BEAR CREEK

DRAINAGE BASIN PLANNING STUDY

Volume I

Prepared for:

City of Colorado Springs
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KIOWA Project No. 88.12.26
D15/R43

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EXECUTIVE SUMMARY

The Bear Creek Drainage Basin Planning Study (DBPS), was authorized by the City of Colorado Springs under an agreement with the City and Kiowa Engineering Corporation dated December 13, 1988.

The purpose of the DBPS is to analyze drainage conditions within the Basin, determine existing and potential drainage and flood control problems, determine the impact of future development upon the storm drainage and flood control systems, develop alternative plans for handling existing and potential problems, and provide a preliminary design of the selected alternate design(s) complete with the estimation of costs and basin fees. The DBPS has been prepared so as to be in general conformance with the City/County Drainage Criteria Manual. The plans have been developed with the recognition that the Basin and its major drainageways have a generally high environmental value which has been reflected in the alternative evaluation process and the resulting selected plan. Multiple use opportunities have been evaluated and incorporated into the Plans wherever practical. Unique to this study relative to past basin planning studies was the preparation of an existing drainage structure inventory database and the processing of a Letter of Permission (LOP) through the U.S. Army Corps of Engineers.

Contained within the report is a complete summary of the basin and its characteristics, the basin and sub-basin hydrology, flood plain and stormwater system hydraulic analyses, the alternative planning and evaluation process, and the presentation of a preliminary design for the selected plan(s). The development of the final design for any segment or portion of the systems identified herein must be include a thorough review of particular site constraints, the hydrology and hydraulics must be verified and coordination with the appropriate agencies conducted.

Coordination

A primary step in the completion of the basin study was the involvement of public agencies, citizen groups, and interested

individuals in the planning process. Prior to the commencement of work on the basin study a mailing list was compiled. This list contains individuals and agencies which were contacted during the preparation of the study materials. At various milestones during the project, a general coordination meeting was held at City offices in order to inform and to solicit input and information from the persons on the mailing list. The coordination process was valuable and key step in the completion of the DBPS and many of the comments received are reflected in the concepts identified for handling stormwater within the Basin. The following agencies were routinely coordinated with during the preparation of this Plan:

City of Colorado Springs Department of Public Works
City of Colorado Springs Department of Utilities
City of Colorado Springs Parks and Recreation Department
El Paso County Department of Public Works
El Paso County Park and Recreation Department
U. S. Army Corps of Engineers
Environmental Protection Agency
Federal Emergency Management Agency
U. S. Fish and Wildlife
Colorado Division of Wildlife
Colorado Department of Transportation
Top of Skyway Homeowners Association
Skyway Homeowners Association

A complete listing of individuals names is provided in Chapter I of the report. Project correspondence has been included within Appendix C of the report.

Basin Description

The Bear Creek Drainage Basin lies in the southwestern portion of Colorado Springs, El Paso County, Colorado. Bear Creek is the major drainageway for the basin, flowing in an easterly direction and entering Fountain Creek approximately one-quarter of a mile downstream of the US-24 bridge over Fountain Creek. Portions of the basin lie within Teller County. Approximately two-thirds of the basin lies within the Pike National Forest. The area below the High Drive (i.e., at the entrance to Bear Creek Canyon Park), has been designated as the Lower Basin. The lower basin which covers approximately 4 square

miles is the portion of the basin containing the greastest amount of developed and developable land. For this reason the lower basin was subjected to a more detailed analysis during the planning. The overallbasin covers a total area of approximately 10.7 square miles.

The Bear Creek Basin has two distinct characteristics, typified by an upper mountain watershed above Gold Camp Road, and a foothills basin below Gold Camp Road. Above Gold Camp Road the watershed is very mountainous and steep, and with the majority of the watershed heavily wooded with pinon pine and juniper. Below Gold Camp Road the basin has a mix of open space, commercial, and residential development. The open space areas are mostly park, and steep hillsides covered with pinon, scrub oak, and juniper.

Major roadway crossings over Bear Creek include I-25, 8th Street, 21st Street, and Gold Camp Road. At these locations the capacity of the creek is limited, causing a spreading of the floodplain, and presenting the potential for damage to the roadways, utilities, and erosion affecting private property.

Several ownerships dominate the watershed. The area above Gold Camp Road is almost exclusively within the Pike National Forest, however, a small portion of the upper basin is within the City of Colorado Springs. Within the lower basin, Bear Creek Regional Park and other County-operated properties exist (i.e., Penrose Stadium). The park areas contain the main Bear Creek drainageway from 8th Street to Gold Camp Road, except for approximately a one-half mile segment, along a reach west of 21st Street. No development has occurred within the Pike National Forest, and none is anticipated. Currently, approximately 35 percent of the lower basin is developed with commercial, industrial and residential land uses. The balance is open space.

Bear Creek Regional Park is owned and operated by the El Paso County Park Department. The park has been developed with traditional park uses such as playing fields in the area west of 21st Street and north of Argus Drive, and the balance has been left in its natural setting. Numerous hiking and biking trails exist within the Park, some of which are aligned along the

drainageways and connect the various park areas together. The Bear Creek Trail is identified on he City of Colorado Springs Trails Plan.

The City of Colorado Springs operates the Bear Creek Canon Park, above Gold Camp Road. A small park in the Polo Point Subdivision is also operated by the City of Colorado Springs. A small portion of the City's North Cheyenne Canon Park is within the Bear Creek Basin.

