EXPANDED FLOOD PLAIN INFORMATION STUDY

WILLOW, ALASKA

MATANUSKA - SUSITNA BOROUGH

- ▲ FLOOD HAZARD IDENTIFICATION
- ▲ FLOOD DAMAGE EVALUATION
- ▲ ENVIRONMENTAL CONCERNS

PRESENT

FUTURE

United States Army
Corps of Engineers
Serving the Army
Serving the Nation

Alaska District

JUNE 1980

PREFACE

Every river, stream, lake, and other body of water has a flood plain - generally a low, flat area, adjacent to the water, which is flooded during times of high water. Flooding of these areas causes little damage under natural conditions. In fact, the natural environment of these flood plains is dependent on periodic flooding for its continued existence. Unfortunately, the fertile soil, flat slopes, nearness to water, natural beauty, and other attributes usually associated with flood plains have historically attracted man and his developments. Flood losses begin to occur when these developments, namely streets, homes, businesses, industrial complexes, etc., are built in the flood plain. Until recently, flooding problems were usually ignored until damages became significant and increasing pressures resulted in engineering projects, such as dams and levees, to control the flooding. Such "flood control" measures, though they have provided some relief, are not without disadvantages. They are expensive, usually provide only partial protection, and in many cases, have environmental drawbacks.

In recent years a new concept, known as Flood Plain Management (FPM), has evolved. Rather than trying to control flooding, itself an act of nature, FPM attempts to manage the activities of man to the extent that exposure to flood hazards is minimized. Early emphasis under this concept focused on delineating flood hazard areas and regulating their use through the adoption of State and local regulations, such as zoning ordinances, subdivision regulations, and building codes. Much flood plain information has been developed under this approach, and in a few years most communities will have detailed information concerning flood levels, flood plain areas, floodways, and other hydrologic aspects of their flood plains for "existing" conditions.

Delineation of the flood plain and adoption of flood plain regulations are the first steps in solving future flood problems, but many other questions must be answered before comprehensive Flood Plain Management becomes a reality.

Flood plain information based on "existing" conditions omits the possible impact that future development in the watershed has on flood characteristics. This study considered a 1978 existing land use condition and future land use conditions, with and without a new capital city. The future land uses are represented by conceptional zoning maps which do not represent explicit demand at a given point in time or detailed locational decisions. The results of this study indicate that the future land uses in the Willow Creek basin will increase the frequency and the depth of flooding. Encroachment on the flood plain will also increase flood stages and flood damages. Future flood damages can be reduced, however, if future construction allows for the hydrologic effects of that development. Similarly, land use changes, both on and off the flood plain, may also affect water quality and create other adverse environmental effects. These and other problems concerning the effects of land use changes on the flood plain must be considered in a comprehensive flood plain management program. Although generalized trends may be apparent, wise decisions cannot be made until detailed evaluations are available for specific areas. What works in one area may not work in another.

This Expanded Flood Plain Information Study for the Willow Creek Basin is designed to provide a basis for such a comprehensive program. The study defines the hydrologic, economic, and environmental factors for existing conditions and evaluates the effects of future changes, both on and off the flood plain. It also makes available to State and local planning officials a computerized planning tool that can be used to evaluate the impact of changes in land use that might be proposed.

This study was undertaken at the request of the Alaska Department of Natural Resources. It was prepared by the Alaska District, Corps of Engineers, under continuing authority provided in Section 206 of the 1960 Flood Control Act as amended.

EXECUTIVE SUMMARY

The purpose of this Willow Creek Expanded Flood Plain Information Report is to provide information to serve as a decision framework for State and local officials relative to the implications of land use change on three major areas of concern. These areas are:

1. Basic Flood Hazard Information

2. General Flood Damage Potential

3. Environmental Considerations

These areas of concern were addressed for an existing (1978) land use condition and two assumed future land use conditions that are based on input from the State of Alaska and the Matanuska-Susitna Borough. Three flood plain regulatory policies were also evaluated to determine their effects on the future flood damage potential.

The study serves to establish a base for future planning activities in the Willow Creek area. A data management and comprehensive analysis system was developed for this area, allowing the Alaska District, Corps of Engineers, to provide comprehensive planning assistance to the Matanuska-Susitna Borough and the State of Alaska in decisions related to flood plain management. The system, however, is not limited to flood plain management aspects but is also capable of addressing many other aspects of Water Resource Planning, providing a valuable tool for numerous planning functions.

The analyses undertaken during this study centered on the use of a computerized grid cell data bank containing spatially specific data. This data bank was accessed by a system of computer programs to accomplish the desired types of analyses and provide information to State and Borough officials.

The most significant findings of these analyses and evaluations for the three areas of concern are presented on the following pages.

SIGNIFICANT FLOOD HAZARD INFORMATION FINDINGS

1. Approximately 3,900 acres are in the 1978, existing condition 100- year frequency flood plain of the Willow Creek study area.

2. Future urbanization in the study area will increase the number of acres flooded by increasing peak flood flows and depths of flooding. The increases in peak flows depend on the character and size of development, location of development, soil types, and size of the drainage area.

3. Increases in flood depths depend on the change in flood flows, the channel slope, and the degree of urbanization. The more significant increases in flood depths, due to increased development, occurred in small drainage areas.

SIGNIFICANT FLOOD DAMAGE EVALUATION FINDINGS

1. Flood damage potential exists in the Willow Creek basin for the land use conditions existing in 1978 (1.5 percent of the Willow Creek watershed is developed).

a. $1,233,100 in flood damages can be expected if a 100-year frequency (1 percent chance each year) flood should occur.

b. $625,700 in flood damages can be expected on an average annual basis. This does not mean that this amount of in flood damages will be experienced every year, but it is an annual average over a long period of time.

2. Flood damages will increase for future conditions if unconstrained flood plain development occurs.

a. Development existing in the flood plain will be subject to greater flood damages because future development will lead to increased flood depths.

b. Some existing (1978) structures with their first floor at or above the calculated level of the 100-year flood, based on existing conditions, will sustain damages in a future flood of that magnitude if they are not elevated or flood-proofed to compensate for increased flood levels caused by new development upstream.

c. New structures, built outside the 100-year flood plain based on existing conditions, will sustain damages in future floods of that magnitude because of increased flood depths caused by new upstream development.

3. Average annual flood damages will increase to $2,371,800 for the future land use condition without the new capital city (3.6 percent of Willow Creek watershed is developed) if this future land use pattern is allowed to occur without any policy restrictions on the location or elevation of new development.

4. Average annual damages will further increase to $4,403,800 for the future land use condition with the new capital city (12.3 percent of Willow Creek watershed is developed) if this future land use pattern is allowed to fully develop without any policy restrictions on the location or elevation of the new development.

5. Increases in flood damages, from the existing or base conditions, will be significantly reduced if policy restrictions on the location and elevation of new development are implemented.

a. Significant reductions of flood damages can be expected if the finished floor of all new structures is required to be placed at or above the level of the 100-year flood based on existing conditions. However, flood damages will still occur to some of the new structures because the additional development will result in greater rainfall-runoff volumes, in some of the smaller subbasins, thereby increasing flood depths for the 100-year flood in these areas.

b. The floodway concept of regulating future development is the most effective policy of the three analyzed for reducing future damages with increasing watershed development. (New structures prohibited with a central zone of the 100-year flood plain but permitted in the fringe area as long as finished floors are 1 foot above the level of the 100-year flood, calculated based on existing conditions.)

ENVIRONMENTAL CONSIDERATIONS

1. The Willow Creek study area is not ecologically unique.

2. There are several species that are rare, threatened, endangered, or of special concern that can possibly occur within the study areas; however, no recent observations have been documented.

3. Increased growth pressures causing further urbanization will cause a conversion from rural to urban habitat types. Therefore, there will be a decrease in number and diversity of species and stability of community types.

SCENES OF WINTER FLOODING ON WILLOW CREEK - NOVEMBER 1975.

WITH INCREASED DEVELOPMENT FUTURE FLOODING CAN BE MORE DAMAGING.

EXPANDED FLOOD PLAIN INFORMATION STUDY
FOR THE WILLOW CREEK BASIN
WILLOW, ALASKA

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INTRODUCTION

GENERAL

A flood plain is the relatively flat area or lowlands adjoining a river, stream, lake, or ocean, which has been or may be covered by floodwater. It defines an area which requires special planning considerations because of its proneness to flooding. In part, it is transitional between land and water. Through past experience, man has learned that floods quite often cover portions of the flood plain, damaging, or sweeping away roads, buildings, and homes, and often pose a severe threat to human life and health.

Adverse effects from flooding include damage to structures and their contents, to lawns, shrubs, gardens, livestock, roads, and utilities. Additionally, there is a danger of injury or drowning. Waterlines can be ruptured by deposits of debris and the force of floodwaters, thus creating the possibility of contaminated domestic water supplies. Floods also cause pollution problems since septic tanks would be noneffective and sanitary sewer lines could be damaged. The polluted waters would create a health hazard. Isolation of areas by floodwaters could create hazards in terms of medical, fire, or law enforcement emergencies. Commercial and industrial areas could also expect a loss of revenue due to flooding, and employees could expect a loss of wages. Willow Creek has experienced damaging floods in recent years, usually as a result of ice jams or winter glaciation. Traditional Corps studies show what can happen when existing development is located in these flood plains, but what are the implications of new development in, or even outside the flood plain? Does this new development cause more frequent and extensive flooding for those people living downstream? Does this new development cause environmental damages such as increased water pollution from storm water runoff? Should the development philosophy and resultant regulatory policies be geared to protect downstream areas from increased flooding?

In an effort to develop a methodology that would provide answers for these and other related questions, the U.S. Army Corps of Engineers initiated a pilot study in 1975, which resulted in the funding of ten similar studies nationwide. These Expanded Flood Plain Information (FPI) Studies, which include the Willow Study, were initiated because of an urgent need to provide more than just information on flood hazard areas for a static time-frame as typically provided in the Corps' Flood Plain Information reports or the Flood Insurance Studies such as the one the Corps completed on Willow and Deception Creeks for the Federal Insurance Administration in October 1979.

While this type of information on present conditions is sufficient to initiate the planning process, it does not reflect the accompanying changes in land use that will alter conditions on the flood plains.

Recognizing the impact that a new capital city would have on the watershed, the State of Alaska requested that the Alaska District, Corps of Engineers undertake an Expanded FPI to evaluate future development plans.

This Expanded Flood Plain Information Study provides the hydrologic, economic (flood damage evaluation), and environmental information and data necessary for government officials, planners, developers, and others to make appropriate decisions on the future uses of flood plains in the Willow Creek basin. Data management and analytical techniques have been developed largely by the Corps of Engineers' Hydrologic Engineering Center (HEC) for application in these studies. The techniques make extensive use of gridded geographic data files and emphasize consistent comprehensive assessments of the effects of alternative land use patterns on the flood hazard, general damage potential, and environmental factors in the basin.

This Willow Expanded FPI Study report presents an overview of the findings of the flood hazard, flood damage, and environmental evaluations. It also includes a synopsis of the concepts and methodologies utilized (Appendix A, Data Management for Expanded FPI Studies), a detailed description of the hydrology and hydraulic analysis procedures (Appendix B, Hydrology and Hydraulics), a detailed description of the flood damage economics procedures, (Appendix D, Economics), background environmental information (Appendix E, Environmental Considerations), and definitions of terms used in this report (Appendix F, Glossary).

The report also displays computer-printout plates for several data variables stored in the Willow Creek basin study area data bank, and flooded area plates for existing conditions (Appendix C).

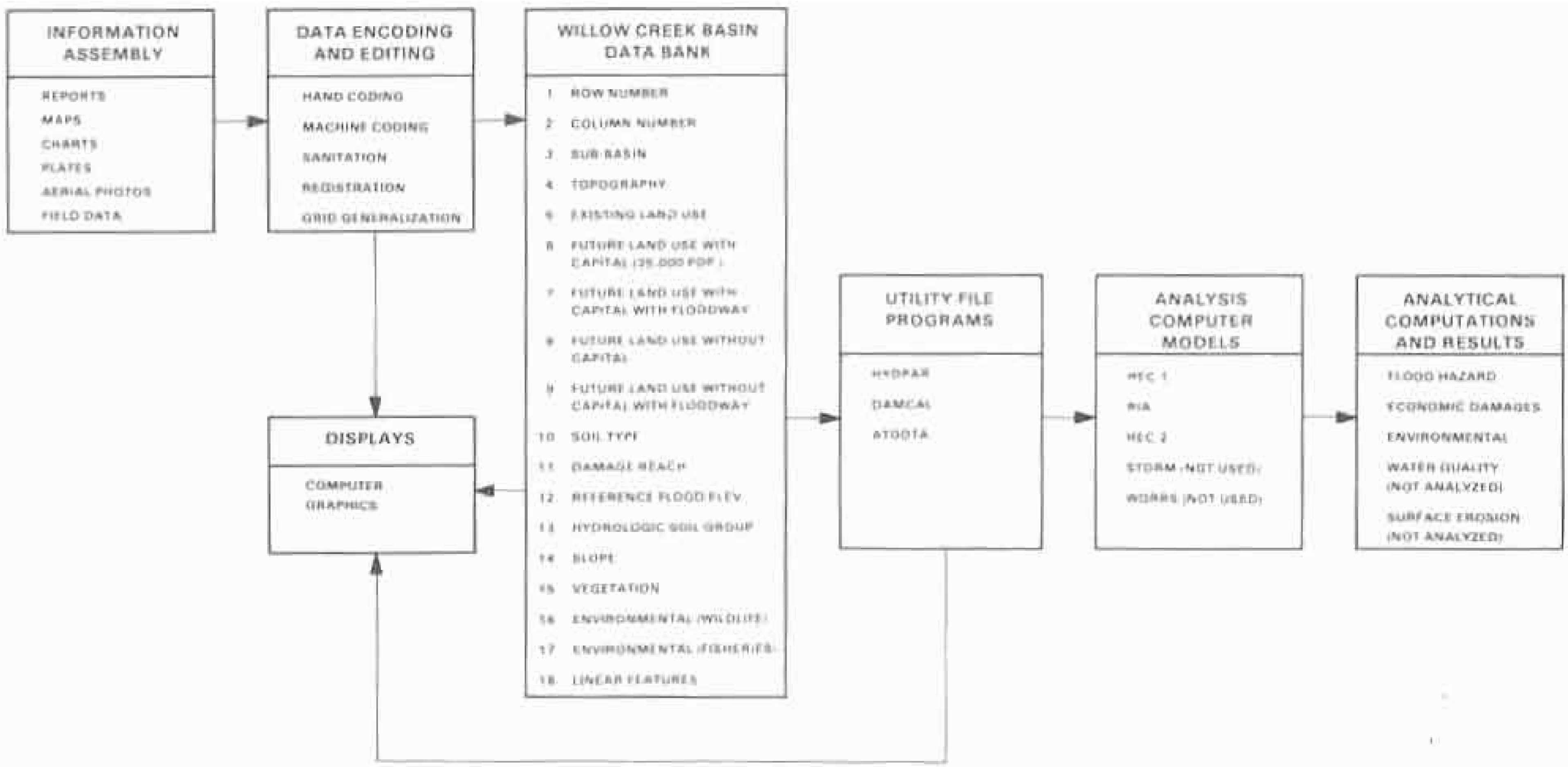
PURPOSE

The purpose of this report is to present the results of the Expanded FPI study on the Willow Creek basin. The study was designed to define hydrologic, economic (flood damage), and environmental conditions for existing (1978) conditions; to evaluate the effects of future land use changes, both on and off the flood plain; and to make available to both State and Borough planning officials a computerized planning tool that can be used to evaluate the impact of changes in land use that are being or that may be proposed, especially if a new State capital and city are developed within the basin.

STUDY APPROACH

The Willow Expanded FPI Study objectives were to develop basic information on flood hazards (flood flows, flood depths, and flood plain delineations), general flood damage potential information (average annual and single event flood damage values), and information on the impacts of land use change on the environment of the study area. These types of information are desired not only for the existing land use condition (1978), but also for future land use conditions, which could include a new State capital in the study area. The study approach selected linked data management techniques to proven analysis procedures. These data management techniques are described in Appendix A. Figure 1 is a generalized schematic of the concept utilized for the Willow Expanded FPI Study. Simply stated, the basis of this concept is the creation of a computerized data bank that contains the spatial identity (location) of individual tracts of land (grid cells) and the data for each cell necessary to accomplish desired types of analyses (flood hazard, flood damage potential, environmental, etc.). The Willow Creek "detailed" study area is divided into about 57,000 grid cells, each cell being equivalent to a parcel of land 200 feet by 250 feet or 1.1478 acres. For each of these grid cells, the data bank contains information on topographic elevation, 1978 land use, future land uses, soil type, vegetation, environmental habitat, and other variables. The data bank is accessed by a system of interrelated computer progams which manage the data, perform the desired analyses and present the results in either tabular or computer graphic form. Although relatively complex, this system is straightforward in this analysis approach. Throughout, decision points are reached that require professional judgment to evaluate the intermediate results prior to beginning the next analysis step. The strength of this concept lies in the capability to perform consistent, systematic, and repetitive analyses on many land use conditions in a highly efficient manner. It is highly flexible in that analysis results may be presented for any spatially defined area.

The approach taken for the study included subdividing the entire watershed into rectangular grid cells and assigning values, which defined physical parameters such as existing and future land use, environmental habitat, topographic elevation, soil type, and spatial location, to these individual cells. The cells, which are the basic unit for analysis purposes, are aggregated to make up an extensive computer data bank which can be readily accessed by utility computer programs to analyze various conditions that might occur in the watershed. Each of the cells in the Willow-Deception Creek data bank has a unique spatial location, ground elevation, both existing (1978) and future land use, soil type, environmental habitat, etc., and can be accessed individually or as a group for either informational purposes, for analysis of storm runoff (imperviousness characteristics), for flood damage calculations, or for assessment of environmental change.



DATA PROCESSING AND ANALYSIS PROCEDURE

Figure 1

BACKGROUND INFORMATION

STUDY AREA

The Willow Creek watershed, as shown on the Location Map, Plate 1, is located in southcentral Alaska, approximately 30 air miles and 70 miles by highway, north of Anchorage. Situated in the southwestern foothills of the Talkeetna Mountains near the historic farming and homesteading area of the Matanuska Valley, the site lies near the junction of the Matanuska and Susitna River valleys. The basin, with a total drainage area of 258 square miles, is tributary to the Susitna River and lies entirely within the boundaries of the Matanuska-Susitna Borough. The predominant soils in the watershed are glacial drift and alluvial sediments consisting of mixed sands and gravels. In addition, there is a mantle of silty loess over much of the basin and deposits of very poorly-drained peat in low-lying areas. Below timberline, which is approximately 2,000 feet above sea level, paper birch-white spruce stands predominate on the better drained soils and the slower growing black spruce is found on the poorly drained soils associated with the numerous sphagnum bogs. Cottonwood is commonly found in the flood plains. Alder and willow thickets are found in the poorly drained soils adjacent to many smaller streams and are also common to most subbasin flood plains.

Physiographic characteristics of the basin are quite varied. Elevations range from approximately 100 feet MSL at the lower end of the basin to about 5,500 feet in the upper end. The upper portion is characterized by mountainous terrain with alpine vegetation while the lower portion is typified by a mixture of spruce and deciduous forest and low lying, swampy areas. It was this lower portion of the basin that was studied in detail. Both Plates 1 and 2 show the extent of the basin and the detailed study area. It should be noted that the upper portion of the basin at the higher elevations is virtually undeveloped at present. A few abandoned gold mines dot the area, but due to the very steep topography and remote location, no appreciable additional development is expected to take place within the time frame of the study projection (i.e. by the year 2000). Therefore, this area was removed from the "primary" data bank, leaving 104 square miles in 20 subbasins for the detailed study area.

The region is in a transitional climatic zone, having between maritime and continental weather conditions. Pronounced temperature variations and cloudy weather are common during a large portion of the year. The Chugach Mountain Range to the south acts as a barrier to the influx of warm, moist air from the Gulf of Alaska, resulting in an average annual precipitation which is only 10 to 15 percent of that at stations located on the Gulf of Alaska side of the range. Annual precipitation in the study area averages 25 inches, with much of it comprised of 100 to 120 inches of snowfall. Rainfall is generally heaviest in August and September with monthly precipitation amounts about equal for the rest of the year. The Alaska Mountain Range, lying in a long arc approximately 70 miles north of the study area, serves as an effective barrier to the flow of extreme cold winter weather from the north. The annual temperature range is from about -45° F to 85° F.

The population of the study area has shown a rapid increase in recent years as landowners subdivide their property, making it available for residential and recreational development. The Trans-Alaska Pipeline project and other general construction projects within recent years have caused a heavy immigration to Alaska from the lower 48 states.

The Matanuska-Susitna Borough had a 1976 population of 15,500 people with approximately 300 in the study area. Projected growth indicates a population of 1,500 in the study area by the year 2000, without the new capital. Various population forecasts exist for the future condition with the capital, the actual figure depending on the plan selected for the move of the capital and construction of the new city.

Should the State relocate the capital to its proposed Willow site, nearly all the development for it is planned to take place in the upper portion of the Deception Creek Basin. Additional development resulting from induced population growth is expected to occur in the areas that are already built up and also in the area between the capital and lower Willow Creek.

The detailed study area includes only a portion of the lands selected for the new capital city. The city though, "as planned" would be located partially within the basin. Although data variables were encoded for the entire capital site and placed in the data bank, the drainage area outside the Willow basin is small, with no streams of significant size. This study, therefore, only covered the flood related problems in the lower portion of the Willow Creek watershed.

The lands within the capital site area are owned almost entirely by the State of Alaska and are virtually untouched by human development. Lands along Willow Creek, however, are in private or borough ownership and have been developed to a limited extent. There are two major roads or highways that presently cross the study area. The Parks Highway runs north and south near the west boundary of the study area, with the Alaska Railroad paralleling it less than a mile to the east. Hatcher Pass Road, from its junction with the Parks Highway, follows Willow Creek upstream, easterly through the basin.

Developments outside the detailed study area, but within the basin, are presently minimal to nonexistent and are expected to remain so during the planning period. A large portion of the study area is drained by Deception Creek, a tributary to Willow Creek. This particular area is part of the 100 square mile parcel of land that was selected by Alaskan voters as the site for the new State capital. The remainder of the detailed study area adjoins Willow Creek, both upstream and downstream of the confluence with Deception Creek.

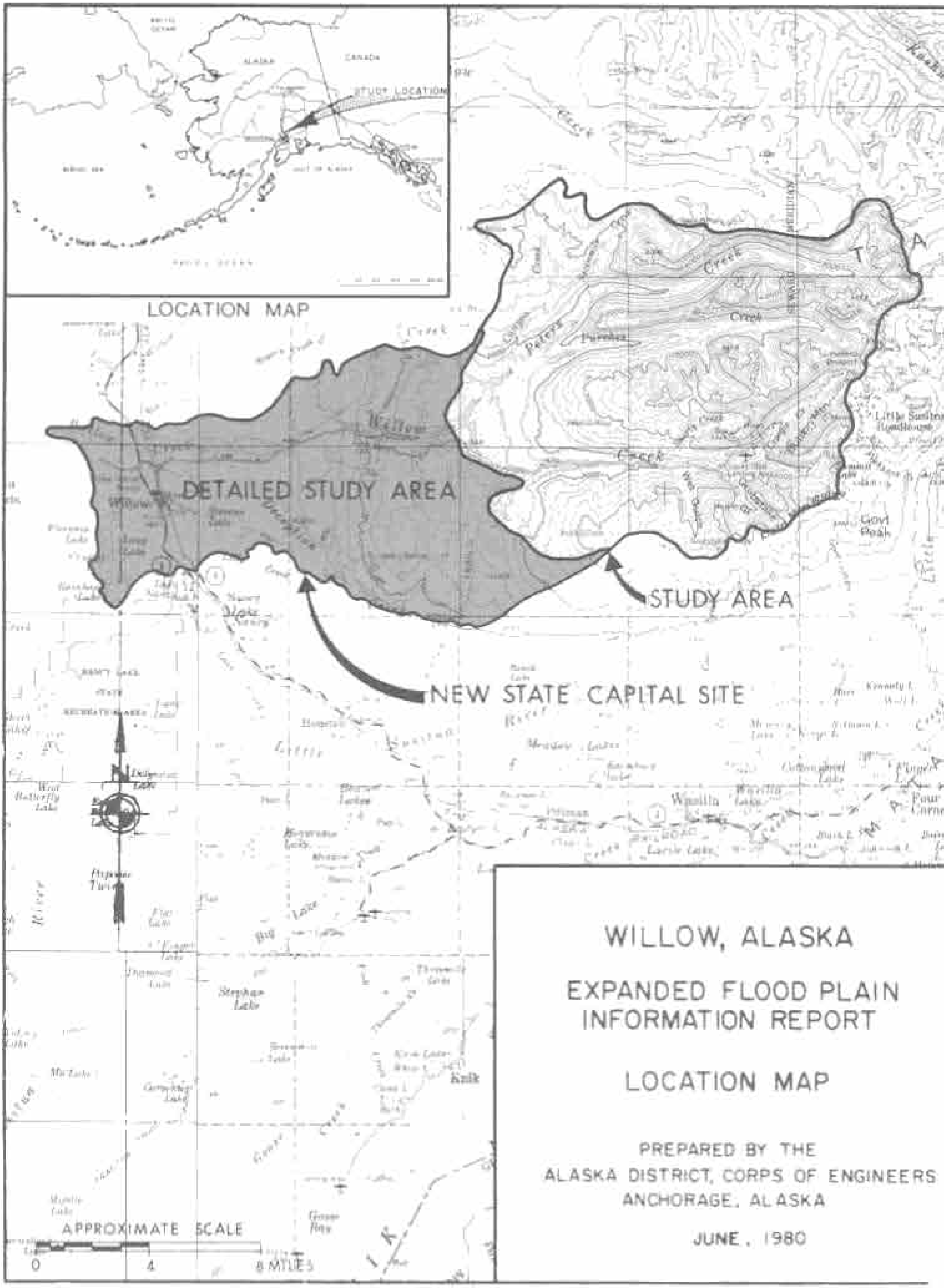
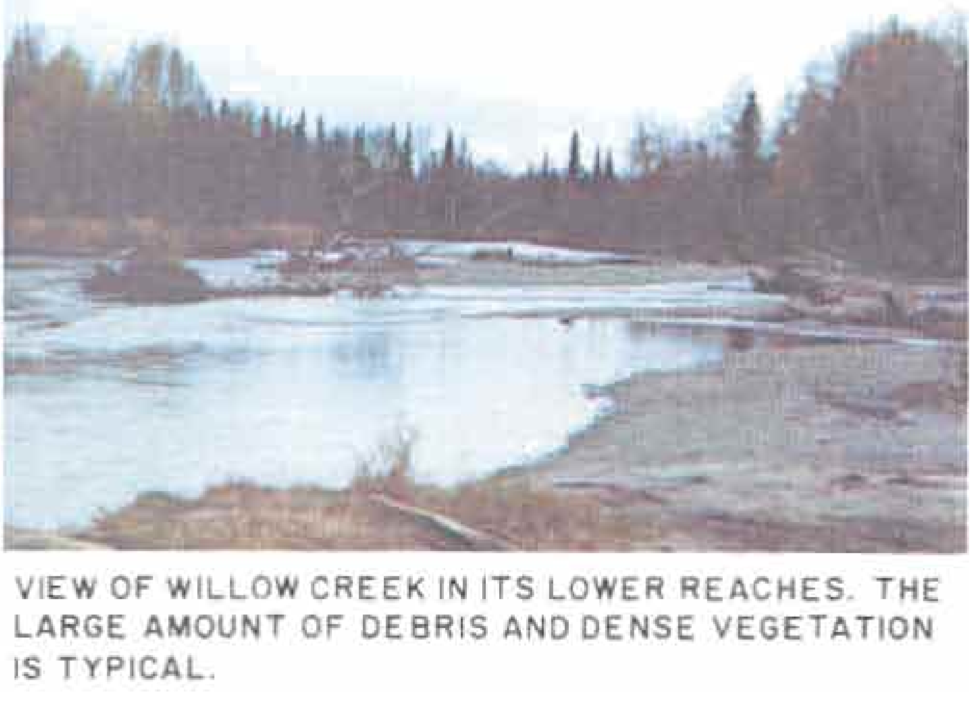

LOCATION MAP
STUDY LOCATION
ALASKA
CANADA
DETAILED STUDY AREA
STUDY AREA
NEW STATE CAPITAL SITE
Willow
Creek
Little Susitna Roadhouse
Govt Peak
Wasilla
Knik
APPROXIMATE SCALE
0
4
8 MILES
WILLOW, ALASKA
EXPANDED FLOOD PLAIN INFORMATION REPORT
LOCATION MAP
PREPARED BY THE
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
JUNE, 1980

PLATE I

VIEW FROM GENERAL AREA OF THE PROPOSED CAPITAL SITE TO THE NORTHWEST (Photo Courtesy of Capital Site Planning Commission).



VIEW OF WILLOW CREEK IN ITS LOWER REACHES. THE LARGE AMOUNT OF DEBRIS AND DENSE VEGETATION IS TYPICAL.

Efforts to move the capital to Willow have met with serious opposition, however, speculation has made this area one of the most rapidly growing areas in the State. The area has also become a focal point of increasing use for recreational activity that can be attributed to the area's esthetic qualities and its closeness to Anchorage, the largest city in the State. Extensive subdivision activity, stressing recreational lots, has been occurring in recent years. Planning for the accompanying growth is a major task faced by both State and Borough planners. To insure that this growth is orderly, consistent with maintaining the desired quality of life and within the assimilative capacity of the environment, goals and objectives must be clearly defined and strived for. As a means of achieving the desired objectives, relatively new data management and analytical techniques, which have great potential as planning tools for future efforts, have been developed and adopted for use in this study.

FLOOD SEASON AND FLOOD CHARACTERISTICS

Floods on Willow Creek can occur as a result of a combination of several factors, including heavy snowpack, temperature, solar radiation, and precipitation. Spring floods may occur as a result of an above normal snowfall during the previous winter, followed by an unusually cold spring and then a rapid snowmelt. Summer and fall floods usually result from intense precipitation. In addition, an ice jam could occur during the winter or during spring breakup causing overbank flooding. Historically, the larger floods have been caused by ice jams or rapid runoff from heavy precipitation. Ice jams have caused the highest flooding on these streams but the recurrence frequency of this type of flood is not known. Typical of most of Alaska, there is little information available concerning historical floods in the Matanuska-Susitna Borough. There is no record of a major flood with known discharge and documented water levels. Public agencies and long-time residents however, substantiate that floods have occurred. Information on historical floods was obtained primarily from interviews with residents in the area. A tabulation of floods in recent years and an analysis of conditions resulting from these floods is shown in Table 1. Other high-flow events resulting in flood problems have been due to log jams; natural and manmade obstructions along the banks and the accumulation of brush and debris along and within the streambed cause most of the problems.

TABLE 1
HISTORICAL FLOODING IN THE WILLOW CREEK BASIN

1938 Willow Creek. Water overtopped the railroad, caused by ice jam.

1955 Willow Creek. Heavy rainfall, damaged railroad.

1964 Willow Creek. Ice jam flooding.

1971 Willow Creek. Log jam caused flooding near Willow, damage to highways and residences.

1975 Willow Creek. Ice and log jams and glaciation caused flooding. Approximately five homes flooded off Hatcher Pass Road, 2 to 5 miles east of the Parks Highway.

1979 Willow Creek. Repeat of 1975 flooding, but more homes affected.

To date, there has been virtually no development along Deception Creek, so little information is available on that stream's flooding characteristics. However, since most development for the capital would be along this stream, the development of flood hazard information is of primary importance. It is expected that Deception Creek would behave similarly to Willow Creek, having periodic floods from jams due to ice and debris but larger ones from heavy summer rains. Being a narrower basin than Willow and having a greater proportion of it in the steeper hills would give Deception Creek a slightly faster response time.

There are no existing flood control structures on either Deception Creek or Willow Creek. Historically, flooding danger or flood plain development has not been considered a major concern by local residents. With the present basin population of less than two people per square mile, development pressures in the past have not been as significant as in several other areas within southcentral Alaska. Presently however, especially with the speculation of the capital move, these development pressures are increasing tremendously and are associated with the growing trend to subdivide streamfront property. As a result, State and Borough planners have made the prevention of increased flood damages associated with new development a high priority resource objective. The Matanuska-Susitna Borough recently passed a zoning ordinance to restrict development in areas noted for flood hazard. These areas along Willow and Deception have been determined by this study and a concurrent Flood Insurance Study which was also performed by the Alaska District, Corps of Engineers.

PROCEDURES

GENERAL

The concept followed in this Expanded Flood Plain Information Study was to develop flood plain information for an existing (1978) land use and for possible future land use patterns. Perhaps, more important though, was the development of a data base for the new State capital site with the capability of providing special investigations and analyses of future development plans. The analysis concepts were designed to make maximum use of traditional methods and to provide for automation of analysis and computer displays where appropriate while providing the capability of performing consistent analyses over a very broad range of detail.

The basis for all analyses is a gridded computer data file. Within this file, or data bank, are data variables, such as land use, topography, soils, and vegetation, for each 1.1478 acre grid in the Willow Creek basin. Utility computer programs were developed that are able to access these files, coordinate, and interpret the data into specific analytical parameters. These parameters are subsequently used by the modeling computer programs which perform the necessary computations, and which are also able to return certain types of data to the files for either display or further use.

ASSESSMENT METHODOLOGY

The purpose of this study is to define the hydrologic, hydraulic, economic, and environmental characteristics of flood plains in the Willow Creek basin for existing conditions and to determine the impact of future land use changes on these flood plain characteristics. Land use changes both on and off the flood plain affect flood characteristics and must be considered in a comprehensive study. The techniques that were developed and used in this Expanded FPI study were designed to accomplish this goal.

It is generally recognized that changes in land use affect the hydrologic characteristics of a stream. This is most often discussed as the increase in flood discharges caused by increased urban development. Several analytic techniques designed to measure this effect are available. Most of these techniques attempt to relate an increase in flood flows to the increase in impervious areas that normally accompanies urbanization. Using these techniques, planners can estimate the impact that future land use patterns or development proposals will have on flood characteristics. Each land use pattern or development proposal that is considered requires a separate analysis, resulting in lengthy computations if more than one or two futures are studied. Therefore, the Expanded FPI Study was designed to evaluate variable futures rather than a single fixed future.

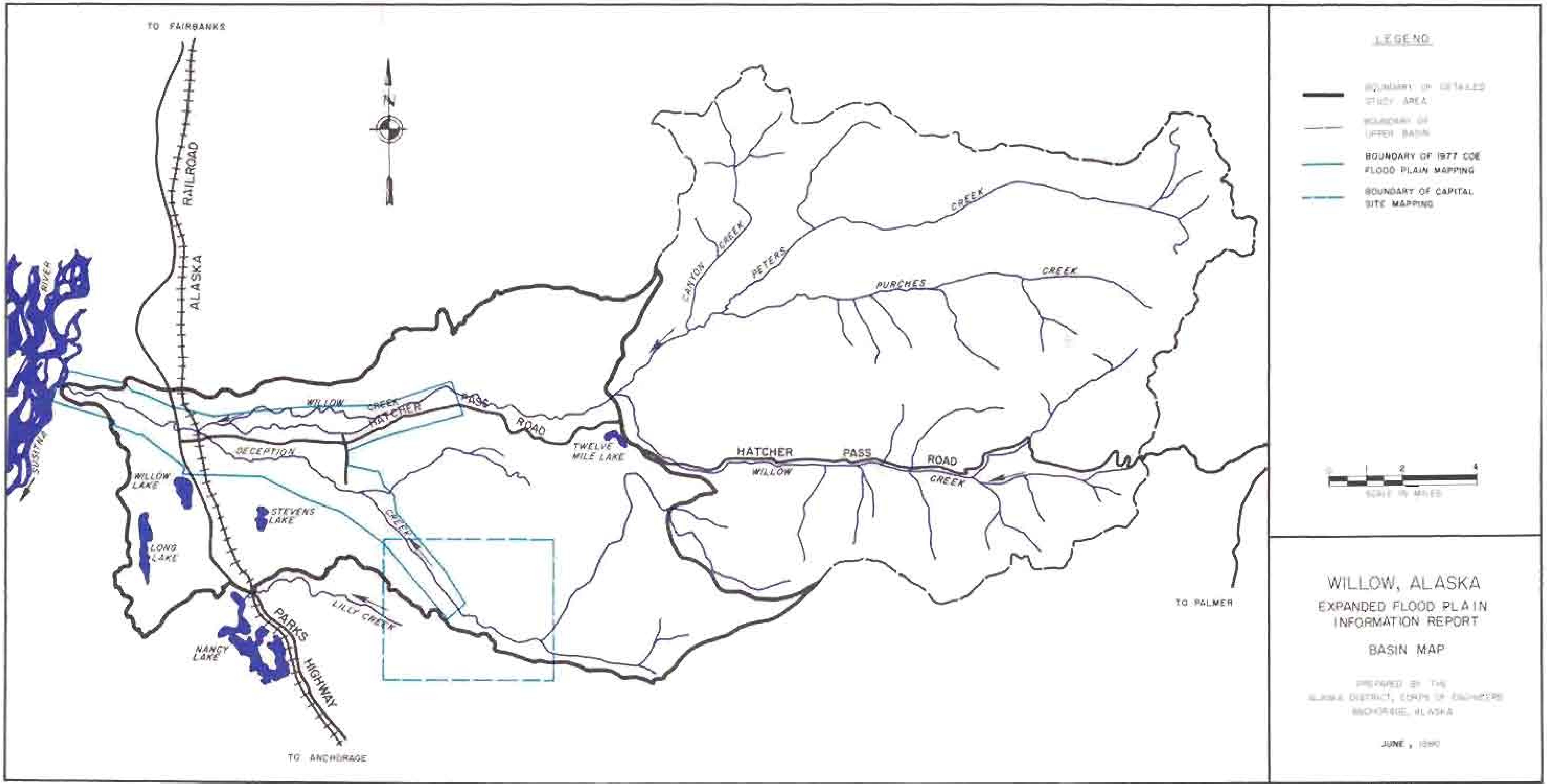
A system of interrelated computer models was developed that would simulate existing and future land use conditions and determine the hydrologic, hydraulic, economic, and environmental impacts of changes in land use. The system is designed to make maximum use of existing computer models and provide for automation of analysis and display where appropriate. Its operation is centered on the integrated use of a gridded geographic data bank. The entire detailed study area is divided into a grid system similar to a giant bingo card. Each grid cell is identified by its location within the grid system and data such as land use, slope, soil type, etc., are coded into the computerized data bank for each separate cell. Data stored in the data bank are then available for use in the various computer models that make up the system.

