of determining storage in a reservoir is the use of several storage equations. The storage equation generally is:

$$(I - O)\Delta T = \Delta S$$

in which I is total inflow rate, O is total outflow rate, ΔS is the change in volume in storage, and ΔT is the length of time period.

The amount of storage capacity to provide for flood detention should be determined by the process of routing the design flood through the reservoir. Flood routing through reservoirs serves to aid in the determination of the size of reservoirs, spillways, and other outlet works. It also provides information regarding the sequentialization of flood flows, and permits calculations of the time delay of the peak flow as it passes through the reservoir.

Detention Basin

Detention generally refers to holding runoff for a short period of time and then releasing it to the natural water course, where it returns to the hydrologic cycle (on-site detention). Detention basins can be used as a means of reducing losses and inconvenience caused by flooding from storm runoff. The function of detention basins is to capture peak flood flows and hold them temporarily until downstream flows subside. Generally detention facilities do not reduce the total volume of flood water, but simply redistribute the rate of runoff over a time period. The reduced runoff rates have a tendency to reduce erosion in the downstream receiving channels.

The storm waters from the main channel at an upstream location could usually be diverted into a detention site by a diversion dam. At the termination of the storm, the impounded water could be slowly released back into the main channel through an outlet gate. Figure (4-4).

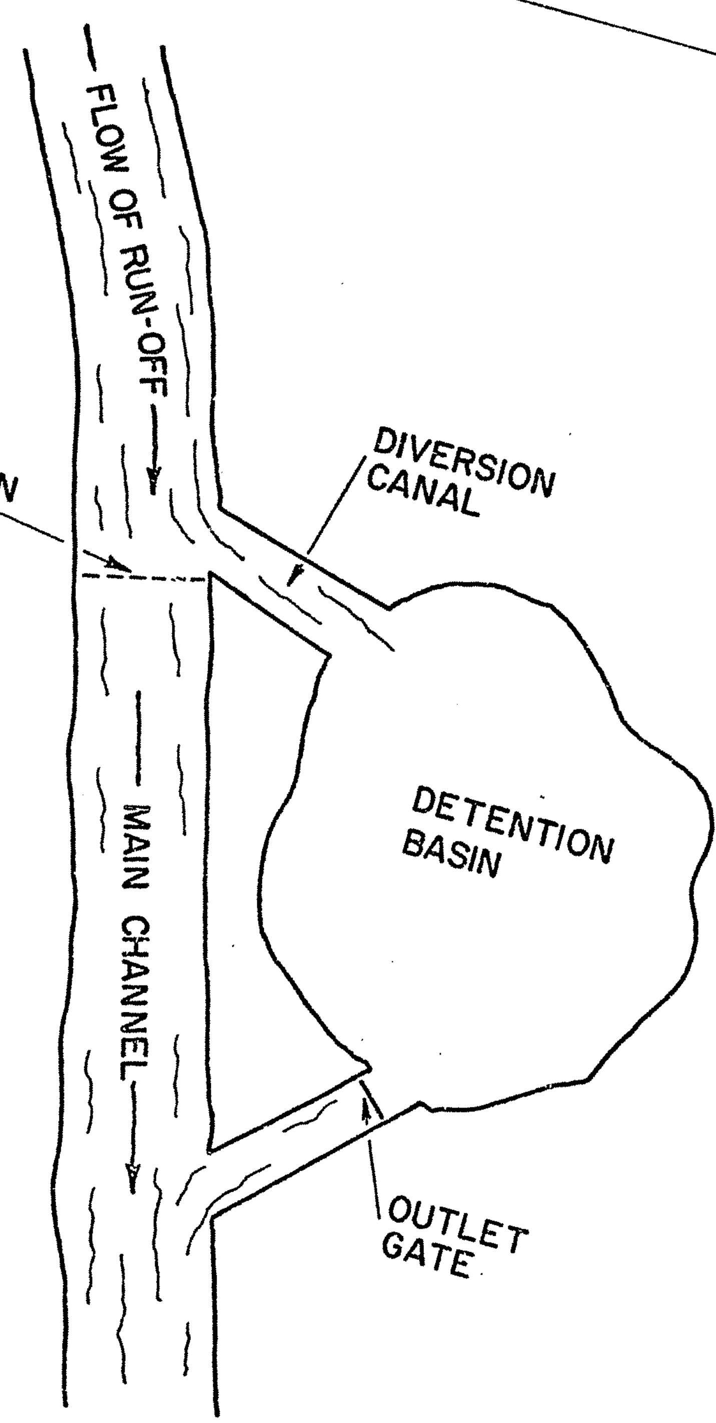

Figure 4-4 Schematic diagram of a detention basin

Figure (4-5) is an illustration of a typical detention structure suggested by Smith et al. [39] for uban flood control on Mingo Creek in Tulsa County. Control structure (A) which regulates downstream waters flow causes upstream water elevations to rise during highwater flow and caused flood water flow over Weir (B) into the storage basin. The flood waters are held within the detention site until flow in the downstream channel subsides below the elevation of the discharge pipe (D). The impounded waters then are completely drained into the downstream channel.

On-site detention of runoff is another alternative method of urban storm water runoff management. This method can be applied as an effective and economical means to reduce peak runoff flow rates and to attenuate or eliminate problems of flooding, pollution, erosion and siltation. However, design of detention facilities is complicated by a number of factors, such as achieving accurate determinations of present and future runoff rates, availability of space for site construction, capacity of downstream facilities to handle outflows, and the need to build the facilities to be aesthetically pleasing and compatible with the local environment. Since most detention stroage would be inundated only once every several years, it can be carefully designed to serve multiple purpose uses, especially in the area of recreation.

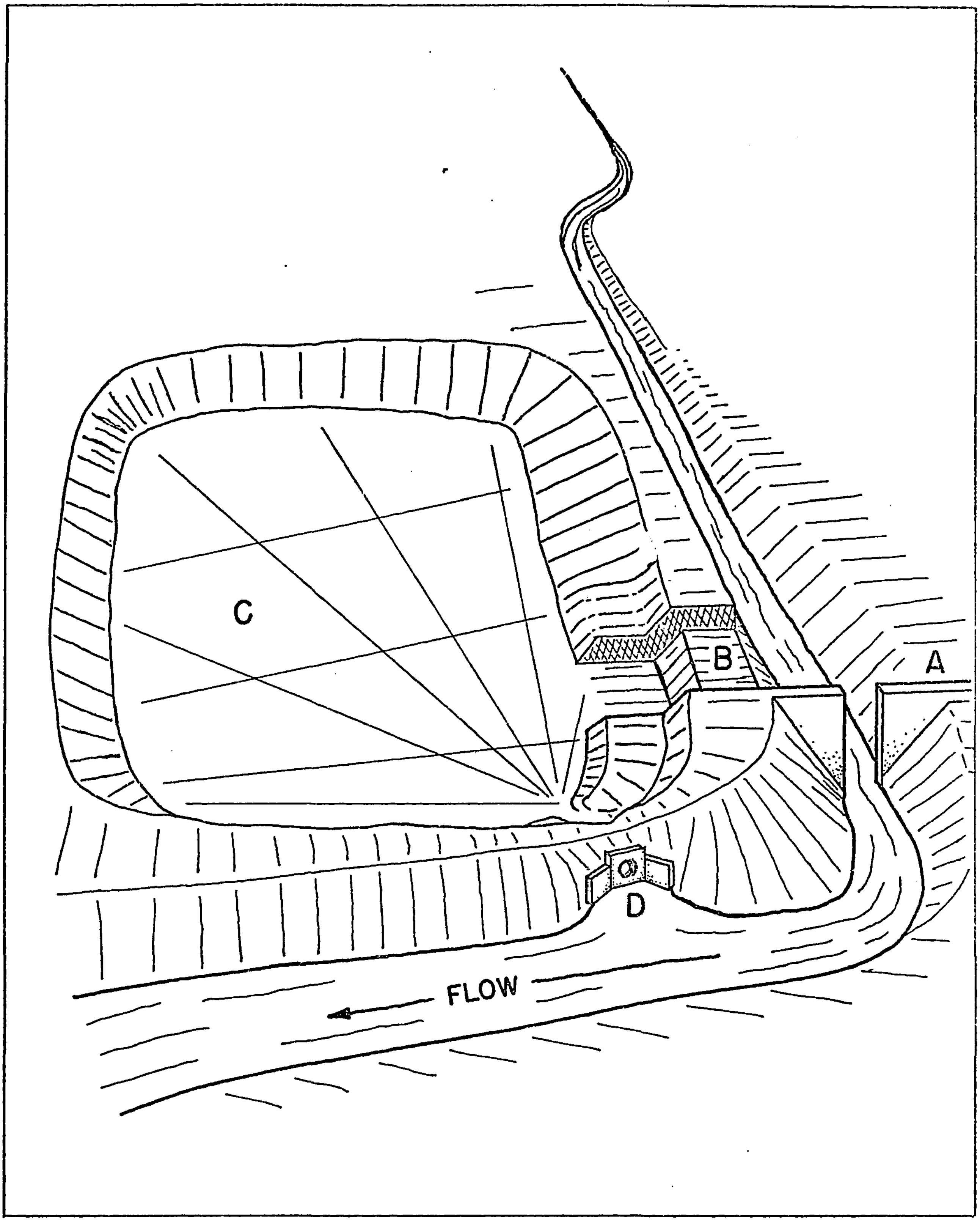

Figure 4-5 An illustration of a typical detention structure

Non-Structural Urban Flood Control

Since 1936 the nation has spent about $11 billion dollars on dams, levees, and channels for flood control purposes. Yet annual economic losses from floods are still increasing. According to the U.S. Water Resource Council's estimation urban flood losses now exceed $1.5 billion each year [35].