An environmental review of the basin was conducted in order to identify the existing environmental features. The upper portions of the drainage basin is within the Pike National Forest and has montane forest and drainages. These montaine areas are heavily forested with fir and ponderosa pine trees with scrub oak and junipers on the understory. The forested areas act to control runoff from the upper Bear Creek watershed to a low rate compared to the lower areas of the basin.

The topography in the study area is complex and steep in the upper portion to moderately flat in the east, nearer the city. The Bear Creek main channel is confined to a narrow floodplain and is somewhat incised. The vegetation and habitat types are also varied from dry grasslands, scrub, and forests to riparian and subirrigated wetlands. Wildlife species are a mixture of woodland, riparian and forest types at this boundary between the mountains and plains habitats.

The most sensitive areas in the study area are the riparian and wetland habitats which together comprise less than five percent of the study area. These areas have the most diverse plant communities and use of habitats by wildlife and other animal species. At the present time these two types are well protected except where previously disturbed by development.

Hydrology Analysis

The hydrologic analysis portion of the Drainage Basin Planning Study was conducted in order to determine peak discharges and runoff volumes for various storm types, and basin development conditions. This data was used in the evaluation of

flood problems, identification of feasible plans, and in the preliminary design of the selected drainage facilities.

The runoff model used to determine the peak flow and volumes within the study area is the 1985 version of the HEC-1 Flood Hydrograph Package Computer Program developed by U.S. Army Corps of Engineers (COE). The use of this hydrologic model is in compliance with the City of Colorado Springs/El Paso County Drainage Criteria Manual.

Three basin studies related to the Bear Creek basin have been prepared previous to this study. The first study was done by R. Keith Hook and Associates in 1972. The Hook study contains very detailed descriptions of individual sub-basin characteristics and existing drainage facilities, but revealed little information on the hydrological approaches with respect to storm distribution and depth, soil loss, and land use categories. The second study was completed by Lincoln DeVore, Inc., in 1980 which is an update of the 1972 Hook study. This study included a thorough review of past storm records and soil characteristics more from geologic point of view. The third study related to the Bear Creek basin is the 1986 Flood Insurance Study (FIS), prepared by the Federal Emergency Management Agency (FEMA).

Land uses for existing and future basin conditions were determined from the available City zoning maps, aerial photographs, El Paso County park maps, and future development plans provided by the City Planning Division. The existing basin condition is defined as the present basin condition as of January 1989. Historic conditions (i.e. fully undeveloped), was not considered in this study. Land use density and corresponding curve numbers were determined from the drainage criteria manual and from recommendations from the City Planning Department.

Two types of storm distributions were evaluated in order to determine a controlling storm for the sizing of drainage structures. The first type of storm is 24-hour, Type II-A storm with an antecedent moisture condition (AMC) of two (2). The second type of storm is a 2-hour distribution with an AMC of

three (3). Rainfall depths of the 24-hour storms are 4.7 inches and 3.2 inches for the 100-year and 10-year, respectively.

The results of the hydrological analysis are summarized herein for several design points within the basin, and for the existing and future development condition. The 24-hour storm duration with an antecedent moisture condition of two was selected for use in the design of the drainageway facilities within the basin. Previous studies have utilized the 6-hour storm duration which generally produces lower runoff amounts.

The hydrologic results recommended herein should be used for planning purposes only. Peak discharges to be applied in the final design of drainage facilities within the Bear Creek Basin must be verified. Actual drainage basin characteristics may vary for specific areas and locations within the Bear Creek Basin.

Hydraulic Analysis and Floodplain Delineation

A hydraulic analysis along the major drainageways was conducted to establish the flow capacities of existing structures, and to identify areas of flooding. The major drainageways were divided into reaches in order to better organize the planning effort. The reaches were selected based upon their particular drainageway characteristics and/or problems. The 100-year floodplain for future basin conditions is presented on the preliminary design drawings.

As part of the field investigation, the existing drainage facilities were evaluated and inventoried. The size, type, and condition was recorded for all the bridges, culverts, channels, inlets, pipes and a database provided to the City. As part of the strucure inventorythe hydraulic capacity was estimated for the larger existing culverts and bridges for use in the hydrologic routing and the floodplain evaluation.

No recorded flood events exist for Bear Creek or its tributaries. Flooding caused by heavy rainfall in the lower basin has caused the 21st Street culvert to be overtopped, as well as several of the bridges within Bear Creek Park West of 21st Street. Heavy thunderstorms in the past have caused runoff

to exceed the street section along Orion Drive, particularly the north/south segment of Orion Drive west of Bear Creek Park.

The Federal Emergency Management Agency (FEMA) developed a 100-year floodplain and floodway for Bear Creek in 1986. This floodplain is based upon a higher peak 100-year discharge than estimated in this report. Base flood elevations range from one to two feet lower in this report, as compared to the FEMA study.

Water quality within the Bear Creek Basin is currently good, with the major impact to water quality coming from sediment entering the major drainageway from tributaries. Industrial and commercial development is expected to occur in the lower portion of the basin, and pollutants associated with this type of urban development would not be expected to greatly degrade the quality of the base flow.

Development of Alternative Plans

Alternative drainageway improvement concepts were been examined that address the existing and future stormwater management needs of the basin. Alternatives have been identified for each reach of the drainageway on a conceptual level. Quantitative and qualitative comparisons are presented, and a recommendation made as to which plan is most feasible to advance to preliminary design and eventually implementation. Other planning goals were developed through the coordination process, and common or mutual goals of the interested agencies identified prior to the initiation of the alternative development phase. One result of this coordination effort was the development of a list of design and planning parameters which were considered when evaluating a particular alternative. The preservation of existing vegetation, flood control, land use and open space, and erosion control were determined to be the most important parameters impacting the Bear Creek Basin.