One of the first steps taken in this study was to determine the levels of effort required and to delineate the area to be studied by detailed methods. This report presents the findings for the detailed study area. It should be noted, however, that a data bank, containing most of the variables, was created for the entire basin and capital site. All areas meeting one or more of the following criteria were included in the detailed study area.

- High concentrations of existing development
- High potential for land use change
- Flood plain areas affected by land use changes

The area meeting these criteria and therefore selected for detailed analysis is shown on the Basin Map, Plate 2. Virtually all present development occurs within this area, and plans for the capital city are limited to this portion of the basin.

Subsequent study procedures called for the gathering and encoding of data for existing conditions. Next, information concerning possible alternative future conditions was developed in cooperation with the Matanuska-Susitna Borough planning staff and State planning agencies and then entered in the computer data bank. Analysis of the hydrologic, economic, and environmental characteristics of the flood plains for existing and future land use patterns was performed by the computer models that are linked to the gridded data bank. Results of these various runs were then compared to determine the impacts of future land use changes. Subsequent analysis of any major proposed development or other changed land use can be provided upon request by encoding the proposed changes into the data bank, executing the proper computer programs, and interpreting the results. In looking at alternative futures, it is necessary to insert or change data for only those grid cells that differ from a base condition.


TO FAIRBANKS
ALASKA RAILROAD
N
RIVER
SUSITNA
WILLOW CREEK
HATCHER PASS ROAD
DECEPTION CREEK
WILLOW LAKE
STEVENS LAKE
LONG LAKE
NANCY LAKE
PARKS HIGHWAY
LILLY CREEK
TWELVE MILE LAKE
CANYON CREEK
PETERS CREEK
PURCHES CREEK
HATCHER PASS ROAD
WILLOW CREEK
TO PALMER
TO ANCHORAGE
LEGEND
BOUNDARY OF DETAILED STUDY AREA
BOUNDARY OF UPPER BASIN
BOUNDARY OF 1977 COE FLOOD PLAIN MAPPING
BOUNDARY OF CAPITAL SITE MAPPING
0 1 2 4
SCALE IN MILES
WILLOW, ALASKA
EXPANDED FLOOD PLAIN INFORMATION REPORT
BASIN MAP
PREPARED BY THE
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
JUNE ,
PLATE 2

PRESENT AND FUTURE LAND USE

Land use is a key factor in this study because it was used to develop the hydrologic and economic (flood damage) analyses for existing (1978) and future conditions. The study assesses the impacts of projected future land use patterns on the major flood plains in the basin. These future land use patterns represent conditions that were reasonably expected to occur, but are not expected to be interpreted as predictions of specific future development patterns. The future land use patterns used in the study could be described as conceptual zoning maps. The land use classifications are broadly defined and do not represent explicit demand at a specific time or represent detailed locational decisions.

Three basin-wide land use conditions were developed for use in this study. These included the 1978 (or base) land use condition, a future condition reflecting development of the new capital city, and a future condition without the new capital. Computer generated maps (RIA Mapping Option, discussed in ENVIRONMENTAL CONSIDERATIONS) illustrating these conditions are shown on Plates 3 to 5. To evaluate the impacts of future urbanization, each future land use scheme was analyzed as initially encoded and for conditions reflecting implementation of various flood plain regulatory policies. This concept is more fully described in the section on Flood Plain Regulation Policies.

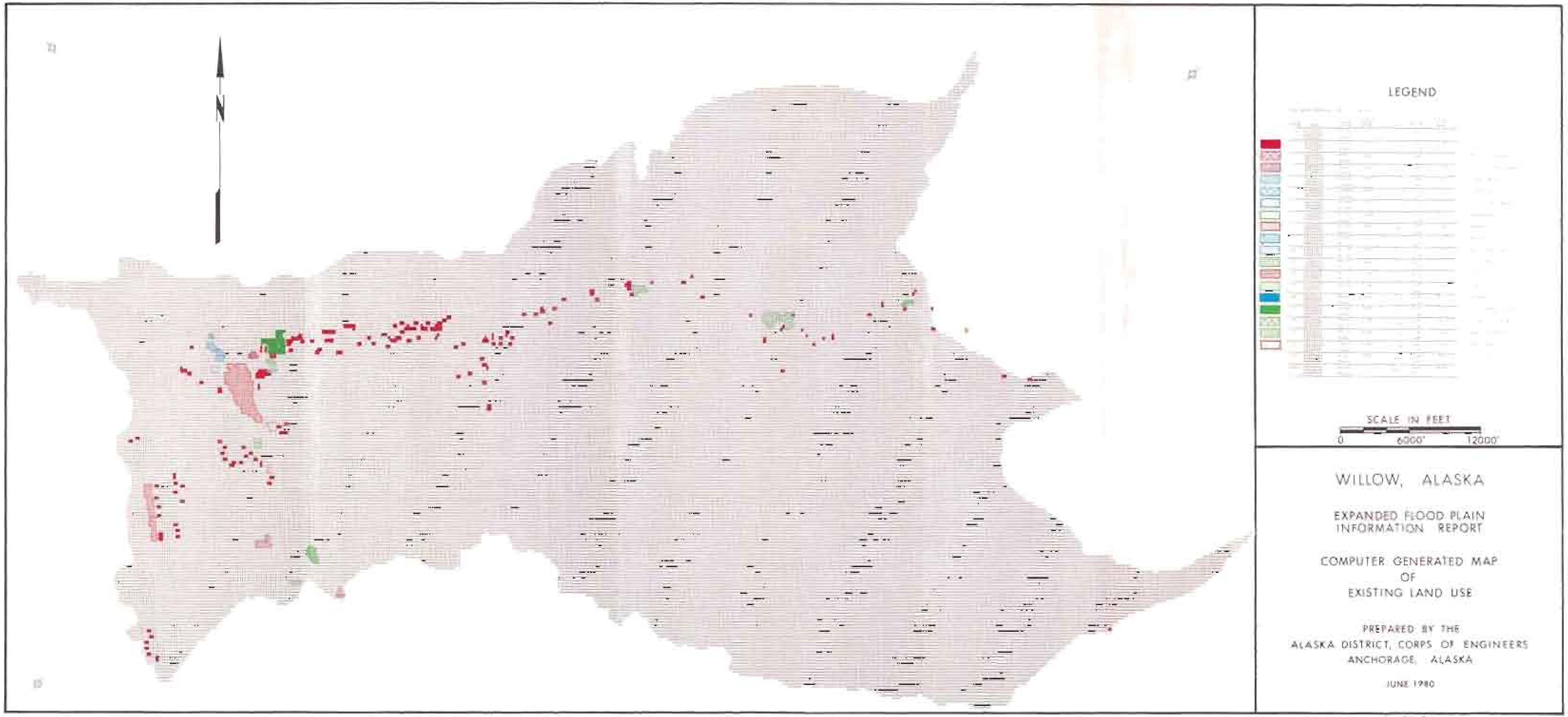
Twenty land use categories were specified to adequately describe the three land use conditions and meet the hydrologic, flood damage, and environmental analysis needs of the study. Table 2 lists these categories and gives the acreages included in each for each land use condition. The principle characteristics of the three basin-wide land use conditions are described in the following paragraphs.

TABLE 2
WILLOW EXPANDED FLOOD PLAIN INFORMATION
ADOPTED LAND USE CATEGORIES

	Land Use Conditions		
Land Use Categories	Existing 1978 (acres)	Alternative B Future Without Capital (acres)	Alternative A Future With Capital (acres)
1. Low Density Residential, Single Family: 0.5 unit/acre	368	1,235	2,243
2. Medium Density Residential, Single Family: 1.5 units/acre	7	7	53
3. High Density Residential, Single or Multi Family: 3.5 units/acre	23	23	1,051

TABLE 2 (CONT.)

Land Use Categories	Land Use Conditions: Existing 1978 (acres)	Alternative B Future Without Capital (acres)	Alternative A Future With Capital (acres)
4. Hotel, Motel:	10	34	26
5. Commercial:	14	115	242
6. Governmental Offices:	7	7	104
7. Educational Facilities:	3	3	3
8. Airport Facilities:	236	209	194
9. Public Utilities:	0	0	379
10. Landfill, Solid Waste Disposal:	5	23	177
11. Sewage Treatment:	0	0	173
12. CoGeneration (Power) Plant:	0	0	84
13. Cemetery:	7	7	7
14. Industry: Building Supplies, Industrial equipment, Machinery, etc.	0	54	357
15. Public Parks:	55	467	2,840
16. Private Resort: Park Campsites, swimming pools, golf courses, etc.	32	87	39
17. Resource Extraction: Gravel & sand pits	85	78	78
18. Mixed Urban: Combination of different land uses	18	26	38
19. Water Bodies	2,055	2,052	2,047
20. Undeveloped Land	62,804	61,302	55,594



WILLOW, ALASKA

EXPANDED FLOOD PLAIN
INFORMATION REPORT

COMPUTER GENERATED MAP
OF
EXISTING LAND USE

PREPARED BY THE
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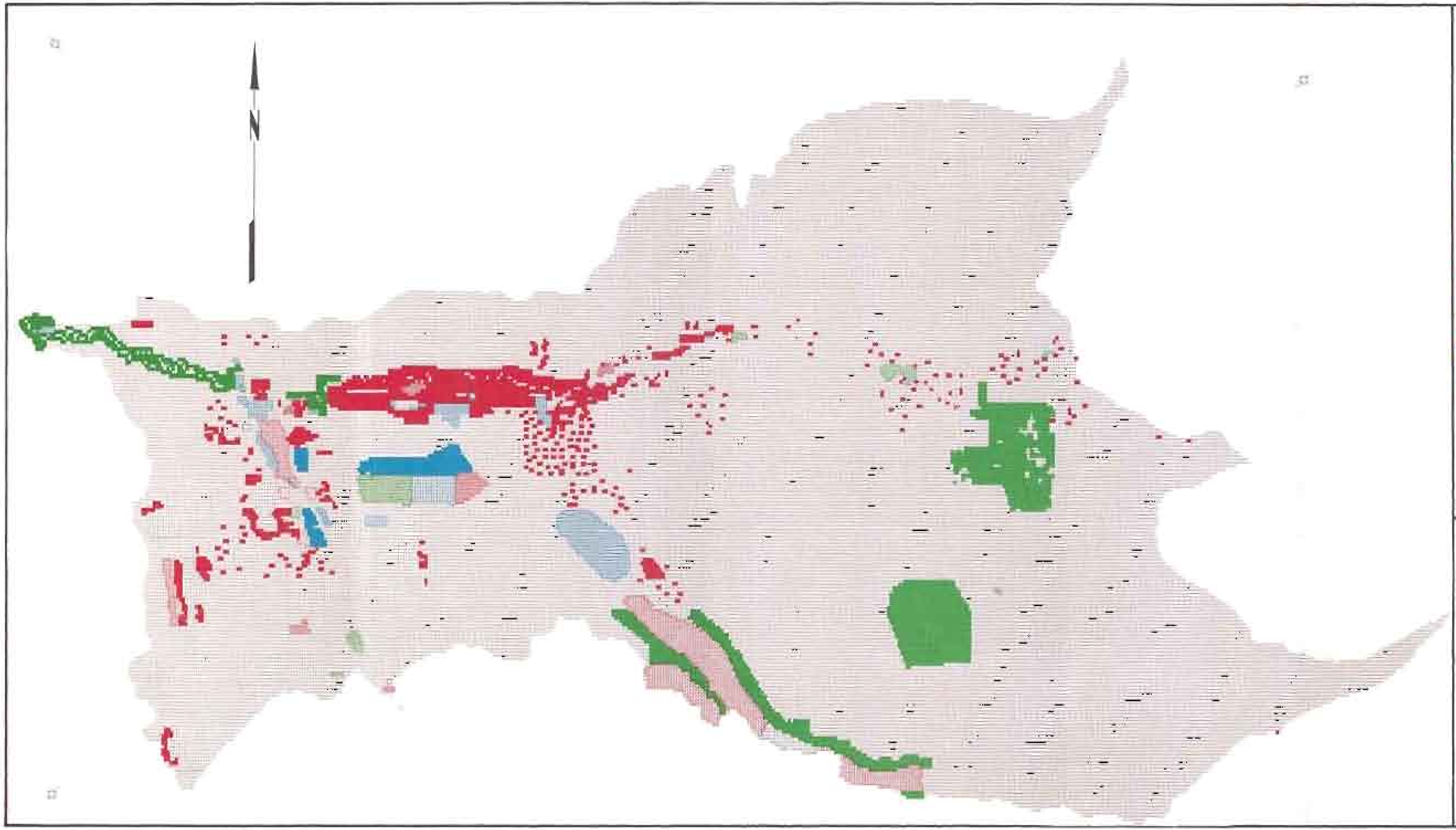
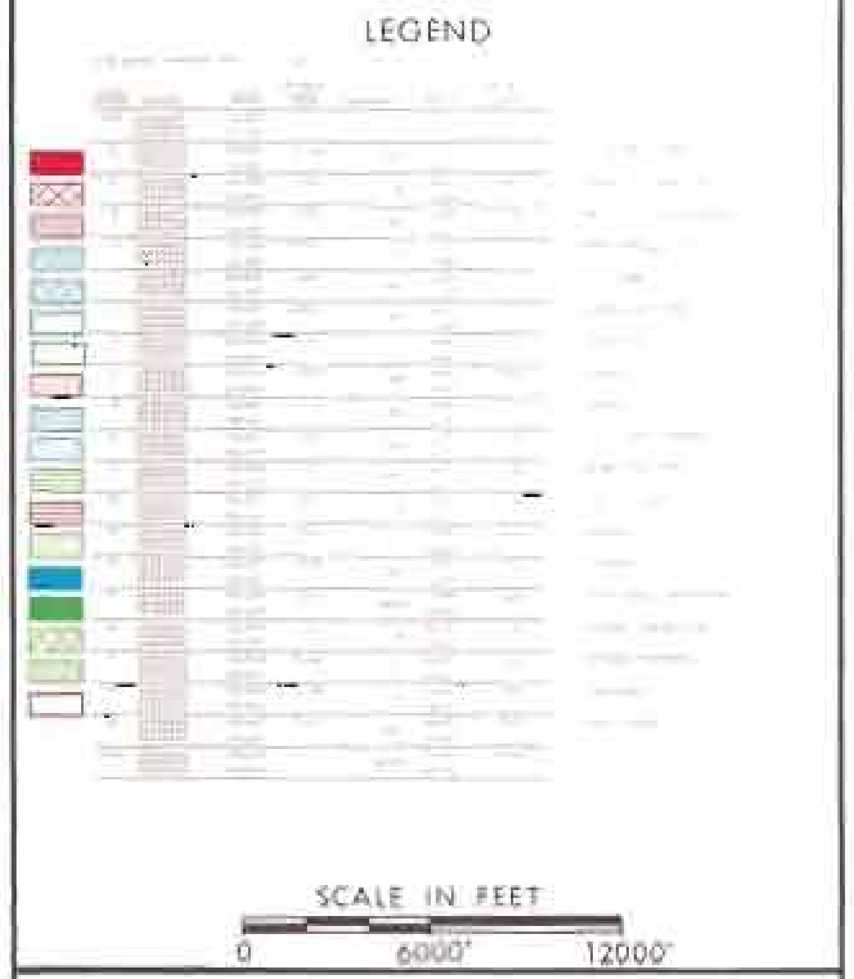
ANCHORAGE, ALASKA

JUNE 1980

PLATE 3





WILLOW, ALASKA

EXPANDED FLOOD PLAIN
INFORMATION REPORT

COMPUTER GENERATED MAP
OF
FUTURE LAND USE WITH CAPITAL

PREPARED BY THE
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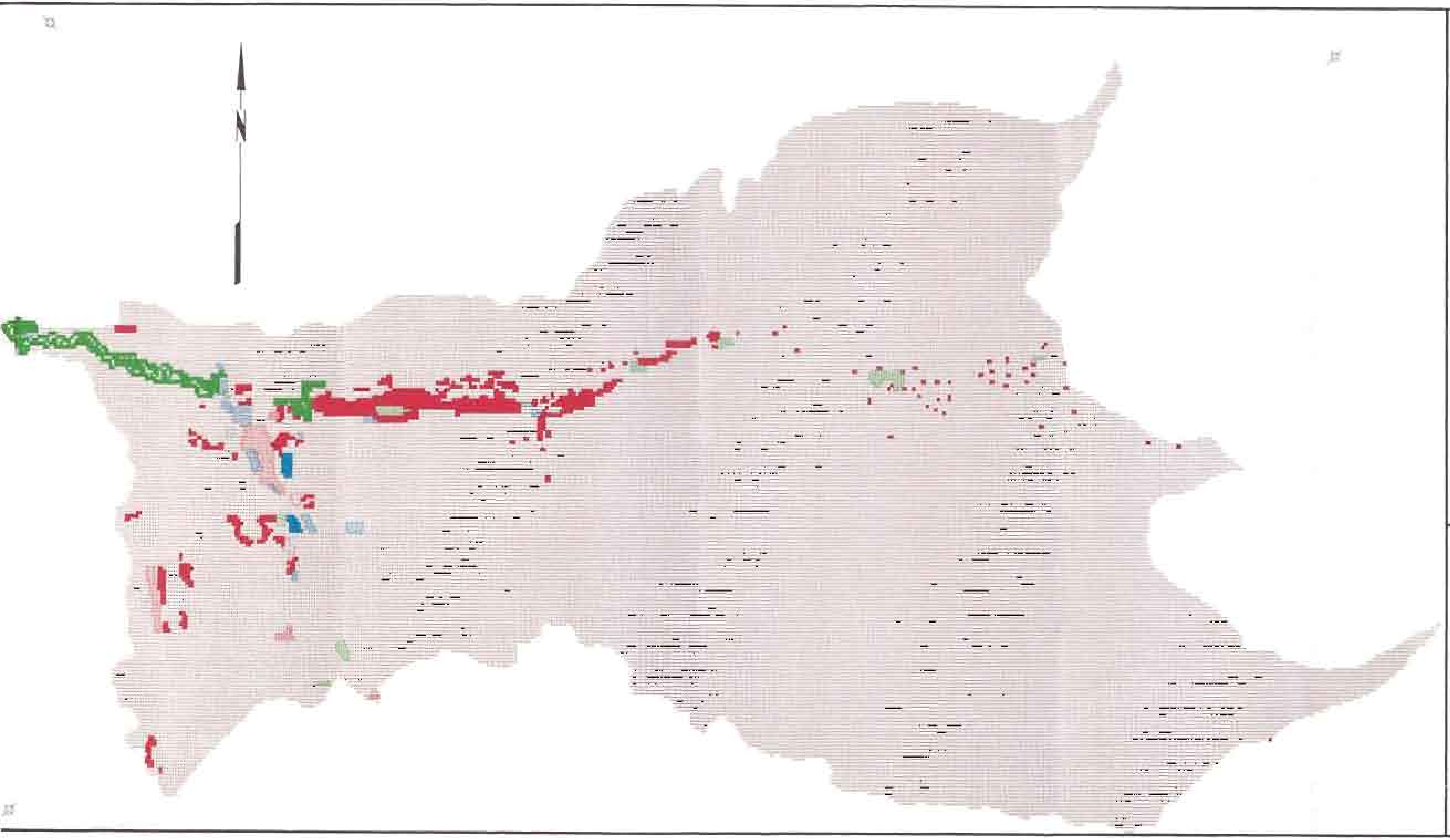
JUNE 1980

PLATE 4



LEGEND

SCALE IN FEET

0 6000' 12000'

WILLOW, ALASKA

EXPANDED FLOOD PLAIN INFORMATION REPORT

COMPUTER GENERATED MAP
OF
FUTURE LAND USE WITHOUT CAPITAL

PREPARED BY THE
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ANCHORAGE, ALASKA

JUNE 1980

PLATE 5

Base Year

The year 1978 was selected as the base year for all land use related study efforts. Since the area had been selected by the voters in August 1976 as the site of the new State capital, there was an immediate need to obtain base line data on this almost totally undeveloped area for use by State planners. As a result, substantial data was gathered in late 1977 and in 1978 for use in this study. Input from the Matanuska-Susitna Borough Tax Assessor (1978 Appraisals), the U.S. Department of Agriculture, Soil Conservation Service and Alaska Department of Natural Resources (Susitna Basin Study), and the Corps of Engineers (high and low level aerial photography and flood plain mapping) was used extensively to develop this base land use condition.

The 1978 base land use condition reflects the undeveloped nature of the basin and predominant low density residential category which accounts for the area's 300 residents. As might be expected, the small pockets of development are concentrated along the major transportation routes and along Willow Creek, a recreational fishing stream.

Alternative Future A

Alternative Future A was based on the assumption that the State capital would be relocated from Juneau to the site at Willow. It uses the Development Plan for the new city that the New Capital Site Planning Commission presented to the State Legislature in 1978 as the basis for the land use conditions for this alternative future. The plan centered on the establishment of a new urban center for a target population of 75,000 on land that is presently completely undeveloped. According to the plan, by the late 1990's the 8,650 central State positions, combined with other primary and service jobs, would result in an estimated population of 37,500. A land use plan corresponding to this population figure and related stage of growth was input as Variable 6 (Future with Capital) and Variable 7 (Future with Capital with Floodway) to the data bank. Flood plain development was minimal within the new city as strong desires for greenbelts and parks along Deception Creek, the natural topography, and flood plain concerns, helped to minimize exposure to flood hazards.

Induced, or secondary development in the basin as a result of the construction of a new city was also considered and reflected in the overall land use plan for this future condition. An additional 2,700 people, primarily concentrated along the Parks Highway and the Hatcher Pass Road, was considered by Borough planners to be realistic of the growth induced by a capital city of this size in this time frame. Borough planners provided assistance in determining the appropriate land use categories and their spatial location that would be associated with this induced growth.

VIEW LOOKING UPSTREAM AT THE CONFLUENCE OF WILLOW CREEK AND PETERS CREEK.

VIEW LOOKING TOWARD UPPER WILLOW CREEK BASIN.

WINTER VIEW OF RECREATION ORIENTED BUSINESSES DOWNSTREAM OF THE PARKS HIGHWAY.

1978 SUMMER SALMON FISHING ACTIVITY ON WILLOW CREEK, DOWNSTREAM FROM PARKS HIGHWAY. (Photo Courtesy Of State Of Alaska, Dept. Of Fish And Game).

Alternative Future B

Alternative Future B reflected a probable land use condition that would exist in the year 2000 if pro-move forces are unsuccessful in relocating the capital. Development, for the most part, would be non-existent along Deception Creek, concentrating instead along Willow Creek and existing roads. An annual population growth of 7.6 percent, from the current figure of 300 to 1,500, was used in determining the land use changes and the level of development for this alternative. Again input and assistance from the Matanuska-Susitna Borough Planning Department aided in the determination and spatial location of the appropriate land use categories for this future land use condition.

Two criteria were foremost in the development of these alternative futures. First, the alternatives were based on land use changes and levels of population growth that were consistent with projections used by State and Borough planners. The selection and adoption of a conceptual plan for a new capital city at Willow by the Capital Site Planning Commission proved to be the basis for Alternative A. Since the Borough had recently entered into the Federal Flood Insurance Program, and therefore adopted basic flood plain regulations, minimal flood plain development was considered. Additionally, due to areas of poor drainage, flood plains, soils, slope restrictions, and plans for a major park, a majority of the acreage within the basin was considered undevelopable. As a result of this and the fact that existing development is minimal and spotty and access is extremely limited, projected development for both alternatives was concentrated in only a few areas.

Second, rather than selecting alternative futures with enough variation in development patterns to demonstrate impacts that these land use changes impart, it was the intent to analyze future conditions that may in fact materialize, including the development of a new city. In August 1974, the voters of Alaska approved an initiative to relocate the capital of Alaska and subsequently chose the site at Willow in August 1976. The major goal of Alaskans in supporting this relocation was to make the government more accessible to the majority of people in the State. Naturally then, the plan for the new capital city, which was selected and refined by the Capital Site Planning Commission, was used as a basis for one of the alternative futures (Alternative A). Due to strong opposition forces and delays to progress on the move thus far, a realistic assessment would also have to consider the aspect of no capital relocation and only normal growth for the basin (Alternative B).

Perhaps most importantly, the study, through the creation and use of the data bank, demonstrated a capability to analyze various land use plans. Through the use of the data bank and the computer programs, future plans or modifications to those plans examined in this study may be systematically and rapidly analyzed by State or Borough planners responsible for land use planning in the basin.

NOTES

1. THE TOPOGRAPHIC PERSPECTIVE OF THE LANDS IN THE PROPOSED CAPITAL CITY AREA WAS GENERATED BY A COMPUTER FROM TOPOGRAPHIC DATA IN THE WILLOW DATA BANK. VIEW IS LOOKING NORTH. VIEWS IN VARIOUS DIRECTIONS OR OBLIQUE ANGLES CAN BE GENERATED FOR THIS AREA OR ANY AREA IN THE WATERSHED.

2. THE ARCHITECTUAL RENDERING OF THE CAPITAL CITY WAS BASED ON THE PLAN PRESENTED BY THE NEW CAPITAL SITE PLANNING COMMISSION. IT USED THE TOPOGRAPHIC PERSPECTIVE AS A BACKGROUND, AIDING IN THE DEVELOPMENT OF THE RENDERING AND IN THE VISUAL PRESENTATION.

WILLOW, ALASKA

EXPANDED FLOOD PLAIN INFORMATION REPORT

COMPUTER PERSPECTIVE and CAPITAL CITY RENDERING

PREPARED BY THE
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

JUNE, 1980

PLATE 6

Plate 6 provides a simple illustration of one of the many capabilities in using the data bank and the available computer programs. A small area within the basin, specifically the capital site area, was "windowed" and, from the topographic data in the bank, a computer generated perspective, looking north at the site, was developed. A rendering of the proposed capital city was then made, superimposing it on the computer drawn perspective. This provides a more realistic view of the site and the development than would have been possible without the perspective. Perspectives such as this can be obtained showing the entire basin or any portion within the basin. In addition to views from any direction, changes to the topography, which may result from large scale developments, may be input to the bank and viewed. This allows the alterations to be visually reviewed prior to actual field work. These views can also be expanded upon for public presentation of various development plans.

SELECTION OF FLOOD EVENTS

This report displays one flood event, namely the 100-year flood. The 100-year flood identifies serious flooding conditions and has been accepted, almost universally, as the basis for flood plain regulations and other planning purposes. It represents a flood with a 1 percent chance of being equalled or exceeded in any given year. Expressed in another way, it is a flood that has a 26 percent chance of occurring during the life of a 30-year mortgage.

It is recognized that significant damages can accrue over a period of time as a result of smaller floods which have a greater frequency of occurrence. For this reason and the fact that a Flood Insurance Study (FIS) for the Federal Insurance Administration, requiring analysis of these events, was being performed concurrently, the 10- and 50-year floods were also selected and analyzed in detail although they were not displayed on the flooded area maps in this report.

It is also important to realize that floods larger than the 100-year flood are possible and are expected to occur sometime in the future. For this study and the concurrent FIS, the 500-year flood was evaluated. If a critical development is expected to locate in or near a flood plain area then flooding from such an event as the 500-year flood should be considered in any planning and design.

FLOOD PLAIN REGULATION POLICIES

To provide local and State officials with expanded information to determine the implications of land use changes, each of the two alternative future land use conditions were further analyzed assuming three different flood plain regulation policies. Evaluations were made to determine flood damages that would occur under each policy. The effectiveness of a given policy in preventing flood damages can be evaluated by comparing the flood damages that would occur with that policy in effect to the flood damages occurring without flood plain regulations. The flood plain regulation policies evaluated in this study are summarized below:

POLICY 1 - No constraints are placed on the siting of future developments. Structures may be located within the 1978, base condition 100-year flood plain. This policy conveys a graphic picture of the economic hazards of flood plain development.

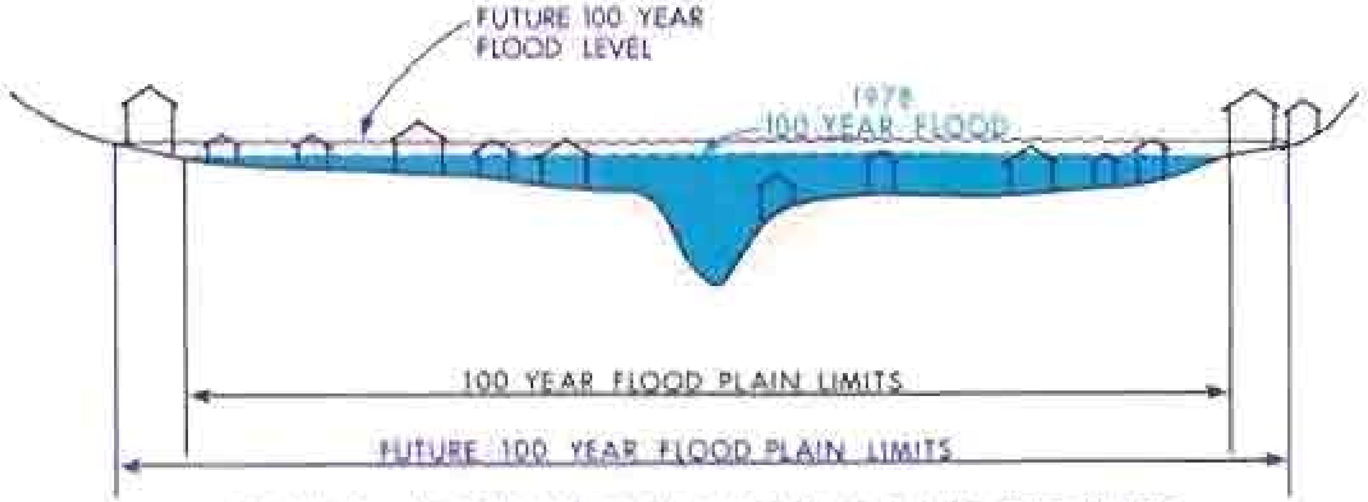
POLICY 2 - Future structures within the flood plain are placed with finished floors at the 1978, base condition 100-year flood elevation.

POLICY 3 - Future flood plain structures are prohibited within the floodway limits, but allowed within the floodway fringe when sited 1.0 foot above the 1978 100-year flood elevation. For this policy, a floodway is defined as that portion of the flood plain, including the stream channel, that is necessary to hydraulically convey the 100-year flood without raising the water surface elevation at any point more than 1.0 foot over the base condition. The floodway concept is shown schematically in Figure 2.

These three flood plain regulatory policies are graphically displayed on Plate 7.

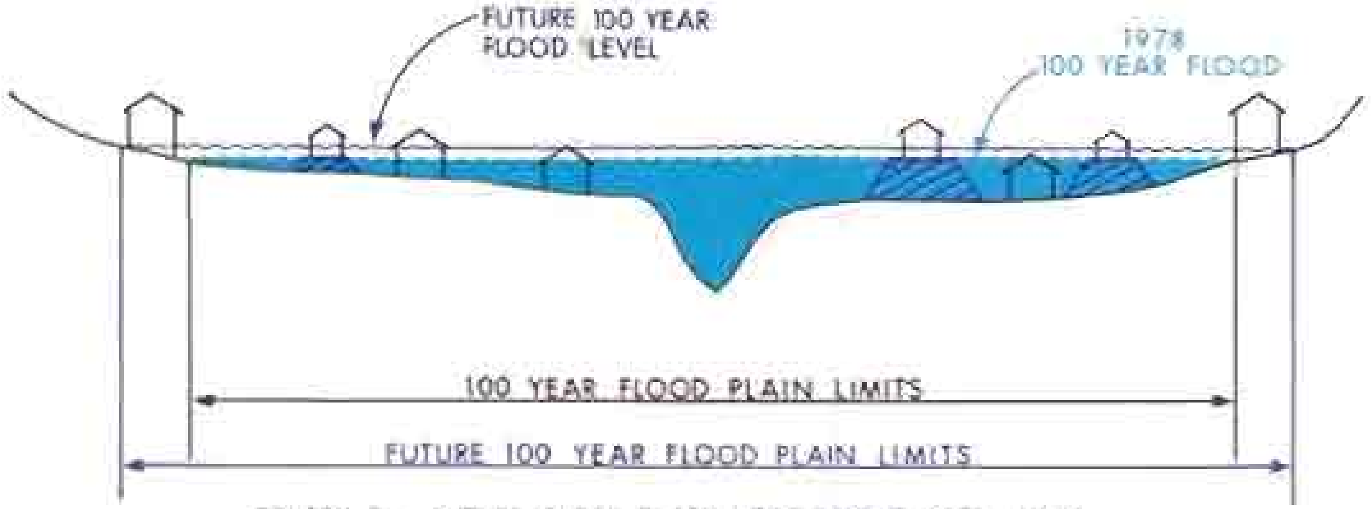
EXISTING CONDITIONS

POLICY 1



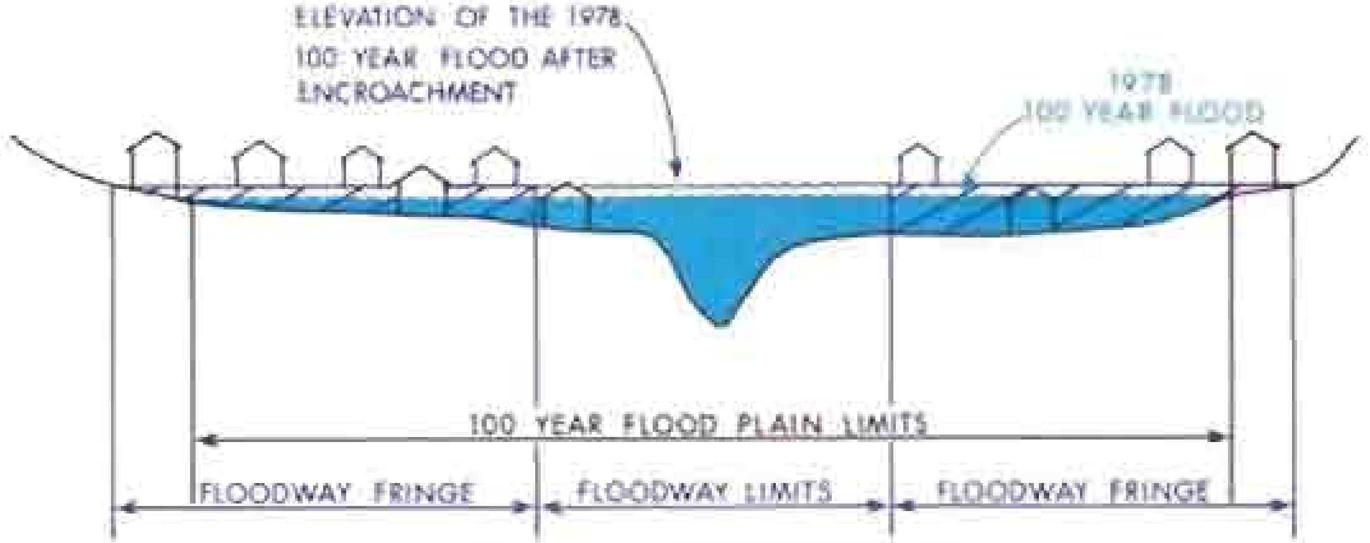
POLICY 1: NO CONSTRAINTS ON LOCATION OF FUTURE DEVELOPMENT. STRUCTURES MAY BE LOCATED IN THE 1978 100 YEAR FLOOD PLAIN.

POLICY 2



POLICY 2: FUTURE FLOOD PLAIN DEVELOPMENT SITED WITH FINISHED FLOORS AT THE 1978 CONDITION 100 YEAR FLOOD ELEVATION.