Massive investments in structural controls and steadily mounting flood losses has reduced reliance on structural flood control works to solve flood problems and have caused more thrust toward non-structural solutions.

The Water Resources development Act of 1974, gave full attention to non-structural solutions for federally financed projects and it has been estimated that a 30 percent reduction of mean annual flood losses might be achieved over 20 years using non-structural solutions nationally [62].

In spite of local government tendencies for orienting the efforts within the structural solutions, the Water Resources Act of 1974, P.L. 93-251 formalized non-structural approaches to flood control. Section 73 of the act specified that "in the survey, planning, or design by any federal agency of any project involving flood protection, consideration shall be given to non-structural alternatives to prevent or reduce flood damages including, but not limited to, flood proofing of structures; flood plain regulation; acquisition of flood plain lands for recreational, fish and wildlife, and other public purposes; and relocation with a view toward formulating the most economically, socially and environmentally acceptable means of reducing or preventing flood damages".

It was recognized that the non-structural solution for flood problems is a more natural approach. "it is working with nature rather than against it," [61]. It is the only alternative to continously mounting flood loss, especially when we consider the tremendous expenditures required on protective works.

The concepts of non-structural solution strategies generally involves land acquisition and regulation and careful management technology.

Land Acquisition

A most promising method of regulating development of areas subject to flooding is through governmental acquisition of these lands for some type of open public use. Much of this land can be acquired through gifts and by purchase. Other means of acquiring such land may be through tax delinquency. However, a program of this nature requires a well-prepared comprehensive plan. For such a plan, money is available under the Federal Open Space Program. This program provides funds to cover up to 30 percent of the cost of undeveloped land which could be used for parks and recreation, conservation, historic or scenic purposes.

Land Regulation

Regulation of flood plain lands is a legitimate use of zoning power to protect public health, safety and welfare, to protect natural scenic areas, and provide for the conservation of natural resources. It is a preferred way where park or other limited or controlled public uses of flood plain are contemplated. These regulations are designed to regulate the control uses within the flood hazard area.

In regulating flood plain development, local government may use a variety of devices, such as zoning ordinances, subdivision regulations, building codes or flood proofing.

Zoning Ordinances

Zoning is the most useful device for regulating land development which would indicate the uses permitted in a particular zone. Most uses of land and buildings and the construction of other improvements situated in flood hazard areas can be legally exercised through zoning. Zoning power is delegated to municipalities and the legal basis for zoning rests on the policies and procedures set up by the appropriate council or division.

Subdivision Regulations

The primary objective of the subdivision regulations is to insure that subdivisions will provide health, comfort, convenience and beauty. Comprehensive subdivision regulations should include a minimum building elevation, indicate the area subject to flooding and describe the subdivider's responsibility for constructing drainage ways in addition to prohibiting the development of flood-prone lands. The legal basis for subdivision regulations rests on police power as does zoning.

Flood Plain Management

The objectives of flood plain management are:

(a) to improve land use practices, programs and regulations in flood prone areas.

(b) to reduce the need for reliance on local and federal disaster relief programs.

(c) to provide a balanced program of measures to reduce losses from flooding.

The use of non-structural methods of flood control is the essence of flood plain management which includes the following techniques and approaches [61]:

1. - Flood Plain Evaluation

(a) set boundary marker in order to define lateral limits of the contigous flood plain.

(b) establish highwater marks in the flood plain in order to designate the depth of flood waters for 100-year and standard project flood (SPF)

(c) study flood plain to define flow routes and the direction of impact by using maps and aerial photos.

(d) inspect culverts and bridges to determine wash-out capacity

(e) determine the best strategy to greatly reduce damage to property, including relocation, acquisition, razing and flood-proofing.

2. Flood Proofing

Flood proofing is one of the tools used in flood plain management and in urban drainage problem areas. It consists of making changes to structures and adjusting building contents in order to reduce flood damages. Flood proofing techniques will help reduce damage from high water where local regulations permit building in the flood plain, or where structures already exist in the flood plain and need to be protected. Flood proofing should include consideration of the following items for a building:

a. - use of water resistant materials to reduce seepage

b. - water proofing and reinforcement of basement walls

c. - reinforcement or drainage of floor slab

d. - anchorage of walls against uplift and lateral movement

c. - checking the one way valves on sewer lines

f. - employing stand by pumps to remove water

g. - underground piping

Use of flood proofing as a means of reducing damages in a flood-hazard area depends upon projected water elevation, duration of flooding, flow velocity, and the availability of other flood control measures. However, flood proofing should not be thought of as an ideal solution as it is difficult to economically justify, particularly for residential structures.

3. - Land Use Management

Refers to implementation of local, state and federal legislation to regulate flood prone areas. These regulations are a guide to land use in flood hazard areas and it can play an important role in reducing flood losses to future developments.

4. - Warning and Prepardness System

Warning has an important role in flood plain management. The interest of public officials in prepardness is another matter of public response to warning. The National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA) is the organization with an important role in an early warning system. The following information centers or agencies will complete the warning program:

- Civil Defense Organization

- Public Works Department
- Radio Stations and Television.

5. - Insurance

Flood insurance policy would serve as a constructive force in aiding communities to develop a secure future based on sound flood plain management practices. A program of flood insurance in which premiums accurately reflect the risk would be an effective way of informing prospective builders or buyers of the true cost of floods and as a consequence an effective method of flood damage reduction.

6. - Parks and Recreation

Development of parks and recreational areas in flood plain areas offers another effective tool in flood plain management strategy. Purchase of flood plain land for parks and recreational uses is an option to local interests.

Specific recommendations for flood plain management should be developed from a careful study of each flood plain. The best solution will vary from stream to stream depending on the geometry of the flood plain area, the hydrologic characteristics of the stream, and the nature of the prospective uses of flood plain areas.

Regulatory Approaches in Flood Plain Management

The following is an outline and brief discussion of the engineering and legal requirements and regulatory approaches applied in flood plain management. The regulations should meet the requirements of the federal program providing for the National Flood Insurance [NFI Act of 1968 (Title XIII of Housing and Urban

Development Act of 1968), effective January 28, 1969 (33 FR 17804, November 28, 1968), as amended (42 U.S.C. 4001-4128); Executive Order 12127, 44 FR 19367; and delegation of authority to Federal Insurance Administration.] This law requires local community action of flood plain protection based on flood regulations.

Flood elevation determination:

100-year flood elevation are the basis for the flood plain management measures that the community is required to either adapt or show evidence of being already in effect in order to qualify or remain qualified for participation in the National Flood Insurance Program.

The Federal Insurance Administration gives notice to the proposed determination of base (100-year) flood elevations for selected locations in the nation, in accordance with Section 110 of the Flood Disaster Protection Act of 1973 (pub. L. 93-234), 87 Stat. 980, which added Section 1363 to the National Flood Insurance Act of 1968.

These elevations, together with the flood plain management measures required by Section 60.3 of the program regulations, are the minimum that are required. They should not be construed to mean the community must change any existing ordinances that are more stringent in their flood plain management requirements. The community may at any time enact stricter requirements on its own, or pursuant to policies established by other Federal, State, or Regional entities. These proposed elevations will also be used to calculate the appropriate flood insurance premium rates for new building and their contents and for the second layer of insurance on existing building and their contents.

A flood elevation determination under Section 1363 forms the basis for new local ordinances, which if adopted by a local community, will govern future construction within the floodplain area. The elevation determinations, however, impose no restriction unless and until the local community voluntarily adopts flood plain ordinances in accord with these elevations. Even if ordinances are adopted in compliance with Federal standards, the elevations prescribe how high to build in the flood plain and do not prescribe development. This this action does not impose new requirements only forms the basis for future local actions.

Executive Order 11988:

Flood plain Management, May 24, 1977, issued August 10, 1966, establishes a general policy and includes the requirements for compliance by Federal executive agencies. Order requires agencies to avoid the direct or indirect support of flood plain development whenever there is a practicable alternative. The order also requires agencies to avoid the long and short-term adverse impacts associated with modification of flood plain. To satisfy this requirement one should refer to the definition of floodplain, and the term floodplain referes to any land area susceptible to being inundated from any source of flooding. Sometimes the term used in regulation are "base flood plain" and 500-year flood plain" where is referred to critical actions. Base flood plain is the area subjected to occurance of

100-year flood and the critical action flood plain is subjected to occurance of 500-year flood.

Order requires that decision-making by Federal agencies clearly recognize that main goal is to reduce the risk of flood losses through flood plain management.

The Unified National Program includes a broad Federal effort in order to pursue the wise and non-hazardous use of flood plains including recognition of the aspects of natural and beneficial flood plain values.

After almost 15 years the Order provision in most cases in order to protect the communities through the guidelines and regulations are not satisfactory, the occurances of disasters continue.

A further review and study about compliance of Order is necessary and providing the opportunity for these reviews, the public participation and past experience can be a key solution.

Obviously, the purpose of all regulations is to provide the methods for removal of excess flood waters in ways that will not endanger life or property or cause destruction of the natural environment.

It will be desireable to collect all the local regulations and engineering aspects applied in flood prone area and to investigate the efficiencies and deficiencies of each one and to study the engineering reasons if any one works better than others. This is an area which needs more review, study and attention.

It is beyond the scope of this discussion, however, which is limited to discuss about only some general acts and regulations.