The alternative planning process began with the evaluation of general drainageway planning alternatives. Alternatives which are generally available in the majority of urban drainage basins include:

1. Floodplain preservation,

2. Channelization,
3. Detention, on-site or regional,
4. Diversion between sub-basins, and
5. Closed conduits.
6. Combinations of the above.

These concepts were evaluated for each reach of the basin. The results of the alternative evaluation showed that floodplain preservation, selective channelization of 100-year or lower flows, closed conduits and various combinations of the above were feasible for implementation along the various planning reaches. It was determined that detention ponding could not be effectively implemented within the Bear Creek basin.

Letter of Permission Submittal Summary

A Letter of Permission (LOP), submittal was made to the U.S. Army Corps of Engineers as part of the basin planning process. The LOP is a process whereby certain categories of routine drainageway construction and maintenance activities can be generally permitted without the need for an individual 404 permit, as long as the activity has been identified in the drainage basin planning study.

Preliminary Design

The results of the preliminary design analysis are summarized in Chapter 6 and on the prelimianry design drawings for each of the reaches of the basin. The City of Colorado Springs, El Paso County Drainage Criteria Manual was used in the development of the typical sections and plans for the major drainageways within the Bear Creek Basin. The City/County manual was supplemented by various criteria manuals with more specific application. Design plans for the 8th Street and the 21st Street improvement projects have also been incorporated into the design. Due to environmental concerns fully lined concrete or riprap channels were eliminated from consideration.

In general, selective riprap banks and invert improvements are recommended along the main Bear Creek drainageway. Below 8th Street a trapezoidal riprap section has been selected with drop structures to stabilize the invert at a higher elevation. Between 8th Street and 21st Street, a "stabilized" section has

been selected. Riprap low flow areas should be provided to protect the adjacent land from damages due to bank sloughing during a 10-year frequency event. Above 21st Street only limited bank improvements have been identified, in combination with the construction of check structures across the existing low flow areas. The existing channel is well vegetated and stable except at confluences with side drainages. West of the Bear Creek Nature Center, riprap lining and channel clearing is recommended to increase the channel capacity and protect the roadway from being damaged in a 100-year event. A riprap bank stabilized channel section with drop structures has been recommended for Constellation Gulch below Cresta Road. Within the existing residential areas below Gold Camp Road (Skyway and Top of Skyway), channel check structures and localized channel riprap protection have been specified, particularly in the vicinity of Electra Drive. Outlet structures have been suggested in order to limit scouring at the outlets of culverts. A stabilized road side channel has been suggested for the Gold Camp Road basin. The channel section will vary from grasslined to riprap-lined trapezoidal sections, depending upon the slope of the adjacent roadway.

For the forest areas above Bear Creek Road (i.e., the Upper Bear Creek Basin), no improvements have been suggested. During the field inventory process, the natural drainageway was found to be stable and not in need of substantial modification.

Drop structures have been sited along Bear Creek and Constellation Gulch, in order to slow the channel velocity, reduce the physical depth of the channel invert where degradation has occurred, and to protect the channel from headcutting over a long period of time. Through the park areas, drops have been sited where the most severe invert degradation has occurred. The drop height has been limited to three-feet maximum. In some cases, the construction of a drop(s) in combination with localized riprap bank and low flow improvements may be sufficient to stabilize the channel for a considerable distance upstream of the drop(s). Check structures have been specified along the

major drainageways. The check structures will act to maintain the current invert upstream of the checks. Over time this will help to prevent bank sloughing due to invert degradation, and will further stabilize existing vegetation adjacent to the main channel. The materials for the construction of drops range from sheet piling to concrete. Boulder drops offer a possible alternative within park areas so that the structures blend better with the surroundings.

As previously presented, the Bear Creek Trail is a primary trail corridor in the area. Linkage to the proposed Fountain Creek trail can be accomplished once the channel is reconstructed between 8th Street and I-25. It is suggested that the trail be sited on the south side of Bear Creek from I-25 to upstream of the proposed 8th Street bridge. From this point, trail systems exist to allow a trail user to pass through Bear Creek Park, and eventually to the Bear Creek Nature Center. In reaches where a trail is needed adjacent to the low flow area, the trail mat should be constructed to withstand maintenance equipment typically used by public works and parks forces.

Maintenance of drainageway facilities is essential in preventing long term degradation of the creek and its environs. Within the park areas, clearing of debris and dead vegetation should be considered within the low flow area. Yearly clearing of trash and debris at roadway crossings is also recommended to ensure the design capacity of the crossing, and to enhance the crossings for trail users. Along Constellation Gulch, a ten-foot maintenance trail is recommended.

The majority of Bear Creek is currently within City or County jurisdiction, and therefore acquisition of a formal right-of-way is not necessary for the construction of drainageway improvements. The exception to this is below 8th Street, and within the "Pinello" property, west of 21st Street. Lower Constellation Gulch is currently within a public right-of-way, easement or dedicated tract of land, or City ownership. Above Parkview, an existing platted road and drainage easement exists,

however, the gulch has meandered outside of these areas at several locations.

Along reaches 1 through 5 of Bear Creek, the existing structures at Eighth Street and 21st Street over Bear Creek are of insufficient capacity to convey the 100-year developed flow without overtopping the roadway. Both of these roads are key arterials within the City and be criteria should not be overtopped in the 100-year event. New structures have been sized at these locations.