POLICY 3



POLICY 3: FUTURE FLOOD PLAIN DEVELOPMENT PROHIBITED WITHIN FLOODWAY LIMITS, BUT ALLOWED IN FLOODWAY FRINGE WHEN SITED 1/2 FOOT ABOVE THE 1978 100 YEAR FLOOD ELEVATION. NOTE: THE FUTURE 100 YEAR FLOOD ELEVATION AT A SPECIFIC LOCATION MAY BE ABOVE OR BELOW THE FILL ELEVATION.

WILLOW, ALASKA

EXPANDED FLOOD PLAIN INFORMATION REPORT

FLOOD PLAIN REGULATION POLICIES

PREPARED BY THE
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

JUNE 1980

PLATE 7

HYDROLOGY AND HYDRAULICS

GENERAL

The objective of the hydrologic and hydraulic studies is to determine the magnitude of particular flood events and to delineate the high water marks of such flows along the streams, establishing the basis for flood damage analyses between different land use conditions. Hydrology is used to determine the flows and their exceedance frequencies, and hydraulic studies relate these flows to depths and water surface elevations.

Conventional techniques have been used for the background hydrology (described in detail in Appendix B, HYDROLOGY AND HYDRAULICS) to determine a flow-frequency curve, but the detailed analysis was performed using a computer grid cell data bank. The primary advantage of the computer data bank approach is that changes in land use within the study area, due to natural economic growth, proposed policy changes, or other future activities can be analyzed on a large scale in a systematic, relatively rapid manner. The computer program HEC-1, Flood Hydrograph Package, was used extensively in both the initial development of flow data and in the detailed investigation.

Given the peak magnitudes of streamflow for the exceedance intervals of interest, the HEC-2 computer program, Water Surface Profiles, was used to determine the water surface elevation at several stream cross sections. These flow vs. elevation data were then used in the detailed HEC-1 runs to determine the flood damages associated with particular flow magnitudes.

HYDROLOGIC METHODOLOGY

Since very little recorded streamflow data exists for the creeks in the study area (Deception Creek and Willow Creek), a regional correlation analysis was performed to derive their frequency curves. Other watersheds in the vicinity which do have streamflow records were analyzed, and exceedance frequency curves were obtained and adopted for the mouths of Deception and Willow Creeks.

In a separate analysis synthetic precipitation events for four exceedance frequencies (corresponding to 10-, 50-, 100-, and 500-year frequency floods) were also derived. The total study area, consisting of 258 square miles, was divided into 28 subbasins for better definition of the hydrologic conditions. Using the generated precipitation events with these subbasins, the HEC-1 computer model was calibrated so the resulting streamflows were in close agreement with those on the adopted frequency curves.

The first computer program used in the data bank analysis sequence was HYDPAR, which examined the hydrologic soil group, land use, and land surface slope for each individual grid cell and then computed hydrologic parameters for each subbasin. These hydrologic parameters were then organized by the program ATODTA, with other input data, into a more usable format. One run of the HYDPAR program was required for each type of land use condition analyzed. The different land uses generated different runoff curve numbers and consequently have different hydrograph lag times. The three general land use plans that were considered in the study are the existing (1978) conditions, future (year 2000) conditions with the new State capital, and future (year 2000) conditions without the new capital.

The HEC-1 program (actually a modified version of HEC-1, called HEC-1GS) accepts the output information from ATODTA and some other input data related to precipitation and streamflow routing, then it computes, by the SCS curve number technique, the runoff hydrographs for each subbasin and for the watershed as a whole. With input of economic and hydraulic data, the program is also capable of computing the expected average annual flood damages at selected locations in the study area for each proposed "plan" of development, and it can make comparisons between them. The expected average annual damages are the results ultimately sought in the analysis.

HYDRAULIC METHODOLOGY

The input data required for the HEC-2 water surface profile computation program are stream cross sections (obtained from maps or surveys), roughness coefficients (Manning's "n" from observation and engineering judgment), and streamflows at selected locations (obtained from initial HEC-1 runs). In addition, detailed analysis requires information on bridges and other features affecting the flow profiles.

The flood peaks derived in the frequency analysis and the HEC-1 computations, discussed briefly in the Hydrologic Methodology above, were entered in the HEC-2 streamflow system at the appropriate locations. The program then determined the depth of flow and the water surface elevation at each cross section. Using this information, the 100-year flood plains (flooded areas) were delineated along the streams, defining the regions expected to be inundated by a 100-year (1 percent) flood. The flooded area maps, one phase of the hydraulic studies, were thus developed.

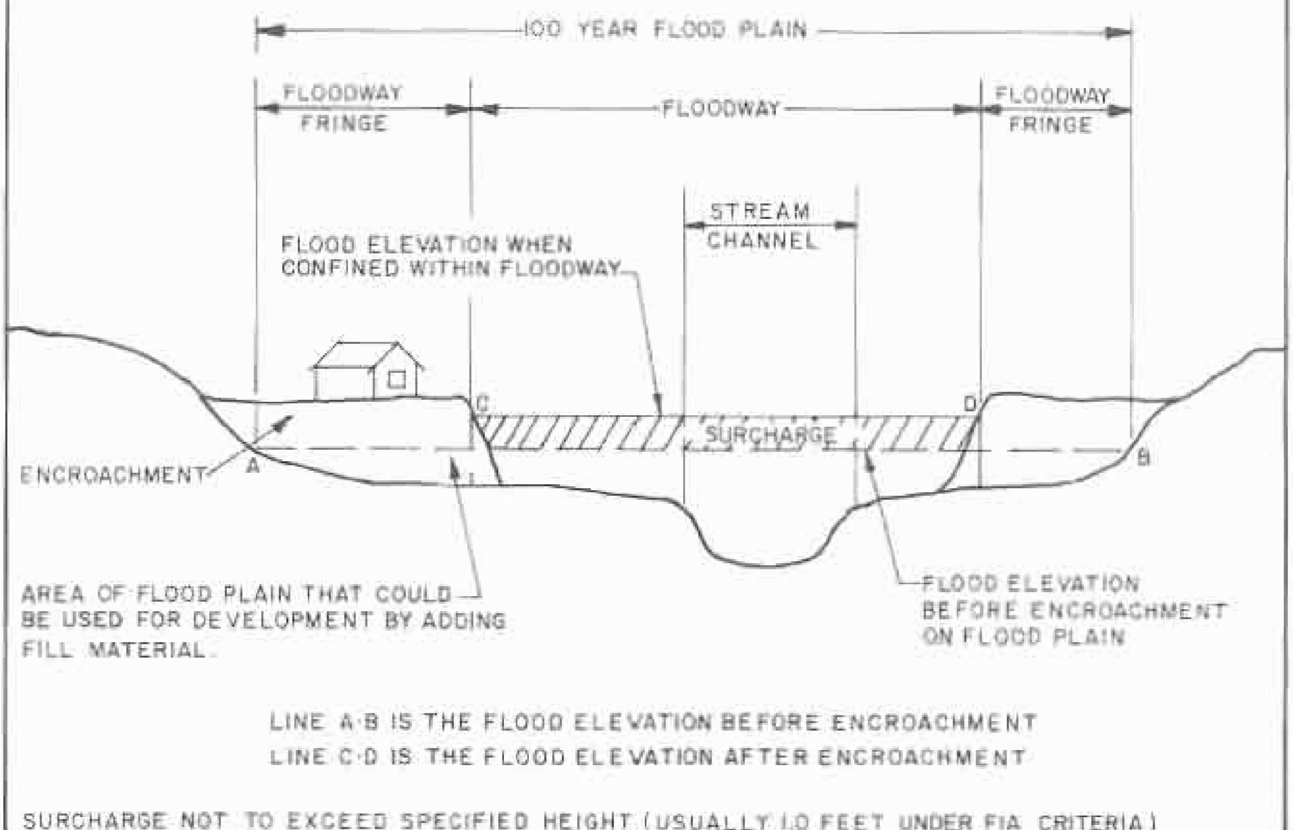
Within the study area, seven stream reaches, each with fairly uniform hydraulic characteristics and exhibiting a fairly uniform economic character of development, have been defined. Computations were made at each of these damage reaches (which are specified by a single index location within each reach) for the damages expected from a given flood. A second aspect of the hydraulic analysis was definition of the discharge-elevation rating curve at each of the index locations. This curve is used as an aid in determining a particular flood's elevation. Finally, the single event flood damages and average annual flood damages were calculated for each stream reach.

The third phase of the hydraulic studies was definition of a floodway for each of the creeks (Deception and Willow) in the study area.

Encroachment on flood plains, such as artificial fill, reduces the flood-carrying capacity and increases flood heights, thus increasing flood hazards in areas beyond the encroachment itself. One aspect of flood plain management involves balancing the economic gain from flood plain development against the resulting increase in flood hazard. The concept of a floodway is used as a tool to assist communities in this aspect of flood plain management. Under this concept, the area of the 100-year flood is divided into a proposed floodway and a floodway fringe. The floodway is the channel of a stream plus any adjacent flood plain areas that must be kept free of encroachment in order that the 100-year flood can be conveyed without substantial increases in flood heights.

Criteria adopted for this study limit such increases in flood heights to 1.0 foot, provided that hazardous velocities are not produced. The floodway was determined for only the existing land use condition.

The area between the floodway and the boundary of the 100-year flood is termed the floodway fringe. The floodway fringe thus encompasses the portion of the flood plain that could be completely obstructed without increasing the water surface elevation of the 100-year flood more than 1 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to flood plain development are shown in Figure 2.



FLOODWAY SCHEMATIC

FIGURE 2

SIGNIFICANT FLOOD HAZARD FINDINGS

There is serious potential for flood damage to existing structures in the Willow study area. A flood with a 100-year frequency would inundate approximately 3,900 acres along Willow and Deception Creeks, damaging many of the structures which are presently concentrated along Willow Creek. Future development, if allowed to take place without regard to the flood hazards, will result not only in increased flood damages but also increases in the areas flooded. Uncontrolled development will subject additional structures to flooding and would increase flood flows and depths of flooding, whether this development is located inside or outside the actual flood plain.

The effect of future development on flooding characteristics is dependent on many factors, perhaps most importantly on the location and size of the development. Major development projects, such as the construction of a new capital city in the upper portion of the Deception Creek watershed, can have significant impacts on flood characteristics and should be thoroughly evaluated to determine these impacts.

A detailed discussion on the hydrology-hydraulics methodology and analysis findings is presented in appendix portion of this report.

FLOOD DAMAGE ANALYSIS

GENERAL

Flood damage evaluations were made for existing (1978) and future land use conditions. Flood damages to the future land use plans were analyzed for a case where unconstrained flood plain development was assumed and for two conditions where all new development would be built in accordance with various flood plain regulation policies. The unconstrained development situation is a "worst case" condition and is not likely to occur. However, it is useful as a reminder of what could happen if the flood hazard in the Willow study area is completely ignored. Much of the existing land use will change in the future. It was assumed that the new land use would be developed in accordance with the flood plain regulation policy being evaluated. Unconstrained flood plain development was assumed for the "no policy" condition. Some of the existing land use will remain unchanged in the future and will suffer increased flood damages regardless of which flood plain regulation policy is adopted.

The inevitable change of a study area from rural to urban provides the basis for establishing management policy. The impact of these policies on flood damage under given development alternatives is summarized in this section of the report.

The detailed study area was about 1.5 percent developed under 1978 existing conditions. Projected development increased to 3.6 percent under the Alternative B (Future Without Capital) condition and to 12.3 percent for Alternative A (Future With Capital). The land use relationship for the two future alternative is not expected to change as urbanization increases: that is, the major use will continue to be low density residential with the introduction of a limited amount of commercial development in the long range future. The following table shows the relationship between lands developed to any degree and virgin land in the Willow and Deception Creek detailed study area, as a percent of this area.

TABLE 3
DEVELOPED LANDS IN THE DETAILED STUDY AREA

	Existing		Alternative B		Alternative A	
Area	% Developed	% Undeveloped	% Developed	% Undeveloped	% Developed	% Undeveloped
Willow Creek (excluding Deception Creek)	3.6	96.4	6.2	93.8	9.1	90.9
Deception Creek	0	100	1.3	98.7	15.1	84.9

FLOOD DAMAGE EVALUATION

Under the present condition of land use there is a real potential that extreme damages can result. Future flood damage increases will be directly related to the degree that urbanization occurs and the extent to which management policies are adopted.

The Matanuska-Susitna Borough has recently become a participant in the Flood Insurance Program administered by the Federal Insurance Administration. This participation guarantees that federally subsidized flood insurance coverage is available to owners and occupiers of all buildings and mobile homes (including contents) within the borough, including the Willow Creek basin.

As required by this program, the borough has adopted land use management regulations which require that all new construction in flood hazard areas be designed to minimize flood loss. These regulations specify that all new construction or substantial improvements have the first floor (including basement) level at or above the 100-year flood elevation and that all utilities be flood proofed.

With these regulations in effect it is expected that damages to future residential, commercial, and industrial flood plain development will be minimized or substantially reduced. This presupposes that the 100-year flood plains will be identified as they have been in the Willow Creek basin and that the flood plain ordinances are strictly enforced. Should this fail to occur, the damage potential will increase drastically with population growth.

As previously discussed in this report, three flood plain regulation policies were evaluated in this study. Policy 1 reflected the situation where no controls or ordinance existed or where the existing ordinance was not enforced. Policy 2 assumed that the current Borough ordinance incorporates the delineation of the 100-year flood for the 1978 year conditions, as determined and shown in this study. The last policy evaluated, Policy 3, assumes that the two zone concept, floodway and floodway fringe, is adopted by the borough as an integral part of the flood plain ordinance for the Willow area.

The actual evaluations were made using the methodology and computer programs described in Appendix D, ECONOMICS (Flood Damage Analysis).

FLOOD DAMAGE ANALYSIS RESULTS

Flood damages that could be expected to occur in the area for the various land use alternatives, with and without regulation policies are shown summarized in Table 4. This summary includes single event damages for the 10- and 100-year frequency floods as well as the average annual flood damages for each alternative.

TABLE 4
SUMMARY OF FLOOD DAMAGES
FOR
WILLOW CREEK STUDY AREA

	1978	ALTERNATIVE B	ALTERNATIVE A
SINGLE EVENT DAMAGES ($1,000)			
10-YEAR FLOOD EVENT			
EXISTING POLICY	903.8		
POLICY 1		3330.0	6613.3
POLICY 2		1291.7	1965.6
POLICY 3		1043.1	1252.8
100-YEAR FLOOD EVENT			
EXISTING POLICY	1233.1		
POLICY 1		4343.1	9149.0
POLICY 2		2084.2	3652.9
POLICY 3		1544.9	2067.4
AVERAGE ANNUAL DAMAGES ($1,000)			
EXISTING POLICY	625.7		
POLICY 1		2371.8	4403.8
POLICY 2		822.7	1150.5
POLICY 3		687.6	812.7

FLOOD PLAIN REGULATION POLICIES

POLICY 1: NO CONSTRAINTS ON LOCATION OF FUTURE DEVELOPMENT. STRUCTURES MAY BE LOCATED IN THE 1978 CONDITION 100-YEAR FLOOD PLAIN.

POLICY 2: FUTURE FLOOD PLAIN DEVELOPMENT SITED WITH FINISHED FLOORS AT THE 1978 CONDITION 100-YEAR FLOOD ELEVATION.

POLICY 3: FUTURE FLOOD PLAIN DEVELOPMENT PROHIBITED WITHIN FLOODWAY LIMITS, BUT ALLOWED IN FLOODWAY FRINGES WHEN SITED 1.0 FOOT ABOVE THE 1978 100-YEAR FLOOD ELEVATION.

This table shows that flood damages in the future will decrease if policy restrictions are implemented. The flood plain regulation policy of prohibiting future structures within the floodway limits and elevating structures in the floodway fringe 1-foot above the 1978 existing condition 100-year flood elevation is the most effective policy analyzed for reducing future damages.

Although the damage threat to occupied buildings is expected to be arrested to varying degrees, depending on which policy (2 or 3) is adopted, it is doubtful that the same will be true of highways and railroads. Transportation networks are often found in and adjacent to flood plain lands as a result of cost considerations. Even when flood damage costs are added to construction, operation, and maintenance costs, it often remains less expensive to build on flat lowland areas than on more rugged upland terrain.

The regulatory measures analysed do not prevent flooding but, instead, reduce the threat of damage or loss of life from floods by discouraging development of homes and other buildings on flood plains. Without additional measures, damage to existing property will continue, and road and bridge related damages are likely to increase. As a means of alleviating this situation the following alternatives should be considered.

For Existing Properties

a. Permanent measures built as an integral part of the structure, such as raising the elevation of the structure, waterproofing of basement or foundation walls, anchorage, and reinforcement of floors and walls, and use of water resistant materials.

b. Contingency measures which require action to be taken to make them effective, such as manually closable sewer valves and removable bulkheads.

c. Emergency measures carried out during floods according to prior emergency plans, such as sandbagging, pumping, and relocating contents to flood-free areas.

d. Reclamation of flood plains which includes the permanent evacuation of developed areas subject to inundation and the acquisition of these lands by purchase or land swaps, the removal of structure, and the relocation of the population from such areas.

e. Use of flood watch or warning systems to provide advance notice of impending flood danger.

f. Buildings and mobile homes within or adjacent to the delineated flood hazard areas shown in Appendix C of this report should carry flood insurance on the structure and its contents. Although this will not reduce existing damage potential, it will have the effect of spreading the flood hazard risk.

For Future Road And Bridge Construction

a. When analyzing proposed alternative transportation routes, the costs of potential flood damage should be investigated and included for use in the decision making process.

b. Construction designs should reflect sound engineering judgement with regards to flood hazard potential. This includes the analysis of soils, geology, hydrology, and hydraulics, as well as adequacy of construction materials.

ENVIRONMENTAL CONSIDERATIONS

GENERAL

To fully assess the effects on the environment resulting from developmental activities proposed by Federal, State, and private entities a thorough understanding of ambient conditions is required. An increased awareness of the necessity for comprehensive analysis prior to developmental action has led to the promulgation of numerous land use planning regulations designed to insure that both short-term and long-term project effects are evaluated. This report outlines the 1978 baseline environmental conditions identified at Willow, Alaska, and presents methodologies which can be utilized to ascertain the relative effects of altering given conditions in the study area.

To aid local planners in the preparation of functional land use plans for the Willow area, a detailed investigation describing known and potential flood effects in the Willow drainage basin was undertaken by the Alaska District, Corps of Engineers. The potential impacts on the local environment due to the implementation of these future land use plans can only be adequately assessed with a thorough understanding of local conditions. This is a precursor to sound decision making. To gain this information, an environmental inventory of the study area was conducted through literature search, contract studies, and onsite investigations. Color, color infrared and black and white aerial photo imagery was also utilized to develop the 1978 environmental data base. The environmental inventory and resource management analysis is presented in Appendix E of this report. Study topics addressed during the expanded flood plain investigation included:

Environmental Inventory and Evaluation

Water Quality

Resource Management

ENVIRONMENTAL INVENTORY AND EVALUATION

The purpose of the environmental inventory developed during the study is to document those biotic conditions occurring in the Willow study area prior to habitat alteration resulting from proposed future development. Land cover habitat categories were delineated for the 1978 base year condition. From this data, alternative future land use plans were subjectively evaluated and the results presented. The methodology used and the evaluation of future land use plans was intended to serve as an example of the capabilities for the future use of State and local planners in their decision making processes relative to the future development in the Willow Creek drainage basin.

Significant findings resulting from the environmental inventory process and subsequent analysis of the alternative development strategies in the study area include:

1. The Willow Creek study area, while displaying a diverse habitat regime, is typical of the southcentral railbelt ecosystem.

2. There are no known threatened or endangered animal or plant species inhabiting the area.

3. The American Peregrine Falcon (*Falco peregrinus anatum*) is a possible migrant throughout the study area.

4. An increase in developed lands resulting from the expansion alternatives evaluated will result in increased runoff rates, reduced water quality and a reduction of wildlife habitat.

5. The habitat categories within the 100-year flood plain will experience little cultural development and be affected least on an acreage reduction basis. The habitat categories occupying the flood plain fringe will incur the most significant habitat category modification resulting in species dispersion in these areas.

WATER QUALITY

An important aspect of environmental analysis within a watershed is the existing water quality and projected change in quality directly or indirectly attributable to development actions. There are many methodologies available for the evaluation of water quality, each with its own advantages and disadvantages. The overriding requirement for any meaningful water quality analysis, however, is a known period of record to calibrate the analysis parameters. Once calibrated, models such as Storage, Treatment, Overflow, Runoff Model (STORM), and Water Quality for River - Reservoir Systems (WQRRS) can be utilized to predict effects on the hydraulic system. The lack of historical water quality data in the Willow Creek drainage basin precluded the attempt at identifying existing or projected future water quality conditions. Future studies in the Willow basin should outline a water quality sampling program to develop stream and lake base data for calibrating such models.

RESOURCE MANAGEMENT

To adequately assess the implications of future development within a given study area a quantitative approach to impact evaluation must be utilized. The development of computer modeling techniques has greatly enhanced man's ability to quickly and efficiently analyze the large data base necessary to fully document existing conditions. However, with the introduction of subjectivity in the assignment of numerical values for computer simulation this form of analysis is not absolute. Armed with the knowledge of these constraints, a detailed simulation process can be performed and the interpretation of results accomplished. The Resource Information and Analysis (RIA) program, developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Center (HEC), is one example of simulation technology available for planning purposes.

The RIA program performs four distinct analyses and allows the option of either graphics or tabular displays of the results. The four programs include:

1. Distance Determination. This program calculates the linear distance of each grid cell from the nearest cell containing a data variable category of interest, such as the distance of each grid cell from the adjacent cells categorized as cultural influence.

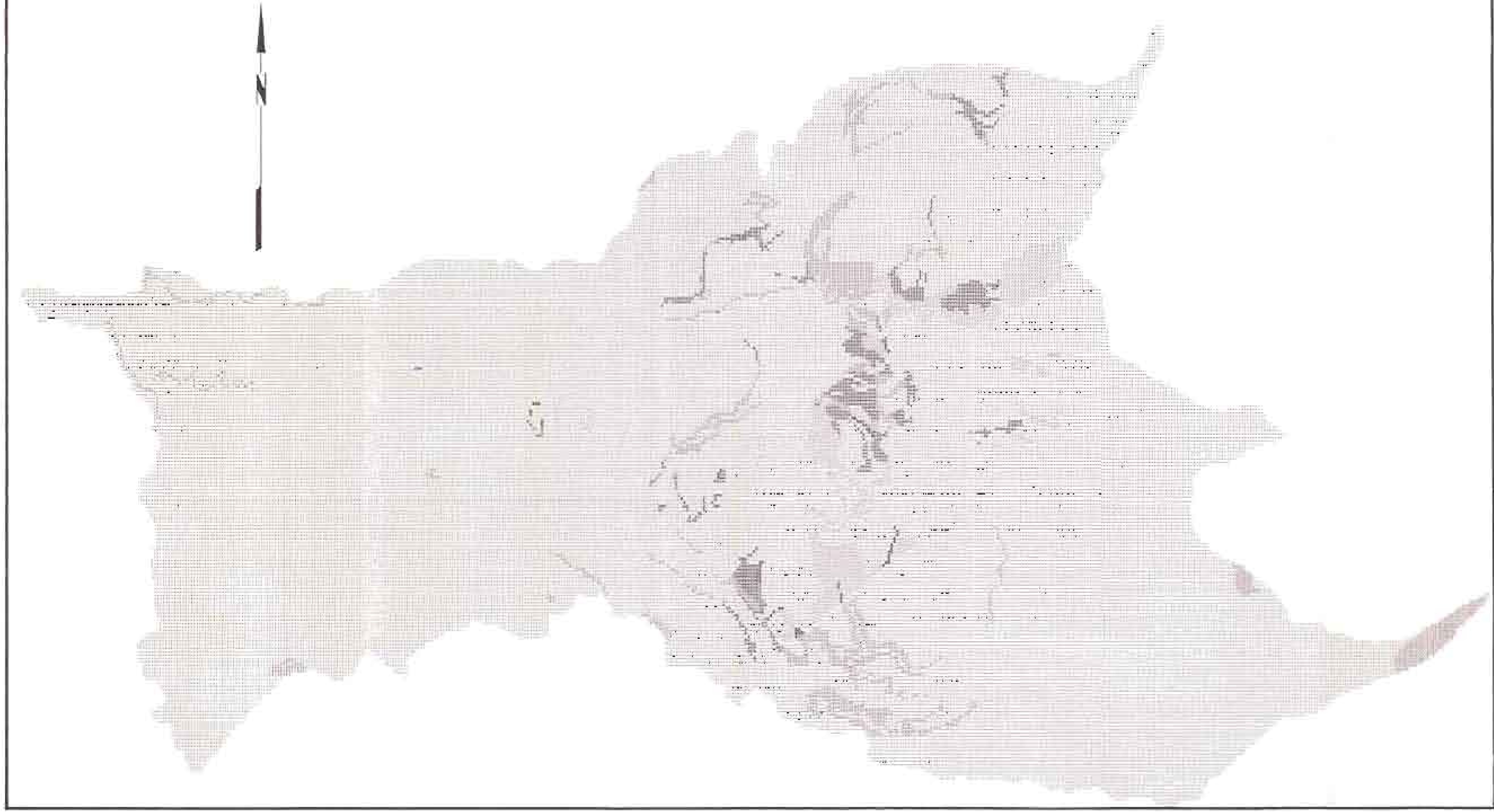
2. Impact Assessment. This program is designed to determine locations of high environmental impact potential resulting from a development activity. The impact potential to be analyzed is flexible and definable by the system user.

3. Locational Attractiveness. This program is an environmental land use analysis which emphasizes the identification of combined locational characteristics that would be attractive for a particular activity. The procedure develops numerical attractiveness index values for each grid cell for the desired activity, based upon subjective judgments as to attractive locational characteristics for a particular land use of interest. An example would be the delineation of park spaces or a ski slope.

4. Coincident Tabulation. This program accounts for coincidence of categories between two data variables within the categories of a third data variable. The third variable usually denotes a geographic boundary such as the drainage basin boundary. This allows for a graphic display of the quantitative changes in land use.

5. The Mapping Package. This program provides computer line printer graphic displays of the variables listed in the base data file as well as results of the four previously mentioned computer programs. Several analyses can be performed in a single computer run. In an effort to demonstrate the use of RIA capabilities, a typical planning problem is presented in the following paragraphs.

With the potential for the capital city relocation into the Willow area, recreational needs for the anticipated population influx must be evaluated. The development of a winter sports area could be a prime development desire by the local planners. Using the attractiveness model capabilities of RIA, a determination of the most desireable area for such a development can be mapped, based upon any number of planning criteria established for site locations. The example shown on Plate 8 presents an evaluation based upon ground slope and known moose habitat. The program allows the planner to subjectively weight each input variable. In this example the requirement of slopes ranging from 12 to 45 percent was a requirement for a ski area and therefore of primary concern. Moose habitat was then weighted to insure that no areas known as critical spring or winter habitat would be identified as a prime development locations. This is a simplified example of the program's potential. Additional parameters could easily have been added to further define the best possible area for winter recreation development. Distance from



SCALE IN FEET

0 6000' 12000'

WILLOW, ALASKA

EXPANDED FLOOD PLAIN INFORMATION REPORT

LOCATION ATTRACTIVENESS FOR WINTER RECREATION SITE SELECTION

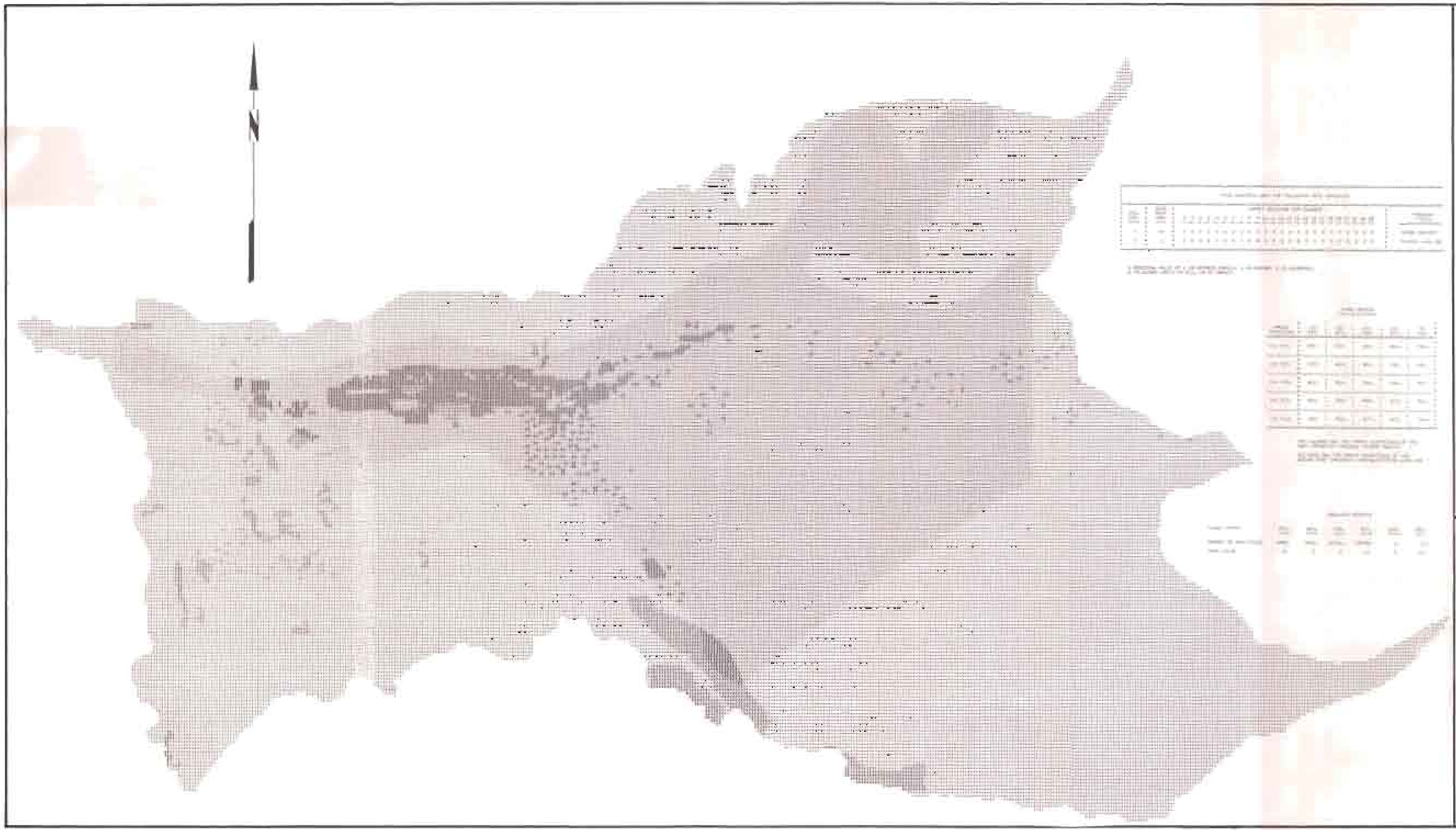
PREPARED BY THE
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

JUNE 1980

existing roads, vegetation cover, habitat categories, soil types, land status (developed vs undeveloped), land ownership, critical habitat areas, etc., could be specified to insure delineation of an area posing the least environmental damage while meeting the recreational needs of a new community. The model develops an index value for each grid cell (1.15 acres) based upon the user specified combinations of data variables. The computed index value represents the relative attractiveness of each grid cell for the desired activity based upon the information stored for each grid cell location. The basis for such a program is from McHarg's manual technique of composite color overlays to define an area or activity of interest.

The analysis process requires the selection of variables contained in the data bank. The categories found in each variable must then be reclassified on a relative scale of zero to ten, with ten being most attractive. Raw attractiveness index values are then computed based on the relative importance of each data variable in the analysis. The raw index values of one analysis are not comparable to those of another analysis which compares different data categories. The attractiveness model results are displayed utilizing the overprint (grey shading) option of the mapping package of KIA, with the most attractive areas in the example printed as the darker areas. This allows a direct comparison of the attractiveness output to a mylar base map of the same scale, allowing for site specific development analysis.

Another example of this capabilities of KIA is the impact assessment program. An example of this analysis is displayed in Plate 9, which shows the results of an analysis of the potential alteration of seasonal critical moose habitat through residential development. By encoding a subjective weighting factor for each category identified in the base data file for Moose Habitat and Future Land Use with the Capital City, the Impact Assessment package was able to establish an impact matrix. A computer printed graphic display of this matrix was generated, detailing grid cells classified as either no potential impact, slight potential impact, moderate potential impact, severe potential impact or extreme potential impact. A review of Plate 9 reveals those specific areas where incompatable wildlife critical habitat and proposed future land use interface, yielding a classification of extreme potential impact. With this information available, side by side comparisons with proposed land use sites can be accomplished to insure minimal impact on resident fish and wildlife resources.



WILLOW, ALASKA

EXPANDED FLOOD PLAIN INFORMATION REPORT

IMPACT ANALYSIS OF FUTURE LAND USE ON MOOSE HABITAT

PREPARED BY THE
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

JUNE 1980

PLATE 9

APPENDIX A
DATA MANAGEMENT
FOR
EXPANDED FLOOD PLAIN INFORMATION STUDIES

APPENDIX A
DATA MANAGEMENT FOR EXPANDED FLOOD PLAIN INFORMATION STUDIES

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DATA MANAGEMENT
FOR
EXPANDED FLOOD PLAIN INFORMATION STUDIES

GENERAL

The purpose of this appendix is to describe the overall approach and concepts of the computerized modeling techniques which have been developed by the Corps of Engineers Hydrologic Engineering Center (HEC) for application in Expanded Flood Plain Information (FPI) Studies. This study-type is "Expanded" from traditional Corps flood plain information studies in that both present and future basin-wide land use conditons are analyzed, and environmental concerns and flood damage potential are considered in addition to the basic flood plain mapping.

The Expanded FPI methodology, in blending traditional methods of computing flood flows, profiles and damages with the recently developed utility and modeling programs that were designed to systematically handle large amounts of data for analysis and display, is a significant departure from past Corps study procedures. The objective of this new type of study is to develop broadened flood plain information, including hydrologic, hydraulic, flood hazard, general damage potential and environmental information for existing and selected alternative future land use patterns in the watershed. In addition to this large scale assessment capability, the capability is also provided for the analysis of specific proposals, such as determining the impact of a new residential subdivision or a large shopping center, on downstream development. The general concept embodied in the Willow study is to develop flood plain information for existing conditions (1978) and for future land use patterns that consider development in the watershed with and without a new capital city. The study provides the continuing capability to perform special investigations and analysis as the need arises.

Included in this appendix is a discussion of the methods of analysis, the computer programs, data collection and management procedures, and the interaction of the variables being considered (soils, land use, environmental habitat, damage reaches, topography, etc.). The analysis methodology involved the integrated use of spatial, gridded geographic data files. The basic unit in these data files is a rectangular grid cell with an area of 1.1478 acres, which has specific values assigned for each variable being considered (i.e., topographic elevation, soil type, land use, etc.). The entire watershed was subdivided into these units, creating a massive data bank which was then used by computer utility programs to analyze various conditions of development. The ultimate aim of the study effort is to provide Federal, State, and local officials, as well as other planners, information which will assist them in making land use decisions for those areas in or near the flood plains of the study area. Input from Borough and State planners, especially on future land use patterns, added to the validity and usefulness of the results. Rather than presenting strictly a report as an end product, this study provides a basis and a "continuing" capability, through the use of the data bank, for planners to rapidly and consistently assess the impacts of various development plans for the Willow Creek basin.

STUDY PROCEDURES

The study procedures to be used for the Willow Creek Expanded FPI Study can best be summarized as shown in the following chart and schematically on Figure A-1.