Section 2

Sand Mining

Sand mining from river has been practiced for many years. This was done for purposes of business and used by the construction industry. Practically, there is no sand mining without affecting the river channel and its hydraulic characteristics. The case is more critical when commercial operators mine the sand from the streams or rivers in such a way that profits are the main purpose.

Sand and gravel are mined from two types of stream channels: active and inactive channels. In active channels only the stream flows occasionally in most years, shallow excavation are made which are partially refilled with sediment during times of stream flow. Sand pits in inactive channels are larger and more permanent. Both types of mining operations will affect the stream system and create hazard to engineering structures, [5].

Recently, the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers have both expressed great concern over the physical, chemical and biological effects upon stream beds and believe that regulations are needed to ensure that sand mining is conducted in a responsible manner.

It is the purpose of this section to review current practices, to consider detrimental and beneficial effects of sand mining and finally to determine the changes that sand and gravel removal causes in stream from the point of view of hydrological and hydraulic aspects. In fact, in each stage the legal aspects of sand mining will be considered and in case of contradiction the important points will be mentioned.

Current Practices

In 1976, a total of 885 million tons of sand and gravel was reported sold or used in the United States. Of these totals, construction sand and gravel was 855 millions tons, with a value of $1,064 billion [10]. Also, 6,162 sand and gravel processing plants were reported in operation. Of these, 5,593 plants were associated with dredging operations. The U.S. consumption of construction sand and gravel was equivalent to 855,242,000 tons, nearly 97 percent of all sand and gravel consumption.

The mining of sand and gravel in urban areas greatly increase profit margins, due to the reduced transportation cost of aggregates [5]. Such mining has a potential impact on both the stream system from which the gravel is taken and on engineering structure in the flood plain or in the vicinity of the stream.

In 1978, U.S. sand and gravel production was 966 million tons and in 1979, production inclined to 979 million tons, and the value reached a record high of $2.43 billion [25]. Of this tonnage 97 percent was construction, sand and gravel extracted from streams.

Approximately 97 percent of the total sand and gravel output in the United States is used in the construction industry, with concrete aggregate and concrete products being the largest use segment.

Legal Aspects of Sand Mining

Michigan State law enacted in April, 1976, was a new law that requires mining companies to be obtained permits to mine sand withing 15 miles of the lakeshore of Lake Michigan. In addition, an advance mining plan must be filed and land must be reclaimed after any mining is completed. A royalty of one cent per ton must be paid by companies in order to finance the legislation.

The Connecticut Department of Environmental Protection (DEP), recognized the need for regulation of sand and gravel mining land useage in as early as 1975. Many states and cities in the United States have zoning laws and land within each governmental unit is zoned to indicate acceptable land uses. If the mining is permitted in a zone and the company wants to start mining, it must apply for a use permit to begin operating. If the parcels to be quarried are on lands under both city and county jurisdictions, permits usually should be obtained from each.

An acceptable reclamation plan that satisfies the guidelines or regulation of the related governmental agency must also be approved. Environmental concerns such as dust, beautification, and storage of wastes must be accounted for in a manner acceptable to the governmental entity involved. If the deposit to be worked is on a river or land controlled by a river or water or flood control agency, whether municipal, state or federal, those requirements should be satisfied.

In some states, new sand and gravel operations require an Environmental Impact Report (EIR). If an EIR has all the subjects mentioned above, then the approval process could be facilitated.

Hydrologic and Hydraulic Response

Urban stream channels are a convenient source of high quality aggregate because fewer impurities occur in stream bed deposits. The mining of sand and gravel in urban areas greatly increases profit margins because of transportation costs which may decrease to as much as one-half [5]. Mining of sand from the intermittent rivers has a potential impact both on the stream system and on engineering structures in the vicinity of the stream. Mining of sand has an important effect on stream hydraulic characteristics and geometry as well as the biological and chemical characteristics.

The major changes will occur on stream cross-sections after excavation. Mining of sand increases the cross section area of the river at excavation location as shown in figure (4-6). Since flows are unchanged, a decrease in velocity is obvious.

An increase in cross sectional area also affects the depth of water in stream channel. Because of constant flow rate, depth in the broadened channel will naturally be less than it was before.

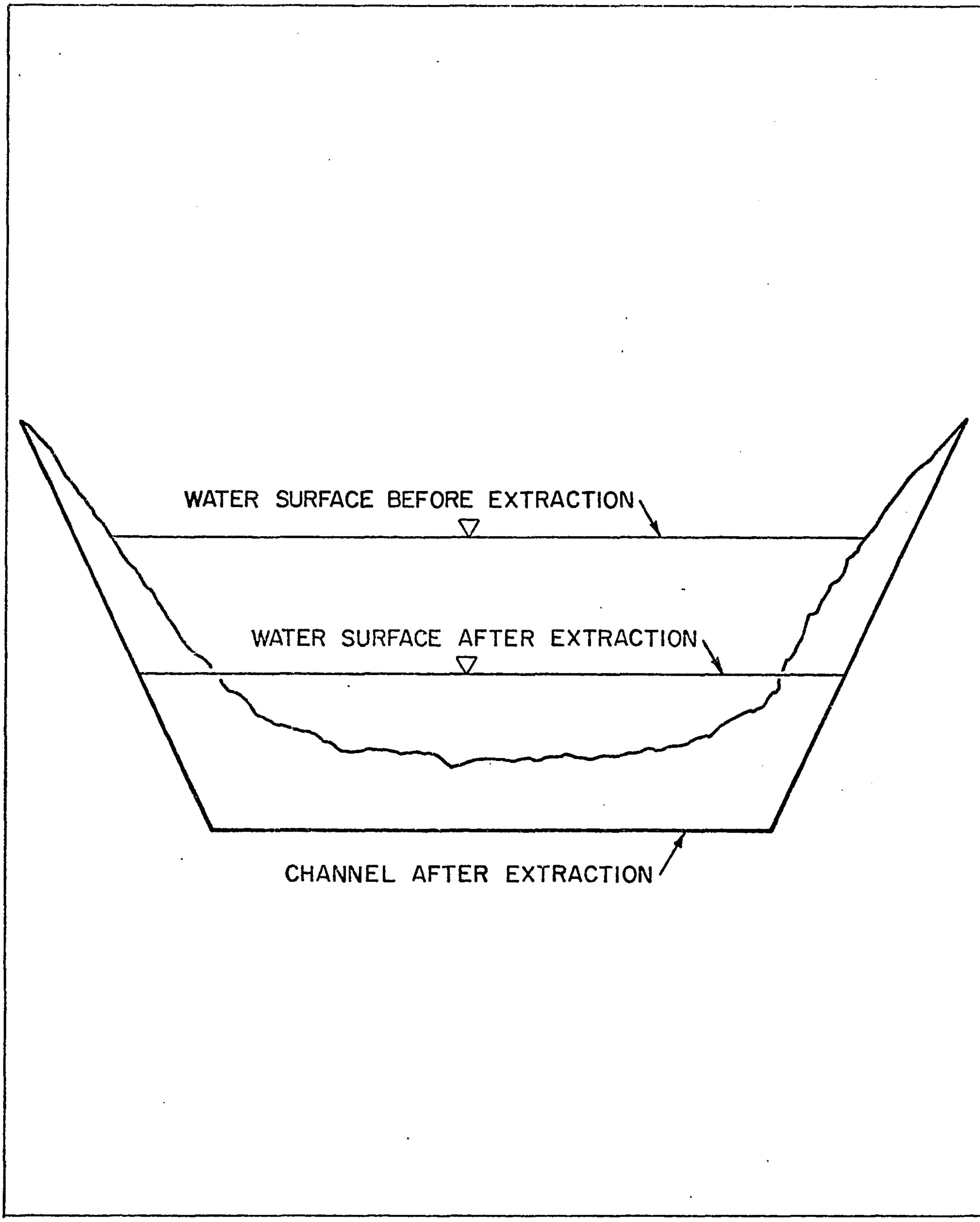

Figure 4-6 Channel cross section
before and after sand removal

Flow rate in the stream after mining can be calculated using the Manning or other appropriate equation.

Values of the river friction coefficients change as a result of sand removal which in turn affect the water velocity (increase or decrease in velocity depends on the type of soil beneath the sand removed).

Other variables that may be affected to either a major or minor degree are energy gradient and critical depth. Since depth of water after excavation decreases, a decrease in both energy gradient and critical depth will occur.

Erosion

Water velocity has an important effect on hydromechanic variables especially on rate of erosion and sedimentation in a stream channel. There is a direct relationship between velocity and rate of erosion. Since velocity will decrease after sand and gravel removal, erosion will be decreased as well. The greater the amount of sand removed from a stream, there will be lesser danger of erosion.

Sedimentation

Unlike erosion, sedimentation has an inverse relation with velocity. Since velocity decreases as a result of sand mining, the rate of sedimentation will be increased. The larger particles carried by water will settle first, smaller particles will deposit further downstream. The total amount of sediment that a stream is able to carry depends on flow rate and the relationship with the suspended load. This is the well known sediment rating curve, figure (4-7).

Effects of sand mining and stockpiling on the river regime such as changes in river bed profile and stream course, sedimentation and erosion of bank and hydromechanic variables of the site can be determined by employing the HEC-2 generalized computer program, which was developed by the U.S. Hydrologic Engineering Center of the U.S. Army Corps of Engineers. For the purposes of flood analysis the most important capability of HEC-2 for the purpose of this study is the subroutine CHIMP and the Encroachment Routines.

Ground Water Recharge

Removing sand from a river may have a significant impact on the groundwater resources beneath the stream-bed since changes in the river can affect its ability to recharge these resources. Mining from the stream bed may reduce recharge to the groundwater table. Low flows into abandoned pits deposit layers of clayey sediments that greatly reduce the percolation from streamflow, even if there are sand and gravel deposits above the clayey layers [5].