Soils in the Bear Creek Basin vary widely and because of this, areas within the basin are subject to varying degrees of hazard resulting from sediment being transported to the drainageway(s). In general the soils of the basin are highly erosive. Numerous areas in the basin were noted which were being impacted by either erosion (of one form or another), or sediment deposition. The areas impacted ranged from localized bank failures to roadway embankments and slopes thousands of square feet in area. The disturbance of the native vegetation and failure to properly revegetate areas impacted by site development, utility, roadway and landscape construction activities has in some cases negatively affected downstream portions of the basin.

The City of Colorado Springs has enacted an erosion control policy to address these problems. In general, it is the responsibility of the entity conducting any land disturbance activity to properly control surface runoff, erosion and sedimentation during and after the activity. Technical criteria identifying measures which help mitigate the impacts of erosion and sedimentation is available and being used throughout the Front Range area. Minimum requirements for erosion control have been established in this Plan.

Plan Implementation

Improvements along Bear Creek within the park areas should be completed with several goals in mind: (1) to provide a more stable drainageway, (2) to maintain and enhance the visual

Construction of drops or checks could be combined with trail crossings of the creek. Localized creek improvements will be necessary as trails transition at roadway crossings, or at stream crossings. Construction of checks and culvert outfall structures within the Skyway Heights and Top of Skyway developments should be completed at the time of roadway grading.

In existing areas where the drainage facilities are inadequate, capital improvement projects will be necessary. This will be particularly true within the existing Skyway, Parkview, developments, and existing residential areas adjacent to Constellation Gulch. Runoff from streets has caused damage to private residences in some locations.

Costs have been estimated by reach and also divided into improvements which are considered reimbursable and non-reimbursable relative to the drainage and bridge basin funds. For systems in need of upgrading, that is existing stormwater systems which are inadequate to convey the future condition design discharge, the total costs were prorated based upon the area of existing platted versus unplatted acreage tributary to a particular system.

Non-reimbursable improvements within the Bear Creek Basin are considered to be capital improvement costs. This type of funding will be required where required systems are either non-existent or inadequate, or where the area tributary to such systems are either fully developed or have no unplatted developable acreage draining to the system.

Basin Fee

Using El Paso County Tax Assessor maps, plats, and ownership records, the amount of unplatted acreage was estimated. From these records a total of 717 acres is unplatted, and subject to future development. Park areas have been excluded from the unplatted acreage total. Presented on Tables 13 and 14 of this report are the drainage and bridge fees calculated for the Bear Creek Basin. Drainage basin fund deficits have been included in the fee calculation, and are current as of December, 1991.

ENGINEER'S STATEMENT:

The attached drainage plan and report were prepared under my direction and supervision and are correct to the best of my knowledge and belief. Said drainage report has been prepared according to the criteria established by the City/County for drainage reports. I accept responsibility for any liability caused by any negligent acts, errors or omissions on my part in preparing this report.

Kiowa Engineering Corporation, 419 W. Bijou, Colorado Springs, Colorado 80905-1308

_____ _____

Registered Engineer #19310 Date

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I. INTRODUCTION

Authorization

This evaluation of the stormwater facilities within the Bear Creek Drainage Basin was authorized under the terms of the agreement between the City of Colorado Springs (City) and Kiowa Engineering Corporation by the Colorado Springs City Council, December 13, 1988.

Purpose and Scope

The purpose of the study is to identify feasible stormwater management plans to satisfy the existing and future needs within the Bear Creek Drainage Basin. The specific scope of work for this study included the following tasks:

1. Meet with the City to: insure compliance with the services required by this agreement, obtain existing data and general information from participating entities, solicit desires of participating entities and other interested agencies or groups in order to develop alternate plans, procure current information relative to development plans in the basin, procure information relative to right-of-way limitations, proposed stormwater projects, potential hazards due to flooding, and avoid duplication of effort whenever possible by utilizing existing information available from other agencies.

2. Contact the City, County, individuals, and other agencies who have knowledge and/or interest in the study area.

3. Utilize City policies and criteria and applicable information wherever possible.

4. Perform hydraulic and hydrologic analyses within the study area.

5. Identify environmental setting of basin.

6. Identify existing and potential drainage and/or flooding problems.

7. Develop improvement alternatives to reduce existing and potential flooding problems, and to mitigate the impact of stormwater runoff upon environmentally significant areas along the drainageway(s).

8. Examine the operation and maintenance aspects of feasible alternatives.

9. Conduct an economic analysis of each alternative.

10. Recommend and prepare a preliminary design for a selected alternative plan.

11. Develop drainage and bridge fees for the basin.

12. Prepare a written report discussing all items examined in the study.

13. Conduct presentations to public and private entities in order to define project goals, and to involve agencies with specific interest to help define feasible alternatives.

Summary of Data Obtained

Listed below is the technical report collected for the use in this study:

1. Soil Survey for El Paso County, Colorado, dated June 1981.

2. "City of Colorado Springs/El Paso County Drainage Criteria Manual", prepared by City of Colorado Springs, El Paso County, and HDR Infrastructure, Inc., dated May 1987.

3. "Flood Insurance Studies for Colorado Springs, and El Paso County, Colorado", prepared by the Federal Emergency Management Agency (FEMA), 1986.

4. "Bear Creek Drainage Basin Study", prepared by R. Keith Hook and Associates, Inc., July, 1972.

5. "Engineering Study of the Bear Creek Drainage Basin, Colorado Springs, Colorado", prepared by Lincoln/Devore Inc., December, 1980.

6. "Stormwater Discharge Inventory", prepared by United Planning and Engineering, Inc., December, 1988.

7. "Orion Drive Storm Sewer Design Plans", prepared by HDR, Inc., March, 1989.