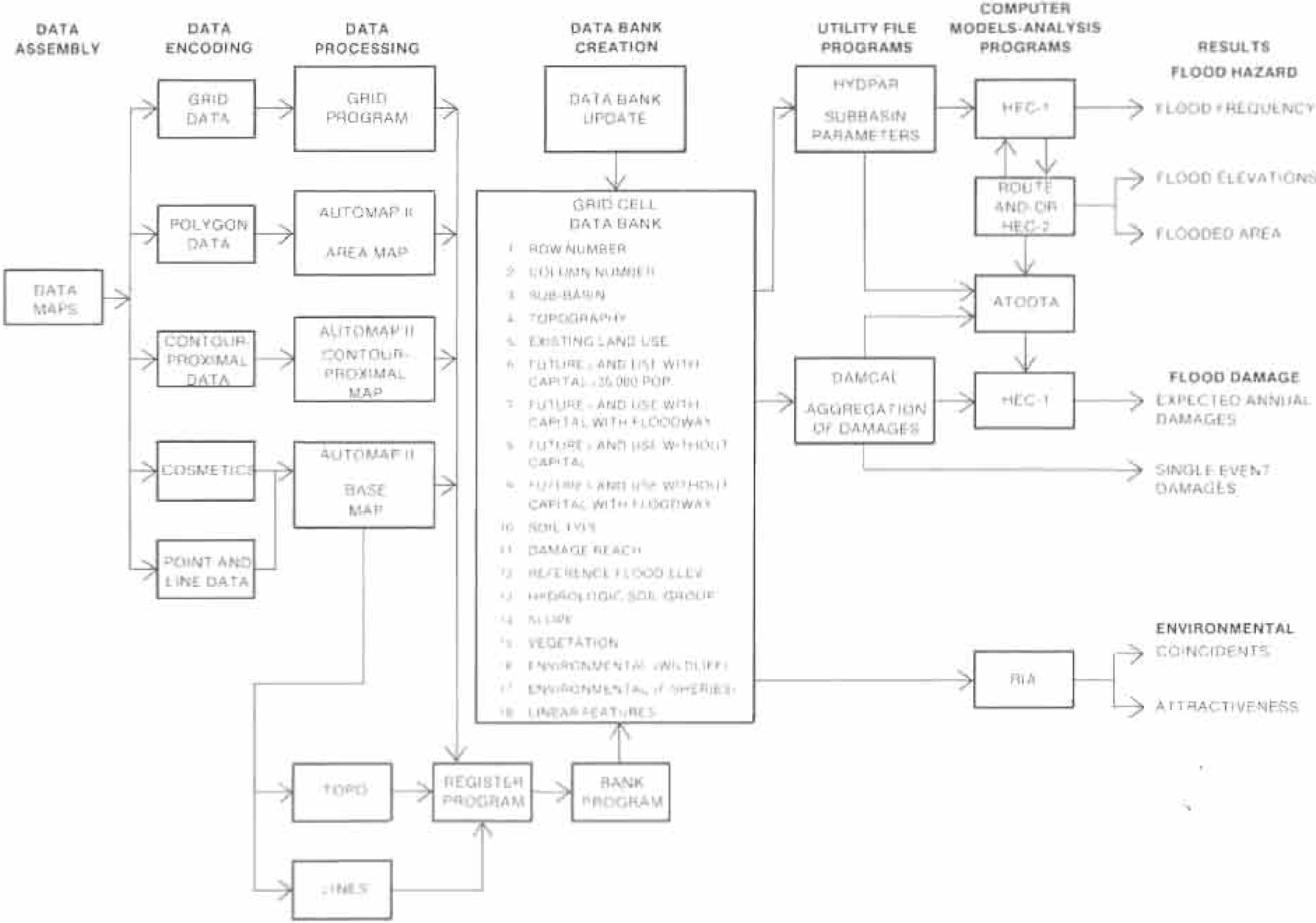
STUDY PROCEDURES

DATA MANAGEMENT	ANALYSIS	RESULTS
Data Collection	Hydraulics	Flood Hazard Information
Data Encoding	Hydrology	Flood Damage Information
Data Processing	Economics	Environmental Information
Data Bank Creation	Environmental	Resource Management Information
Accessing Data Bank	Resource Management	

DATA MANAGEMENT

Data management, as defined for this appendix, begins with the collection of raw data and extends through the development of a computerized data bank capable of being rapidly and efficiently accessed for subsequent analyses in each of several functional areas. In order to achieve this objective, a procedural concept was selected which allowed aggregation of one or more of the variables within the overall data set from some small, spatially oriented units to one of several other spatial units of greater areal extent. Use of this data management approach is neither new nor unique, as it has been used by landscape architects and planners for many years. However, the potential for using this approach as a viable tool, capable of performing specific engineering and related water resources analyses, has gained much impetus recently as a result of the development efforts of the Hydrologic Engineering Center of the U.S. Army Corps of Engineers (HEC), as well as other agencies, institutions, and private firms.

The spatial units selected for this study, in order of increasing areal extent are; grid cell, subbasin, and basin. The grid cell selected for this study is rectangular in shape and is 0.1 inch in the X-direction by 0.125 inch in the Y-direction at a scale of 1" - 2,000'. This cell size is not arbitrary, but is equal to the size of one character on the computer printer utilized for this study. The area equivalency of one cell is 1.1478 acres, which can be calculated as follows: given that the base map system utilized is at a scale of 1 inch = 2,000 feet (blown up 1:63,360 scale USGS Quadrangle) and using a computer printer character of 0.1 inch by 0.125 inch, the areal coverage of one computer printer character at this base map scale is an area of



DATA MANAGEMENT AND MODELING PROCESS

Figure A-1

200 feet by 250 feet or 1.1478 acres. Use of a grid cell of this size and shape enables preparation of undistorted computer graphical output of either data stored within the data bank or specific analysis results.

Data Collection

The four classifications of data which were considered when establishing the study objectives are as follows:

1. Area data (such as subbasin boundaries, land use, and soils)

2. Contour proximal data (such as topography)

3. Line data (such as transportation routes)

4. Point data (such as archeological sites)

At this point, it should be emphasized that a base map was prepared early in the study. This allowed all study team members to work from a common map and decreased the potential for data registration problems.

During the data collection phase, new mapping obtained for the flood hazard delineation and for the capital site was controlled to the base map system. Delineation of the existing land use and environmental habitat categories, controlling the final maps to the base map system, was prepared. Table A-1 contains a listing of major variables within the Willow Creek data bank.

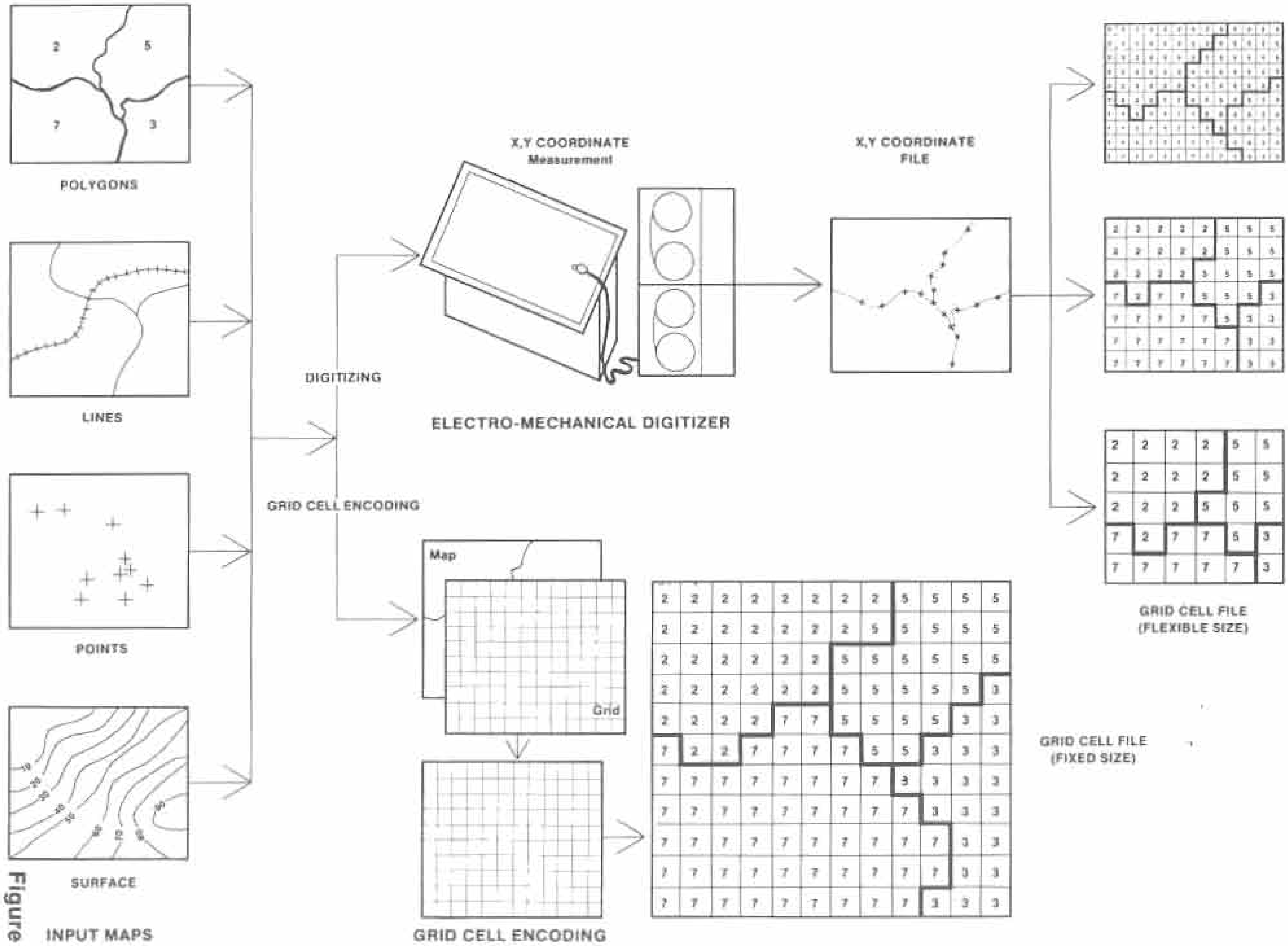
Data Encoding

Encoding is the conversion of spatially related data into digital or grid cell form for subsequent processing into a grid cell data bank. Two procedural methods were utilized for this study. The more easily understood method is the grid cell approach, wherein a transparency of the grid cell system is placed over a mapped variable. Each grid cell is then assigned, by visual inspection, a value corresponding to individual categories of the particular variable being encoded. This method is relatively simple for variables such as subbasins and damage reaches; however, it is a very time-consuming task for the more complex variables such as soil delineations. This method is reliable, but offers no flexibility for sensitivity testing of the effects of a different grid cell size unless the data is reencoded.

The second method of encoding is referred to as digitization. The approach for this method is to transfer the mapped data to a sufficient number of X-Y coordinates to define the spatial extent of the data variable being encoded, whether that data is areal, line, point, or contour proximal data. It can be accomplished manually or automatically (such as with a line-follower digitizer). Under these procedures, the original data maintains its identity, but further processing is required to convert the digitized data to grid cell data. This concept was

TABLE A-1
WILLOW CREED EXPANDED FPI STUDY
MAJOR DATA VARIABLES DIRECTORY

Number	Description
1	Row
2	Column
3	Subbasin
4	Topography
5	Existing Land Use
6	Future Land Use With Capital
7	Future Land Use With Capital With Floodway
8	Future Land Use Without Capital
9	Future Land Use Without Capital with Floodway
10	Soil Type
11	Damage Reach
12	Reference Flood Elevation
13	Hydrologic Soil Group
14	Slope
15	Vegetation
16	Environmental (Wildlife)
17	Environmental (Fish)
18	Linear Features


POLYGONS
LINES
POINTS
SURFACE
INPUT MAPS
DIGITIZING
GRID CELL ENCODING
X,Y COORDINATE
Measurement
ELECTRO-MECHANICAL DIGITIZER
X,Y COORDINATE
FILE
Map
Grid
GRID CELL ENCODING
GRID CELL FILE
(FLEXIBLE SIZE)
GRID CELL FILE
(FIXED SIZE)

Figure

utilized on several of the Willow Creek study variables, and was performed for the Alaska District by Philadelphia District, U.S. Army Corps of Engineers. Both methods of encoding are shown in Figure A-2.

Data Processing

After the basic data has been encoded, it is processed to produce a grid cell data file for insertion into the data bank. The major tasks in this effort include editing of the encoded data to remove encoding errors, preprocessing of point and line data, and registration of the data to a common base. The editing task is primarily manual with some assistance by computer searches for inconsistent data.

For the cell-encoded data, the first process after encoding is to produce a computerized graphical output (map) of the particular variable under consideration. This is accomplished by using the mapping option of the Resource Information and Analysis (RIA) Program (described later). The data source map initially used for the encoding procedure, in transparency form, can then be placed over the computer printer graphical output. A visual editing procedure is used to isolate encoding errors. For data variables digitized by automated means, a plotted map (via a flatbed plotter, etc.) is placed under the transparent data source map and visually edited. Errors can then be corrected via a cathode ray tube (CRT) terminal. The next step involves the registration or exact matching of the edited, digitized data to a common base map. This step is essential to assure that for a specific cell, simultaneous acquisition would yield an accurate set of data for that specific location. Registration is accomplished by the HEC computer program "REGISTER" which utilizes a multiple linear regression fitting technique. With this program it is possible to register digitized data, for any portion of the overall study area and at any scale, to the base map system by procedures which change scale, transfer the origin, compensate for rotation, and remove distortion. A system of match points, at least seven of which must be on any given piece of digitized data to be registered, must be established for the area of concern. The next step involves generation of grid cell files from the digitized data. This is accomplished using the computer program AUTOMAP II, developed by Environmental Systems Research Institute of Redlands, California.

Data Bank Creation

Basic data that have been (a) cell encoded, edited, and corrected and/or (b) digitized, edited, corrected, registered, and converted to grid cell representations via AUTOMAP II are then ready for insertion into the data bank. In simplified terms, the data bank was created by using the computer program BANK developed by HEC to produce a systematic stacking of individual grid cell representations onto magnetic tape. This grid cell storage concept produced a sequential cell by cell arrangement which can be accessed and manipulated efficiently. The method permits efficient retrieval of multiple data variables for each cell so that, regardless of the number of variables in the data bank to be used in an analysis or the number of grid cells for each variable, only one search of the data bank is necessary and only computer storage capacity to process the number of variables involved is required.

Figure A-3 illustrates conceptually how a single data variable may be visualized as a numerical matrix and also illustrates how portions of the grid cell data bank contain several data variables. Creation of a data bank is a demanding rather tedious task that is neither trival nor inexpensive. The validity of the analysis, naturally, will only be as good as the quality of the data bank.

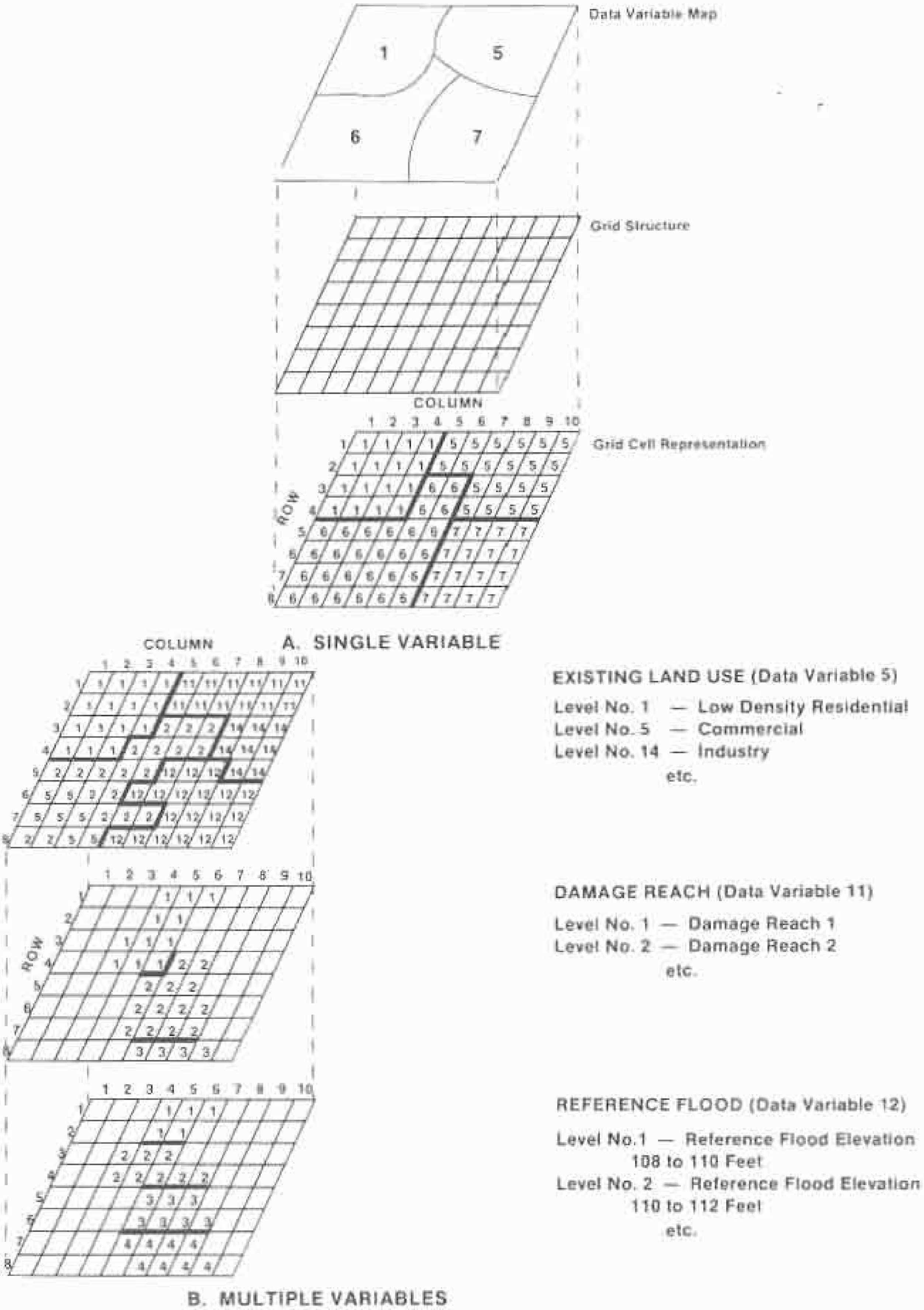
The grid cell data bank was initially envisional to include the entire study area (i.e. all 28 subbasins and their 258 square miles) and even the area outside the Willow Creek watershed but within the State capital site. However, to encompass all that area with grid cells of the selected size of 1.1478 acres per cell would have required a bank 420 rows long by 820 columns wide, or almost 350,000 grid cells, each cell with 19 variables. This turned out to be too large an undertaking for this study; the data handling task alone was extremely cumbersome and proved impractical for the available computer facilities. Thus, the bank was trimmed to the bare essentials for performing the required analyses. The "detailed" study area, consisting of approximately 57,000 grid cells, is shown on the Location Map, Plate 1.

The lands in the capital site area, which are outside the watershed, were not necessary for any of the hydrologic or economic analyses, so they were deleted from the "primary" bank (the data that had been encoded for these cells were retained for future reference, but they were not used by any of the data bank analysis programs).

ANALYSIS CAPABILITIES

After the data bank of all needed variables was created, "utility" computer programs were used to access the files and manipulate the data for use by the analysis computer programs. The real value of centralized data storage in such a grid cell data bank is that an unlimited number of these simple, special purpose programs can be written quickly and easily to manipulate the data for either further processing or for direct analysis. The user has the capability of using these utility programs for updating or maintaining the data bank, and obtaining specific data from the bank, either for the entire basin or a selected area (window).

The analysis concepts that were used in this study were designed to make use of "traditional" methods where possible, utilizing the generally available HEC supported computer programs. The study departed from traditional approaches in the areas of basic data gathering and management, and in the use of the utility computer programs to access the data for analysis. Table A-2 contains a description of all computer software that comprise integral components of the techniques developed. The listing indicates the title and gives a brief description of its role in the overall process. These utility and modeling programs make necessary data manipulations, perform the computations and analysis, and return certain types of data to the files for either display or further use.



GRID CELL DATA BANK CONCEPTS

Figure A-3

TABLE A-2
EXPANDED FPI COMPUTER PROGRAMS

TITLE	DESCRIPTION
Data Assembly, Encoding, Processing, and Data Bank Creation	
AUTOMAP II	Generates grid file from polygon data and performs contouring. Purchased from ESRI by HEC - some minor modifications. Key data management program in study.
REGISTER	Utility program developed by HEC to register all data sets to common coordinate and match points based on polynomial fit.
BANK	Utility program developed by HEC that places grid data sets into project grid file.
GRIPS	Series of program developed by ESRI to generate a base map image file of the study area from polygon, line, and point data for a specific variable for use by mapping programs prior to entry into the data bank.
Flood Hazard Evaluation	
HYDPAR	Utility program developed by HEC that accesses data bank and generates hydrologic model parameters (loss rates and unit hydrographs parameters).
HEC-1	General hydrologic model available from HEC, modified to accommodate SCS methods.
HEC-2	General water surface profile program available from HEC. No modifications, off the shelf and traditional use only.
DAMCAL	Single-event, computer generated flooded area map.
Economic Damage Evaluation	
DAMCAL	Develops elevation damage functions by damage reach and land use for grid data file and standard composite damage functions.
HEC-1	Accepts damage functions and frequency curves and computes expected annual damages for present and future conditions.

TABLE A-2 (Con't.)

TITLE	DESCRIPTION
ENVIRONMENTAL EVALUATION	
RIA	HEC program that performs index computations for spatial environmental locational attractiveness analysis. Develops printed maps utilizing the data bank for specific variables.
GENERAL PROCESSING/UPDATING	
DELTA	Utility program for managing data files, and updating the data bank with new or revised data.
RUNLEFT, RUNRITE, COMBINE & FINAL	Locally written programs to strip down run-length encoded data to 4 row X 4 column from 1 row X 1 column for left (to col 360) and right (col 360 to 820), to combine this data into a single strip row, and to process this strip data into appropriate slots for the specific variable into the data bank.
CLEAN	Locally written program which takes appropriate file information which was digitized by Philadelphia District and obtains from it only polygon data to be processed.
GPSFMTI	Local program which takes the digitized polygon data and puts it into a "GRIPS" acceptable format.
ATODTA	Utility program that organizes the data files from the HYDPAR and DAMCAL analyses.

The advantages of a spatially gridded data file system are:

1. It provides a centralized, coordinated data set that encourages consistent analysis in each functional area.

2. It enables consistent and expedient assessments of the effects of alternative land use patterns.

3. It provides for flexibility in the scope and detail of analysis.

4. It provides a permanent data set that may serve as documentation or as a foundation for future studies.

Specifically the system provides a capability that allows access to the data files, providing for semiautomated assessments of changes in land use patterns or specific location modifications. Sensitivity assessments can be made of the effects of future development within a subbasin for a given time period whether it is large scale pattern of development or simply an assessment of individual plans and sites.

Hydraulic Analysis

The hydraulic analyses needed to define the flood elevations and flood plain limits of the various streams are an integral part of the Expanded FPI Study. The HEC-2 water surface profile backwater program is the basic hydraulic analysis tool and was used in the traditional manner. Water surface profiles for the 10-, 50-, 100-, and 500-year frequency floods were computed for both Willow Creek and Deception Creek. The hydraulic model for each stream was based on existing channel and overbank conditions, with all existing bridges considered.

The 100-year frequency flood profile for each stream was utilized as the reference flood profile for the economic analyses. Damage reaches, which are selected along the streams on the basis of uniform profile slope, have index stations where flood damages are mathematically accumulated. The flood profiles are used to develop rating curves (discharge vs elevation) at these index stations for use in the economic analysis calculations. Appendix C, Flooded Area Plates, includes delineations of the 100-year flood plain for the detailed study area for the 1978 existing conditions.

Hydrologic Analysis

The hydrologic analysis utilized in the study was accomplished with the use of HEC-1, Flood Hydrograph Package Computer Program. A utility program called HYDPAR was used to access the grid cell data file for information on imperviousness and to compute subbasin or watershed parameters which were then used as input into the HEC-1 unit hydrograph procedures. The watershed was subdivided into subbasin areas for unit hydrograph and flood hydrograph development at each discharge location. Flood hydrographs were routed from one discharge location to the next by the Muskingum Routing Method. The HYDPAR program computes subbasin or watershed parameters by selectively processing data variables from the grid cell data bank. The principal hydrologic parameters that are calculated are drainage area, areal breakdown of land use categories within the subbasin, average subbasin curve number, and the subbasin lag (the curve number and lag are two parameters used in the SCS unit hydrograph technique, which was employed here).

Economic Analysis

General flood damage potential analysis consisted of delineation of land use in flood prone areas, single event flood damage computations, and the computation of average annual flood damages. The Hydrologic Engineering Center has developed an automated method of generating damage potential functional relationships from the grid cell data bank. This method, which utilizes a program called DAMCAL, constructs a unique elevation-damage relation for each grid cell within the flood plain (based on ground elevation, land use and damage potential) and aggregates the individual cell functions to the index location for each designated damage reach. The index locations used for aggregation of flood damages are shown on the Flooded Area Plates in Appendix C. The damage functions are then merged with flood frequency and hydraulic stage data within the HEC-1 program so that average annual flood damages for each damage index location, land use category (commercial, industrial, residential, etc.) and evaluation condition (present or future) can be computed.

The DAMCAL program accesses the master data bank and seeks specific variables to be used in the economic analysis. It must determine from the data bank such information as: (1) which individual cells are within a damage reach; (2) the land use classification of each of those cells; (3) the topographic elevation assigned to those cells; and (4) the reference flood elevation at or nearest to those cells. Combining this information with direct input data such as the composite damage functions (a stage-damage unit area function for each land use category) and the reference flood elevations at the index locations, the program aggregates and then tabulates the elevation-damage data for all pertinent land use categories and damage reaches.

The HEC program ATODTA is designed to provide an automatic interface between the information generated by DAMCAL, basic hydrologic and economic data derived from HYDPAR and the other sources, and the HEC-1 computer program which provides the average annual flood damage analysis. The program reads discharge-frequency and discharge-elevation data cards, elevation-damage data generated by DAMCAL and then performs consistency checks, damage category aggregation and writes input data, formatted for HEC-1, onto magnetic tapes for direct use by that program.

Environmental Analysis

The environmental analysis capabilities for this study focus on the use of the Resource Information and Analysis (RIA) Program developed by the Hydrologic Engineering Center. The RIA Program is an adaptation of a series of short computer programs developed at the Harvard Laboratory for

Computer Graphics and Spatial Analysis; however, these concepts have been extensively reworked with numerous modifications and additions.

The RIA Program was designed to access a grid cell data bank for selected environmental and other related information in order to perform specific environmental analyses. Four major types of analyses, as well as computer printer graphic displays and tabulations, are possible with the RIA Program. These available options, as well as some of their capabilities as directly related to planning efforts, are described and illustrated in the Resource Management heading within the Envrionmental Considerations Section of this report.

APPENDIX B
HYDROLOGY AND HYDRAULICS

APPENDIX B
HYDROLOGY AND HYDRAULICS

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HYDROLOGY AND HYDRAULICS

HYDROLOGY

Flood plain hydrology is the science of determining the relationships between rainfall and runoff. Parameters considered are size and shape of the watershed study area, soil types and vegetative cover, the imperviousness associated with different land uses, drainage improvements and meteorological records (rainfall). These studies result in values which define the probability of peak runoff rates (discharge) at each point of interest along a stream. Hydrologic analyses were conducted during this study for the present and future watershed conditions.

Basin Description

Willow Creek watershed is located in southcentral Alaska, about 30 air miles north of Anchorage. Before emptying into the much larger Susitna River, downstream of the Willow townsite, the creek drains about 258 square miles of land, of which 58 square miles are in the tributary basin of Deception Creek. The relationship of the two watersheds is shown on the map, Figure B-1.

The topography of the study area consists generally of steep hills above timberline, rising to about elevation 5,000 feet in the upper portions; rolling, forested slopes in the middle areas; and flat, poorly drained lands at the downstream end. Land surface slopes range from practically zero to 45 percent, forming a variety of hydrologic conditions. There is a wide range of soil and vegetation types found in the area. The vegetation types are described in Appendix E, ENVIRONMENTAL. The soil types have been mapped by the U.S. Department of Agriculture, Soil Conservation Services (SCS). The SCS has identified over 130 soil types in the basin.

To achieve better hydrologic definition, the Willow Creek basin was divided into 28 subbasins. The detailed study area was then reduced to 20 subbasins or about 104 square miles.

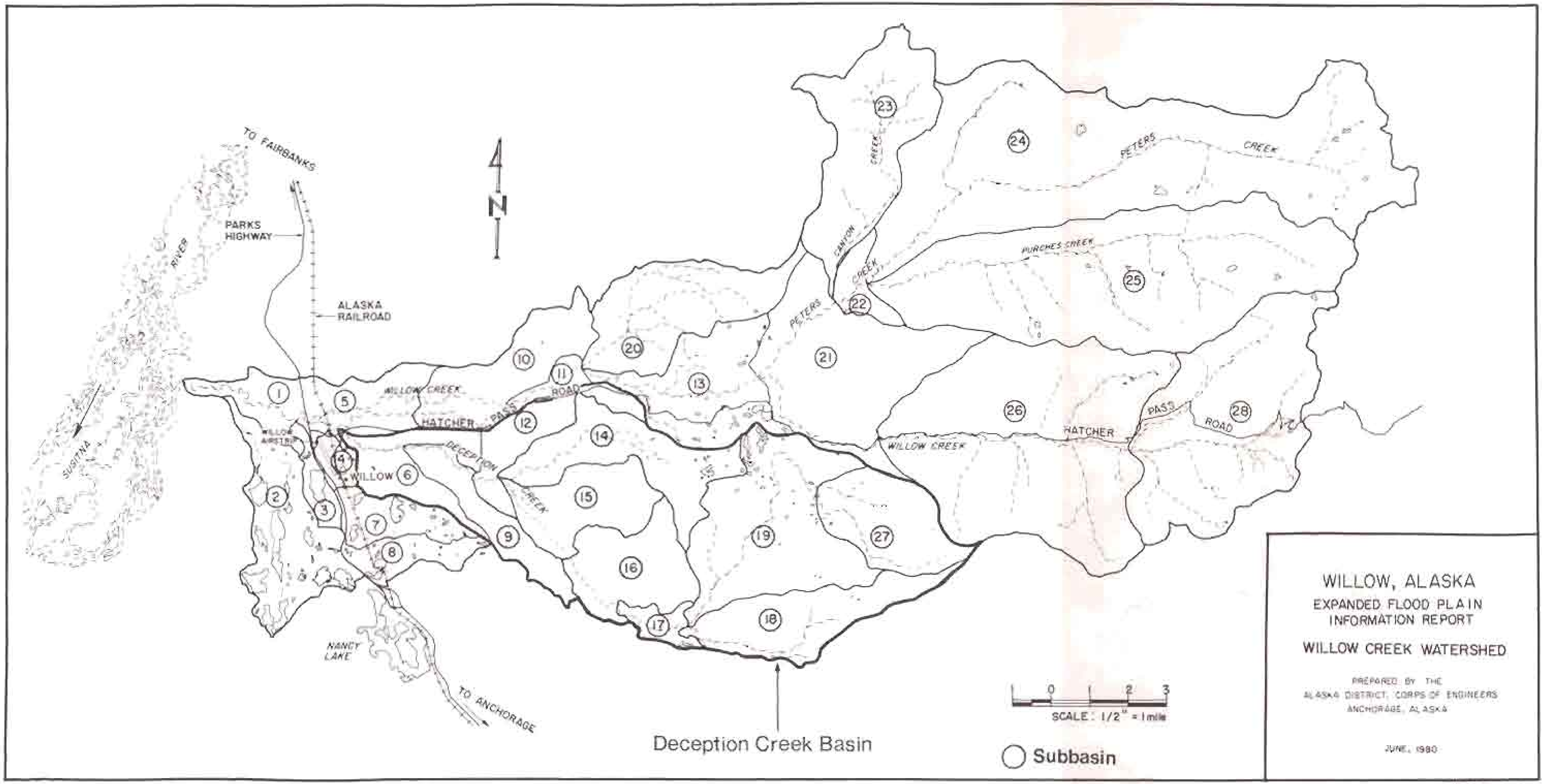
Floods on Willow and Deception Creeks can be caused by a number of environmental factors, including heavy snowpack, temperature, solar radiation, and precipitation. Ice problems, such as ice jams or glaciation in the stream cannel can also cause flooding. These ice-created floods, while not necessarily causing the greatest dollar damages, have caused the highest flood levels on the streams. Ice jams usually occur during either spring breakup or winter warm periods when the channel ice melts in large pieces that float downstream until they encounter an obstruction or an unnegotiable bend in the stream, at which point they effectively dam the river and may cause a significant increase in stage. Glaciation flooding generally occurs when an abnormally cold period lasts for an extended duration. This cold weather may cause the water in the channel to freeze to the bottom in shallow or slow moving locations, forcing the streamflow to the top of the ice and possibly overbank. Due to the highly localized nature of this type of flooding and the interrelationship of several causal factors (temperature magnitudes and sequence, snow cover, stream level, amount of debris in the channel), there is as yet no reliable technique for establishing a flood frequency for ice-caused floods. Thus, the frequency analysis done for the present study dealt only with precipitation-instigated streamflows.

Streamflow data for the study watershed are sparse. The National Weather Service has been collecting water stage data during open water periods at the Parks Highway Bridge since August 1973. Also, the U.S. Geological Survey installed streamflow gages on both Deception and Willow Creeks in June 1978. However, at the time the frequency analysis was performed for this study, the short duration of record was not felt to be adequate for discharge frequencies to be projected from standard statistical procedures. Instead, peak streamflows for four selected recurrence intervals (10, 50, 100, and 500 years) were determined utilizing Clark's time-area unit hydrograph analysis technique in the Corps of Engineers' computer program HEC-1.

Hydrologic Methodology

The hydrologic studies for the Willow Expanded FPI Report required computation of streamflow hydrographs for selected storm events and the development of exceedance frequency curves at index locations of interest. The overall strategy included application of synthetic storm precipitation data to a hydrologic watershed model, which had been calibrated from regional historical information, for the various conditions of interest. The adopted system of models allowed for interjection of engineering judgment, while basically automating the analysis of the effects of watershed changes on peak discharges, elevations, and damages. The HEC-1, Flood Hydrograph Package, and HEC-2, Water Surface Profiles, computer programs developed by the Corp of Engineers, Hydrologic Engineering Center, Davis, California, were the primary analysis tools used in this study. The HEC-1 model was run for both a 24-hour storm and a 96-hour storm. It was felt that the 96-hour storm was more representative of floods expected in the area since most of the heavy precipitation amounts are associated with low-pressure systems. Thus, this was the storm used in the computer program analysis. Precipitation values were obtained from the U.S. Weather Bureau Technical Papers No. 47 and No. 52 and provided as input to the HEC-1 program. The program computed the associated discharges, which were then plotted on probability paper so that smooth frequency curves could be obtained.

These flood frequencies were confirmed through a regional frequency analysis based on gaged stations in the geographical area. As a further check, frequency curves were derived utilizing the generalized regression equation presented in the U.S. Geological Survey (U.S.G.S.) Open File Report "Flood Frequency in Alaska". Fairly good comparisons were observed in both cases. The flows for the four recurrence intervals are listed for each stream in Table B-1, and the adopted frequency curves are shown in Figure B-2.


TO FAIRBANKS
PARKS HIGHWAY
ALASKA RAILROAD
N
SUSITNA
RIVER
WILLOW AIRSTRIP
WILLOW
WILLOW CREEK
HATCHER PASS ROAD
DECEPTION CREEK
NANCY LAKE
TO ANCHORAGE
CANYON CREEK
PETERS CREEK
PURCHES CREEK
1
2
3
4
5
6
7
8
9
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23
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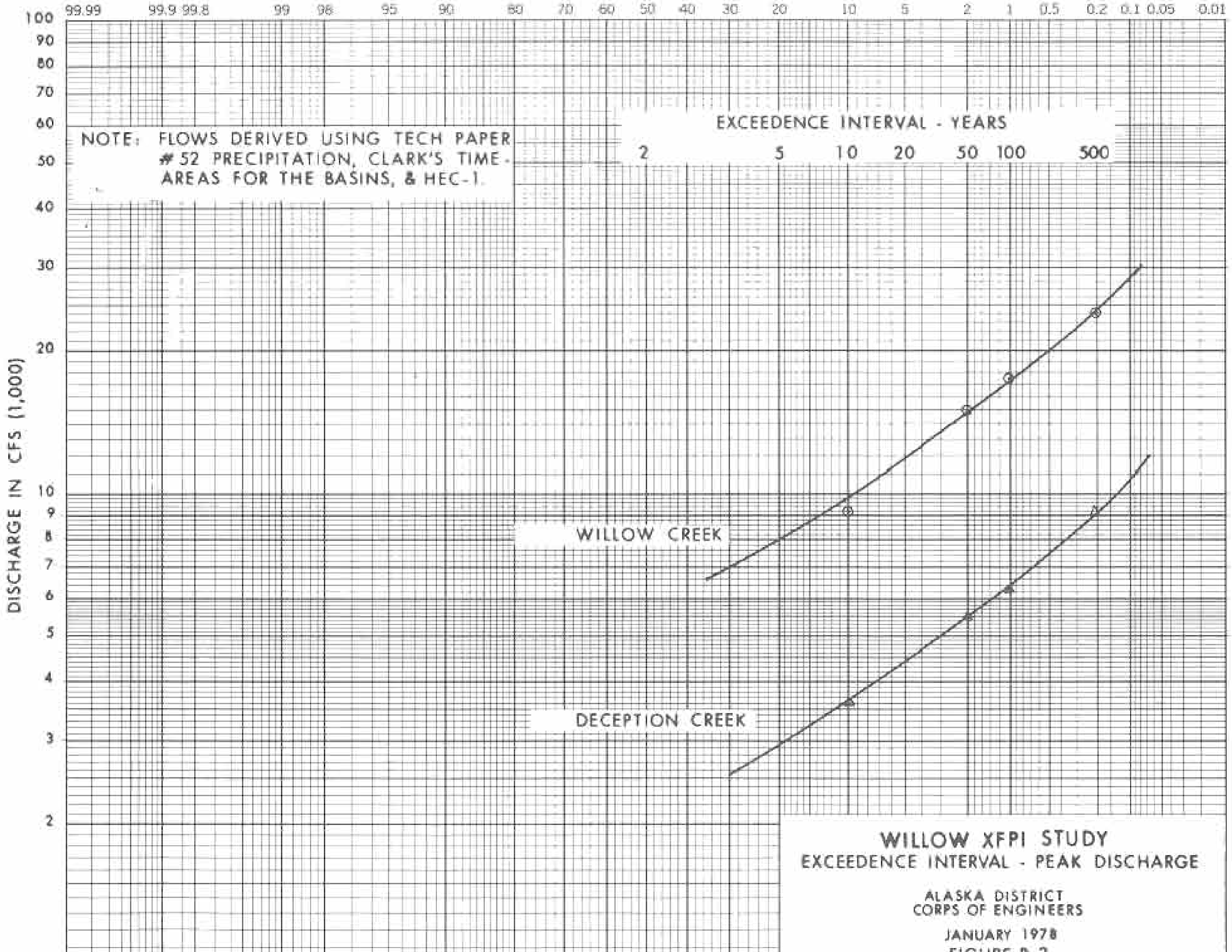
25
26
27
28
0 1 2 3
SCALE: 1/2" = 1 mile
Deception Creek Basin
Subbasin
WILLOW, ALASKA
EXPANDED FLOOD PLAIN INFORMATION REPORT
WILLOW CREEK WATERSHED
PREPARED BY THE ALASKA DISTRICT, CORPS OF ENGINEERS ANCHORAGE, ALASKA
JUNE, 1980

FIGURE B-1



WILLOW XFPI STUDY
EXCEEDENCE INTERVAL - PEAK DISCHARGE

ALASKA DISTRICT
CORPS OF ENGINEERS

JANUARY 1978

Hydrologic Model Calibration

The original HEC-1 analysis, which was used to derive the frequency curve flows, was based on subdividing the Willow Creek watershed into only two subbasins, Deception Creek and Willow Creek. Because this approach was rather rough for the ultimate scope of the study, the area was subsequently divided into 28 subbasins, 10 of which drain Deception Creek. Each of these subbasins were then defined in terms of Clark's unit hydrograph parameters, and routing between watershed outlets was specified for the Muskingum routing method. For reference, a map showing the location of the 28 subbasins is given in Figure B-1, and Figure B-3 shows schematically how the system is set up, i.e. how the HEC-1 model "sees" the watershed.