Benefits of Sand Mining

Mining of sand and gravel is the largest mining business in the United States. In early days, man discovered this important resource in order to make a composite material used in the construction

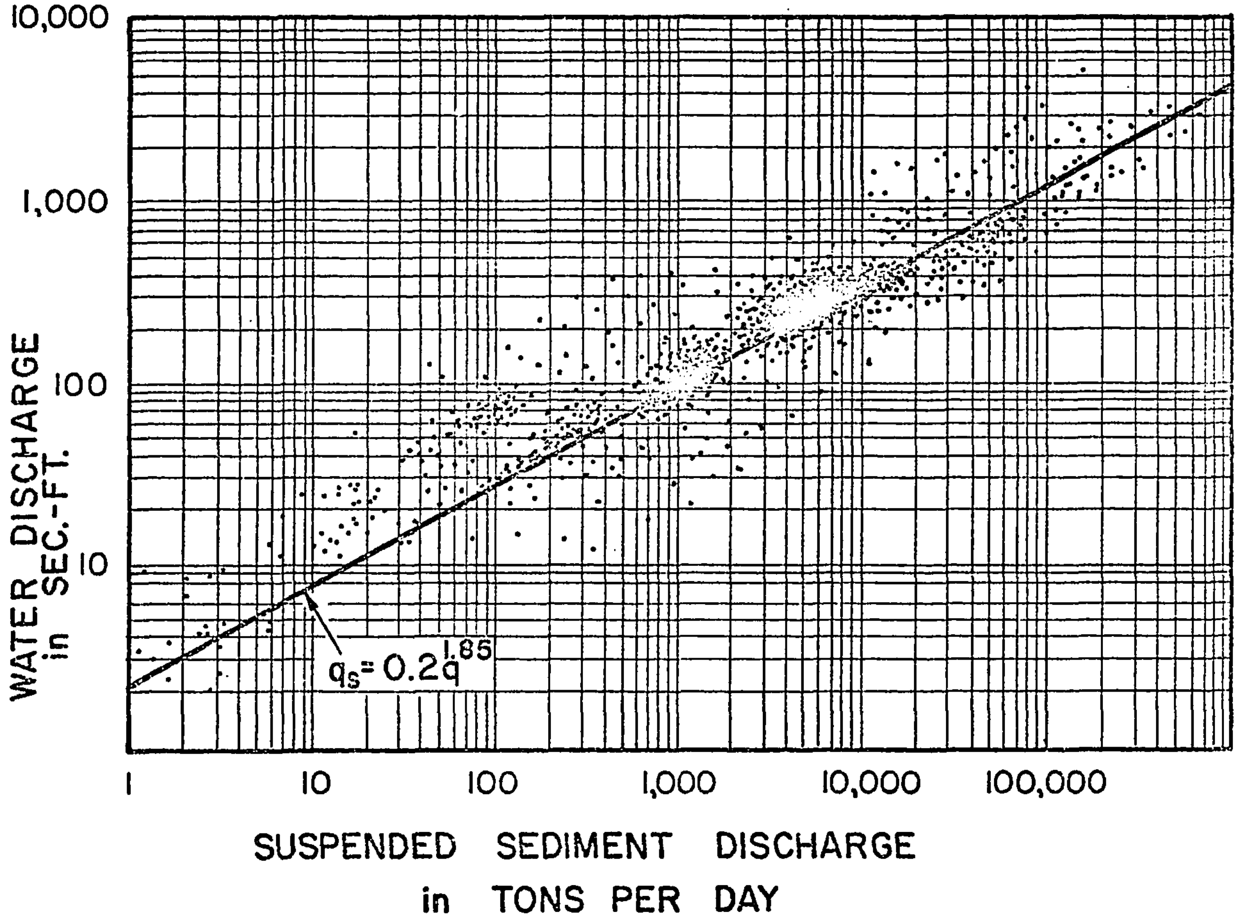

Figure 4-7 Typical sediment-rating curve

industry. The need for sand is unavoidable. In soil mechanics, without sand it is impossible to have a well graded soil, therefore, all earth structures should have sand as a necessary element in order to improve the texture of the soil. For instance, a soil in an embankment or earth dam with fine grained soil such as clay is a cohesive soil. Swelling will destroy the structure but combining it with sand, thereby changing the texture to one which is well-graded will produce a desirable soil for an earth structure. A mixture of sand and cement and other aggregates are used in residential construction mostly for homes and apartments and in engineering construction for dams, sewers, docks, etc.

<u>Beneficial Effects of Sand Mining</u>

1. - Control of erosion

   Removal of sand from a stream causes an increase in cross section in the area being excavated. Increased cross section lead to a reduction in velocity which in turn lessens erosion. The greater the amount of sand removed from a stream, the lesser will be the danger of erosion. The degree to which erosion is reduced depends on the texture of soils exposed after excavation because different soils show different resistance to erosive forces.

2. - Control of Flooding

   Mining of sand provides a channel geometry wherein more water storage will become available and therfore flooding is reduced [15].

Detrimental Effects of Sand Mining

Sand mining activities along a river destroys the natural environment of an area and causes aesthetic degradation in addition to destroying fish and other aquatic life of sand mined areas.

Sand mining from a river also affects sedimentation not only in the area where sand is extracted but also affects the downstream portion of the river. Extraction of sand causes an increase in the downstream sedimentation rate and consequently a decrease in both depth and velocity downstream will occur.

Velocity is an important factor which should be controlled during sand mining to consequently minimize erosion. Sometimes, mining near the banks creates unstable slopes or cuts in which during rises and falls of the stream water surface, the action upon the banks causes erosion of these unstable walls.

Transportation of sand mined from the stream is another factor that can change the feature of the area adjacent to the streams. Heavy trucks and machinery causes compactions in some part and contribute erosion, meanwhile, creating temporary channels that can carry a flow during rainfall and cause some adverse effects on recreation plan.

When sand is removed from different locations, with a rate that exceeds the rate of replenishment of sand and gravel from the natural watershed, the consequences create considerable changes in the hydraulic characteristics of the stream. One of the important effects of lowering the stream bed is the increased potential for undermining bridge piers during the high discharge that produce scour and all the related hazards. Stream deepening also make the stream banks more susceptilble to erosion.

Section 3

Recreational Use of Urban Flood Plain Corridors

Recreational development represents the best use of most lands which are immediately adjacent to stream channels in urban areas. Flood history indicates that these lands are frequently subjected to periodic flooding and are not suitable for residential or commmercial developments. There is ample evidence that patterns of land use on flood plains affects level of flooding especially in rapidly urbanizing areas. It is obvious that if developments susceptible to water damage are not allowed in flood plains, the need for expensive dams, levees and channelization will not be necessary. However, most flood plain areas were developed in the past, either through lack of information, lack of municipal regulation and zoning, or in some cases just the land developer's irresponsibility. Today flood plain corridors can be developed for uses compatible with any order of flood flows and can provide a viable facility that can serve all interests of the community now and preserve it ecologically for the future. Enjoyment of natural surrounding in the company of people with similar interests contributes to social pleasure. Of even greater importance riverine corridor areas provide opporutnity for development of physical skills as well as cultural and intellectual interests. Obviously, allocaiton of these lands to recreation areas, such as ball fields, golf courses, picnic areas, bike and nature trails, and parking areas are all compatible with flood events and lend themselves to proper riverine corridor management.

Responsible land management practices could prevent irreversible damage to important natural resources, while allowing land development to take place in a reasonable and appropriate manner. To develop a plan capable of achieving these objectives an anlysis of natural features (climate, geology, pedology, hydrology, topography, vegetation and wildlife) and cultural features is necessary to determine the suitability of land to support the proposed plan. It is also required to define the lateral limits of a flood plain in order to design recreation sites of proper size and location. An environmental inventory is necessary as a first step in corridor development.

Natural Features

Climate

Climatic factors such as precipitation and temperature patterns must be examined in planning and developing recreational facilities in riverine corridors to ascertain the average number of days available for outdoor recreational activity. The weather, with its daily and seasonal variations, may either contribute to or detract from the quality of some outdoor recreations. The frequency of heavy rainstorms and persistent droughts is obviously basic importance in river corridor areas that are proposed for recreational use. Seasonal changes in the appearance of the natural landscape are also the source of significant aesthetic values. The best source for this information is the national weather service, or the municipal records of rainfall and runoff.

Geology

The geologic base of a river corridor should be examined in order to identify possible constraints that may be expected to cause problems in the development of recreation facilities within the flood plain. The characteristics of the consolidated or unconsolidated parent materials underlying a watershed are reflected in the surficial topography, the drainage network and the soil profile. Certain materials, because of their position, thickness and degree of hardness, tend to form, over long periods of geologic time, cliffs, gorges, caves, table rocks and other items of scenic and aesthetic value. Consolidated sands, gravels and clay in the flood plain areas also are of adequate stability to suport intensive recreational development. Sources of surface toppographic information include the sometimes available aerial mosaic contour maps and the USGS quadrangle sheets. The U.S.G.S. provides a wide source of geologic data, and county geologic maps of varying accuracy.

Pedology

Of all the natural features soil is perhaps the most immediately important to the development of outdoor recreational facility. Soil is the basic ingredient for all development, and knowledge of its characteristics for a proposed project is a must. Compressive strength, stability and erosive susceptibility of the soil determine the constraints encountered in the construciton of a flood control system and outdoor recreation facility. Soil structure limitations may preclude construction of some sites, or may require extra design in order to overcome the limitations. The physical soil characteristics of texture, plasticity, permeability, etc., may impose serious limitations on the construction of roads, buildings and other improvements necessary to proper development.