In addition to the above listed reports there were a number of drainage study reports, sketch plans, preliminary and final design drawings, land use maps, proposed development plans, and existing drainage facility maps that were provided by the City, local agencies, private entities, and individuals for the use of the project.

Mapping and Surveying

As part of the agreement, detailed mapping for the study area at a scale of 1" = 200' with 2-foot contour intervals was prepared by Landmark Mapping in December 1988, with the exception of the area lying west of the current City of Colorado Springs corporate limits. Mapping for the basin above the corporate limits dated November, 1980, was obtained from the 1980 Lincoln/DeVore, Inc., Drainage Basin Study.

Stream cross-section data for Bear Creek was obtained from the aerial mapping. These sections were verified against the cross-sections compiled in the 1986 City of Colorado Springs Flood Insurance Study (FIS).

A detailed site inspection of the study area was conducted, and photographs were taken documenting the key drainage features. This data is contained in the Structure Inventory, presented in Section IV of this report.

Acknowledgements

During the course of the preparation of this study, officials from the City of Colorado Springs and others provided technical input and guidance. Specifically, we would like to thank the El Paso County Parks Department, and the City Planning Department for their time and assistance in providing technical information. We would also like to thank the Top of Skyway and Skyway Homeowners Associations for contributing site specific observations relevant to the project.

During the preparation of the study, several government agencies and interested individuals were routinely involved in the coordination activities. Representatives from the Colorado Division of Wildlife, U. S. Army Corps of Engineers (COE), and various City Departments provided valuable commentary during the development of the alternative plans. A listing of the individuals and agencies routinely coordinated with during the study has been presented below:

Name	Agency
Alan Morrice	El Paso County Department of Public Works
John Fisher	El Paso County Land Use Department
Sue Johnson	El Paso County Parks Department
Ray Brown	Colorado Department of Highways
DeWitt Miller	City of Colorado Springs, Department of Public Works
Gary Haynes	City of Colorado Springs Engineering Division
Bruce Thorson	City of Colorado Springs Engineering Division
Bob Adamczyk	City of Colorado Springs Engineering Division
Bruce Goforth	Colorado Division of Wildlife
Dan Bunting	Regional Building Department
Sarah Fowler	Environmental Protection Agency
John Liou	Federal Emergency Management Agency
Bill Noonan	U.S. Fish and Wildlife
Anita Culp	U.S. Army Corps of Engineers
John Maynard	Aiken/Audobon Society
Ed Spence	Soil Conservation Service
Thomas Huber	Interested Individual
John Covert	Palmer Foundation
Debra Little	City Planning Department
Gene Fuhlrodt	City Parks and Recreation
Bill Ruskin	City of Colorado Springs Parks and Recreation Dept.
James Armstrong	Skyway Homeowners Association
Morris Esmiol, Jr.	Top of Skyway Homeowners Association

II. STUDY AREA DESCRIPTION

Location

The Bear Creek Drainage Basin lies in the southwestern portion of Colorado Springs, El Paso County, Colorado. The general location of the basin is shown on Figure 1. Bear Creek is the major drainageway for the basin, flowing in an easterly direction and entering Fountain Creek approximately one-quarter of a mile downstream of the US-24 bridge over Fountain Creek. Portions of the basin lie within Teller County. Approximately two-thirds of the basin lies within the Pike National Forest.

The Bear Creek Basin has two distinct characteristics, typified by an upper mountain watershed above Gold Camp Road, and a foothills basin below Gold Camp Road. Above Gold Camp Road the watershed is very mountainous and steep, and with the majority of the watershed heavily wooded with pinon pine and juniper. Below Gold Camp Road the basin has a mix of open space, commercial, and residential development. The open space areas are mostly park, and steep hillsides covered with pinon, scrub oak, and juniper. Total area covered by the basin is approximately 10.7 square miles. The average stream slope along Bear Creek is nine percent above Gold Camp Road and two to five percent below Gold Camp Road.

Major roadway crossings over Bear Creek include I-25, 8th Street, 21st Street, and Gold Camp Road. At these locations the capacity of the creek is limited, causing a spreading of the floodplain, and presenting the potential for damage to the roadways, utilities, and erosion affecting private property. Modifications to 8th Street roadway section, and the widening of I-25 are currently being considered. There are no major irrigation structures which impact the basin, however, the City of Colorado Springs does have a raw water intake on Bear Creek in the upper portion of the watershed. Further discussion with respect to the physical characteristics of the basin, floodplain, and existing facilities are presented in later sections of this report.