Essentially, calibration consisted of running the HEC-1 program four times, once for each of the four selected return intervals (10, 50, 100, and 500 years). The flood of each frequency was generated by applying the derived precipitation event of the same frequency to the watershed. Due to the variation in topography within the study area, basin average precipitation values were not used in the model. Orographic effects were considered by using slightly greater stroms in the upper elevations. After each run, the peak flows at the main watershed outlets - the mouth of Deception Creek where it flows into Willow Creek (combining point WC06 in Figure B-3) and the mouth of Willow Creek where it flows into the Susitna River (the downstream combining point 102 in Figure B-3), were compared with the corresponding flows on the adopted frequency curve.

TABLE B-1
PEAK DISCHARGES
WILLOW AND DECEPTION CREEKS

Recurrence Intervals Years	Deception Creek Flow (cfs)	Willow Creek Flow (cfs)
10	3,650	9,800
50	5,400	14,600
100	6,300	16,900
500	9,000	24,200

NOTE: Discharges shown are for the mouths of the creeks.

The methodology used for fine-tuning the model involved working first with Deception Creek basin, getting it fairly close to the required peak flows. This was done primarily by adjusting Clark's R (storage coefficient) and the loss rate parameters. When the flows agreed with 5 percent, the model was considered calibrated. After Deception was established, the same technique was used on Willow, applying the same criterion for final selection. The Clark time of concentration and storage coefficients for each subbasin are listed in Table B-2, along with the precipitation loss rates and base flow parameters. The

TABLE B-2
SUBBASIN HEC-1 PARAMETERS
WILLOW CREEK EXPANDED FPI STUDY

Subbasin	STRTL	CNSTL	RTIMP	TC	R	STRTQ	QRCSN	RTIOR
1	0.2 in	0.10 in/hr	0.25	2.58 hr	2.3 hr	11 cfs	32 cfs	1.2
2	0.2	0.10	0.22	2.14	2.8	32	96	1.2
3	0.2	0.10	0.26	1.03	2.5	8	19	1.2
4	0.2	0.10	0.08	.77	2.8	6	12	1.2
5	0.2	0.10	0.25	2.33	2.2	20	50	1.2
6	0.2	0.09	0.21	2.13	2.2	20	50	1.2
7	0.2	0.10	0.12	1.84	2.7	10	36	1.2
8	0.2	0.10	0.10	1.49	2.9	10	30	1.2
9	0.2	0.09	0.08	5.68	2.2	11	45	1.2
10	0.2	0.13	0.04	3.78	3.5	38	80	1.2
11	0.2	0.16	0.02	1.58	2.6	8	14	1.2
12	0.2	0.11	0.02	5.87	2.0	20	48	1.2
13	0.2	0.16	0.02	3.40	3.0	31	97	1.2
14	0.2	0.14	0.02	4.88	1.8	30	91	1.2
15	0.2	0.14	0.03	3.37	1.5	22	67	1.2
16	0.2	0.13	0.01	2.93	1.5	21	50	1.2
17	0.2	0.13	0.02	1.81	1.6	9	15	1.2
18	0.2	0.14	0.01	4.61	1.6	30	80	1.2
19	0.2	0.11	0.03	5.20	2.2	51	158	1.2
20	0.2	0.16	0.03	4.57	2.8	40	110	1.2
21	0.2	0.16	0.02	4.03	3.5	61	175	1.2
22	0.2	0.16	0.02	2.53	3.4	10	20	1.2
23	0.2	0.16	0.01	4.93	3.2	40	135	1.2
24	0.2	0.16	0.14	8.43	3.1	165	472	1.2
25	0.2	0.16	0.12	7.24	3.1	122	363	1.2
26	0.2	0.16	0.04	4.48	3.2	121	347	1.2
27	0.2	0.14	0.01	3.39	1.9	30	80	1.2
28	0.2	0.16	0.20	5.06	2.9	81	232	1.2

Explanation of Terms

- STRTL — initial rainfall loss, in inches
- CNSTL — uniform rainfall loss, in inches/hour
- RTIMP — proportion of drainage basin that is impervious, must be ≤ 1
- TC — time of concentration for Clark unit Hydrograph, in hours
- R — storage coefficient for Clark unit hydrograph, in hours
- STRTQ — flow at start of storm (i.e. base flow), in cfs
- QRCSN — flow in cfs below which base flow recession occurs in accordance with the logarithmic recession constant RTIOR
- RTIOR — ratio of recession flow, QRCSN, to that flow occurring 10 tabulation intervals later, must be 1

Muskingum parameters for each of the routing reaches are shown in Table B-3. Hydrologic continuity was maintained between the eight upper-basin subbasins and the 20 subbasins in the detailed study area in the HEC-1 model by using the same Clark parameters in the upper basins and routing their hydrographs downstream in the same manner as previously. The lower basins' hydrographs were computed by using the SCS curve number technique, but HEC-1 is very flexible and permits meshing of the various methods between subbasins.

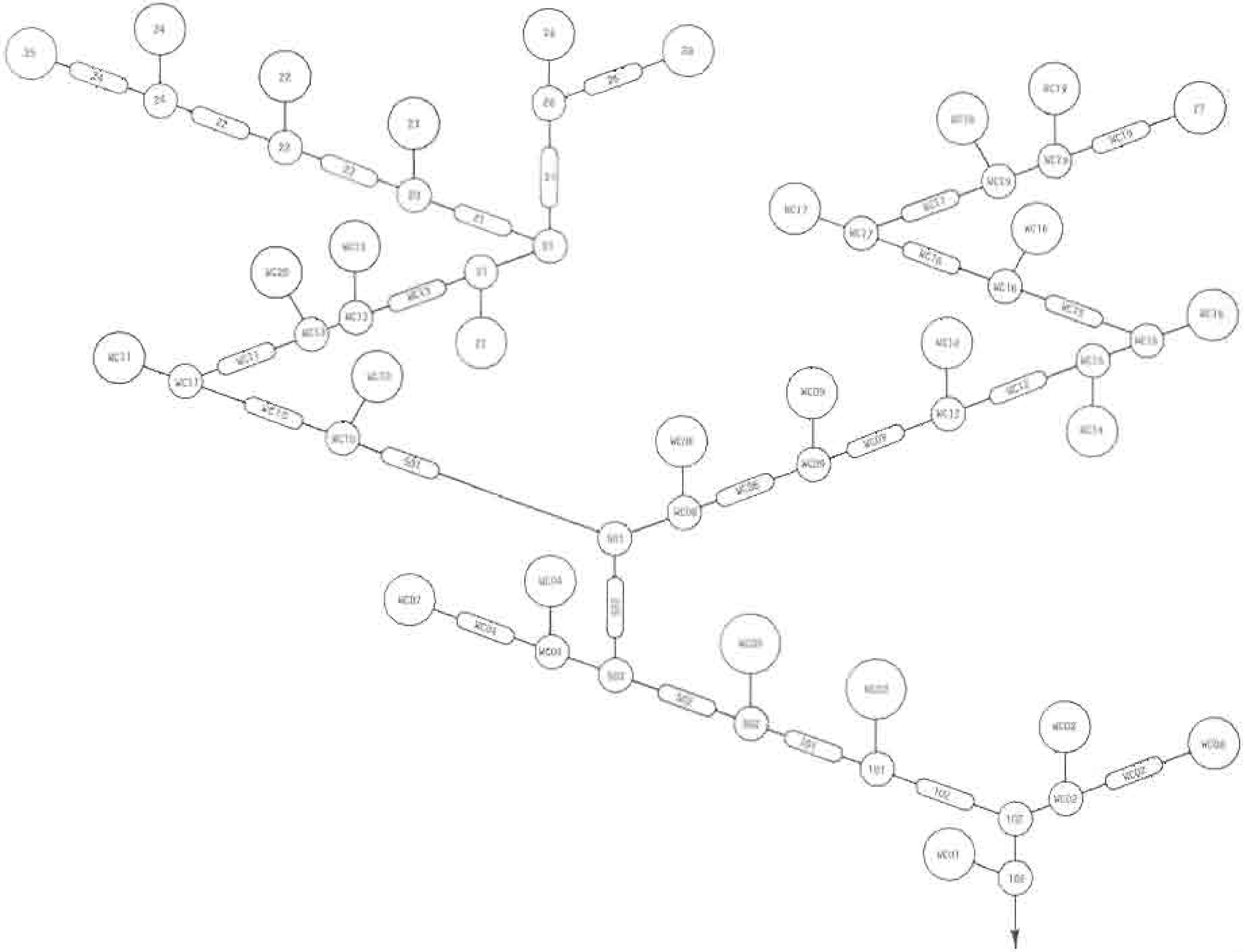
Derivation Of Hydrologic Parameters

The computer data bank played a large role in the derivation of hydrologic parameters. The variables in the bank that were required for the hydrologic analysis were the subbasin number (#3), existing and future land uses (#5, 6, 7, 8, and 9), hydrologic soil group (#13), and the land surface slope (#14).

Somewhat related were the hydraulic and economic analyses done for the damage calculations, which utilized the cell elevation (#4), land uses (#5, 6, 7, 8, and 9), damage reach (#11), and reference flood elevation (#12) variables. Hydrologic soil groups and land surface slopes were defined indirectly for each grid cell within the data bank. The soil type was first entered into the data bank. This data was collected from soils maps published by the U.S. Department of Agriculture, Soil Conservation Service (SCS) for the Susitna River Valley and for the Matanuska River Valley, as well as from some mapping done by the SCS for the capital site area and some soil typing done by airphoto interpretation by special arrangement with the SCS. The areas on these maps were digitized for the Alaska District by the Philadelphia District, Corps of Engineers, whereupon they were assigned to the proper grid cells and entered into the data bank. Then, since each soil type has a unique hydrologic soil group and surface slope associated with it (determined by the SCS), the corresponding values for these two variables were simply assigned based on the soil type. Thus, variables 13 and 14 were created, and the data required for hydrologic analysis were available in the data bank.

The next step in deriving the hydrologic parameters, after establishment of the necessary variables in the grid cell data bank, was operation of the computer program HYDPAR. The program required some input data, then it utilized the data bank to compute hydrologic values for each subbasin, for subsequent use by the other computer programs. HYDPAR's output data were stored on a computer tape or disk, which was then accessed by the program ATODTA. By using some additional input data, ATODTA organized the HYDPAR output into a form readily usable by the program HEC-1 for hydrograph computation and analysis. All three programs HYDPAR, ATODTA, and HEC-1 were developed by the Corps' Hydrologic Engineering Center in Davis, California.

Operation of HEC-1 was the final step in determining the flood hydrographs for the watershed. In deriving the hydrologic parameters from the data bank, two basic hydrograph techniques were available for use. These were the composite imperviousness or Snyder method, and the Soil Conservation Service (SCS) method. The SCS method was selected for use because it was felt to be better adapted to consideration of changing land uses.



WILLOW, ALASKA

EXPANDED FLOOD PLAIN INFORMATION REPORT

SCHEMATIC DIAGRAM OF
HEC-1 COMPUTER MODEL

PREPARED BY THE
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

JUNE, 1980

FIGURE B-3

The SCS method involved two main steps for determination of the flood hydrograph from a given subbasin. First, the amount of surface runoff generated by the particular storm event was determined. Then, a single parameter was used to define the shape of the discharge hydrograph, this parameter being the subbasin lag time. Runoff volume was a function of basic curve number, which is explained below, and the basin lag was computed in HYDPAR by an empirical equation recommended by the SCS.

Subbasin curve number (CN) is a function of antecedent moisture conditions, soil type, and land use. In the HYDPAR program, the subbasin CN was computed as the average of the CN's for all the individual grid cells contained within the subbasin. The program read the data bank one cell at a time, and, based on the specific hydrologic soil group (HSG) and land use of the cell, it assigned a CN to the cell. Then, for each subbasin, the cells' individual CNs were added arithmetically and divided by the number of cells to get the average subbasin CN. When the land use condition under analysis changed, the land use of an individual cell may have changed, which may have changed it's CN, consequently affecting the subbasin curve number.

TABLE B-3
MUSKINGUM ROUTING COEFFICIENTS
WILLOW CREEK EXPANDED FPI STUDY

Reach Point U/S	D/S Point	AMSKK	X
28	26	3.43 hr	0.32
26	21	2.15	0.30
24	22	0.49	0.38
23	21	1.81	0.30
21	13	3.22	0.36
13	11	1.18	0.35
11	10	1.46	0.25
10	501	1.20	0.24
27	19	3.28	0.33
19	17	1.03	0.36
17	16	0.98	0.35
16	15	1.27	0.30
15	12	0.34	0.38
12	9	0.98	0.26
9	6	1.13	0.25
501	503	0.32	0.22
7	4	0.64	0.10
503	502	0.09	0.22
502	101	0.44	0.23
101	102	1.81	0.23
8	2	1.81	0.15

Explanation of Terms

AMSKK - Muskingum K coefficient (reach travel time), in hours
X - Muskingum X coefficient

The hydrologic soil group in the curve number assignment was a measure of a given soil's runoff potential. All soil types in the data bank had a characteristic runoff potential associated with them. Each was indentified with a letter A, B, C, or D (1, 2, 3, or 4, respectively, in the data bank), corresponding to the soil's capacity to absorb water (see Table B-4).

The other important hydrologic parameter computed in HYDPAR, the subbasin lag, is a little more complex, in that there were more input values required. It was only computed once, however, for each subbasin. The equation used for determing the lag is:

$$\text{Lag (Hours)} = \frac{(L)^{.8} * (S + 1)^{.7}}{(1900) * (Y)^{.5}}$$

Where L = hydraulic length of subbasin (the water course length from the subbasin outlet to the upstream boundary yielding the longest time of travel), in feet

S = (1000/CN) -1

CN = arithmetic average curve number

Y = arithmetic average subbasin land slope, in percent

Values of L were entered as input data for each subbasin (entered in miles and converted internally to feet), and Y, the subbasin average slope, was computed in a manner similar to the CN procedure. Each cell's slope was read directly from the data bank, and the sum for each subbasin was divided by the number of cells to give the subbasin average (each cell was assigned a number corresponding to an appropriate average slope - an input function shown in Table B-5 - defined in the SCS soils mapping).

The hydraulic stream lengths and the computed curve numbers, average slopes, and subbasin lags that were input for the 20 detailed study area subbasins are shown in Tables B-6 and B-7, respectively.

TABLE B-4
DEFINITIONS OF HYDROLOGIC SOIL GROUPS

A. (Low runoff potential.) Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

B. Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C. Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

D. (High runoff potential.) Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

SOURCE: SCS National Engineering Handbook, Section 4, Hydrology, 1972.

TABLE B-5
LAND SURFACE SLOPE FUNCTION
WILLOW CREEK EXPANDED FPI STUDY

Slope Class	Range in Percent	Average Slope
1	0-1	0.5%
2	0-3	1.5
3	3-7	5.0
4	7-12	9.5
5	12-20	16.0
6	12-30	21.0
7	20-30	25.0
8	12-45	28.5
9	20-45	32.5
10	30-45	37.5
11	45+	45.0

TABLE B-6
HYDRAULIC STREAM LENGTHS
WILLOW CREEK EXPANDED FPI STUDY

Subbasin	Stream Length
1	4.7 miles
2	6.7
3	3.3
4	1.8
5	4.8
6	5.6
7	3.8
8	3.5
9	7.2
10	7.1
11	2.6
12	5.5
13	6.4
14	8.7
15	5.4
16	3.6
17	2.4
18	8.1
19	8.2
20	8.0

TABLE B-7
HYDPAR-COMPUTED SUBBASIN PARAMETERS
WILLOW CREEK EXPANDED FPI STUDY

Subbasin	Average Curve No.	Average Slope	Subbasin Lag
1	72.5	2.7%	3.2 hrs
2	71.7	6.1	2.9
3	71.2	5.1	1.8
4	75.3	1.7	1.7
5	77.5	1.7	3.5
6	76.0	4.9	2.4
7	73.9	9.7	1.3
8	75.3	4.8	1.7
9	75.1	6.7	2.6
10	72.5	4.3	3.5
11	76.3	7.6	1.1
12	69.6	4.1	3.2
13	67.6	11.2	2.3
14	75.4	7.8	2.8
15	73.1	7.2	2.1
16	70.0	13.3	1.2
17	68.7	17.5	0.8
18	79.0	12.1	1.9
19	78.7	7.7	2.4
20	70.4	10.2	2.6

Figures Derived for Existing Land Use Conditions

After the basic hydrologic parameters had been determined for each subbasin by HYDPAR, the program ATODTA was executed to consolidate the data and arrange it into a form usable by HEC-1. Another program that directly analyzed the data bank but was concerned with economic and depth of flooding information was DAMCAL. DAMCAL is described in detail in Appendix D, ECONOMICS. Both the HYDPAR and DAMCAL outputs are stored on computer tape or disk for subsequent use by ATODTA. Considering only the hydrologic analysis, ATODTA accessed the SCS unit hydrograph data in each HYDPAR file and combined some additional input data to generate an output file corresponding to input requirements of HEC-1. These data identified for the HEC-1 model the method for input of precipitation data, the basin loss rates, and the hydrograph parameters (SCS coefficients and base flow parameters) to be used for each subbasin. The ATODTA run then generated two output files, one of economic data (from DAMCAL) and one of hydrologic data. The hydrologic data have been displayed previously - ATODTA did not compute any new values.

Flood Hydrograph Analysis

The final operation of HEC-1 to obtain the flood hydrographs involved coordination of the eight upper subbasins' hydrographs (determined by Clark's hydrograph method, as explained previously), the output data from the program ATODTA, and the additional input data accompanying HEC-1. The ATODTA output consisted of the base flow parameters and the coefficients for computing the hydrographs with the SCS method for each subbasins, comparable to M, T, W2, and X cards input used with a conventional run of HEC-1. The additional data cards required to accompany the HEC-1 run for each detailed study area subbasin were the following: K cards to identify the subbasins, O cards to give precipi- tation data, Y and Y1 cards to give routing parameters, and Z cards to identify points where damage computations were to be made (i.e. the damage reach index locations).

Application of the SCS curve number (CN) technique is described in general in the previous section, Derivation of Hydrologic Parameters. The appropriate parameters (i.e. subbasin CN and lag time) were computed in the HYDPAR program and passed by the program ATODTA to HEC-1. In HEC-1, a rainfall distribution pattern was applied to each subbasin, and, through use of the hydrograph parameters, flood hydrographs were combined downstream at the proper locations.

As the hydrograph routing progressed downstream, calculations of total damages to be expected on an average annual basis were made at each of the index locations. Economic data were retrieved from the ATODTA-DAMCAL output file for each index location. The economic and hydrologic data for each of the seven land use conditions were kept segregated so that expected average annual damage comparisons could be made between them. The land use plans were generally divided between existing conditions, future land use with the capital move, and future land use without the capital move. In addition, the two future conditions were analyzed for three different flood plain development policies: unrestricted development in the flood plain, development with new structures within the flood plain to be built with finished floors at the 1978 100-year flood elevation, and prohibition of new construction within the floodway but allowance within the floodway fringe when elevated 1 foot above the 1978 100-year flood elevation.

The information passed by ATODTA to HEC-1 consisted essentially of stage-discharge and discharge-frequency relationships for each index location. HEC-1 then determined the hydrograph at each discharge location, as well as the hydrographs corresponding to ratios of the input rainfall event, and computed depths of flooding for each flood at each of the index locations. This was done for each of the land use plans. It should be noted that the frequencies assigned to these discharges are approximate since they were computed based on ratios of rainfalls which were estimated to correspond to the given frequency.

Combining stage-damage and subsequently derived damage-discharge relationships then permitted calculation of the final relationship, flood damage versus frequency. Integration of this curve at each index location gave the expected average annual damages. The damage calculation results are described in detail in Appendix D, ECONOMICS.

HYDRAULICS

The objective of flood plain hydraulics studies is to determine the depth of flow and lateral extent of inundation along streams for flood events of various frequencies. In the Willow Expanded Flood Plain Information Study, hydraulics was used to combine rainfall-runoff values (flood discharges) from the hydrologic model with physical stream characteristics (channel shape, area, vegetation, bridges, and slope) to develop flood profiles on each of the two streams. Utilizing the information generated from the backwater studies, flood plains (flooded areas) were delineated along Willow Creek and Deception Creek, rating curves (depth versus discharge) were plotted for use in flood damage calculations, and theoretical depths of flow for a wide range of storm events were determined for any point on the stream. The basic hydraulic engineering tool used in the Willow study was the computer program HEC-2, Water Surface Profiles, developed by the Corps of Engineers, Hydrologic Engineering Center, Davis, California.

Hydraulic Methodology

The HEC-2, Water Surface Profile Computer Program, is intended for calculating water surface profiles from steady, gradually varied flow in either natural or man-made channels. The computational procedure, which considers the effects of various obstructions such as bridges, culverts, and structures in the flood plain, is based on the solution of the one-dimensional energy equation with energy loss due to friction evaluated with Manning's equation. The computational procedure is generally known as the Standard Step Method.

The program is specially taylored for application in flood plain management and flood insurance studies, evaluating floodway encroachments and determing flood hazard zones. The program was also used in the Flood Insurance Study that was prepared concurrently.

Hydraulic Model Development

Development of the computer backwater models to represent the physical characteristics of the streams included reviewing the meager existing hydraulic data, developing and obtaining data for use in the models, and creating the models. These tasks were performed in conjunction with a flood insurance study that was also being concurrently prepared by the Alaska District, Corps of Engineers.

The necessary data that had to be obtained included field cross section data, bridge data including channel modifications, and horizontal and vertical control data for 5-foot contour mapping of the area. Field trips to verify channel conditions and roughness coefficients, examination of 1978 aerial photographs, comparison with historical highwater marks, and coordination with borough officials were all included as part of the modeling effort. Pertinent data that were input for the backwater models included: cross section geometry, reach lengths between cross sections, roughness coefficients ("n" values), bridge configurations and locations, discharges (from hydrology) and starting water surface conditions. These data were encoded onto computer cards, edited for errors, and then processed by the HEC-2 backwater program. The HEC-2 program computes water surface elevations at each cross section, based on the input data, for each discharge that is provided. These individual elevations could then be plotted along a stream profile, to create a flood profile for each flood that is studied. In addition to profile information, the HEC-2 program was used to compute storage-discharge values for hydrologic routing pruposes. The HEC-2 program was used early in the study to develop these storage-discharge relationships for routing purposes, and then was used again for final profile determination of the 10-, 50-, 100-, and 500-year floods.

Floodway Determinations

In addition to the calculation of water surface flood profiles, encroachment limits, consistent with the Federal Insurance Administration floodway concept, were also computed for the two streams in the detailed study area. This concept considered encroachment (usually by filling) into the flood plain fringe area, wherein the natural condition water surface is raised no more than 1 foot. The computed floodway width, then, included adequate cross sectional area with this additional depth to pass the 1978 100-year flood. The basic hydraulics for the Willow Expanded FPI Study were prepared in conjunction with the flood insurance study for Willow, and included floodway determinations for both purposes.

Relationship With Flood Damage Calculations

The hydraulic data generated from the HEC-2 analyses were also used in flood damage calculations. After the base condition (1978) flood discharges had been finalized and water surface profiles computed and plotted, the reference flood plain was delineated and reference flood elevations were superimposed along the streams. The reference flood was used to relate the hydraulic character of the streams (depths of flow at any point) to the topographic elevation of the flood plain, so that flood damges could be calculated. The 1978 condition 100-year frequency flood was chosen as the reference flood.

After the backwater models were fully developed, edited, and calibrated to available historical information, rating curves were then drawn at index locations. The rating curve, which is the relationship between discharge and stage of a stream, is the basic hydraulic function that was used in performing flood damage calculations. As described in Appendix D, ECONOMICS, the economic counterpart to the stage-discharge function is called the stage damage relationship which represents the flood damages which will occur in a defined stretch (reach) of the stream at various depths of flow.

Usually, the damage represents an aggregate of damages to structures and contents which occur some distance upstream and downstream from the specified location. These two relationships are combined with the discharge-frequency relationship, developed from the hydrologic calculations, to derive the damage-frequency data needed to compute average annual flood damages. In addition, single event flood damages can be developed from these relationships.

An index location is required for each of the damage reaches. It is a point along the particular stretch of stream at which flood damage potential is aggregated. These points were selected from hydrologic, hydraulic, and economic considerations, are representative of the flood profiles in the damage reach, and are near the location of a discharge-frequency determination.

Hydraulic Study Results

The information developed from the hydraulic portion of the Willow Expanded FPI Study included 10-, 50-, 100-, and 500-year flood profiles, flood plain delineations of the 100-year flood, floodway encroachment limits, and rating curves at index locations.

To aid planners, engineers, and Borough and State officials, a set of flooded area maps, with coverage of Willow Creek and Deception Creek within the detailed study area, is included in this report. The flood plain and floodway limits and the flood elevations for the existing conditions (1978) 100-year frequency flood are shown in Appendix C. While this same information for the future land use plans is not presented in this report, it is available from the Alaska District, Corps of Engineers.

APPENDIX C
FLOODED AREA MAPS

APPENDIX C
FLOODED AREA MAPS

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FLOODED AREA MAPS

GENERAL

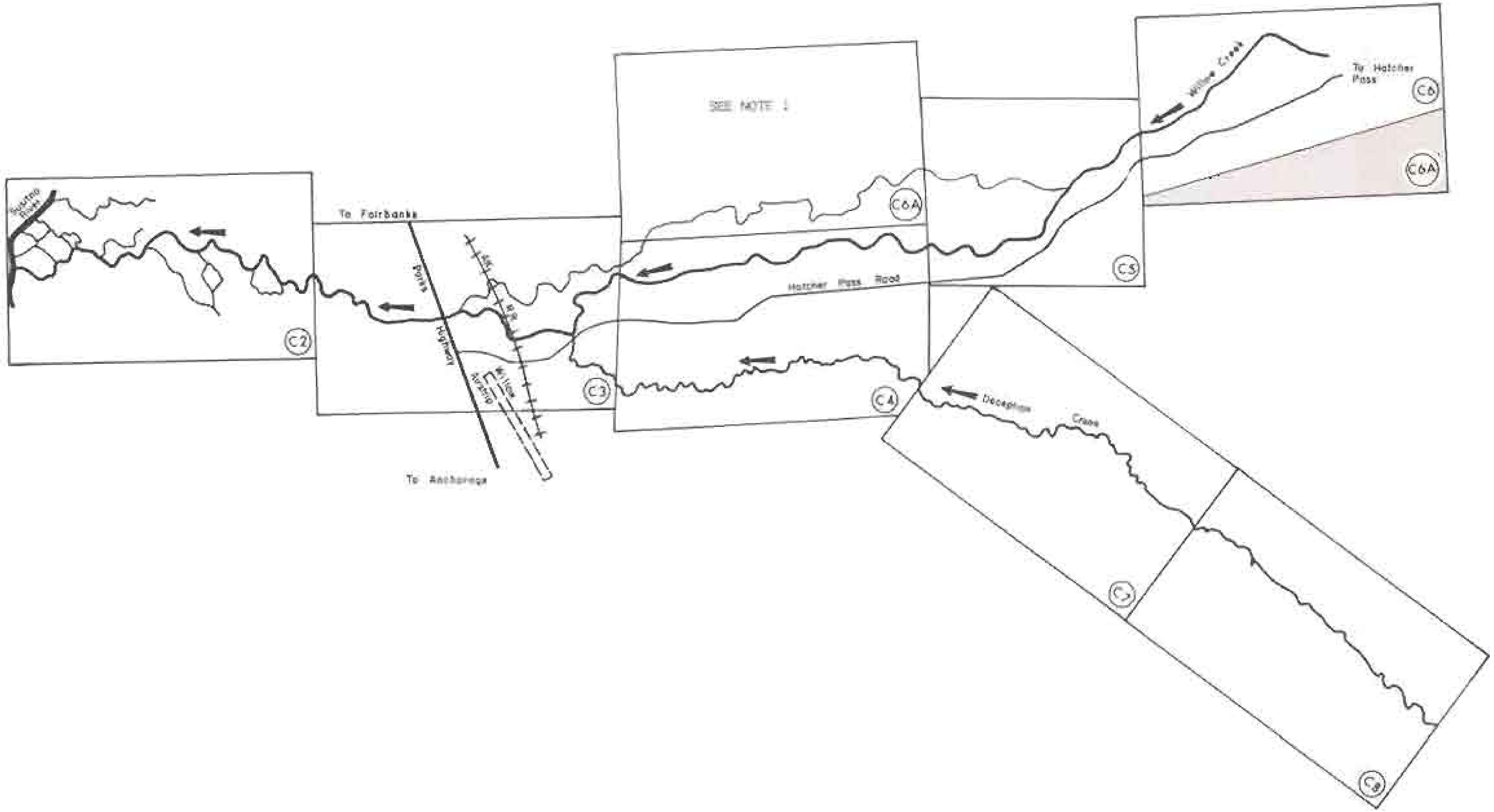
The portion of the Willow Creek study area that would be inundated by the existing conditions (1978) 100-year frequency (1 percent chance in any year) flood is shown on Plates C-2 to C-8. The inundated areas shown on the plates, along each of the streams, were derived from surveyed cross sections, field checks, bridge plans, and from interpretation of topographic maps and aerial photographs. The actual limits of these overflow areas on the ground may vary from those shown because the scales of the available maps do not permit precise plotting of the flooded area boundaries. Additionally, localized drainage patterns, ice or debris jams and winter glaciation problems could result in the inundation of other areas adjacent to these streams. Important land use decisions in specific areas should be verified by field surveys. Changes in the land use, drainage patterns, and structural occupancy of the flood plain may result in different flood elevations than those shown. It should be noted that floods larger than the 100-year frequency are possible and could result in greater depths, velocities, and area flooded. The 100-year flood was chosen to delineate as it represents a major flood and is the basis for the designation of flood hazard areas under the National Flood Insurance Program that the Matanuska-Susitna Borough has recently entered.

Shown on the maps are the extent of the 100-year floodway and floodway fringe. These terms are explained in detail in the section on Hydrology and Hydraulics. The concept has been used extensively in the Flood Insurance Program and is frequently incorporated as part of a community's flood plain ordinance. The wavy blue line and numeral in the shaded area represents the elevation of the 100-year flood at that particular location. Also shown on the plates are the various index locations where flood damages were aggregated in the damage calculations. The 100-year frequency flood discharges that were used in deriving the flood plain limits are shown in Table C-1.

By using the information illustrated on these plates, together with other data such as frequency of occurrence, velocity of flow, and duration of flooding, government entities and individuals can make knowledgeable decisions relative to the use, development, and management of areas subject to inundation.

TABLE C-1
DISCHARGES FOR THE 100-YEAR FREQUENCY FLOOD AT INDEX LOCATIONS

Description	Index Location	Drainage Area (sq mi)	1978 Existing Conditions 100-year Frequency Flood Discharge (cfs)
Willow Creek	1	244	16,965
	2	239	17,059
	3	235	17,055
	4	174	15,244
	5	166	15,922
Deception Creek	6	49	5,269
	7	35	3,933



LEGEND

(C3) PLATE NUMBER

NOTES

1. DUE TO THE SMALL SIZE OF THE PORTION OF THE MAP COVERED BY THIS PLATE, IT WAS COMBINED WITH THE LAST PLATE ON WILLOW CREEK AND DESIGNATED AS PLATE C6A; I.E. PLATE C6 PROVIDES MAP COVERAGE FOR TWO SEPARATE PORTIONS OF WILLOW CREEK.