Intensity of recreation use can be based to some degree on the carrying capacity of the soil, the ability of the soil to support varying land use activities without being damaged, etc. Soil with higher compressive strength can carry greater abuse without severe damage.

The USDA county soil survey is the most readily available and most comprehensive source of pedologic information.

Topography

Natural ground slope is a major consideration in determining land use capability. Percent slope of local physiographic features should be examined in order to determine the impact that recreation development would have on erosion susceptibility.

The aggregate available slopes may limit the type of recreation facility that can be developed within flood plain areas. Excessive slope reduces the range of agricultural uses and increases the cost of residential, industrial and commercial installations. It is apparent that areas of excessive natural slope are generally better suited for forestry, wildlife, recreation and other natural uses. Overall, areas of gentle slope are ideal for intensive use types of recreational development; areas of moderate slope are adequate to very marginal for intensive use and are suitable for scattered picnic sites and walking trails. Areas of greater slope are inadequate for intensive recreational use and usually are subject to severe erosion.

Hydrology

Hydrologic characteristics of a region are an important factor which should be examined in developing a recreation system in order to design the flood control and recreations system and to ascertain the potential for stream runoff. Among the hydrologic factors which should be examined are the amount, frequency, intensity and areal distribution of precipation. Further, the runoff volumes, velocity, peak flow, quality, and frequency of storm runoff can be analyzed and synthesized to provide such data upon which decisions can be based.

Vegetation

In developing a recreation system, it is necessary to study the native vegetative patterns, since vegetative cover stabilizes the soil and prevents severe erosion, porvides habitat protection to wildlife, and is inherent to the character and beauty of the natural setting. Trees, shrubs, wildflowers, grasses and other types of natural vegetation are so related to recreational and aesthetic quality that there is a great need to inventory the environmental assets before anything is even considered.

In examining native vegetation patterns, it is necessary to conduct an inventory of native species and determine the sensitivity of native vegetation to various levels of recreational activities. However, it is important that the inventory present the current situation regarding the areal extent of the major vegetative types found in the region. Such information can be gathered from published listings, local scientific studies and field observation. Interpretation of the latest USDA aerial photographs enables the identification and delination of forested areas and abandoned fields with reasonable accuracy.

Wildlife

Wildlife habitat patterns should be examined in the development of a recreation system to ascertain whether wildlife populations can be protected and incorporated into the recreation system. Although the existence of a variety of wildlife species could enhance the aesthetic quality of a recreation system, development of various modes of recreation may damage wildlife habitats and cause the decline of wildlife populations. In examining wildlife habitat it is necessary to conduct an inventory of wildlife population and species and to identify wildlife habitats so that a recreation system can be designed to have the least possible damaging impact on the fauna. Rookeries and other sanctuaries must be inventoried if preservation is to be acheived.

Cultural Features

Man-made or man-related land use patterns should be examined in the design of a recreation system in order to determine whether a river corridor recreation plan would harmonize with the existing land use patterns. Important factors to be studied when analyzing the cultural features include population patterns, land use, land ownership, and existing recreation plans.

Population

The demand for all types of recreational developments and activity depends on the size and socio-economic characteristics of the population of potential participants in the immediate area. Socio-economic characteristics of the population influence the demand for specific recreational activity. In order to more effectively specify the recreation needs of an area, current and future population patterns should be predicted as a means to project user demand for the recreation system and type of facility. In order to do this, one can employ different methods of forecasting.

Land Use

Present land use controls to a large degree the possibility for future alternate uses, such as recreation. It also plays an important role in expression of aesthetic values. To develop a recreational plan it is necessary to classify the existing land use patterns of the area to determine the best potential uses of land for future development. Land use catagories can be identified from topography maps, aerial photographs, USDA soil surveys and, watershed slope maps.

Land Ownership

Ownership of land adjacent to a stream channel should be investigated as a mean of identifying public lands that could be incorporated into the recreation systems and private lands that should be acquired for recreational development. Municipal and county records are available.

Existing Recreation Plans

The survey of existing facility is important in forecasting need for future leisure facilities. An inventory of existing and projected recreation plans which relates to utilization of river corridor lands and dry stream bed for recreation purposes should be performed in order to reduce duplication and to incorporate new ideas. The inventory may also provide an insight into new engineering techniques and design, and may lead to a coordianted areawide recreation scheme. It is important, however, that the inventory present data on the existing recreational development and facilities and their location.

Lateral Limits of Flood Plain

Basic to all river corridor plan approaches is a comprehensive study of the urban drainage basin to accurately delineate the floodways and floodfringe boundaries for various levels of regulatory floods. The 100-year flood is the regulatroy flood, and it is the flood that has a one percent chance of occurence in any given year. A typical 100-year flood plain, as shown in figure (4-8) consists of the floodway and the floodfringe.

Floodway

A floodway is composed of the stream channel and the adjacent portion of the flood plain lands through which flood waters flow down stream by gravity. It must be kept unconfined or unobstructed either horizontally or vertically in order to carry the 100-year flood with a surcharge not to exceed one foot.

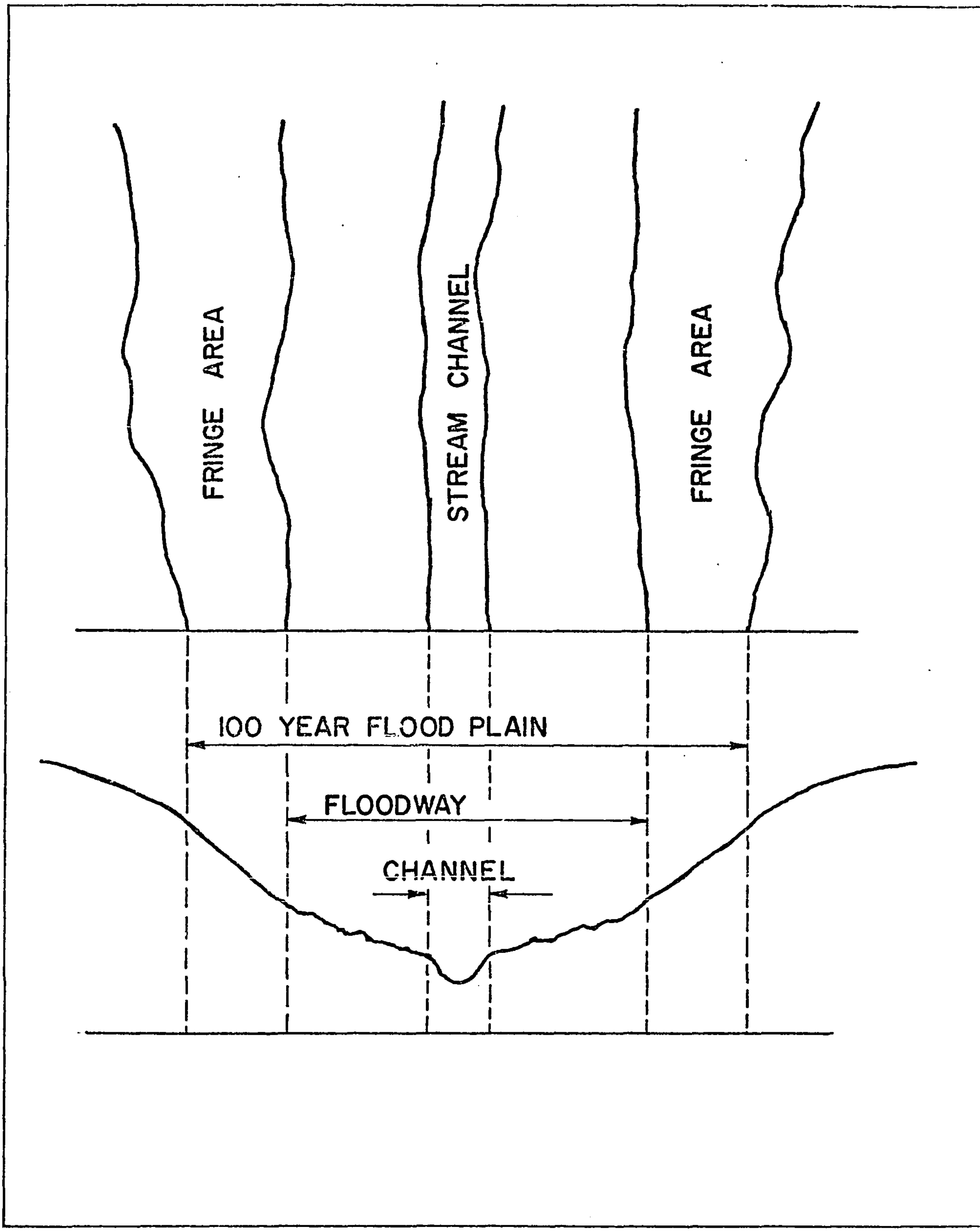

Figure 4-8 A typical 100-year flood plain

Floodfringe

The floodfringe area is that portion of the flood plain that is temporarily flooded by water which is not moving downstream. The floodfringe area acts as a temporary storage area to hold water until it can flow down the floodway. Within this defined area activities should be planned and carried out according to certain standards and regulations. The boundary of floodway or floodfringe varies with different frequencies of floods.

In general, the levels of flooding are measured on a per-year frequency basis and are commonly referred to as the 50-year, 100-year, 500-year level or more. It is the intention of flood plain delineation to determine the boundaries of flooding having 100-year flood frequency.