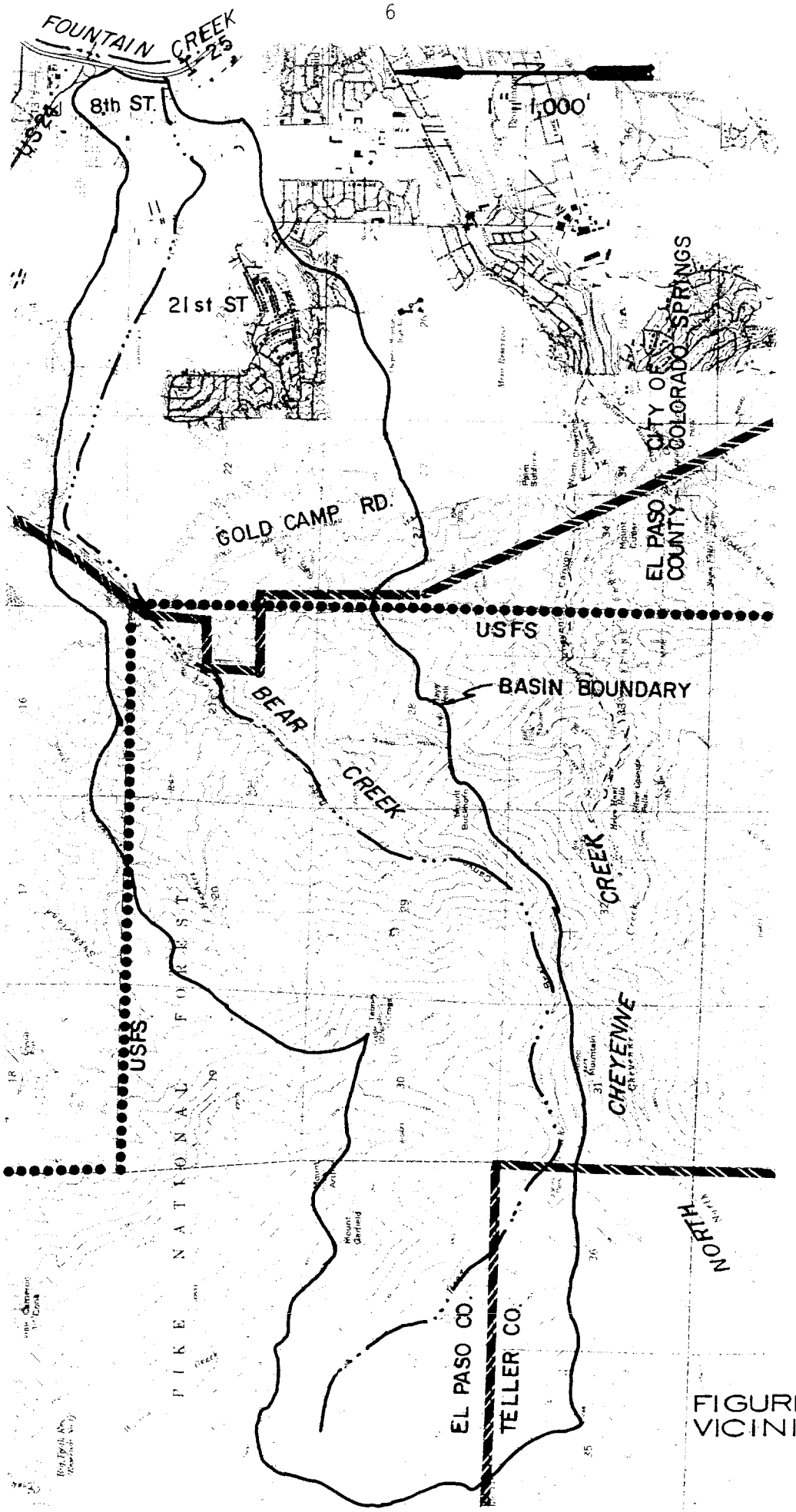


FIGURE 1
VICINITY MAP

Property Ownership

Several ownerships dominate the watershed. The area above Gold Camp Road is almost exclusively within the Pike National Forest, however, a small portion of the upper basin is within the City of Colorado Springs. Within the lower basin, Bear Creek Regional Park and other County-operated properties exist (i.e., Penrose Stadium). The park areas contain the main Bear Creek drainageway from 8th Street to Gold Camp Road, except for approximately a one-half mile segment, along a reach west of 21st Street. Residential development has occurred in both the upper and lower basin, however, within the upper basin development is limited to very low residential density. No significant development has occurred within the Pike National Forest, and none is anticipated.

The heaviest development pressure exists in the lower basin, mainly in the areas east of 8th Street where commercial/industrial development is occurring, and in the Top of Skyway area, where further residential development is anticipated. East of 21st Street private ownership is very limited because of the Bear Creek Regional Park and Penrose Stadium facility. Currently, approximately 35 percent of the basin is developed and the balance is open space.

Bear Creek Regional Park is owned and operated by the El Paso County Park Department. The park has been developed with traditional park uses such as playing fields in the area west of 21st Street and north of Argus Drive, and the balance has been left in its natural setting. Selected stream improvements have been constructed along Bear Creek, mostly in the vicinity of the El Paso County Parks Department headquarters, east of 21st Street. Numerous hiking and biking trails exist within the Park, some of which are aligned along the drainageways and connect the various park areas together.

The City of Colorado Springs operates the Bear Creek Canon Park, above Gold Camp Road, and the Bear Creek Nature Center. A small park in the Polo Point Subdivision is also operated by the

City of Colorado Springs. A small portion of the City's North Cheyenne Canon Park is within the Bear Creek Basin.