SCALE IN FEET

WILLOW, ALASKA

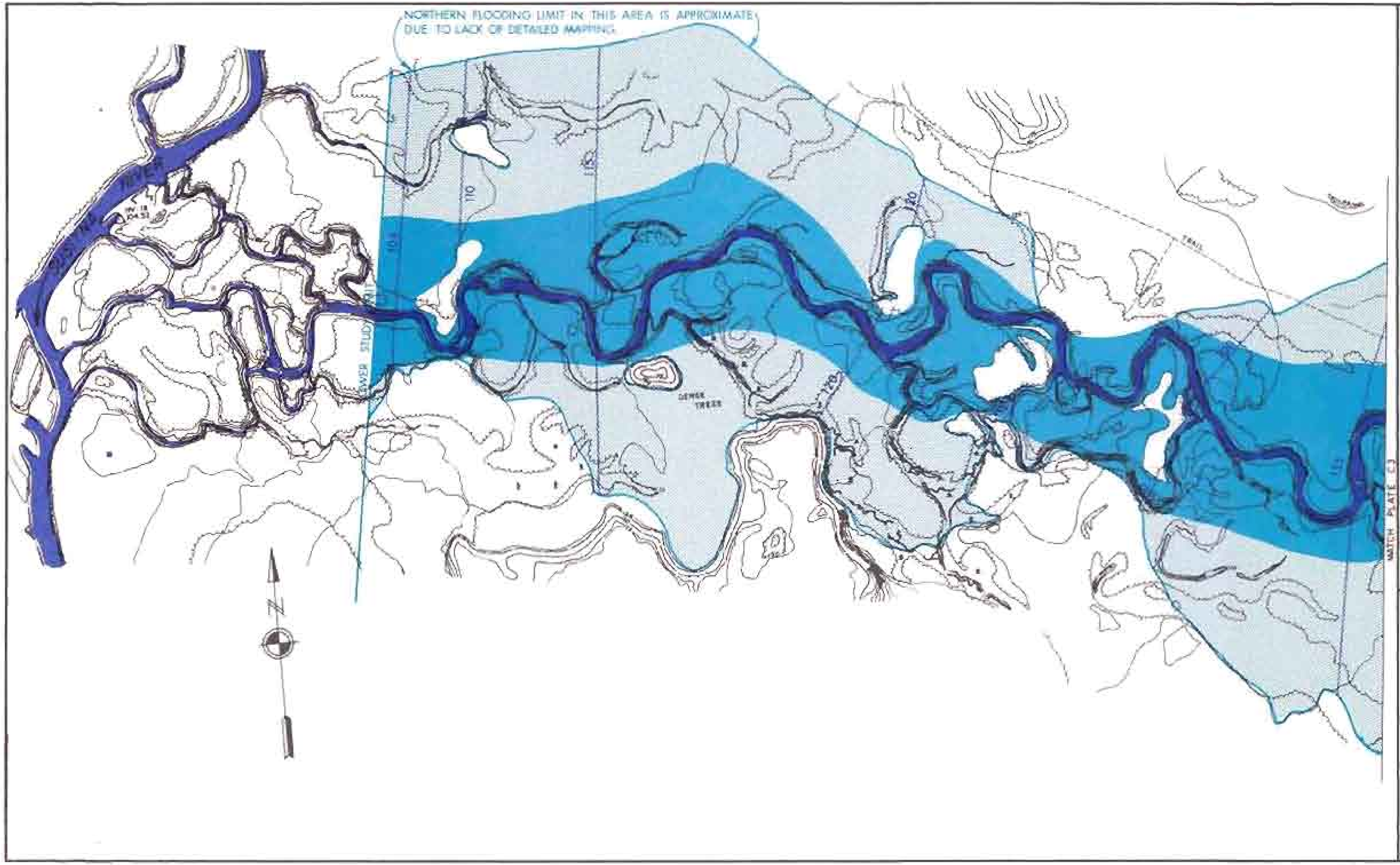
EXPANDED FLOOD PLAIN INFORMATION REPORT

FLOODED AREA INDEX MAP

PREPARED BY THE
ALASKA DISTRICT CORPS OF ENGINEERS
ANCHORAGE, ALASKA

JUNE

PLATE C1



LEGEND

FLOODWAY FRINGE
STREAM CHANNEL — FLOODWAY — EXTENT OF 100 YEAR FLOOD
FLOODWAY FRINGE

220 — 100 YEAR FLOOD WATER SURFACE ELEVATION

M 4.2 — MILES ABOVE MOUTH

INDEX LOCATION

GROUND ELEVATIONS IN FEET MEAN SEA LEVEL DATUM

NOTES

1. MAPPING BASED ON AERIAL PHOTOGRAPHS TAKEN IN OCTOBER 1977
2. LIMITS OF OVERFLOW SHOWN MAY VARY FROM ACTUAL LOCATION ON GROUND AS EXPLAINED IN THE REPORT
3. AREAS OUTSIDE THE FLOOD PLAIN MAY BE SUBJECT TO FLOODING FROM LOCAL RUNOFF

0 800 1600
SCALE IN FEET

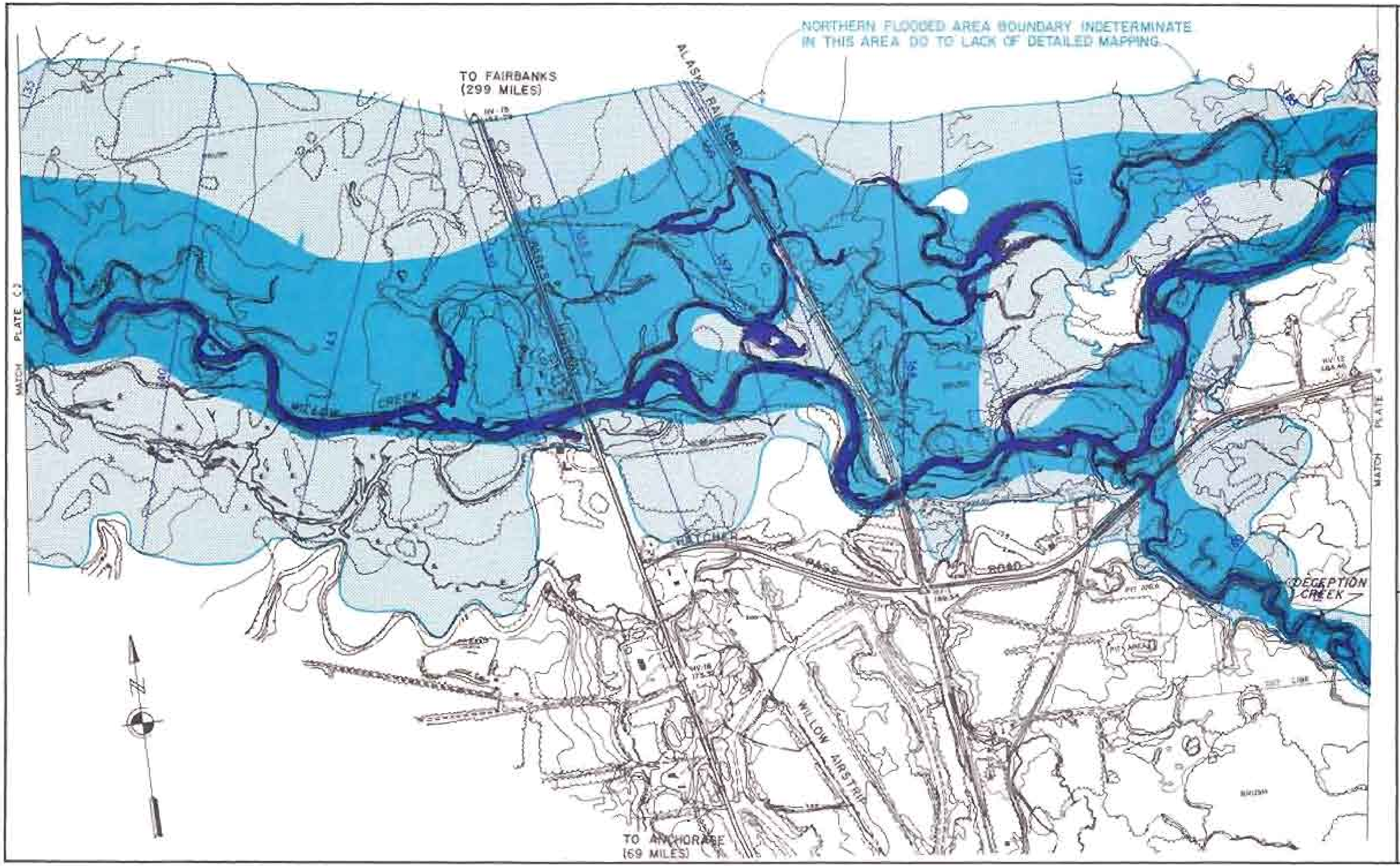
WILLOW, ALASKA

EXPANDED FLOOD PLAIN INFORMATION REPORT

FLOODED AREA MAP

PREPARED BY THE
ALASKA DISTRICT CORPS OF ENGINEERS
ANCHORAGE, ALASKA

JUNE,



LEGEND

FLOODWAY FRINGE
STREAM CHANNEL — FLOODWAY — EXTENT OF 100 YEAR FLOOD
FLOODWAY FRINGE

220 — 100 YEAR FLOOD WATER SURFACE ELEVATION

M = 2 — MILES ABOVE MOUTH

▲ — INDEX LOCATION

— GROUND ELEVATIONS IN FEET MEAN SEA LEVEL DATUM

NOTES

1. MAPPING BASED ON AERIAL PHOTOGRAPHS TAKEN IN OCTOBER 1977
2. LIMITS OF OVERFLOW SHOWN MAY VARY FROM ACTUAL LOCATION ON GROUND AS EXPLAINED IN THE REPORT
3. AREAS OUTSIDE THE FLOOD PLAIN MAY BE SUBJECT TO FLOODING FROM LOCAL RUNOFF

SCALE IN FEET

WILLOW, ALASKA

EXPANDED FLOOD PLAIN INFORMATION REPORT

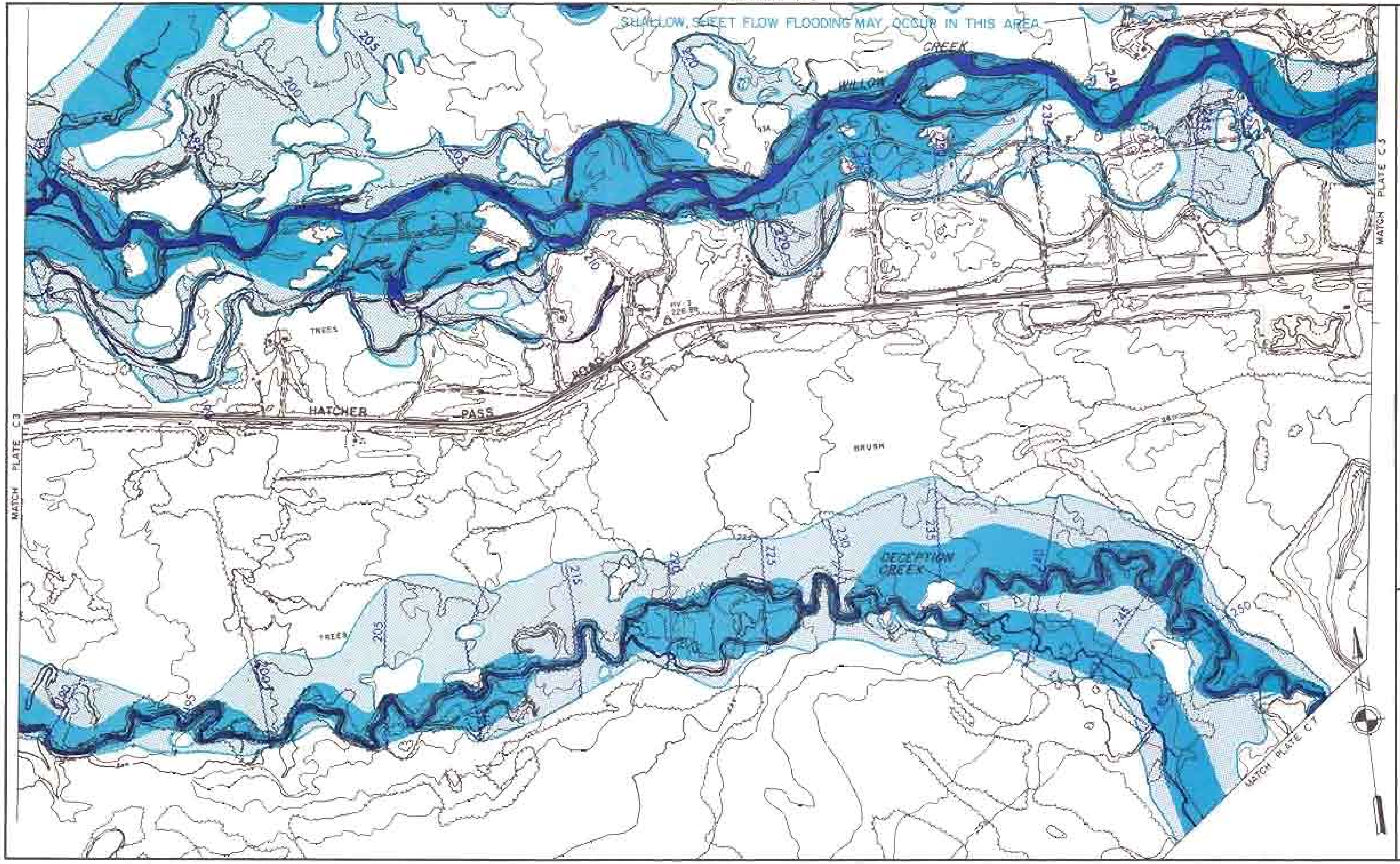
FLOODED AREA MAP

PREPARED BY THE
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

JUNE, 1980

PLATE C-3

MATCH PLATE C6A



LEGEND

FLOODWAY FRINGE / STREAM CHANNEL — FLOODWAY / FLOODWAY FRINGE — EXTENT OF 100 YEAR FLOOD

220 — 100 YEAR FLOOD WATER SURFACE ELEVATION

M + 2 — MILES ABOVE MOUTH

▲ — INDEX LOCATION

250 — GROUND ELEVATIONS IN FEET MEAN SEA LEVEL DATUM

NOTES

1. MAPPING BASED ON AERIAL PHOTOGRAPHS TAKEN IN OCTOBER 1977
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3. AREAS OUTSIDE THE FLOOD PLAIN MAY BE SUBJECT TO FLOODING FROM LOCAL RUNOFF

0 800 1600
SCALE IN FEET

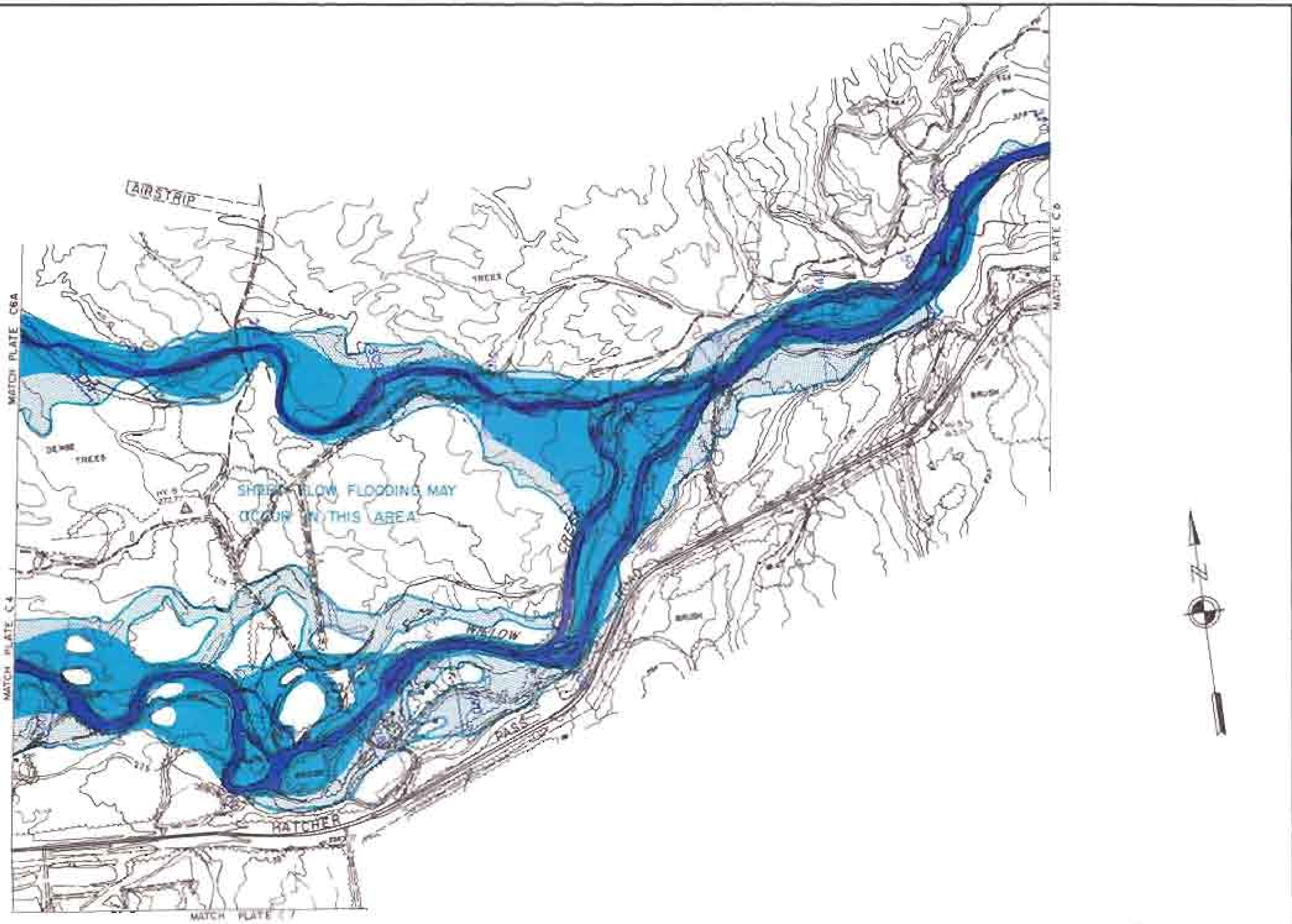
WILLOW, ALASKA

EXPANDED FLOOD PLAIN INFORMATION REPORT

FLOODED AREA MAP

PREPARED BY THE
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

JUNE, 1980



LEGEND

FLOODWAY FRINGE
STREAM CHANNEL — FLOODWAY — EXTENT OF 100 YEAR FLOOD
FLOODWAY FRINGE

220 — 100 YEAR FLOOD WATER SURFACE ELEVATION

M + 2 — MILES ABOVE MOUTH

▲ 7 — INDEX LOCATION

GROUND ELEVATIONS IN FEET MEAN SEA LEVEL DATUM

NOTES

1. MAPPING BASED ON AERIAL PHOTOGRAPHS TAKEN IN OCTOBER 1977
2. LIMITS OF OVERFLOW SHOWN MAY VARY FROM ACTUAL LOCATION ON GROUND AS EXPLAINED IN THE REPORT
3. AREAS OUTSIDE THE FLOOD PLAIN MAY BE SUBJECT TO FLOODING FROM LOCAL RUNOFF

0 — 800' — 1600
SCALE IN FEET

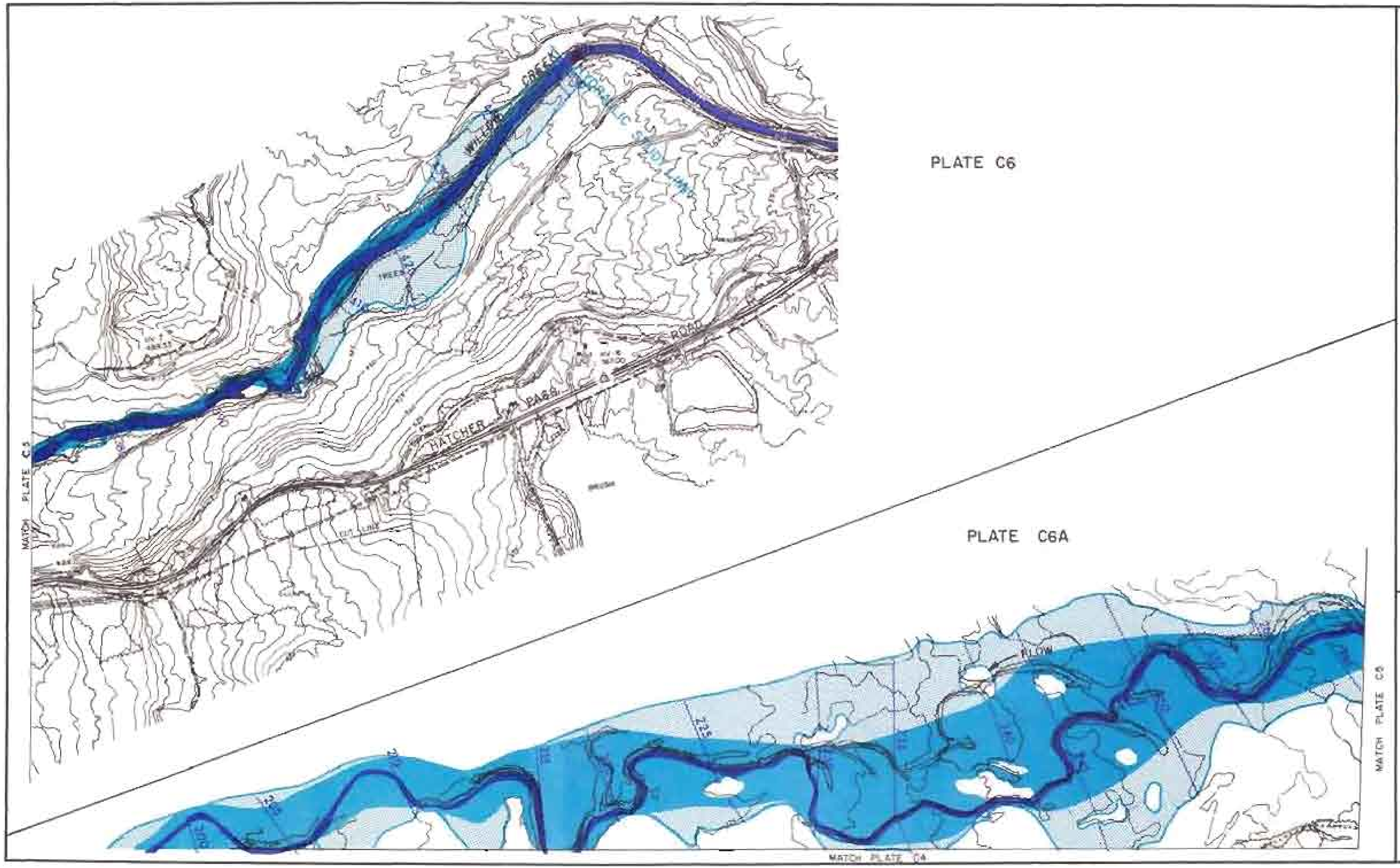
WILLOW, ALASKA

EXPANDED FLOOD PLAIN INFORMATION REPORT

FLOODED AREA MAP

PREPARED BY THE
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

JUNE, [illegible]



LEGEND

FLOODWAY FRINGE
STREAM CHANNEL — FLOODWAY — EXTENT OF 100 YEAR FLOOD
FLOODWAY FRINGE

220 — 100 YEAR FLOOD WATER SURFACE ELEVATION

M + 2 — MILES ABOVE MOUTH

▲ 7 — INDEX LOCATION

— 200 — GROUND ELEVATIONS IN FEET MEAN SEA LEVEL DATUM

NOTES

1. MAPPING BASED ON AERIAL PHOTOGRAPHS TAKEN IN OCTOBER 1977
2. LIMITS OF OVERFLOW SHOWN MAY VARY FROM ACTUAL LOCATION ON GROUND AS EXPLAINED IN THE REPORT
3. AREAS OUTSIDE THE FLOOD PLAIN MAY BE SUBJECT TO FLOODING FROM LOCAL RUNOFF

0 — 800 — 1600
SCALE IN FEET

WILLOW, ALASKA

EXPANDED FLOOD PLAIN INFORMATION REPORT

FLOODED AREA MAP

PREPARED BY THE
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

JUNE 1980

PLATE C6

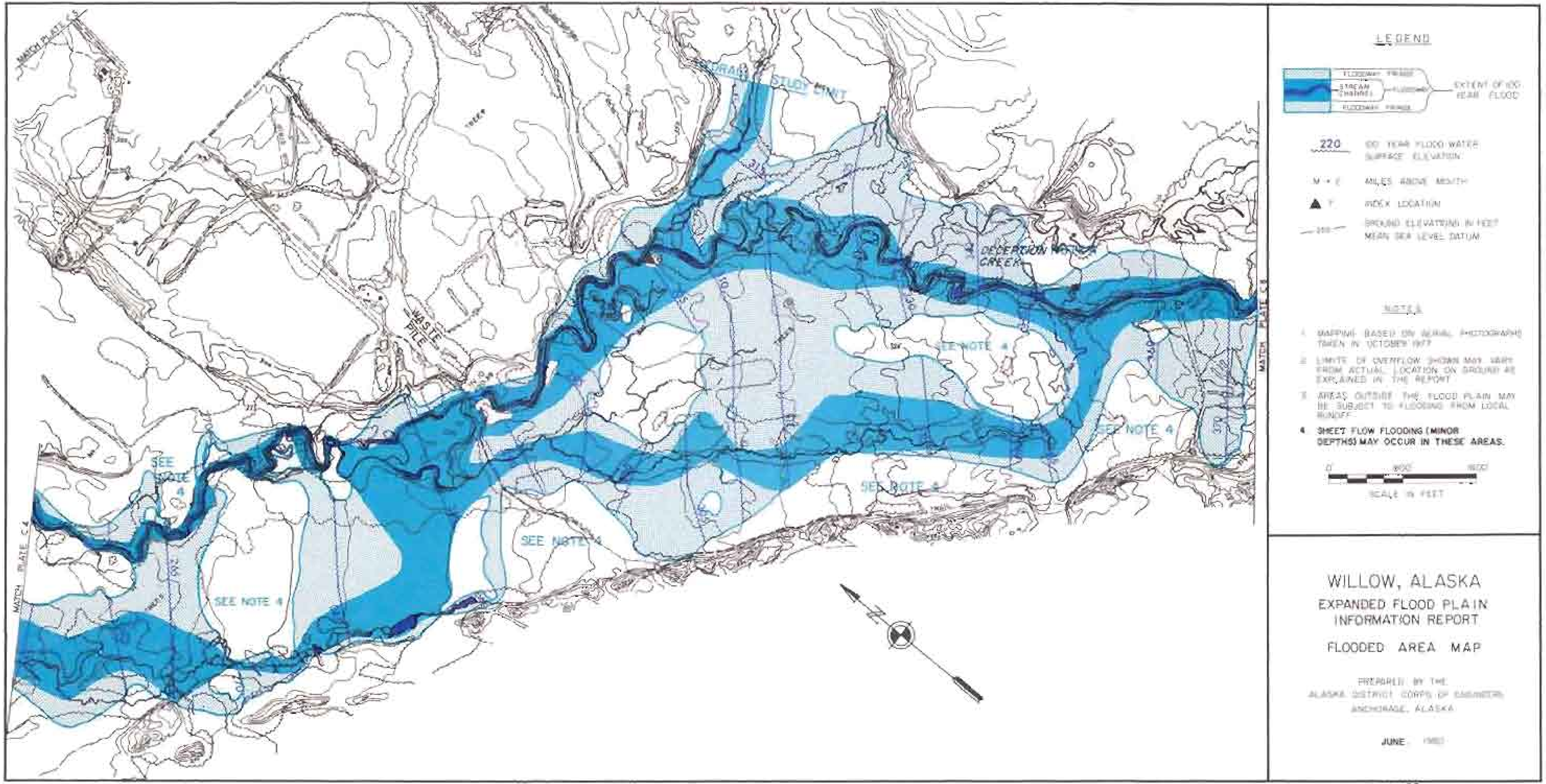
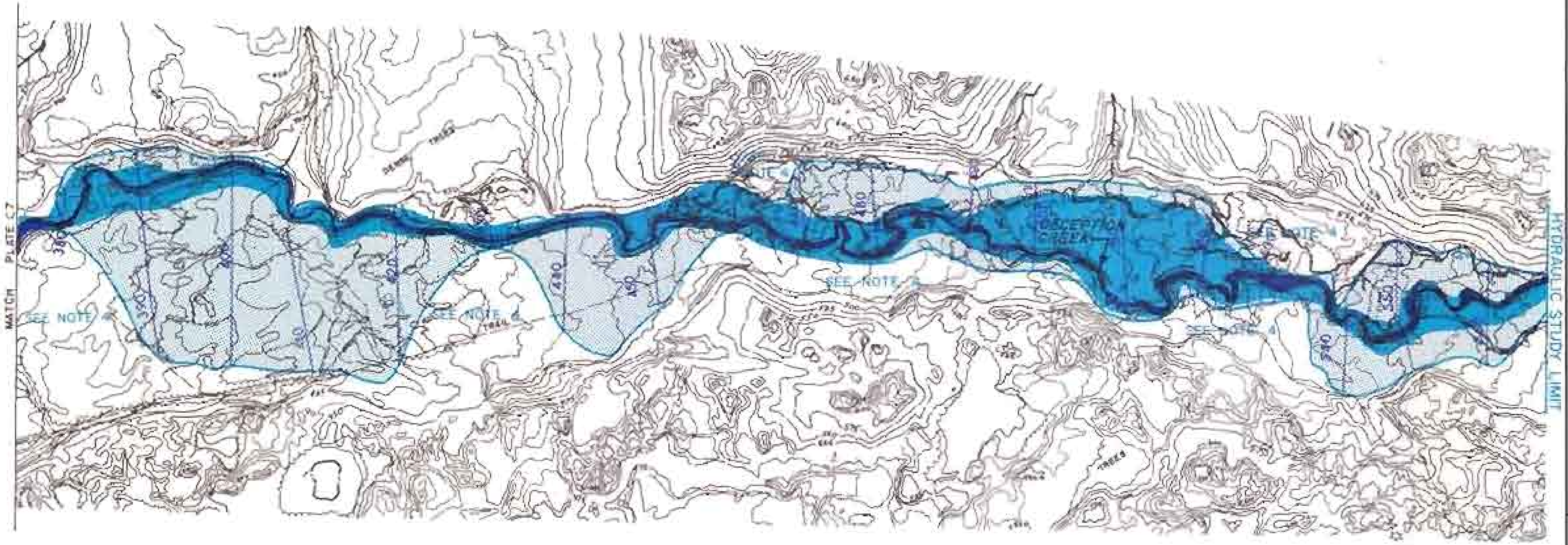

MATCH PLATE C6
HYDRAULIC STUDY LIMIT
WASTE PILE
DECEPTION CREEK
SEE NOTE 4
SEE NOTE 4
SEE NOTE 4
SEE NOTE 4
SEE NOTE 4
SEE NOTE 4
MATCH PLATE C8
MATCH PLATE C4
LEGEND
FLOODWAY FRINGE
STREAM CHANNEL
FLOODWAY
FLOODWAY FRINGE
EXTENT OF 100 YEAR FLOOD
220
100 YEAR FLOOD WATER SURFACE ELEVATION
MILES ABOVE MOUTH
INDEX LOCATION
GROUND ELEVATIONS IN FEET MEAN SEA LEVEL DATUM
NOTES
1. MAPPING BASED ON AERIAL PHOTOGRAPHS TAKEN IN OCTOBER 1977
2. LIMITS OF OVERFLOW SHOWN MAY VARY FROM ACTUAL LOCATION ON GROUND AS EXPLAINED IN THE REPORT
3. AREAS OUTSIDE THE FLOOD PLAIN MAY BE SUBJECT TO FLOODING FROM LOCAL RUNOFF
4. SHEET FLOW FLOODING (MINOR DEPTHS) MAY OCCUR IN THESE AREAS.
SCALE IN FEET
WILLOW, ALASKA
EXPANDED FLOOD PLAIN
INFORMATION REPORT
FLOODED AREA MAP
PREPARED BY THE
ALASKA DISTRICT CORPS OF ENGINEERS
ANCHORAGE, ALASKA
JUNE

PLATE C7



LEGEND

FLOODWAY FRINGE
STREAM CHANNEL — FLOODWAY — EXTENT OF 100 YEAR FLOOD
FLOODWAY FRINGE

220 — 100 YEAR FLOOD WATER SURFACE ELEVATION

M + 2 — MILES ABOVE MOUTH

▲ — INDEX LOCATION

— 250 — GROUND ELEVATIONS IN FEET MEAN SEA LEVEL DATUM

NOTES

1. MAPPING BASED ON AERIAL PHOTOGRAPHS TAKEN IN OCTOBER 1977
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3. AREAS OUTSIDE THE FLOOD PLAIN MAY BE SUBJECT TO FLOODING FROM LOCAL RUNOFF
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0 800 1600
SCALE IN FEET

WILLOW, ALASKA

EXPANDED FLOOD PLAIN INFORMATION REPORT

FLOODED AREA MAP

PREPARED BY THE
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

JUNE, 1980

PLATE C8

APPENDIX D
ECONOMICS
(FLOOD DAMAGE ANALYSIS)

APPENDIX D
ECONOMICS
(FLOOD DAMAGE ANALYSIS)

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ECONOMICS
(FLOOD DAMGE ANALYSIS)

GENERAL

A flood plain is an area that requires special planning considerations because of its proneness to flooding. Basic to a broadened planning attitude, regarding the use of flood plain lands, is a recognition that the flood hazard is a combination of flooding and susceptibility to flood damage in flood plain land use. Through bitter experience, man has learned that floods quite often cover portions of the flood plain, damaging or sweeping away roads, buildings and homes, and often pose a severe threat to human life and health. Adverse effects of flooding include damage from overflow, sediment deposition, sewer backup, creation of unsanitary conditions, rise of groundwater table and fire and pollution damages from chemical plants or gasoline storage facilities.

The primary objectives of the flood damage analyses performed for the Willow Expanded FPI Study were to calculate the single-event and average annual flood damages that can be expected for each basin-wide land use condition and to evaluate the implications of these land use changes (inside and/or outside the defined flood plain area) on the flood damage potential of the study area. These analyses focus upon the potential flood damage consequences of alternative land use configurations as determined by a unique, systematic analysis methodology.

The analysis approach included subdividing the entire watershed into rectangular grid cells of 1.1478 acres (200 feet by 250 feet) and assigning specific values to the cells to define physical parameters. These cells then made up a massive computer data bank which was accessed by utility computer programs to automatically extract information from the data bank for calculation of single-event damages (such as the 100-year event) and average annual flood damages for the alternative basin-wide land use conditions under various flood plain regulation policies.

This chapter presents a description of the basic economic principles and the interrelationships between flood damage economics, hydrology, and hydraulic analyses. The flood damage analysis computer programs are also described.

FLOOD DAMAGE ECONOMICS PRINCIPLES

The principle upon which these flood damage calculations are based is that the flood damage (in dollars) to an individual structure can be calculated by determining the flood stage (depth of flooding) at the specific location under consideration and the relationship between flood depth and damage potential of the structure and its contents. For example, if a 100-year flood produced a stage of 2 feet inside a single family residential structure, the flood damages to the house and furnishings can be determined by reading the amount of damages caused by 2 feet of water from a composite damage function.

Another way of expressing flood damages is by means of "average annual damages" or "expected annual damages." Average annual damages is the frequency-weighted sum of damage for the full range of damaging flood events. It represents the average annual damage for a particular set of hydrologic (rainfall-runoff), hydraulic (depth of flooding), and damage (dollars-depth) conditions. To estimate average annual damage (AAD), the damage corresponding to each depth of flooding is weighted by the probability of that depth occurring, with rare flood events (100-year, 500-year, etc.) being weighted less than the more frequent events. These weighted damage values are added, and the sum represents the average flood damages.

The basic relationships which must be developed to determine either single event (e.g., the 100-year frequency or 1 percent chance each year flood) or average annual damages are:

(1) Stage (depth of flow) to discharge (volume flow rate, flow of water);

(2) Stage to damage (flood damage for each depth of flow); and,

(3) Discharge to frequency of recurrence (rainfall-runoff).

These relationships are then merged with information concerning the composition and spatial location of land uses by means of a computerized data bank containing reference flood, damage reach, and index location information. A description of these concepts is presented in the remainder of this section.

Stage-Discharge Relationship

The stage-discharge relationship is a basic hydraulic function that expresses for a specific location, the relationship between flow rate or discharge (usually expressed in cubic feet per second) and stage or depth of flow (expressed in feet). The function is commonly called a "rating curve," and the data points are usually derived from water surface profile computations. Details of how water surface flood profiles are developed are discussed in Appendix B, HYDROLOGY AND HYDRAULICS.

Stage-Damage Relationship

The stage-damage relationship is the economic counterpart to the stage-discharge function, and represents, at a specific location, the damages expected to occur in a defined stretch (reach) of the stream at various stages. Usually the damage represents an aggregate of damages which occur some distance upstream and downstream from the specified location. The information in a stage-damage curve is usually developed from field damage surveys. This concept is described in the section on Composite Damage Functions.

Discharge-Frequency Relationship

The discharge-frequency relationship defines the relationship between exceedance frequency (or probability of a flood being equaled or exceeded) and any given discharge at a specific location. This is a basic function describing the probability nature of streamflow and is commonly determined from either statistical analysis of gaged flow data or through watershed model calculations. An example of this relationship would be the 10-year frequency flood (with a probability of being equaled or exceeded on the average once every 10 years or a 10 percent chance of recurrence each year) which has a value of 9,800 cubic feet per second at the mouth of Willow Creek.

These three basic relationships were developed by a study team which included an economist (for damage functions), a hydrologist (for rainfall-runoff-frequency functions) and a hydraulic engineer (for stage-discharge functions).

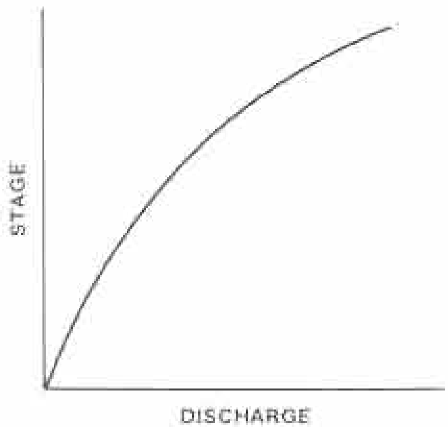
After these relationships were developed, they were combined into two functions, the discharge-damage and the stage-frequency relationships.

Damage-Frequency Relationship

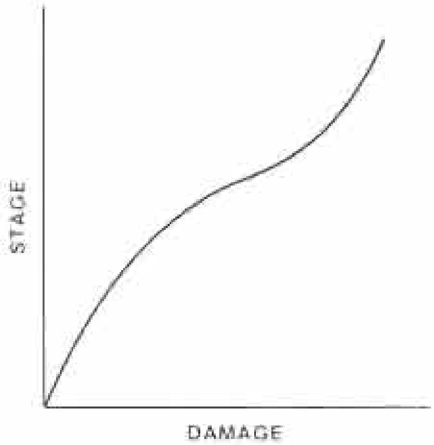
This relationship, the culmination of extensive calculations, is derived by combining the previously discussed relationships, using the common parameters of stage and discharge. Figure D-1 illustrates this procedure. The damage for a specific exceedance frequency is calculated by determining the corresponding discharge from the discharge-frequency function, the corresponding stage from the stage-discharge function, and the corresponding damage from the stage-damage function. The damage-frequency curve relates the amount of damages that could be expected to occur for a specific frequency flood event. An example would be the single event 10-year frequency (10 percent chance) flood in the Willow Creek basin for 1978 conditions which would cause an estimated $903,800 in flood damage.

Because these stage, discharge, frequency, and damage relationships vary along a stream, it is common practice to divide a river into reaches and let a set of these relationships be representative for a specific reach. An index location is selected within each reach and a single stage or discharge-frequency relationship and stage-discharge relationship are applied at that location and considered representative of these variables for the entire reach. For damage calculations several relationships are required, each representative of a particular land use category (residential, commercial, industrial, agricultural, etc.).