A flood plain delineation study could be either detailed or very approximate. A detailed study includes, as a minimum, engineering studies to determine the 100-year flood profiles, whereas an approximate study method results in a determination of the 100-year flood boundaries and does not involve detailed engineering study. As a general guide, studies for developed and developing areas should be detailed and the remaining should be approximated.

Preliminary flood plain boundaries could be estimated by using peakflow data collected by the United States Geological Survey. When peak data flood flows are not readily available, widely used empirical equations may be employed.

Executive order 11988 states that "determination of flood plain location should be made according to a Department of Housing and

Urban Development (HUD) flood plain map or a more detailed map of an area." Two points should be considered in using flood insurance maps: (1) they generally do not delineate a portion of flood plain less than 200 feet wide where headwater flooding may be concerned; and (2) possible adverse consequences from future urban development are difficult to infer from the maps.

Determination of Floodway

Once the boundaries of the 100-year flood plain are determined, equal loss of conveyance from each side of the boundary is taken until the surcharge of the increase of elevation of the water surface reaches one foot. Sometimes, however it is physically impossible to determine the floodway using the equal loss of conveyance method. In such events,any other acceptable engineering method should be employed to delineate the floodway. The Corps of Engineers employs basically four methods to accomplish this. These methods are:

1. Establishing arbitrary encroachment stations.
2. Establishing a fixed top width of encroachment.
3. Increasing the water surface elevation by a specified amount
4. Increasing the energy grad line by a specific amount.

Raising the water surface elevation by one foot is the most widely used method, and is the one used by the Federal Insurance Administration. For detail one can refer to the HEC Computer Manual [13].

The one-foot increase in the water surface elevation is usually the maximum possible rise allowable by law. But in some cases it could be inappropriate, hence it could be less or even greater. For instance, the boundaries of the floodway should stop at the contigous cut banks of the watercourse, even if the increase in water surface elevation is less than one foot, i.e., fringe areas should not stretch into the banks of a river irrespective of the increase in elevation. Although within the one-foot limit, obstructions are not allowed if they are to cause extremely hazardous velocities, or if they cause backwater so as to create more than a one-foot increase in elevation somewhere upstream.

Since the floodway is the part of the flood plain that should be kept free of obstructions, it could be a very controversial area, especially when the subject stream is the border between adjacent communities. Thus, a careful determination of the floodway is imperative in flood plain management.

Type of Recreational Facilities

River corridors with their curvilinear arrangement and configuration have potential to serve a variety of recreational needs and are suitable to be developed into high intensity usage areas such as camping areas, picnicking and game areas, and low intensity usage areas with activities in the walking category. Important natural areas can also be preserved in the park and open space system.

The high intensity development areas can be designed as recreational modules at ideal locations to provide facility for day outings, tourists, and visits by people with different interests. Low intensity usage areas can be designed to provide linkage and access to the designed recreational sites.

The kinds of recreational activity and the number of sites which could take place in each node should be determined based on a detailed study of the corridor's land and a survey of the public demand. However, because of flooding, priority should be given to those activities which lend themselves to short participation periods (day use, overnight or weekends). The types of facilities which are compatible with flooding and can be developed within the flood plains are catagorized and defined as follows:

Parks

Parks, like other recreational fields, create little runoff of thier own and provide excellent detention potential and natural recharge for the storage of runoff from adjacent areas. The use of parks for temporary detention of storm runoff waters can measurably increase benefits to the public, and use of parks for such purposes should be encouraged.

Development of adequate park and recreational systems is based on future demand for such facilities and on the physical environment in which these facilities are to be developed. Parks and other open spaces are necessary to provide a quality of life desired by persons living within an urban environment.

Parks vary greatly in purpose, size and content and include the small neighborhood park which primarily consists of a playground for children, a large city park complete with playgrounds, picnic areas, nature trails, swimming facility and zoos, or county, state or national parks which may contain thousands of acres of natural areas. The National Recreation and Park Association has established standards for parks as follows:

1 - Neighborhood Parks: 5 - 10 acres at a ratio of 2 acres per 1000 population for each neighborhood.
2 - Subcommunity Parks: 20 - 30 acres at a ratio of 1.5 acres per 1000 population. For approximately each four neighborhoods, there should be one subcommunity park.
3 - Community Parks: Minimum 150 acres in size at a ratio of 6.5 acres per 1000 population to serve each major section of the city.
4 - Metropolitan Parks: Minimum 1000 acres in size at a ratio of 10 acres/1000 population with one for the metropolitan area. (Metropolitan areas refers to cities with a population of 100,000 or over.)

A children's park also can be established in a river corridor to provide more play opportunity for younger populations of the area. A children's park should be designed so that children feel completely free to play, to garden or play with earth, sand, water and other playtype facilities.

Campsites

Camping is another leisure activity which could be included in the recreational nodes along river corridors without adverse effect on level of flooding. Three types of camping experience are recognized:

1 - Primitive - living in a tent or temporary shelter for a short period of time while doing without most modern conveniences.

2 - Transient - utilizing a developed campground (trailer camping) as an overnight or short term stopover while enroute to a long term vacational spot.

3 - Group - organized camping, usually involves permanent shelters and facilities. Most people enjoy camping but prefer to avoid the primitive aspect of tent camping such as digging latrines, cooking over open campfires and being without running water. Trailer camping allows people to enjoy the outdoors without being deprived of "civilized" amenities.

Picnic Areas

There are many wooded areas along the river which are very attractive for picnicking. Picnicking is a popular family activity which may be done as an end in itself or in conjunction with other activities such as fishing, hiking or bicycling. The best location for picnic areas is beneath trees which provide shade and cool breezes during the summer. Picnic tables, cooking grills and trash receptacles should be placed in picnic areas. Figure (4-9) is a typical recreational site along the stream corridors.

Game Areas

Grassed recreational fields can be utilized for the temporary detention of storm runoff without adversely affecting their primary functions. Game areas, such as golf courses, baseball or football fields, generally have substantial grass cover, which often has a high infiltration rate. Storm runoff from such fields is generally minimal as in damage of flooding.

In developing river corridors for recreational use, some areas should be set aside for both court and field games. Due to the high cost involved in preparation of court games, such as tennis, basketball and volleyball, such areas should be placed where the land is higher that at the river's edge and therefore less apt to be flooded. Field games such as football, soccer and softball could occupy the lower areas along the river. Backstops and fencing for

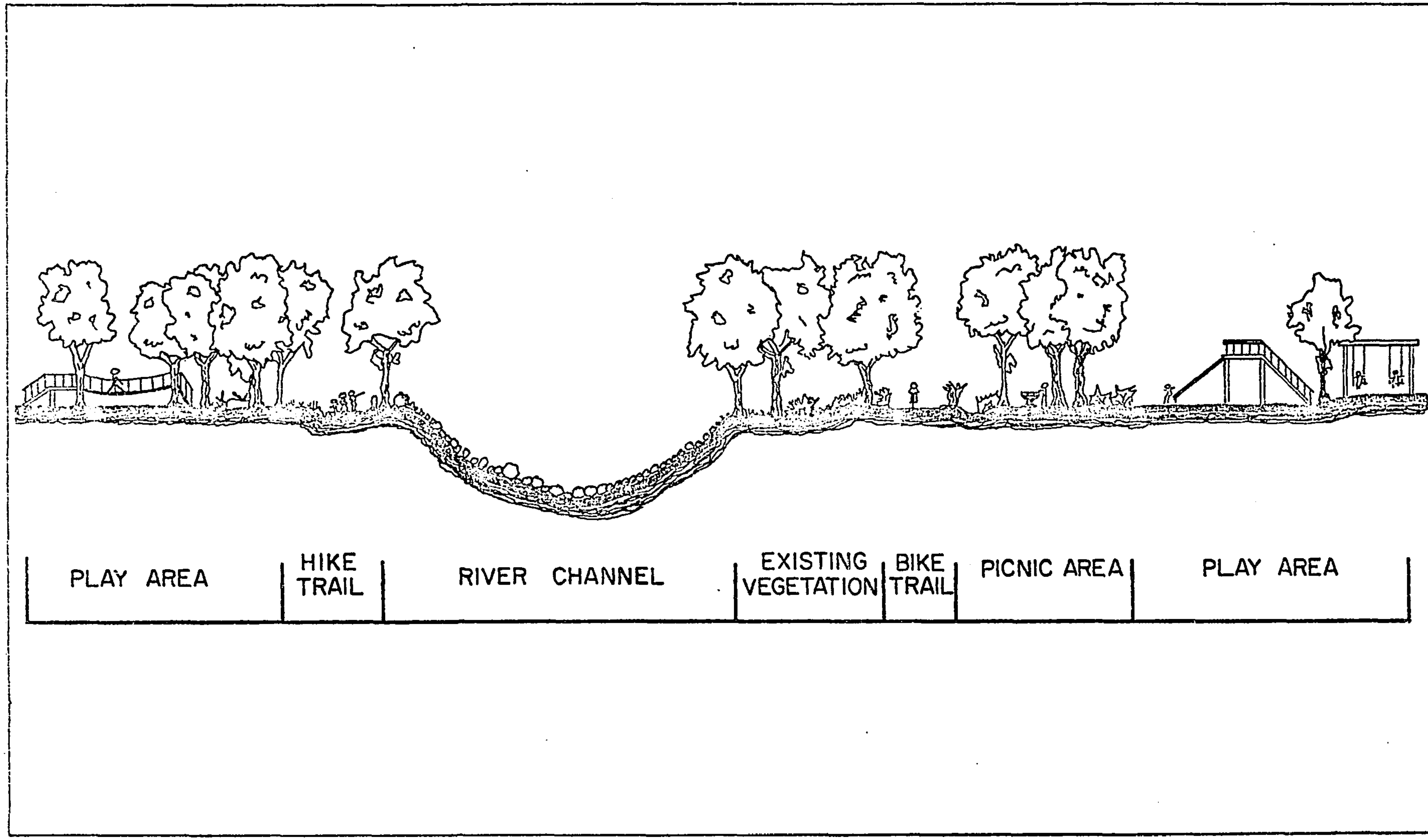

Figure 4-9 A typical recreational site configuration

these sports should also be collapsible in case of flooding and facilities should be placed parallel to the direction of flow in order to avoid obstructions.