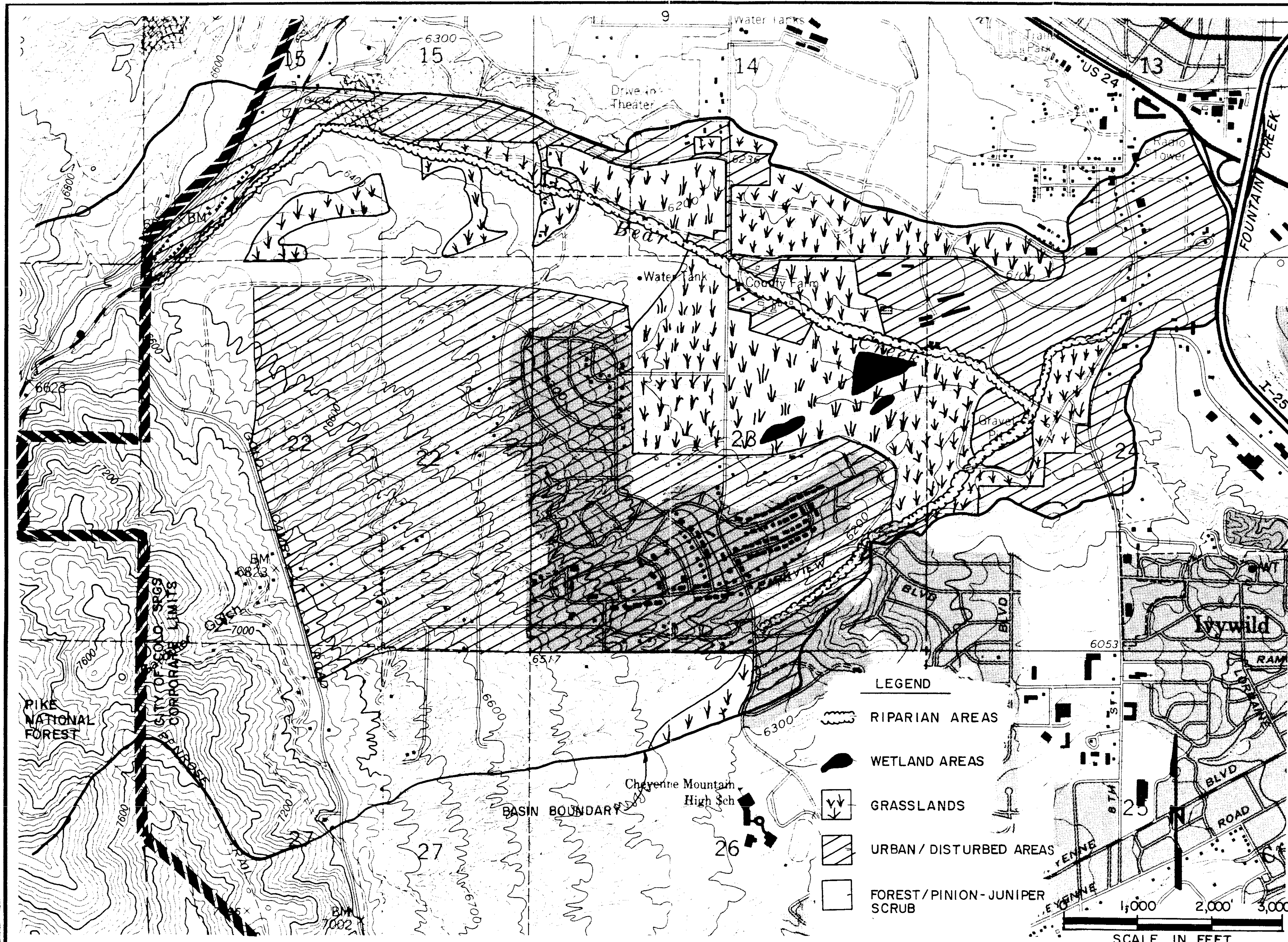
Climate

The study area has a climate typical of the foothills and high plains, with total precipitation amounts typical of a semi-arid region. Winters are generally cold and dry, and summers relatively cool and dry. Precipitation ranges from 14 to 16 inches per year, with the majority of this precipitation occurring in spring and summer in the form of rainfall. Thunderstorms are common during the summer months, and are typified by quick-moving low pressure cells which draw moisture from the Gulf of Mexico into the region. Average temperatures range from about 30°F in the winter to 75°F in the summer. The relative humidity ranges from about 25 percent in the summer to 45 percent in the winter.

Environmental Review

An environmental review of the study area was conducted in order to identify the existing environmental features. The sensitivity of wetland and riparian areas to stormwater runoff, sedimentation and erosion must be taken into consideration in the planning of major drainageway facilities. A description of the existing environmental setting follows. Presented on Figure 2 is a graphic depiction of the environmental setting of the basin.

The Bear Creek drainage is located in the foothills and lower mountains to the west of downtown Colorado Springs. The upper portions of the drainage basin is within the Pike National Forest and has montane forest and drainages. These montaine areas are heavily forested with fir and ponderosa pind trees with scrub oak and junipers on the understory. The forested areas act to control runoff from the upper Bear Creek watershed to a low rate compared to the lower areas of the basin. Bear Creek flows east into the city limits of Colorado Springs. The study area is in the lower one-third of this drainage basin within the city limits. Elevations in the study area are at about 5920 feet at



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BEAR CREEK DRAINAGE BASIN PLANNING STUDY

ENVIRONMENTAL INVENTORY MAP

Project No.:
Date:
Design:
Drawn:
Check:
Revisions:

FIG. 2

the confluence of Bear Creek with Fountain Creek to about 7500 feet at the corporate limits. Within the upper basin, the watershed rises to 11,000 feet.

The topography in the study area is complex and steep in the upper portion to moderately flat in the east, nearer the city. The Bear Creek main channel is confined to a narrow floodplain and is somewhat incised. The vegetation and habitat types are also varied from dry grasslands, scrub, and forests to riparian and subirrigated wetlands. Wildlife species are a mixture of woodland, riparian and forest types at this boundary between the mountains and plains habitats.

Land use in the study area is housing and commercial, open space with parks, playing fields, and bridal paths for horseback riding. The vegetation and habitat types were determined using aerial photographs in conjunction with field surveys to evaluate plant species and conditions. The land use or vegetation types and associated habitats are listed and described as follows.

Residential/Commercial: Development for housing and commercial businesses are throughout the drainage basin study area. Businesses and a riding stable are concentrated in eastern flat areas, while housing lots are developed on the slopes to the west and up to the National Forest boundary. The parks are maintained mostly as open space and natural areas and are mapped into respective vegetation types.