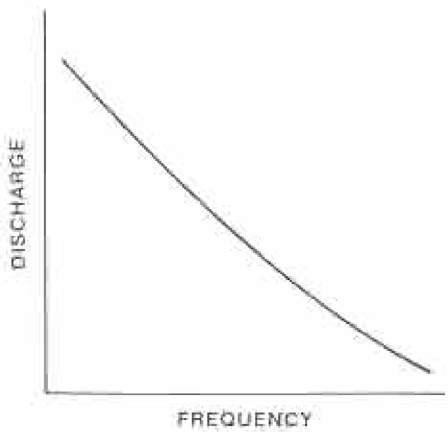
STAGE-DISCHARGE



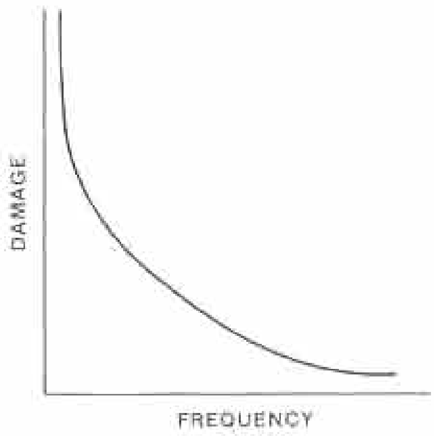
STAGE-DAMAGE



DISCHARGE-FREQUENCY



DAMAGE-FREQUENCY



RELATIONSHIPS FOR FLOOD DAMAGE CALCULATIONS

Figure D-1

Damage Reach Selection

Frequency, discharge, stage, and damage data are used for each stream reach. Thus, these data must be representative of the actual frequency of flood events, flow regime, and flood damage for this reach. Generally, hydraulic and hydrologic factors govern the selection of the index location for each reach. The criteria for determining the extent of damage reaches include maintaining a balance between consistent (parallel) water surface profiles along the stream, while keeping the number of damage reaches to a reasonable number.

Damage reaches were outlined to define the grid cells from which damage data were aggregated to an index location. Because only those grid cells that needed to be analyzed for potential flood damage were of interest, the damage reaches extended laterally only to include about 5 feet of vertical depth above the 1978 100-year flood elevation. Figure D-2, Damage Reach Delineation, illustrates a typical damage reach delineation and the parameters to consider in selecting a damage reach. Seven damage reaches were defined for this study.

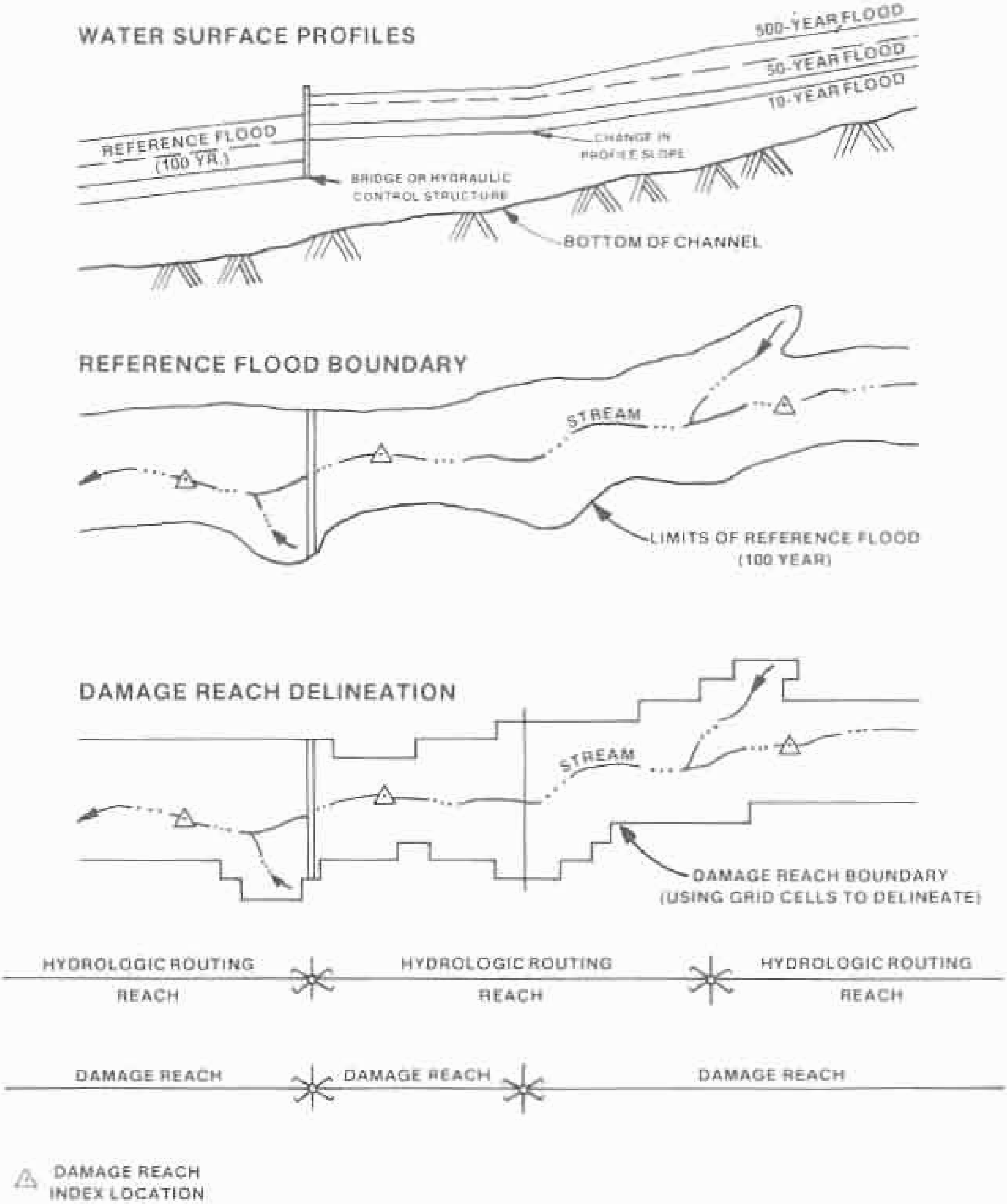
Reference Flood Selection

Since flood water surface profiles generally depict varying elevations (due to stream slope) throughout a damage reach, a reference flood profile is needed to relate ground elevations or structure elevations along the stream to the elevation of each index location. By selecting a reference flood profile which properly represents the slope of the various condition flood profiles and the general slope of the flood plain, damage calculations can be aggregated to the index location where the stage-damage-frequency-discharge relationships are known. If the flood profiles are consistently parallel throughout a potential damage reach, the selection of a specific reference flood is less critical.

An elevation of the reference flood was needed for each grid cell because each grid cell within each damage reach is involved in the construction of the aggregated damage function. The reference flood profile that was used for the study was the 1978 condition 100-year profile.

Index Location Consideration

An index location is required for each damage reach and is used as a point along the particular stretch of stream to aggregate (sum up) the flood damage potential in that reach. The index location should be a point along the stream which is most representative of the flood profiles in the damage reach and is at or near the location of a discharge-frequency determination. The data requirements for each of the seven index locations included the rating curve, the discharge-frequency curve, the reference flood elevation, and the zero damage elevation (lowest elevation at which flood damage can occur). The rating curve and reference flood elevation were obtained from computer program HEC-2 results, the discharge-frequency data was computed by a statistical



DAMAGE REACH DELINEATION PROCEDURE

Figure D-2

regional frequency analysis, and the zero damage elevation was estimated from topographic maps and finished floor elevations. A sample set of index location data is shown in Figure D-3.

Composite Damage Functions

A composite damage function is defined as a stage-damage function for a unit area (grid cell) and was developed for each land use category that has significant damage potential. These functions were developed for each land use category by averaging the structural and related content values.

The composite damage functions may include direct and indirect damages that are associated with each particular land use category. Figure D-4, Composite Damage Function for Low Density, Single Family Residential Land Use Category for Alternative B (Future Without Capital), Policy 1, illustrates an example of a composite stage-damage function. These functions were developed for other land use categories, such as resource extraction and public parks, although the corresponding damages were small compared to those occurring in the urbanized areas.

The concept of using generalized, composite stage-damage relationships for the land use category assigned to each grid cell was selected as the mechanism for performing the analysis rather than the conventional individual structure approach. The use of these generalized functions provides the capability of expediently evaluating alternative future land use patterns relative to the 1978 condition. The concept of a composite damage function appears to be appropriate for future land use assessments since exact building site locations would not be known. The composite damage functions used for the Willow Creek Expanded FPI Study were developed from data compiled for previous studies for the Federal Insurance Administration by the Alaska District, Corps of Engineers. The DAMCAL computer program assisted in the construction of the composite damage functions. This program was furnished the following types of input data for the construction of the composite damage functions:

1. stage vs percent damage for structure

2. stage vs percent damage for contents

3. value of structure

4. value of contents

5. indirect damage (percent of structure and contents value)

6. development density (number of structures per grid cell)

7. vacancy factor (percent of cells that are developed for the specific land use category)

INDEX LOCATION DATA

WATERSHED: WILLOW CREEK

DAMAGE REACH: 4

ELEVATION OF ZERO DAMAGE AT INDEX STATION: 210

ELEVATION OF REFERENCE FLOOD AT INDEX STATION: 218.5

Discharge-Frequency Relationship			Stage-Discharge Relationship	
Flow (cfs)	Frequency (Exceedence/100 yrs)		Flow (cfs)	Stage (ft msl)
560	0.99	1.01 yr	0	211.0
1,290	0.90	1.11 yr	1,600	214.3
1,810	0.80	1.25 yr	2,200	214.9
3,450	0.50	2 yrs	3,200	215.5
6,300	0.20	5 yrs	5,400	216.5
8,400	0.10	10 yrs	7,400	217.4
13,500	0.20	50 yrs	9,000	218.2
15,600	0.01	100 yrs	11,600	218.5
20,300	0.002	500 yrs	18,000	218.9
22,300	0.001	1000 yrs	22,900	219.3

FIGURE D-3

LAND USE CATEGORY NO. 1
ALTERNATIVE B
LOW DENSITIY RESIDENTIAL, SINGLE

DEPTH OF WATER *	PERCENT DAMAGE STRUCTURE	PERCENT DAMAGE CONTENTS	PERCENT DAMAGE OTHER	AMOUNT OF DAMAGE PER GRID CELL IN THOUSAND DOLLARS
−2.0	1.0	0.0	1.0	0.24
−1.0	2.0	1.0	2.0	0.53
0.0	7.0	2.0	5.0	1.76
1.0	12.0	25.0	10.0	4.02
2.0	20.0	40.0	30.0	6.90
4.0	30.0	60.0	40.0	10.25
6.0	40.0	75.0	60.0	13.57
8.0	50.0	80.0	60.0	16.05
10.0	60.0	82.0	60.0	18.39
15.0	60.0	85.0	60.0	18.52

DENSITY OF THE LAND USE UNITS PER GRID CELL = 0.50
BASE VALUE OF THE STRUCTURE = $45,000.00
BASE VALUE OF THE CONTENTS = $9000.00
BASE VALUE OF OTHER = $4000.00
VACANCY FACTOR (PERCENT DEVELOPED) = 100.0

* ABOVE GROUND SURFACE

COMPOSITE DAMAGE FUNCTION

FIGURE D-4

Aggregate damage Functions

In order to perform single-event and average annual flood damage calculations, the damage potential for each land use category and each grid cell was aggregated to the index locations. The technique used to perform the aggregation is described schematically in Figure D-5. The basic process is to develop a stage-damage function for each grid cell by matching the land use category for a specific grid cell with the appropriate composite damage function, while observing the elevation of a grid cell, then aggregating these individual functions to the index location by means of the reference flood.

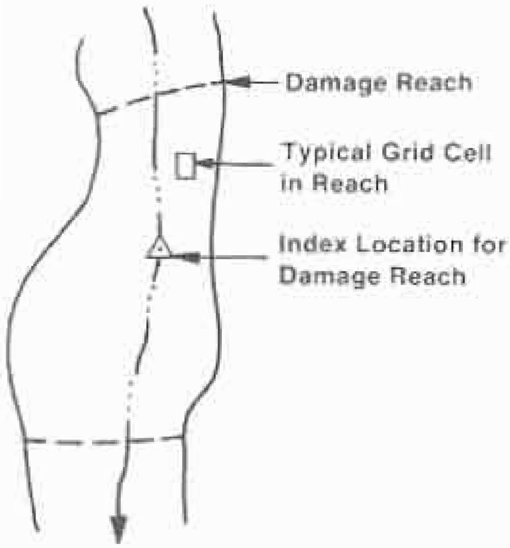
The development of the aggregate damage functions for the alternative future land use patterns was performed by one of two methods. The first was to simply apply the process just described to the future land use patterns. This method placed some future land use within the 100-year flood plain and did not observe any development control (flood plain regulation) policy. The second method accepted flood plain regulation policy elevations for each index location and by essentially a reverse of the process described in Figure D-5, placed all such designated future urban land use at elevations no lower than the policy flood level specified. This procedure provided the analysis capability for evaluating the impacts of restricting flood plain development within the 1978 100-year flood plain. In many cases, the future land use plans that were provided to the Corps by State and borough planners showed significant flood plain development. Each of the plans was analyzed as described above, with various flood plain regulation policies. The section entitled "Procedures," in the main body of the report, includes a more detailed description of the alternative land use plans that were considered. The flood plain regulation policies are also described in detail in that particular section.

EXPANDED FPI FLOOD DAMAGE CALCULATIONS

The spatial analysis methods used in this study provide a mechanism for expedient and consistent economic evaluation of the various land use patterns under study. Each geographic data variable (spatial location, ground elevation, reference flood elevation, etc.) is encoded and a grid cell representation of each data variable is stored in the data bank. In the Willow Study the geographic data variables that were used to perform the damage calculations are: (1) topographic elevation, (2) reference flood elevation, (3) damage reach designation, (4) existing (1978) land use classification, and (5) future land use classifications. Figure D-6, HYDROLOGIC AND ECONOMIC ANALYSIS UNIT HIERARCHY, illustrates the concept of the grid cell as it relates the physical hydrologic (watershed boundaries) and economic (damage reach) parameters.

FLOOD DAMAGE ASSESSMENT

Automated, spatial analysis methods for generating flood damage potential relationships from the grid cell data bank, were successfully applied during the Willow Study. These methods utilized a new program called DAMCAL which constructs a unique stage-damage relationship for



DATA REQUIRED

5	Grid representation of land use.
321.6	Grid representation of topography (elevations).
325.0	Grid representation of reference flood (water surface elevation at reference flood) for each grid cell.
12A	Grid representation of Damage Reach Boundary.
A	Composite stage-damage functions for each significant land use.

INDEX LOCATION DAMAGE FUNCTION CONSTRUCTION

STEP 1. Develop Elevation-Damage Function at Each Cell

a. Determine land use from grid file.
b. Retrieve appropriate composite stage damage function.
c. Determine grid elevation of cell from grid file.
d. Tabulate elevation-damage for cell from above.

STEP 2. Aggregate Cells to Index Location

a. Determine cell damage reach assignment.
b. Determine index location reference flood elevation (X1).
c. Determine cell reference flood elevation (X2).
d. Adjust cell elevation-damage function by (X2-X1).
e. Aggregate cell adjusted elevation damage function at index station.
f. Repeat for all grid cells.

DAMAGE FUNCTION DEVELOPMENT

Figure D-5

each grid cell within the flood plain and aggregates the individual cell functions to the index location for each designated damage reach. The computer program HEC-1 merges these aggregated damage functions with flood frequency and hydraulic stage data so that average annual damages for each damage reach, index location, land use category (commercial, residential, etc.) and evaluation condition (existing or future) can be computed. The DAMCAL program was also used to compute single event flood damages for the 10-year and 100-year frequency floods.

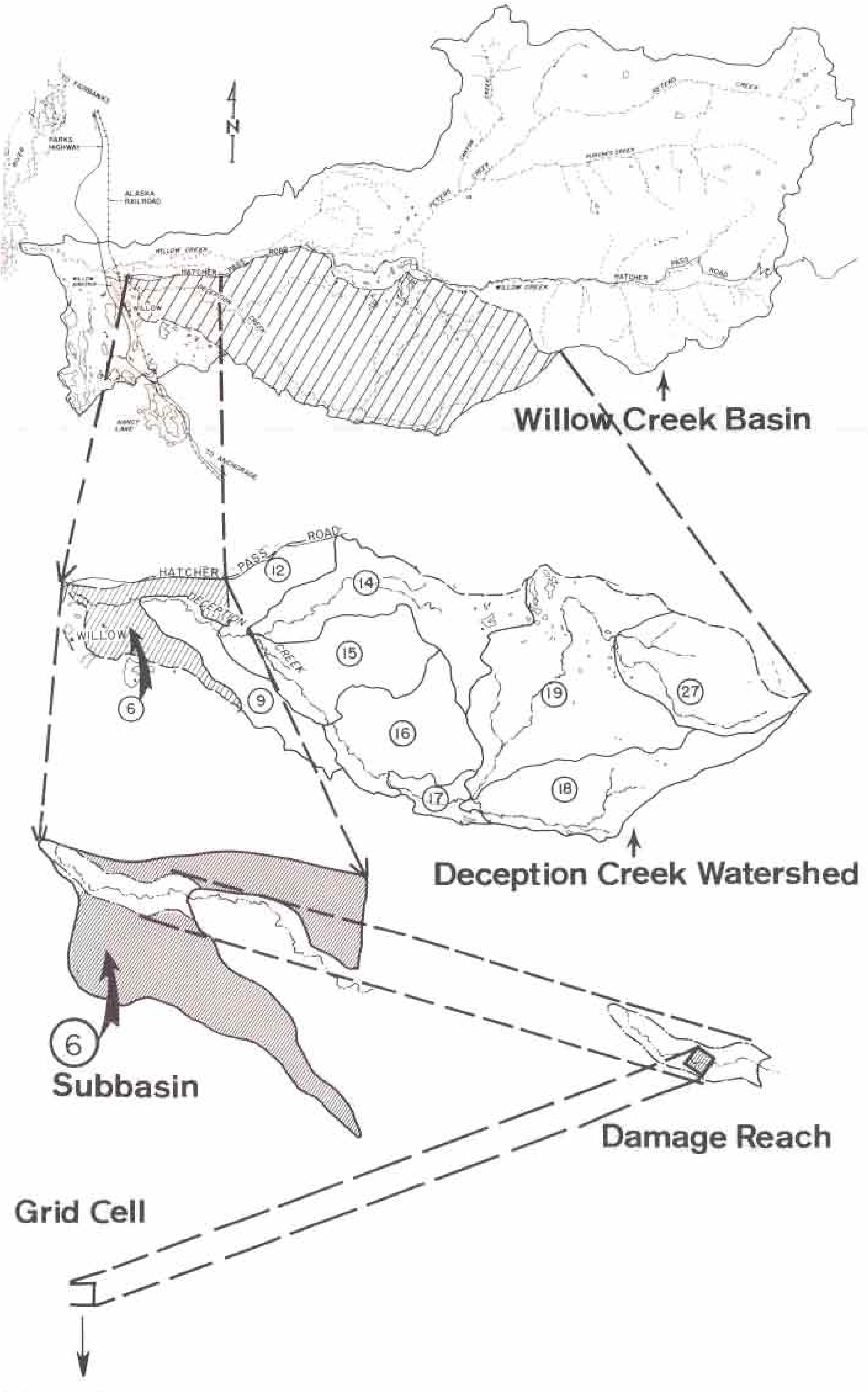
Single Event Damages

DAMCAL used the previously calculated water surface elevations at each damage index location to calculate flood damages. The 10-year and 100- year flood single events damages were computed for all land use conditions and flood plain regulation policies. The single-event calculations per- formed by DAMCAL aggregated damages for the individual land use categories into major land use categories for presentation purposes. The composite and aggregate damage functions that are developed by DAMCAL are also consolidated into the major categories of land use for transfer to the HEC-1 program for average annual damage calculations.

Average Annual Damages

As with single event damages, the damage-frequency relationship is used in the calculation of average annual damages. Points along the damage-frequency curve define specific damage values for specific frequency events for a wide range of floods, from non-damaging up to very rare events with high damage potential. The "frequency weighting" process to derive the average annual damage value consists of computing the total area under the damage-frequency curve. The actual calculations used in deriving this area are called curve integrations. The computer program ATODTA was developed and used to provide an automated data management interface between DAMCAL and the program HEC-1. For the flood-damage calculations, ATODTA reads discharge-frequency and stage-discharge data (see Figure D-4, INDEX LOCATION DATA) from cards and tape data files of stage-damage (aggregate damage) functions generated by DAMCAL, ATODTA then performs consistency checks, damage category aggregation and data file manipulation, resulting in input data cards in a format usable by HEC-1.

HEC-1 develops the discharge-exceedance frequency data at each index location, integrates it with the stage-damage and stage-discharge data and calculates the average annual damages for all the land use conditions (past, present and future) under consideration. The program performs these damage calculations for each land use plan on a reach-by-reach basis, then summarizes the results by watershed and by planning area. The results of the average annual and single event flood damage calculations from DAMCAL and HEC-1 for each of five land use conditions and for all flood plain policies considered, are presented in the section, Flood Damage Analysis Results, in the main body of this report.



Data Bank

1. ROW
2. COLUMN
3. SUBBASIN
4. TOPOGRAPHY
5. EXISTING LAND USE
6. FUTURE LAND USE WITH CAPITAL
7. FUTURE LAND USE WITH CAPITAL WITH FLOODWAY
8. FUTURE LAND USE WITHOUT CAPITAL
9. ETC.

WILLOW, ALASKA

EXPANDED FLOOD PLAIN INFORMATION REPORT

HYDROLOGIC AND ECONOMIC ANALYSIS UNIT HIERARCHY

PREPARED BY THE ALASKA DISTRICT, CORPS OF ENGINEERS ANCHORAGE, ALASKA

JUNE, 1980

FIGURE D-6

APPENDIX E
ENVIRONMENTAL

APPENDIX E
ENVIRONMENTAL

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ENVIRONMENTAL

GENERAL

The objective of the environmental portion of the Willow Expanded Flood Plain Study was to provide a detailed base data file of existing environmental conditions from which future alternative development schemes could be compared to determine the impact of each alternative. Various means of establishing a base data file are available, however each unfortunately incorporates varying levels of subjectivity during the assignment of numerical rating factors to be utilized during the computer simulation processes.

The environmental techniques, discussed and utilized in this study for the analyses, are one method of evaluating land use changes. They can be used effectively, providing planners with a valuable tool for assessing the ecological implications of future development within the Willow drainage basin.

Environmental impact analyses were made on the two future land use conditions that were addressed in this study, and are discussed at some length later in this appendix.

STUDY APPROACH

The primary purpose of this section of the Willow Expanded FPI Study is to analyze the effects of proposed future land use alternatives on the 1978 base year environmental conditions. The steps involved in this analysis include:

1. Define existing habitat categories and prepare a map spatially locating these.

2. Describe biota associated with identified habitat categories.

3. Use computer model study techniques to model change to habitat categories resulting from alternative development schemes.

4. Evaluate identified habitat modifications.

To define existing habitat an extensive data base was developed. Available literature was collected and studied in detail. Additionally, field studies were used to supplement and augment surveyed literature. Primary field investigations were performed by Alaska Department of Fish and Game (ADF&G) and Soil Conservation Service (SCS) personnel.

Vegetation typing was performed by the SCS, utilizing remote sensing techniques. Earth satellite infrared photography and onsite ground truthing provided the basis for vegetation delineation. Wildlife surveys and critical habitat identification was performed by ADF&G. Fisheries population data were also developed, utilizing ADF&G records.

Once these data were input into the data bank for the Willow Creek basin, the Resource Information and Analysis (RIA) computer program was utilized for management of the data and for environmental assessments. RIA provides a capability to perform four major types of analyses and generate computer printer graphic displays or tabulations of the analysis results. These capabilities are explained in more detail in the main body of this report under "Environmental Considerations." The program consists of an executive routine that manages data transfers and controls the sequences of execution, the four analysis packages, and the mapping package that can display output from the analysis packages or the variables directly from the data bank. Figure E-1 illustrates these basic functions of RIA.

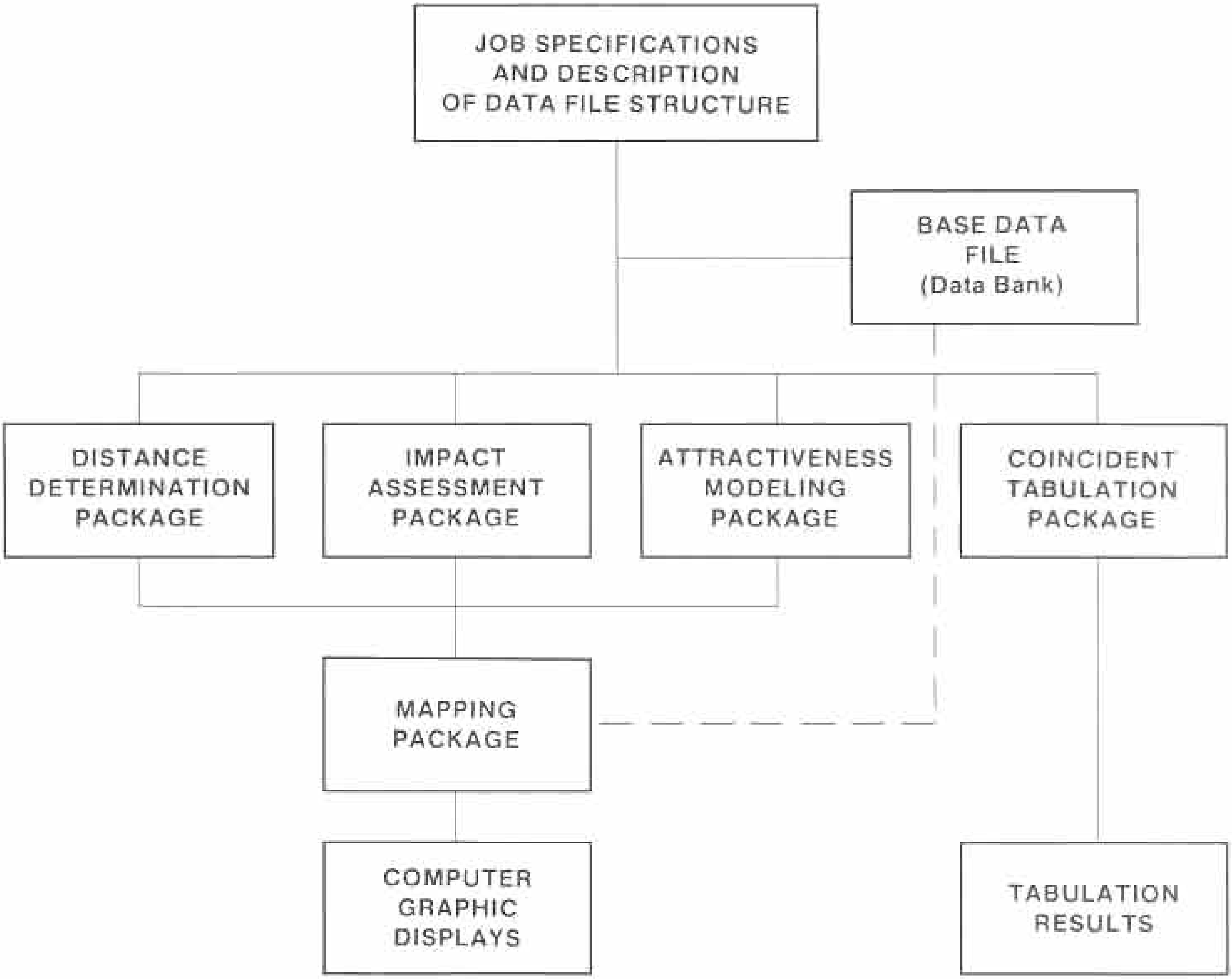
The RIA program requires access to a Base Data File (data bank) stored on magnetic tape, disc, or punched cards. This file compiling all the environmental features of the designated study area is created through literature search, onsite survey, and remote sensing techniques. The information is then digitized and encoded and stored in the base data file. While the variables for analysis must be chosen with the entire modeling process in mind, there is no "set" group of variables that must or should be catalogued into the data bank. Additional variables may be incorporated into the data bank as they are developed.

The development of the grid cell data file requires that each data variable map be individually encoded and geographically registered to a common base. The data variables needed for a specific analysis are retrieved from the Base Data File and processed by RIA programs. A Working Data File generated through the analyses process can be stored for use in subsequent analyses. The Working Data File can therefore become the new Base Data File.

EVALUATION OF FUTURE LAND USE CONDITIONS

The purpose of this section is to describe the results of analysis of the 1978 baseline land use versus the two alternative land use patterns which may occur in the Willow Creek Drainage Basin. The future conditions were developed through discussions with Matanuska-Susitna Borough planners and use of the Development Plan for the new capital city, presented to the State Legislature in 1978 by the New Capital Site Planning Commission. The two alternatives are briefly described below.

Alternative A - This alternative is based upon the assumption that the State capital would be relocated from its present location in Juneau to the voter proposed site at Willow. This area would have a target population of 75,000 persons within the new urban center with a short-term (2000) population of 37,500 persons. The year 2000 development scheme comprises the data input for planning purposes under Alternative A.



FUNCTIONAL SCHEMATIC RIA PROGRAM COMPONENTS

Figure E-1

Alternative B - This alternative is based upon the probable land use anticipated in the study area in the year 2000 without a capital relocation. An annual population growth of 7.6 percent would increase the current population from 300 to approximately 1,500 persons. The majority of this rural development would be expected to occur along Willow Creek and existing roadways in the lower one-half of the Willow Drainage Basin.

Analysis Technique

The method utilized to assess the impact of alternative development during the study centered on the definition of net acreage change for each land use resulting from development activity. To define such change a comparison of each alternative future land use to the existing conditions was made, utilizing the Coincident Tabulation option of the Resource Information and Analysis (RIA) Program. This option provides a matrix analysis of specified variables within the data bank. The comparison of existing and future land uses was performed for each of the 20 subbasins in the detailed study area. The results of the Subbasin 5 analysis are displayed in Plate E-1. The results can be best understood by examination of the change in one specific land use. Category 20, undeveloped land, is discussed below.

Review of figures on this plate reveal that the row categories represent 1978 existing or baseline land use. The column categories identify land use acreages projected under Alternative Future A.

Total 1978 undeveloped lands	= Total Row 20	=	2,171.2 acres
Total Alternative Future A	= Total Column 20	=	1,792.8 acres
	Acreage Lost	=	378.4 acres

The acreage change is expected to result in the following manner.

1. An estimated 287.5 acres will be lost to low density, single unit residential development (Row 17, Column 1).

2. An estimated 27.6 acres would be changed to medium density, single unit, residential development (Row 17, Column 2).

3. An estimated 35.6 acres would be altered from undeveloped lands to commercial uses (Row 17, Column 5).

4. An estimated 32.2 acres would be set aside for public park and/or campground use (Row 17, Column 15).

5. An estimated 2.3 acres currently used for solid waste activities will be reclaimed for open space or greenbelt use (Row 10, Column 20).

6. An estimated 2.3 acres, which is currently being used under resource extration, will be reclaimed into the undeveloped lands classification (Row 17, Column 20).

COINCIDENT TEST

EXISTING AND FUTURE WITH CAPITAL LAND USES

SUBBASINS 5
COINCIDENTS MATRIX

ROW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	ROW TOTAL
1	47.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.1
2	0.0	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7
5	0.0	0.0	0.0	0.0	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.3
8	0.0	0.0	0.0	0.0	1.1	0.0	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7
10	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	3.6
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.1	0.0	0.0	0.0	0.0	0.0	39.1
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	2.3
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37.9	0.0	37.9
20	287.5	27.6	0.0	0.0	35.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.2	0.0	0.0	0.0	0.0	1788.2	2171.2
TOTAL	334.6	33.3	0.0	0.0	47.1	0.0	0.0	4.6	0.0	1.1	0.0	0.0	0.0	0.0	71.3	0.0	0.0	0.0	37.9	1792.8	2323.0

ROW CATEGORIES ARE EXISTING LAND USE

1 LOW DENSITY,SINGLE
2 MEDIUM DENSITY,SINGLE
3 HIGH DENSITY,SINGLE,MULT
4 HOTEL,MOTEL,LODGE
5 COMMERCIAL
6 GOVERNMENT OFFICES
7 EDUCATIONAL
8 AIRPORT
9 UTILITY
10 SOLID WASTE DISPOSAL
11 SEWAGE TREATMENT PLANT
12 POWER GENERATION
13 CEMETARY
14 INDUSTRY
15 PUBLIC PARK,CAMPGROUND
16 PRIVATE RESORT,PARK
17 RESOURCE EXTRACTION
18 MIXED URBAN
19 WATER BODIES
20 UNDEVELOPED LANDS

COLUMN CATEGORIES ARE

1 LOW DENSITY,SINGLE
2 MEDIUM DENSITY,SINGLE
3 HIGH DENSITY,SINGLE,MULT
4 HOTEL,MOTEL,LODGE
5 COMMERCIAL
6 GOVERNMENT OFFICES
7 EDUCATIONAL
8 AIRPORT
9 UTILITY
10 SOLID WASTE DISPOSAL
11 SEWAGE TREATMENT
12 POWER GENERATION
13 CEMETARY
14 INDUSTRY
15 PUBLIC PARK,CAMPGROUND
16 PRIVATE RESORT,PARK
17 RESOURCE EXTRACTION
18 MIXED URBAN
19 WATER BODIES
20 UNDEVELOPED LANDS

PLATE E-1

Total acreages lost/gained equals:

1.	Low Density, single	- 287.5 acres
2.	Medium Density, single	- 27.6 acres
3.	Commercial	- 35.6 acres
4.	Public Park/Campground	- 32.2 acres
5.	Reclaimed Solid Waste Disposal Lands	+ 2.3 acres
6.	Reclaimed Resource Extraction Lands	+ 2.3 acres
	Net Loss	= 378.3 acres

An evaluation of habitat gains and losses for all categories was conducted and is presented in the following section.

Analysis Results

Alternative A - With the achievement of the projected future land use described for Alternative A, residential and urban acreage would grow by more than 6-1/2 times the 1978 baseline condition. Public and private parklands and greenbelt areas would increase from the existing 0.1 percent to 4.4 percent of the study area total acreage. The overwhelming majority of this development would occur in the deciduous and deciduous/coniferous mixed forest habitat categories. Undeveloped lands within the study area will decrease from the existing 98.5 percent to 87.7 percent. The largest impact of this development will be that of losses to moose browse. The entire study area supports a very dynamic moose population which experiences large calf mortality during years of severe winter weather. As a result of increased development and man's use of the study area, a loss of available winter browse would be expected, as would the incidence of road kills due to additional roadways and traffic. The design of greenbelt areas adjacent to Willow and Deception Creeks will greatly reduce the impact on moose populations, providing migrational routes along previously identified critical late winter habitat requirements.

Overall effects on waterbodies will be moderate. The potential exists for water quality degradation resulting from increased runoff quantities due to the impervious nature of man-made structures and roadways. This potential problem can be prevented or minimized through the construction of proper drainage facilities and the insurance of adequate greenbelt buffer zones around the local waterbodies.

Bird species in the area will be little effected by the proposed development as a result of the development scheme retaining existing vegetation wherever possible and the replanting of indigenous species in disturbed areas. Species known to inhabit the area exhibit minor displacement tendencies resulting from man induced change and would be expected to continue to use the developed land habitat and adjacent habitat types.

Mammals using the area would experience displacement from the development of 4,426 acres of previously undeveloped lands. Some species such as vole, mouse, and shrew would be little effected by the proposed development while the larger furbearers would experience extensive dislocation due to their incompatability to human encroachment and hunting pressures. Those species expected to be lost to the immediate development area in the lower drainage basin would include: black and grizzly bear, wolf, wolverine, coyote, shorttail weasel, red fox, lynx and marten.

Impact on anadromous fish and resident fish species could be minimal provided water qualtiy is preserved and sport fishing pressure is closely regulated.

Alternative B - This alternative represents slightly more than a doubling of the existing residential and urban development occurring in the lower portions of the Willow Drainage Basin. Estimates by Borough planners indicate developed lands would increase from 784 acres to 1,822 acres. Parks and greenbelt areas would increase from 0.1 percent to 0.8 percent of the total study area resulting in an increase of established parklands from 87 acres to 554 acres. Waterbodies would remain at their existing land cover levels of roughly 2,053 acres. The environmental effects anticipated from this level of development would be much less than for Alternative A. Moose overwintering and migration habitat would remain very near the existing levels. Hunter pressure would also equate to todays levels due to limited access to the area and the distance to a major population center such as Anchorage.

As in Alternative A, the majority of the development would alter existing deciduous and deciduous/conifer mixed forest habitat type. The alteration of 1,038 acres of undeveloped lands will have a moderate effect on lcoal fur bearers. Dispersal of the larger species which will not adapt to man's encroachment will occur over an anticipated 20 year incremental development period. Development under this alternative would occur under much less rigorous environmental and esthetic development standards which, while impacting a smaller overall area, would effect that area to a much greater degree. Piecemeal development would be more common under this alternative. For this reason, detailed planning activities, outlining development practices and constraints, should be performed at an early date.