Trail Systems

Paths are the primary means for travel between activity areas and should be safe, accessible and convenient. The streams and tributaries form a pattern of merging and diverging corridors which are well suited to the development of various types of trail systems for bicycling, hiking and horsebackriding. Development of a trail system is crucial to the success of the river corridor plan because trails connect important activity areas to each other and to the river and themselves also provide recreational opportunities to meet a variety of needs and interests.

Hiking Trails

There are many interesting places within the corridor areas, such as dense hydric forests, patches of many species of vegetation and wildlife in relatively undisturbed locations, and scenic overlooks, and vistas that can be reached only by foot. A system of hiking trails provides access to activity areas and offers opportunities for hikers to enjoy the natural beauty of the riverine environment.

Bicycle Trails

Bikeways are among the more popular types of facilities that can be developed in a river corridor to provide enjoyment for the cyclist who chooses this type of facility for pleasure or exercise. Generally three types of bikeways are recognized:

1. - Bike path, which is the safest and most enjoyable type of cycling route and is defined as a "completely separated right-of-way designated for the exclusive use of bicycles, with crossflows by pedestrains and motorists minimized." This type of facility is usually located through parks but may also be established within urban areas to serve as connectors to parks, schools and shopping centers.

2. - Bike lane - Bike lanes use existing roadways or paved shoulders of roadways and are separated from automobile traffic by a physical barrier or solid or striped line.

3. - Bike route - Any bikeway that shares its through traffic with motor vehicles. This type of bikeway is the most hazardous of the three, but it is the least expensive and the easiest to implement. Here signage is extremely important, since no spearation of travel modes is used. In order to economize and provide cyclists with a variety of challenge and scenery, a combination of the bike path, bike lane and bike route can be established in river corridors.

Design standards are important in developing a bikeway system in corridor areas to ensure a functional and safe system for cyclists and to provide additional benefits to the flood control system. According to the experienced recreational administrators, a length of 5 to 7 miles sustains the recreational interests and a width of 3.5 feet for one-lane and 8 feet width for two-lane bikeways provides for comfortable riding [39]. Furthermore, bicycle trails require more surface development than do hiking and nature trails. The path must be graded or otherwise surfaced and of necessity may not be as rugged as acceptable surfaces in other trail systems.

Equestrian Trails

Horseback riding is a popular recreational activity which has been growing in recent years. To meet future demand, river corridors with their great scenic potential create a very pleasant atmosphere for this type of leisure activity. Preparation of this type trail system includes some clearing, a small amount of leveling, and trimming or removal of low-hanging tree branches.

Equestrian trail systems, because of their naturalistic setting, do not require extensive maintnenace. The trails usually should be wide enough (approximately 10 feet) to permit two-way traffic. (five feet for single-file horses) [39]. Since horses are imcompatible with cyclists and hikers, in order to avoid conflicts, equestrain trails should be some distance from the generally paralleling bicycle and hiking paths, and use of bicycle and hiking paths should be prohibited to horse riders and vice versa.

<u>Jogging Trails</u>

River corridors can provide opportunities for joggers to take advantage of handsome vistas and cool breezes from the river while jogging. Jogging trails should be well-surfaced and designed based on trail standards. For the safety and conveninece of joggers, trail signs should be established to indicate mileage.

<u>Fun-Fitness Trails</u>

Fun-fitness trails can also be designed in corridor areas to provide a wide spectrum of physical activities and to serve a growing need in the community. A par course is essentially an outdoor exercise course scientifically designed to promote fitness. Fun-fitness trails generally include 20 exercise locations, spaced 100 to 200 yards apart, placed in a large circle of one or two miles in length to provide a start and finish at the same place.

Community Garden

Private gardening has long been an outdoor recreation for millions of people and now is very popular in the United States. According to a survey about 47 percent of American families enjoyed vegetable gardening during 1974. The survey revealed that the number of community gardeners would double in 1975 "if land is available" [58]. Recognizing this, many American cities have begun setting aside tracts of land for community garden plots in order to satisfy the growing demand for this family activity.

River corridor land can be explored as potential garden sites to satisfy millions of would-be gardeners who live in apartments, metropolitan environments, and subdivisions where open land is not available. Some of these sites also can be designed as children's gardens, which provides them a better understanding of growing plants and economics of agriculture and offers a practical educational experience for all age groups. Furthermore, community gardens provide close-to-home recreation for persons with limited mobility and create areas of beauty in developing attractive cities.

Wildlife Habitat

A wildlife habitat is an area of land or land and water of proper size, in an undisturbed condition, where flora and fauna have attained and maintained the ecological climax or balance of the presettlement period. The need for preservation of natural areas for wildlife is apparent, as more existing areas are being encroached upon by urban development. Wildlife habitats within an urban setting provide aesthetic and natural relief from the emotional and physical stresses of modern urban living. To provide more opportunity for people interested in nature, some acreage should be set aside to provide habitats for wildlife, aquatic species and birds. Natural rookeries should be presumed where possible. Various types of trees, shrubs and grasses can be planted in these areas to shelter various animals, and riparian woodland can support a large diversity of nesting and migratory birds and other forms of life. A planting pattern for these trees, shrubs, and grasses should assume a naturalistic setting, providing a mixture of heights and types of plants. Some areas should be heavily planted in order to provide natural cover for some forms of wildlife. The plants also must have several qualities in addition to being conductive to the attraction of wildlife such as being tolerant to periodic flooding, and must be able to be located in the most naturalistic fashion to provide cover and food for expected wildlife species.

Birdwatching, sightseeing and photography are among the most passive types of activity which can be accomplished in corridor areas. They are among the most interesting and exciting hobbies available to nature lovers.

In establishing recreation sites, some open space also should be left for informal sports such as frisbee throwing, badminton, kite flying, etc.

Dune Buggie and Other Rough Terrain Activities

There are almost certainly few legitimate areas in any city for trailbike, dune buggies and other rough terrain vehicular sports. Vehicular use of rivers, particular during periods of low water flow appears to be most popular with teenage groups.

Overbanks and dry stream beds can be designated to provide opporutnity for interested people to test out, race or play with their off-the-road vehicles. Off road motorbiking, minibike and dirtbike riding can be allowed on isolated areas such as sand and gravel pit locations where the bike riders could do very little to degrade the ecosystem or upset the natural and human environments.

Water-based Recreational Activities

There are many other types of recreational activities which are dependent on waters and can be accommodated in a river corridor plan where possible, such as swimming, fishing and boating. Sand and gravel mines have tremendous potential as recreational areas. Reclaimation of mined areas can provide excellent recreational opportunities and eliminate unsightly scars from the landscape. These areas can be converted into lakes and ponds in order to provide water-based leisure activities such as fishing, boating and swimming.

On the otherhand, intermittent flow of streams and tributaries makes them less attractive and less desirable for recreational use than stable water areas. In order to provide more recreational opportunities, low-water dams which do not appreciably impede floodwaters can be designed to impound a year-round conservation water pool area and to create a water park of great interest and attractiveness.

Determination of Recreational Demand

Annual recreational demand for bicycling, walking, picnicking and nature study can be determined using equations developed by the

Galveston District. Recreation demands in this analysis relates to population, household composition, distance, and estimates of participation as controlling factors in establishing expected recreational use. The demand for each activity was evaluated in terms of total recreation days. The factors for evaluating the activities are based on information from local parks and wildlife department [47].

$$X_1 = \frac{Hi}{e^{Xi}} (Bi)\ (Pb) \qquad \text{(for bicycling),}$$

$$X_2 = \frac{Hi}{e^{Xi}} (Wi)\ (Pw) \qquad \text{(for walking),}$$

$$X_3 = \frac{Hi}{e^{Xi}} (Ni)\ (Pn) \qquad \text{(for nature study),}$$

$$X_4 = \frac{Hi}{e^{Xi}} (PKi)\ (Pk) \qquad \text{(for picnicking),}$$

Where: X_1 = Annual demand for bicycling

X_2 = Annual demand for walking

X_3 = Annual demand for nature study

X_4 = Annual demand for picnicking

Hi = Market area number of households

e^{Xi} = Decay function for distance

Bi = Household annual participation days for bicycling

P_b = Percent of annual participation at public facilities for bicycling

Wi = Household annual participation days for walking

Pw = Percent of annual participation at public facilities for walking

Ni = Household annual participatin days for nature study

Pn = Percent of annual participation at public facility for nature study

Pk_i = Household annual participation days for picnicking

P_k = Percent of annual participation at public facilities for picnicking

Impact of River Corridor Plan

Utilization of urban arterial waterways and corridors for recreational purposes would cause several adverse and beneficial economic, environmental and social impacts. The beneficial effects of the river corridor plan will often have a magnifying effect on local or regional water resource management. Generally, there are two types of benefits associated with most planning projects: (1) primary or tangible benefits, which can be expressed in monetary terms (2) secondary or intangible benefits, which include those components of environmental appreciation not directly quantifiable in terms of dollar value.

The major benefits to be derived from a river corridor plan include:

Monetary Benefits

The major monetary benefit is in reduction of property losses due to flooding. By developing flood hazard zones for recreation, there will be essentially little flood hazard to property, which in turn will reduce unnecessary and wasteful public expenditures for relief and rehabilitation.

Another monetary benefit resulting from the river corridor plan is the increase in value of properties adjacent to the river corridor and a consequent increase in property-tax-revenues. Establishing outdoor recreation facilities also would provide other monetary benefits, including charges that recreationists would be willing to pay and any other actual charges.

Providing recreational facilities "at home" will provide a sound means of energy saving, especially in the next decade, because of energy shortages and higher fuel prices. Acquisitions of flood plain land for recreation increases the monetary benefits of river corridor use because the costs are generally lower than with non-flood plain property.

Social Benefits

Social benefits resulting from the recreation plan include mental and physical well-being gained through the use of various recreational sites and facilities. This represents an important though non-monetary benefit which enables the individual to better adjust in society. The physical activity of outdoor recreation is vital in building and maintaining physical fitness and in discharging nervous energy. It is one means of maintaining and improving physical health and is a partial solution to the social problems created by urbanization and increased leisure time. Generally, social benefits accrue from the aesthetic, environmental and recreational aspects of natural and man-made environments. Beautification of river corridors by establishing greenbelt areas, open spaces and preserving natural beauty would enhance the aesthetic and environmental quality of the area and provide pleasure to the city dwellers.

Flood hazard reduction would provide peace of mind to residents of flood hazard areas by providing safety and security; this can be accounted as another intangible benefit resulting from the river corridor plan.

Moreover, acquiring riverine corridors for recreational and open space would also have several other advantages, among them:

- the river corridor plan could be used for two beneficial purposes - conveyance of flood waters and public recreation;
- most scenic areas would be in public ownership for the benefit

of the entire community and their aesthetic value also would be preserved;

- illegal dumping and littering would be discouraged; and
- there would be better maintenance of undeveloped areas.

Adverse Impacts of River Corridor Plan

Recreational development of river corridors would also have some adverse impact on the area. However, major social and environmental adverse impacts are not expected. The major adverse economic impact is due to increase in maintenance and operating costs to the city because of flood damage to the facility. Some of the facilities would be unuseable for short periods of time after flood occurences.

Intensive recreation use could also damage the vegetation cover and lead to soil compaction and severe erosion.

Refuse from various types of recreational uses could cause lowering of water quality and use of off-the-road vehicles might create noise pollution.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATION

Summary and Conclusions

Numerous studies on all aspects of land use, economic and social conditions, and recreational facilities and opportunties were reviewed to assess the most beneficial uses of urban corridors and waterways for community. It was apparent that most of these important natural resources were misused or abused due to lack of user knowledge and responsibility, lack of federal or state rules and regulations or municipal policies to control this important natural urban resource. Most of these important areas have been used for midnight "dumping" or general disposal areas for all manner and types of refuse and cast-off materials. Most commercial operators mine sand and gravel from the stream or river banks and bed in a way that is detrimental to plant and aquatic communities of the river. Most flood prevention practices have not been efficient in preventing flood losses which affect property, health and safety. Because of these detrimental conditions, cities and towns must spend a large amount of money and effort to clean, maintain and protect the corridors within their purview.

Concern about future flooding and about non-use of the nation's urban river corridors has generated the impetus to explore the potential for revitalizing the corridor's role in communities adjacent while protecting the population from flood damage. A river corridor plan on the basis of a study of soil, topography, vegetation, hydrology and cultural features should outline an effective method of flood control while providing for outdoor recreational opportunities for city dwellers. Specifically, flooding problems and methods of flood alleviation, both structural and non-structural have been reviewed and discussed. It is recognized that hydrologic characteristics of watersheds and increase in amount of impervious surface as a result of urbanization are the major factors in increasing the level and frequency of floods. In view of previous large federal investments and continuing flood losses, it is obvious that structural methods of flood prevention are not sufficient to reduce level of flooding problems. Non-structural means of flood control including parks and recreations are a more promising and more natural approach in flood damage reduction, because this "is working with nature rather than against it." However, in many cases the development of the flood plain has already taken place, and structural improvements may be the only feasible solution. Since a variety of conditions can exist along a stream, there will be many instances where a combination of structural and non-structural flood control measures will prove to be the better solution.

Sand mining, mineral removal and gravel extraction are common practices in or near stream and river beds. These activities provide a channel geometry by which more water storage will become available and consequently flooding will be reduced. Increase in cross section of the excavated area will decrease water velocity, and therefore potential erosive forces will be lowered and sediment will be depositied.

The physical effects of certain practices such as sand mining produce undesirable regime changes and create aesthetic degradation, in addition to destroying vegetative cover, fish and other wild life near or adjacent to sand-mining areas. Restrictions should be enforced to ensure that extarction is conducted in a supervised and responsible manner in order to preserve these natural resources for benefit of the community and to maintain the environmental quality and aesthetic value of the riverine corridors.

Outdoor recreation is recognized as a vital need in today's way of life. It is a partial solution to the social problems created by urbanization and increased leisure time. River corridors have potential to serve a variety of recreational needs, especially to people who lack time, money and experience necessary for use of more distant recreational areas. It offers a variety of opportunities for sports, games and exercise as well as a habitate wildlife. Open space or greenbelt areas can be designed between potential recreational sites. Recreational use of the river corridor provides the best means to reduce flood hazards. Recreational areas such as baseball and football fields and golf courses generally have a substantial area of grass cover which often has a hgih infiltration potential and creates little runoff of its own. Storm runoff from such area is generally minimal. These areas provide excellent detention storage potential for runoff from adjacent areas and are the most suitable sites compatible with flooding.

A river corridor plan is necessary for any community that wants to achieve the highest quality of life standards. It provides various recreational opportunities for users of different interests and attitudes while reducing the hazard to the community to periodic flooding and decreasing wasteful public expenditures.

Adoption and implementation of a river corridor plan permits a river to flood where nature intended it to flood, but will prevent further encroachment and consequently will minimize future flood damages. Well-managed river corridors have the potential to improve the quality of life experienced in a community and to prevent irreversible damage to important natural resources while allowing land development to take place in an appropriate manner.

Utilization of a river corridor area for recreational pruposes represents a multi-purpose planning concept with multi-community benefits. The plan must answer the questions about the pattern of development and provide amenity and recreational opportunities close to home in conjunction with flood hazard reductions. This multipurpose, multiple approach program will enhance environmental quality, social well-being and economic stability by emphasizing orderly community growth. In order to provide a good river corridor plan consideration should be given to the following:

1 - The corridor should be managed in an efficient and

effective manner to protect its resources, amenities and natural state.

2 - Land along the river should remain in vegetation to prevent bank erosion and preserve habitat for local wildlife.

3 - In the recreational areas, vegetation that withstands overuse will be favored in order to preserve the beauty of the recreation areas.

4 - Certain areas should be maintained in their wild state.

5 - Opportunities to preserve wildlife and open areas should be encouraged whenever possible.

6 - A river corridor plan should combine conservation and development activities in order to improve the quality of the rivers and broaden opportunities for their use and enjoyment.

7 - Natural beauty of the river corridor should be protected by one of the valuable resources of the community - no disturbance of the nature of the corridor should be permitted except as necessary for approved recreational development.

8 - Any activity center or other functions placed upon the flood plain should not be used during rainfall events.

9 - All local governments should state policy that the flood plain shall be used for purposes which allow them to serve the conveyance of flood waters when needed.

10 - Areas of high-velocity flood flows and wave action require regulation more restrictive than other flood plains.

11 - The sand mining should be limited to the river bed but not extend to the over banks.

12 - Stockpiling should be prohibited.

Recommendations

Most research and study into virtually any subject will reveal a need for further effort in the same or related areas. This study has revealed the need for several recommendations for continued and additional work. Among the envisioned needs are the following:

1. Riverine corridors are most likely to be useful in midwestern and southwestern states. Application and usefulness should be concentrated there.
2. Accurate flood plain delineation in all areas is needed as a completeness effort in the overall riverine corridor plan.
3. Remote sensing and other new techniques should be further utilized, along with land use methods such as Landsat, etc.
4. Based on factual engineering data, resource inventory, and a survey of public attitudes, a master recreational plan should be adopted by local government as the official tool for guidance and future development of river corridors in the area.
5. Better procedure for a more acceptable legal easements or acquistion of the flood plain areas should be studied to ensure their protection and to develop recreational sites compatible with flooding.

6. More restrictive rules and regulations should be adopted to prevent further encroachment and to provide better opportunities to accomplish riverine corridor paln.
7. Hydrological data should be continuously and intensely collected so that annual pattern can be established and used as a broad basis upon which to design a recreation and flood control system.

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APPENDIX

The lists of final key words used in the computerized literary search are as follows:

URBAN CORRIDORS

URBAN STREAM CORRIDORS

URBAN RIVERINE CORRIDORS

RIVER CORRIDORS

FLOOD PLAIN

USES IN URBAN CORRIDORS

FLOOD HAZARD AREAS

USES OF NORMALLY DRY BED STREAM

URBAN ARTERIAL WATERWAYS

STREAM CORRIDORS

INTERMITTENT RIVER CORRIDORS

FLOOD PLAIN ZONING

RIVER BASIN

DEVELOPMENT

UTILIZATION

RECREATIONAL USES

BENEFICIAL USES

SOCIAL USES

PLAN

STUDY