Vegetation changes anticipated from the implementation of this alternative are not severe. Suitable adjacent habitat is available to accommodate the displaced wildlife species which exhibit a low tolerance to the disturbances of man. Residential growth in this area historically has maintained a development attitude harmonious with the natural setting. Removal of vegetative cover on private lands has been limited to that necessary to build living or working structures while preserving the esthetics in the area to the greatest extent practicable. A continuation of this attitude, strengthened by necessary construction codes, would ensure semi-natural setting in the proposed development area.

Avifauna will not experience a significant habitat loss from implementation of Alternative B.

Fisheries species would be slightly affected from an increase in recreational fishing pressure by local inhabitants. Catch limits established by the Alaska Department of Fish and Game should ensure a maximum sustained yield, however, enforcement of these regulations may pose logistics problems.

Overall, the alteration of the 1,038 acres of undeveloped lands to residential and commercial uses will have minor impact on the biotic environment in the project study area. The remaining undeveloped lands, approximating 61,312 acres, should readily facilitate those species displaced.

EXISTING HABITAT INVENTORY

The purpose of this portion of the report is to present the results of the environmental inventory completed for the study area. The results are formated such that each land use/habitat category is described in terms of its biotic characteristic for the 1978 base year condition. The inventory establishes a datum from which changes to the environment resulting from development actions can be accurately evaluated and presented. From such evaluations local planners can better determine the best useage of available area in terms of human needs and identified ecological requirements. Through the modeling process potential problems unforeseen by planning personnel become more obvious through dimensional analyses.

Environmental Data Collection Techniques

Before any detailed analysis of future land use characteristics can be evaluated, a thorough inventory of the ambient environmental conditions must be completed. Vegetation mapping of the study area is an important first step in developing accurate habitat classifications for future comparison studies. This mapping was obtained from the USDA, Soil Conservation Service (SCS) in Anchorage. They obtained this information for use in the USDA/State of Alaska "Alaska Rivers Cooperative Study" which covered the Susitna basin. This information was then made available to the Corps for use in the Willow Expanded FPI Study.

A vegetation map was developed through interpretation of high altitude aerial photography followed by ground truthing at random transect points (Winterberger). An inventory was made of all vegetation growing at each transect to corroborate mapping units and determine the dry weight productivity of the forage. The 1:25,000 vegetation type map developed was derived from NASA high altiude color infrared (CIR) aerial tranparencies enlarged from 1:111,196 to 1:25,000 scale and several 1:63,360 CIR transparency enlargements. Due to the significant variation in elevation within the drainage basin a true 1:25,000 or 1:63,360 scale enlargement could not be obtained; therefore, slight shifting of the type map over segments of the US Geological Survey (USGS) topographic base maps was necessary to adjust to topographic features. This adjustment was compensated for by the selection of known control points throughout the study area to spatially orient the encoded vegetation types into the data bank.

Vegetation mapping units were derived from the SCS - Susitna River Basin Study. This scheme was then modified to make it more compatable with the CIR aerial photograph interpretations. Some of the mapping units yielded large areas of more than one predominant plant species. In these cases the unit was mapped as a complex and given a single numerical designation representing those types found.

Ground truthing transects provided four distinct forms of data including:

a. Timber plot data

b. Habitat plot data

c. Range plot data

d. Soil plot data

A total of 76,380 acres was typed and is summarized in Table E-1.

Land Use/Habitat Category Inventory

The following sections briefly describe in general terms and through species lists the physical/biological characteristics of the major land use/habitat classifications in the Willow Drainage Basin. The information presented serves as the baseline environmental conditions for all future simulation studies.

Cultural Influence: This land use/habitat category encompasses all lands experiencing man induced alterations of the naturally occurring vegetation. No single soil type depicts this randomly occurring category. The most significant factors in locating developed lands are topography, access, and available water supplies. For these reasons the majority of development has been immediately adjacent to Willow Creek along Hatcher Pass Road and the Parks Highway.

TABLE E-1
TYPED ACREAGE SUMMARY

Habitat Category	Conifer-ous Forest	Deciduous Forest	Wet-lands	Grass-land	Shrub	Water bodies	Develop-ed Land	Tota
Acres	20,635	32,650	4,610	1,825	14,060	1,000	1,600	76,38

TABLE E-2

BIOTIC INVENTORY SUMMARY BY HABITAT CATEGORY
1978

Habitat Category	Plants	Birds	Mammals	Fish	Total Species	Species of Prime Concern
Cultural Influence	55	90	8		153	2
Coniferous Forest	89	70	18		177	2
Deciduous Forest	93	72	17		182	2
Shrublands	91	85	19		195	2
Grasslands	51	91	22		164	2
Wetlands	49	110	12		171	2
Waterbodies	24	81	6	10	121	

Approximately 55 species of plants, 90 species of birds, and 8 species of mammals can be found in this category. A listing of common and scientific names can be found in Table E-3.

The vegetation remaining after cultivation has largely maintained native species with relatively few introduced domestic varieties. Climax vegetation types are replaced with a secondary seral type of low growing shrubs and grasses.

Due to the extremes in low temperatures reptilian species are non-existent in the study area or Alaska in general.

Coniferous Forest: This land use/habitat category is composed of both short and tall stands of white and black spruce. These stands can be farther differentiated by their denseness, classifying them as open or closed forests. Approximately 20,000 acres of the study area are classified as coniferous forest habitat category making it the second largest land cover group in the study area.

Deception Creek appears to be the division line between the higher bench lands and the lower ridges, bogs, and lakes. South of the creek, the land slopes away into lower ridges, hills, and bogs. The higher ground consists of better drained soils supporting mature growth of birch interspersed with white spruce. The lower slopes display large stands of birch, white spruce, alder, and willow. The low lying boggy areas are typified by short and tall stands of black spruce.

Deciduous Forest: The largest land cover/habitat type category is the deciduous forest. Approximately 32,650 acres are classified in this category. Paper birch is the predominant three species identified in this habitat category. Quaking aspen and black cottonwood are also common within this land cover type. A list of 76 plant species have been identified within this category and are found in the Inventory Table. The deciduous forest predominates along water courses throughout the drainage basin. The low lying lands found along flood plains exhibit rich organic soils characteristically yielding the deciduous tree species. The porous soils allow for deeper moisture precolation, producing larger root systems and larger tree and shrub growth.

Shrubs: Approximately 14,060 acres of the Willow study area are classified as shrubland. This category can be further defined as low shrub and tall shrub habitat types. This intermediate seral stage of climax vegetative growth provides a large percentage of the summer range for the moose population in the Willow area. Shrubland is found throughout the entire watershed ranging in elevation from the lowest point in the basin to the 3,000 foot level.

Grassland: Approximately 1,825 acres of the study area are classified as grasslands. The predominant species found include bluejoint (Calamagrostis canadensis) and sedges (Carex sp.).

Wetlands: The defining of wetland habitat is difficult as there are numerous legal definitions that can be applied, greatly varying the boundaries of such habitat. Statutes such as Section 404 of Public Law 92-500 (Federal Water Pollution Control Act of 1972), once settled will provide guidance in wetland habitat delineation. The term "wetland" can be defined as that area that is inundated or saturated by ground or surface water at a frequency and duration sufficient to support, and that under normal circumstances, does support a prevalence of vegetation typically adopted for life in saturated soil conditions. The major importance of wetlands includes: feeding, cover, and reproduction habitat for a great diversity of wildlife; the maintenance of drainage, salinity, sedimentation flushing, and circulation patterns; the cycling of nutrients; contaminant filtering; and erosion control to name a few.

Wetland habitat has therefore been identified as the land use category of main concern in this study. An estimated 4,610 acres of wetland habitat have been delineated within the boundaries of the study area.

An examination of the Inventory Table of characteristic biota of the Willow study area wetlands indicates the potential for 49 plant species within this habitat category. Typical indicator species include the sedges (Carex spp.) and the reedgrasses (Calamagrostis spp.).

Waterbodies: A wide variety of vegetation is associated with the lakes, ponds, and streams of the study area. These plants range from the unicellular green and bluegreen algae to the sedges, grasses, and flowering aquatic plants. Mosses and pondweed are examples of highly sought after food species associated with the aquatic environment. A partial listing of aquatic vegetation likely to be found in the study area freshwater streams and ponds is contained in the Inventory Table. The sedges, horsetail, and pondweed are very important food plants for the moose population in the Willow area.

TABLE E-3
ENVIRONMENTAL INVENTORY
GRASS AND GRASSLIKE PLANTS

Scientific Name	Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands
Agrostis scabra	ticklegrass		X	X			
Calamagrostis canadensis	bluejoint	X	X	X	X	X	X
Carex bigelowii	bigelow sedge		X				
Carex rariflora	sedge		X				X
Carex pauciflora	sedge						X
Carex lugens	sedge						X
Carex aquatilis	water sedge	X	X		X		X
Carex mertensii	merten's sedge					X	
Carex sp.	sedge	X	X	X	X	X	X
Deschampsia caespitosa	tufted hairgrass		X	X			
Festuca altaica	Siberian fescue		X		X		
Festuca sp.	fescue			X			
Poa annua	annual bluegrass	X				X	
Poa sp.	bluegrass	X			X		
Agrostis sp.	bentgrass	X			X		
Alopecurus alpinus	alpine foxtail	X			X		
Arctagrostis latifolia	polargrass		X				
Eriophorum brachyantherum	cottongrass		X				X
Phleum pratense	timothy			X			
Poa pratensis	Kentucky bluegrass			X			
Phleum alpinum	alpine timothy				X		
Luzula parviflora	small-flowered woodrush					X	
Agrostis alba	redtop			X			
Agropyron repens	quackgrass			X			
Rumex	dock					X	X

TABLE E-3 (Con't.)
ENVIRONMENTAL INVENTORY
FORBS

Scientific Name	Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands
Aconitum delphinifolium	monkshood		X	X	X	X	
Aster sibiricus	Siberian aster	X	X	X			
Castilleja sp.	Indian paintbrush		X				
Cornus canadensis	bunchberry	X	X	X	X	X	X
Epilobium angustifolium	fireweed	X	X	X	X	X	
Galium sp.	bedstraw		X		X		
Geocaulon lividum	geocaulon		X	X			
Geranium erianthum	northern geranium	X	X	X	X	X	
Heracleum lanatum	cow parsnip	X	X	X	X	X	
Iris setosa	wild iris	X	X				X
Mertensia paniculata	tall bluebell		X	X	X	X	
Moneses uniflora	single delight	X	X				
Parnassia palustris	northern grass-of-parnassus		X	X	X	X	X
Polemonium acutiflorum	Jacobs-ladder		X	X	X		X
Potentilla palustris	marsh fivefinger		X		X		X
Pyrola asarifolia	liverleaf wintergreen		X	X	X		
Pyrola minor	lesser wintergreen		X	X			
Pyrola secunda	one-sided wintergreen		X	X			
Rubus arcticus	nagoon berry		X	X	X		X
Rubus pedatus	five-leaf bramble	X	X	X	X	X	
Sanquisorba stipulata	Sitka burnet	X	X	X	X	X	X
Stelliria crassifolia	fleshy starwort	X	X	X	X	X	
Streptopus amplexifolius	twisted stalk		X	X	X	X	
Swertia perennis	swertia		X		X		X
Thalictrum sp.	meadowrue		X	X			
Trientalis europaea	starflower		X	X	X	X	X
Valeriana capitata	capitate valerian	X	X		X		
Veratum eschscholtzii	false helebore		X		X	X	
Viola sp.	violet	X	X	X	X	X	X
Mimulus sp.	monkey flower			X			X
Spiranthes romanzoffia	hooded ladies tresses		X	X			X

TABLE E-3 (Con't.)
ENVIRONMENTAL INVENTORY
FORBS (Con't.)

Scientific Name	Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands
Angelica sp.	wild celery	X				X	
Taraxacum officinale	common dandelion	X		X		X	
Galium triflorum	sweet scented bedstraw	X	X	X		X	
Achillea borealis	yarrow	X		X	X		
Hedysarum alpinum	alpine sweet-vetch	X		X			
Trifolium pratense	red clover	X		X			
Trifolium repens	white clover	X		X			
Actaea rubra	baneberry	X		X			
Thalictrium sparsiflorum	few flower meadowrue	X		X			
Listera cordata	heart leaved twayblade		X				
Pedicularis labradorica	Labrador lousewort		X	X			
Ranunculus eschscholtzii	eschscholtz buttercup		X				
Antennaria sp.	pussytoe				X		
Aruncus sylvester	goatsbeard				X		
Castilleja caudata	pale Indian brush				X	X	
Epilobium latifolium	dwarf fireweed			X	X		
Galium boreale	northern bedstraw			X	X		
Listera sp.	twayblade				X		
Lupinus sp.	lupine				X		
Petasites frigidus	arctic sweet coltsfoot				X		
Ranunculus sp.	buttercup			X	X		
Rhinanthus minor	rattlebox			X	X	X	
Rubus chamaemorus	cloudberry		X	X	X		X
Saxifraga sp.	saxifrage				X		
Sedum rosea	roseroot				X		
Senecio triangularis	triangular-leafed groundsel				X	X	
Delphinium glaucum	glaucous larkspur					X	
Plantago major	common plantain			X		X	
Boschniaka rossica	ground con				X		
Cruciferae (family)	mustard				X		

TABLE E-3 (Con't.)
ENVIRONMENTAL INVENTORY
FORBES (Con't.)

Scientific Name	Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands
Urtica lyallii	stinging nettle				X	X	
Calla palustris	water arum				X		
Impatiens noli-tangere	western touch-me-not				X		
Goodyera repens	rattlesnake plantain			X			
Lupinus polyphyllus	large leaf lupine			X			
Solidago sp.	goldenrod			X			
Artemisia tilesii	wormwood			X			
Mentha arvensis	field mint			X			
Osmorhiza depauperta	sweet cicely			X			
Saussurea augustifolia	saussurea			X			
Stellaria sp.	chickweed			X			
Drosera anglica	long-leaf sundew						X
Drosera rotundifolia	round-leaf sundew						X
Gentiana douglasiana	swamp gentian						X
Menyanthes trifoliata	buckbean						X
Pedicularis sp.	lousewort						X
Erigeron elatus	fleabane						X
Solidago lepida	Canada goldenrod						X
Viola epipsila	marsh violet						X
Potentilla norvegica	Norwegian cinquefoil			X			

TABLE E-3 (Con't.)
ENVIRONMENTAL INVENTORY
WOODY PLANTS

Scientific Name	Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands
Alnus sinuata	Sitka alder	X	X	X	X	X	
Andromeda polifolia	bog-rosemary		X				X
Betula glandulosa	resin birch		X				
Betula nana	dwarf arctic birch		X	X	X		X
Empetrum nigrum	crowberry	X	X	X	X		X
Ledum groenlandicum	Labrador tea	X	X	X			X
Linnaea borealis	twin flower	X	X	X			X
Oplopanax horridus	devils club		X	X	X	X	
Potentilla fruticosa	tundra rose		X		X		X
Rosa acicularis	prickly rose	X	X	X	X	X	X
Rubus idaeus	American red raspberry	X	X	X	X	X	
Rubus spectabilis	salmonberry		X	X			
Salix brachycarpa	barren-ground willow		X				
Salix fuscescens	Alaska bog willow		X		X		X
Salix novae-angliae	tall blueberry willow		X	X	X		
Spiraea beauverdiana	beauverd spirea		X	X	X	X	X
Vaccinium ovalifolium	early blueberry		X	X			
Vaccinium oxycoccos	bog cranberry		X	X			X
Vaccinium uliginosum	bog blueberry		X	X	X	X	X
Vaccinium vitis-idaea	lowbush cranberry	X	X	X	X		X
Viburnum edule	highbush cranberry	X	X	X	X		
Sanguisorta sitchensis	Sitka great burnet		X				
Alnus crispa	American green alder	X		X	X	X	
Alnus tenuifolia	thinleaf alder	X	X	X	X		X
Ribes hudsonianum	northern black currant	X		X			
Ribes triste	American red currant	X	X	X	X		
Menziesia ferruginea	rusty menziesia	X		X		X	
Salix bebbiana	bebb willow	X	X	X	X	X	
Salix glauca	greyleaf willow	X		X			

TABLE E-3 (Con't)
ENVIRONMENTAL INVENTORY
WOODY PLANTS (Con't.)

Scientific Name	Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands
Salix alaxensis	feltleaf willow			X	X		
Salix barclayi	barclay willow				X		
Salix commutata	undergreen willow				X		
Salix interior	sandbar willow				X		
Salix myrtillifolia	low blueberry willow		X		X		X
Salix planifolia	diamondleaf willow			X	X		
Salix reticulata	netleaf willow				X		
Ribes laxiflorum	trailing black currant			X	X	X	
Myrica gale	sweet gale		X		X		X
Ribes glandulosum	skunk currant			X			
Salix barrattiana	barratt willow			X			
Salix sp.	willow			X			
Sambucus callicarpa	Pacific red alder			X		X	
Sorbus scopulina	Green mountain-ash			X		X	
Shepherdia canadensis	buffalo berry			X			
Chamaedaphne calculata	leatherleaf		X				X
Ledum decumbens	narrow-leaf Labrador-tea		X				X

TABLE E-3 (Con't.)
ENVIRONMENTAL INVENTORY
TREES

Scientific Name	Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands
Betula papyrifera	paper birch	X	X	X	X	X	X
Picea glauca	white spruce	X	X	X	X	X	
Picea mariana	black spruce	X	X	X	X		X
Populus tremuloides	quacking aspen	X		X		X	
Populus trichocarpa	black cottonwood	X		X	X	X	

TABLE E-3 (Con't)
ENVIRONMENTAL INVENTORY
MAMMALS

Scientific Name	Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands
Clethrionomys rutilus	Redback vole		X	X	X	X	
Peromyscus maniculatus	Deer mouse	X	X	X	X	X	
Microsorex hoyi	Pygmy shrew		X	X	X	X	
Sorex obscurus	Dusky shrew	X	X	X	X	X	X
Mustela erminea	Shorttail Weasel		X	X	X	X	
Marmota caligata	Hoary Marmot		X		X		
Lepus americanus	Snowshoe/Varying hare	X	X	X	X	X	
Gulo gulo	Wolverine		X		X	X	
Ursus americanus	Black bear		X	X	X	X	
Ursus arctos	Grizzly bear		X		X	X	
Canis lantrans	Coyote		X	X	X	X	X
Canis lupis	Wolf		X	X	X	X	X
Vulpes vulpes	Red fox		X	X	X	X	X
Lynx canadensis	Lynx		X	X	X		X
Alces alces	Moose	X	X	X	X	X	X
Tamiasciurus hudsonicus	Red squirrel		X	X			
Glaucomys sabrinus	Northern flying squirrel		X	X			
Microtus miurus	Alaska vole	X		X	X	X	
Zapus hudsonicus	Jumping mouse	X		X	X	X	
Microtus pennsylvanicus	Meadow vole	X				X	

TABLE E-3 (Con't.)
ENVIRONMENTAL INVENTORY
TREES

Scientific Name	Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands
Betula papyrifera	paper birch	X	X	X	X	X	X
Picea glauca	white spruce	X	X	X	X	X	
Picea mariana	black spruce	X	X	X	X		X
Populus tremuloides	quacking aspen	X		X		X	
Populus trichocarpa	black cottonwood	X		X	X	X	

TABLE E.3 (Con't.)
ENVIRONMENTAL INVENTORY
CRYPTOGRAMS

Scientific Name	Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands
Clubmoss							
Lycopodium annotinum	stiff clubmoss	X	X	X			
Lycopodium complanatum	ground cedar			X			
Lycopodium sp.	clubmoss		X			X	
Ferns							
Athyrium filix-femina	lady fern	X	X	X	X	X	
Dryopteris dilatata	spinulose shield-fern	X	X	X	X	X	
Gymnocarpium dryopteris	oak fern		X	X	X	X	
Matteuccia struthiopteris	ostrich fern	X		X			
Polystichum sp.	prickly shield-fern				X	X	
Horsetail							
Equisetum arvense	meadow horsetail	X	X	X	X	X	X
Equisetum fluviatile	swamp horsetail						X
Equisetum sylvaticum	woodland horsetail		X	X	X	X	X
Lichens							
Cetraria		X	X				
Cladonia		X	X				X
Nephroma			X				
Peltigera			X	X			
Moss							
Feathermoss-hylocomium			X				
Feathermoss-pleurozium			X				
Feathermoss sp.				X			X
Hypnum sp.				X			
Polytrichum sp.			X	X			
Sphagnum sp.			X				X

TABLE E-3 (Con't.)
ENVIRONMENTAL INVENTORY
BIRDS

Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grasslands	Wetlands	Waterbodies
Mourning Dove *	X	X	X	X	X		
Snowy Owl					X		
Hawk Owl	X	X	X	X	X		
Great Gray Owl		X	X	X	X		
Boreal Owl	X	X	X	X	X		
Hairy Woodpecker		X	X	X	X		
Downy Woodpecker		X	X	X	X		
Black-back Three-toed Woodpecker		X	X	X	X		
Northern Three-toed Woodpecker	X	X	X	X	X		
Eastern Kingbird			X	X	X		
Say's Phoebe				X	X		
Western Wood Pewee	X	X	X	X	X		
Gray Jay	X	X	X	X	X		
Steller's Jay		X	X	X	X		
Black-billed Magpie	X	X	X	X	X		
Black-capped Chickadee	X	X	X	X	X		
Boreal Chickadee	X	X	X	X	X		
Red-breasted Nutnatch	X	X	X	X	X		
Brown Creeper		X	X	X	X		
Winter Wren	X		X	X	X		
American Robin	X	X	X	X	X		
Saw-whet Owl				X			
Mew Gull	X						
Glaucous-winged Gull	X						X
Common Loon							X
Red-throated Loon							X
Herring Gull							X
Bonaparte's Gull							X

*Casual sitings in study vicinity

TABLE E-3 (Con't.)
ENVIRONMENTAL INVENTORY
BIRDS (Con't.)

Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands	Waterbodies
Baird's Sandpiper	X			X		X	X
Pectoral Sandpiper						X	X
Dunlin						X	X
Arctic Tern	X					X	X
Great Horned Owl	X	X	X	X	X	X	
Short-eared Owl	X				X	X	X
Rufous Hummingbird*			X	X	X	X	X
Belted Kingfisher					X	X	X
Common Flicker	X	X	X	X	X	X	
Alder Flycatcher	X	X	X	X	X	X	X
Olive-sided Flycatcher	X	X	X	X	X	X	
Violet-green Flycatcher	X	X	X	X	X	X	X
Tree Swallow	X	X	X	X	X	X	X
Bank Swallow		X	X	X	X	X	X
Cliff Swallow		X	X	X	X	X	X
Common Raven	X	X	X	X	X	X	X
Dipper						X	X
Wheatear		X		X	X		
Starling	X	X			X		
Yellow-rumped Warbler	X	X	X		X		
Blackpoll Warbler	X	X	X		X		
Rusty Blackbird	X	X	X	X	X		X
Bullfinch*				X	X		
Lapland Longspur	X			X	X		
American Krestel	X	X	X	X	X		
Spruce Grouse	X	X	X	X	X		
Willow Ptarmigan	X	X	X	X	X		
Rock Ptarmigan	X	X	X	X	X		
White-tailed Ptarmigan				X	X		
Solitary Sandpiper				X	X		

*Casual sitings in study vicinity

TABLE E-3 (Con't.)
ENVIRONMENTAL INVENTORY
BIRDS (Con't.)

Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands	Waterbodies
Oldsquaw	X					X	X
Harlequin Duck	X					X	X
White-winged Scoter						X	
Black Scoter						X	
Common Merganser	X					X	X
Red-breasted Merganser						X	X
Goshawk	X	X	X	X	X	X	
Sharp-shinned Hawk		X	X	X	X	X	
Red-tailed Hawk	X	X	X	X	X	X	
Rough-legged Hawk		X	X	X	X	X	
Golden Eagle	X	X	X	X	X	X	
Bald Eagle		X	X	X	X	X	X
Marsh Hawk	X	X	X	X	X	X	X
Osprey					X	X	X
Gyrfalcon				X	X	X	
Peregrine Falcon		X	X	X	X	X	X
Merlin		X	X	X	X	X	X
Sandhill Crane*						X	X
American Coot						X	X
Killdeer					X	X	X
Upland Sandpiper					X	X	X
Greater Yellowlegs	X					X	X
Lesser Yellowlegs	X					X	X
Spotted Sandpiper	X					X	X
Northern Phalarope						X	X
Common Snipe	X					X	X
Short-billed Dowitcher						X	X
Long-billed Dowitcher						X	X
Western Sandpiper	X					X	X
Least Sandpiper	X					X	X

*Casual sitings in study vicinity

TABLE E-3 (Con't.)
ENVIRONMENTAL INVENTORY
BIRDS (Con't.)

Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands	Waterbodies
Snow Bunting	X			X	X	X	
Arctic Loon						X	
Red-necked Grebe						X	
Horned Grebe						X	
Pied-billed Grebe *	X					X	X
Fork-tailed Storm Petrel*						X	
Great Blue Heron	X	X	X			X	X
Whistling Swan	X					X	X
Trumpeter Swan	X					X	X
Canada Goose	X					X	X
Brant						X	
White-fronted Goose	X					X	X
Snow Goose						X	X
Mallard	X					X	X
Gadwall						X	X
Pintail	X					X	X
Green-winged Teal	X					X	X
Blue-winged Teal						X	X
Cinnamon Teal						X	X
Northern Shoveler	X					X	X
European Wigeon						X	X
American Wigeon	X					X	X
Canvasback	X					X	X
Redhead						X	X
Ring-necked Duck*						X	X
Common Eider						X	X
Greater Scaup	X					X	X
Lesser Scaup						X	X
Common Goldeneye						X	X
Barrow's Goldeneye						X	X
Bufflehead						X	X

*Casual sitings in study vicinity

TABLE E-3 (Con't.)
ENVIRONMENTAL INVENTORY
BIRDS (Con't.)

Common Name	Cultural Influence	Coniferous Forest	Deciduous Forest	Shrub Land	Grassland	Wetlands	Waterbodies
Varied Thrush	X	X	X	X	X	X	
Hermit Thrush	X	X	X	X	X	X	
Swainson's Thrush	X	X	X	X	X	X	
Gray-cheeked Thrush	X	X			X	X	
Townsend's Solitaire	X	X	X	X	X	X	
Golden-crowned Kinglet	X	X	X	X	X	X	
Ruby-crowned Kinglet	X	X	X	X	X	X	
Water Pipit	X	X		X	X	X	X
Bohemian Waxwing	X	X	X	X	X	X	
Northern Shrike	X	X	X	X	X	X	
Orange-crowned Warbler	X	X		X	X	X	X
Yellow Warbler	X	X	X	X	X	X	X
Townsend's Warbler	X	X	X	X	X	X	
Northern Waterthrush	X	X	X	X	X	X	X
Wilson's Warbler	X	X	X	X	X	X	X
Red-winged Blackbird	X			X	X	X	X
Pine Grosbeak	X	X	X	X	X	X	
Gray-crowned Rosy Finch	X	X	X	X	X	X	
Hoary Redpoll	X		X	X	X	X	
Common Redpoll	X	X	X	X	X	X	
Pine Siskin	X	X	X	X	X	X	
Red Crossbill	X		X	X	X	X	
White-winged Crossbill	X	X	X		X	X	
Savannah Sparrow	X			X	X	X	X
Dark-eyed Junco	X	X	X	X	X	X	X
Tree Sparrow	X	X	X	X	X	X	X
White-crowned Sparrow		X	X	X	X	X	X
Golden-crowned Sparrow	X		X	X	X	X	X
Fox Sparrow	X		X	X	X	X	X
Lincoln's Sparrow	X	X	X	X	X	X	X
Song Sparrow	X	X	X	X	X	X	X

APPENDIX F
GLOSSARY

GLOSSARY OF TERMS

ALTERNATIVE FUTURE. A land use configuration which could occur in the future and which is consistent with population projections and land use regulations. In this study, the future population figures were obtained from the Matanuska-Susitna Borough Planning Department and the Capital Site Planning Commission.

ASSESSMENT. A quantitative and/or qualitative evaluation. This study evaluated the impact on hydrologic, hydraulic, economic, environmental, and wildlife habitat conditions that would result if any one of a selected number of alternative futures were to occur.

COMPUTER DATA BANK. Data which are stored geographically by and in a computer system and which can be rapidly recalled for use. The data for this study were stored on a 1.1478 acre grid cell basis.

DAMAGE REACH. A segment of a flood plain along a stream in which uniform hydraulic conditions prevail and, hence, provide a workable basis for hydrologic and economic computations.

DISCHARGE. As applied to a stream, the rate of flow or volume of water flowing in a given stream at a given place and within a given period of time, usually measured in cubic feet per second (cfs) or gallons per minute (gpm).

DRAINAGE AREA. The area tributary to a lake, stream, sewer, or drain. Also called catchment area, watershed, or river basin.

ENCROACHMENT LIMITS. A limit of obstruction to flood flows. These encroachment "lines" are roughly parallel to a stream but do not have to be equidistant from the centerline of a stream channel to each bank. Encroachment lines are established by assuming that the area landward (outside) of the lines will be ultimately developed in such a way that it will not be able to convey flood flows.

FLOOD. An overflow of land not normally covered by water and that is used or usable by man. Floods have two essential characteristics; the inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river or stream or an ocean, lake, or other body of standing water. Normally, a "flood" is considered as any temporary rise in streamflow or stage, but not the ponding of surface water, that results in significant adverse effects in the vicinity. Adverse effects may include damages from overflow of land area, temporary backwater effects in sewers and local drainage channels, creation of unsanitary conditions or other unfavorable situations by deposition of materials in stream channels during flood recessions, rise of goundwater coincident with increased streamflow and other problems.

FLOOD CREST. The maximum stage or elevation reached by the waters of a specified flood at a given location.

FLOOD DAMAGE. Damage to property resulting from a given flood.

FLOODED AREAS. The land area covered by a given flood.

FLOOD FREQUENCY. A means of expressing the exceedance probability of flood occurrences as determined from a statistical analysis of representative streamflow or rainfall and runoff records. A 10-year frequency flood would have an average frequency of occurrence on the order of once in 10 years (a 10 percent chance of being equalled or exceeded in any given year). A 500-year frequency flood would have an average frequency of occurrence on the order of once in 500 years (a 0.2 percent chance of being equalled or exceeded in any given year).

FLOOD HEIGHT. The water surface elevation reached by a given flood at a given location.

FLOOD HYDROGRAPH. A graph showing flow (discharge) values against time at a given point, usually measured in cubic feet per second (cfs). The area under the curve indicates total volume of flow.

FLOOD PEAK. The maximum instantaneous discharge of a flood at a given location. It usually occurs at or near the time of the flood crest.

FLOOD PLAIN. The relatively flat area or lowlands adjoining the channel of a river, stream, or watercourse or ocean, lake or other body of standing water, which has been or may be covered by floodwater.

FLOOD PLAIN MANAGEMENT. Any action which is directed toward the wise use of flood plains. This action generally involves the reduction and/or prevention of flood damage and protection of environmental values, while at the same time leading to the prudent use of the flood plain.

FLOOD PROFILE. A graph showing the relationship of water surface elevation to location, the latter generally expressed as distance above mouth for a stream of water flowing in an open channel. It is generally drawn to show the water surface elevation for the crest of a specific flood, but may be prepared for conditions at a given time or stage.

FLOODWAY. The minimum area of a flood plain required to convey a flood peak of a selected magnitude with no more than a specified increase (usually 1 foot) in water surface elevation. This area usually consists of the most hazardous portion of the flood plain where water velocities are appreciable. Areas on the landward site of a floodway normally convey little or no flood flow although they are inundated by water during floods.

HYDRAULICS. The branch of physics having to do with the mechanical properties of water and with the application of these properties in engineering.

HYDROLOGY. The branch of science dealing with water, its properties, laws, and distribution.

LAND USE. The purpose for which land is used.

MEAN SEA LEVEL. A determination of mean sea level that has been adopted as a standard datum for heights or elevations. Elevation therefore is a measurement vertically above this datum as used in surveys and engineering reports.

METHODOLOGY. A method or system of methods or ways of accomplishing an objective.

ONE HUNDRED YEAR FLOOD. A flood having one chance in 100 of being exceeded in any year, at a designated location, although the flood may occur in any year and possibly in successive years. It would have a 1 percent chance of being equalled or exceeded in any year. In the past, this flood has been referred to as the Intermediate Regional Flood.

SPATIAL. Relating to, occupying, or having the character of a limited extent in one, two or three dimensions: distance, area, volume.

STAGE HYDROGRAPH. A graph showing stage (elevation) values against time at a given point, usually measured in feet.

SYSTEM ANALYSIS. An inquiry intended to advise a decision maker on the policy choices involved in major decisions. To qualify as a system analysis, a study must look at the entire problem as a whole. Characteristically, it will involve a systematic investigation of the decision-maker's objectives and of the relevant criteria; a comparison of the costs, effectiveness and risks associated with the alternative policies or strategies for achieving each objective; and an attempt to formulate additional alternatives if those examined are deficient.

WATERSHED. The area contained within a divide above a specified point on a stream; the area drained by a river.

APPENDIX G
BIBLIOGRAPHY

BIBLIOGRAPHY

1. New Capital City Environmental Assessment Program - Phase I, Source Document No. 2, Fish and Wildlife Studies. Alaska Department of Fish and Game, December 1978.

2. Childers, Joseph M. "Flood Frequency in Alaska," United States Department of the Interior, Geological Survey, Water Resources Division, Alaska District, Open-File Report, 1970.

3. Willow Capital City Planning Procedures, Environmental Guidelines and Assessment, Permits and Procedures, Thomas Dowell, Jr. Ph. D, March 15, 1978.

4. Wildflowers of Alaska, Christine Heller, Heller Enterprises, 1966.

5. Miller, John F. "Probable Maximum Precipitation and Rainfall-Frequency Data for Alaska," United States Department of Commerce, Weather Bureau, Technical Paper No. 47, Washington, D.C., 1963.

6. Miller, John F. "Two-To-Ten-Day Precipitation for Return Periods of 2 to 100 years in Alaska," United States Department of Commerce, Weather Bureau, Technical Paper No. 52, Washington, D.C., 1965.

7. Identification of Environmental Impacts of Energy Conservation Technologies for Proposed New Capital Site at Willow, Alaska. R&M Consultants, Inc., April 1974.

8. Field Guide to Western Birds, Roger Tory, Peterson Houghton Mifflin Company, 1961.

9. Birds of North America, Robbins, Bruun, Zim and Singer, Golden Press, New York, 1966.

10. Schoephorster, Dale B. "Soil Survey of Matanuska Valley Area, Alaska," United States Department of Agriculture, Soil Conservation Service, U.S. Government Printing Office, Washington, D.C., issued June 1968.

11. Schoephorster, Dale B. and Robert B. Hinton "Soil Survey of Susitna Valley Area, Alaska." United States Department of Agriculture, Soil Conservation Service, U.S. Government Printing Office, Washington, D.C. issued December 1973.

12. New Capital City Environmental Assessment Program - Phase I, Source Document No. 2, Moose Habitat Analysis, U.S. Soil Conservation Service. December 1978.

13. United States Department of Agriculture, Soil Conservation Service. SCS National Engineering Handbook, Section 4, Hydrology, U.S Government Printing Office, Washington, D.C., August 1972.

14. Soils of the Capital Relocation Site, Alaska U.S. Department of Agriculture, Soil Conservation Service, February 1978.

15. Soil Survey of Matanuska Valley Area, Alaska; U.S. Department of Agriculture, Soil Conservation Service, June 1968.

16. Soil Survey of Susitna Valley Area, Alaska; U.S. Department of Agriculture, Soil Conservation Service, December 1973.

17. United States Army, Corps of Engineers, Hydrologic Engineering Center. Hydrologic Parameters (HYDPAR) - User's Manual, Preliminary Draft, Davis, California, November, 1978.

18. United States Army, Corps of Engineers, Hydrologic Engineering Center. HEC-1 Flood Hydrograph Package - User's Manual. Davis, California, January, 1973.

19. United States Army, Corps of Engineers, Hydrologic Engineering Center. HEC-2 Water Surface Profiles - User's Manual. Davis, California, August, 1979.

20. U.S. Army Corps of Engineers, Hydrologic Engineering Center, Draft User's Manual for DAMCAL Computer Program, undated.

21. U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, California, Phase 1 Oconee Basin Pilot Study, Trail Creek Test, dated September 1975.

22. U.S. Army Corps of Engineers, Hydrologic Engineering Center, Draft User's Manual for ATODTA Computer Program, undated.

23. Alaska Trees and Shrubs, U.S. Department of Agriculture, Agricultural Handbook, No. 410, Leslie A. Viereek, Elbert L. Little.


TO FAIRBANKS
PARKS HIGHWAY
ALASKA RAILROAD
WILLOW CREEK
HATCHER PASS ROAD
DECEPTION CREEK
WILLOW
TO ANCHORAGE
WILLOW CREEK
HATCHER PASS ROAD
N