Grasslands: Open grasslands occur scattered on the dry lower portions of the study area and as small open areas on the upper ridges in the foothills. The grasses are mostly low species of blue grama and western wheatgrass with scattered shrubs and yucca. These grasslands are in fair to good condition due to protection from grazing and other disturbances at the present time. These are small isolated areas of plains habitat cut off from the extensive plains to the east by the City of Colorado Springs.

Pinon-Juniper and Scrub: These areas occur on the upper foothills slopes and north-facing slopes at lower altitudes. The principal plant species are pinon pine and juniper with shrubs of mountain mahongany, scrub oak, and buckbrush. There is an occasional ponderosa pine and Douglas fir scattered in this type, and an understory of grasses and forbs common in the grassland. This is a foothills scrub habitat that has been impacted by housing developments.

Ponderosa Pine Foothills Forest: These open forest occur on north-facing slopes in the foothills and canyons in the study area. There is secondary cover by Douglas fir with understory shrubs of mountain mahogany, snowberry, and oak. This is foothills forest habitat also with some housing development.

Riparian: There is a mixed riparian forest and shrub zone along Bear Creek and tributaries on the floodplain and lower moist slopes. The trees are cottonwood, Douglas fir, ponderosa pine, and with shorter trees and shrubs of willow, alder, scrub oak, snowberry, and mountain mahogany. There is a good ground cover of grasses, sedges, vines, and forbs that grow on the floodplain and lower slopes. This is a riparian habitat type common along streams and drainage throughout the region and is in good condition due to protection and preservation in the parks. The lower portion of the riparian zone near Fountain Creek has been disturbed by commercial development.

Wetlands: Subirrigated wetlands occur in the flat lower drainages that are wet throughout most of the growing season and have typical wetlands plants. These plants include baltic sedge around the drier perimeters with sedges, rushes, and cattails in the wetter interior of the wetlands. This type if well developed in the areas just south and west of Penrose Stadium across Bear Creek. The wetlands along Bear Creek are small and not well developed since the creek is incised and does not have large flat areas next to the channel. The Bear Creek corridor is a productive wetland habitat type in good condition, but covers a small area in the total drainage area. The wetlands have been recently designated for restriction of human and horse access.

The Colorado Division of Wildlife was consulted for animal species in the Bear Creek Drainage. Most of the information is from their surveys recorded in the Wildlife Resource Information System with some field observations during these surveys. Portions of the study area is within or adjacent to the Pike National Forest, so the whole drainage is described for animal species. Common large animals and herbivores are the white-tailed and mule deer at lower elevations, black bear and elk in the upper drainages. Other mid-sized and smaller animals include the beaver, coyote, skunks, badger, Abert's squirrel, rabbits, and smaller rodents. The area is listed within the overall range of bald eagles, band-tailed pigeon, golden eagle, and the peregrine and prairie falcons, which have active nests in the upper basin west of the study area. The area has occasional use by waterfowl such as ducks and geese but there are no large

bodies of water to attract them. Smaller birds use the area for nests and foraging, especially the wetland and riparian habitats.

The most sensitive areas in the study area are the riparian and wetland habitats which together comprise less than five percent of the study area. These areas have the most diverse plant communities and use of habitats by wildlife and other animal species. At the present time these two types are well protected except where already disturbed or developed. Consideration should be given to enhancing the areas along the streams and drainages, and continuing protection for the wetlands.

Park Land

Presented on Figure 3 are the developed park areas and trails within the basin. The Bear Creek trail has been identified on the City of Colorado Springs Trails Plan, and begins at the confluence within Fountain Creek.

BEAR CREEK REGIONAL PARK (COUNTY)

PENROSE STADIUM (COUNTY)

COUNTY LAND (SECTION 16)

BEAR CREEK TRAIL

BEAR CREEK CANYON PARK (CITY)

NORTH CHEYENNE CANON PARK (CITY)

FOUNTAIN CREEK TRAIL

USFS

FOREST

(CITY)

EL PASO COUNTY

CITY OF COLO SPRINGS

LEGEND

PARK LAND

0' 2000' 4000'

N

Kiowa Engineering Corporation
419 W. Bijou Street
Colorado Springs, Colorado
80905-1308

BEAR CREEK DRAINAGE BASIN PLANNING STUDY

PARK & TRAIL MAP

Project No.	88.12.26
Date:	10/89
Design:	
Drawn:	EAK
Check:	
Revisions:	

FIG. 3

III. HYDROLOGIC ANALYSIS

The hydrologic analysis portion of the Drainage Basin Planning Study was conducted in order to determine peak discharges and runoff volumes for various storm types, and basin development conditions. This data was used in the evaluation of flood problems, identification of feasible plans, and in the preliminary design of the selected drainage facilities. Detailed computer printouts of input data and output are contained within the Technical Addendum to this report.

Runoff Model

The runoff model used to determine the peak flow and volumes within the study area is the 1985 version of the HEC-1 Flood Hydrograph Package Computer Program developed by U.S. Army Corps of Engineers (COE). This version is available for the IBM-PC or compatible. The use of this hydrological model is in compliance with the City of Colorado Springs/El Paso County Drainage Criteria Manual.

The HEC-1 model is designed to simulate the surface runoff response of a river basin to precipitation by representing the basin as an interconnected system of hydrologic and hydraulic components. It assumes that the hydrologic processes can be represented by model parameters which reflect average conditions within a subarea. This model contains several different methods for determining runoff.

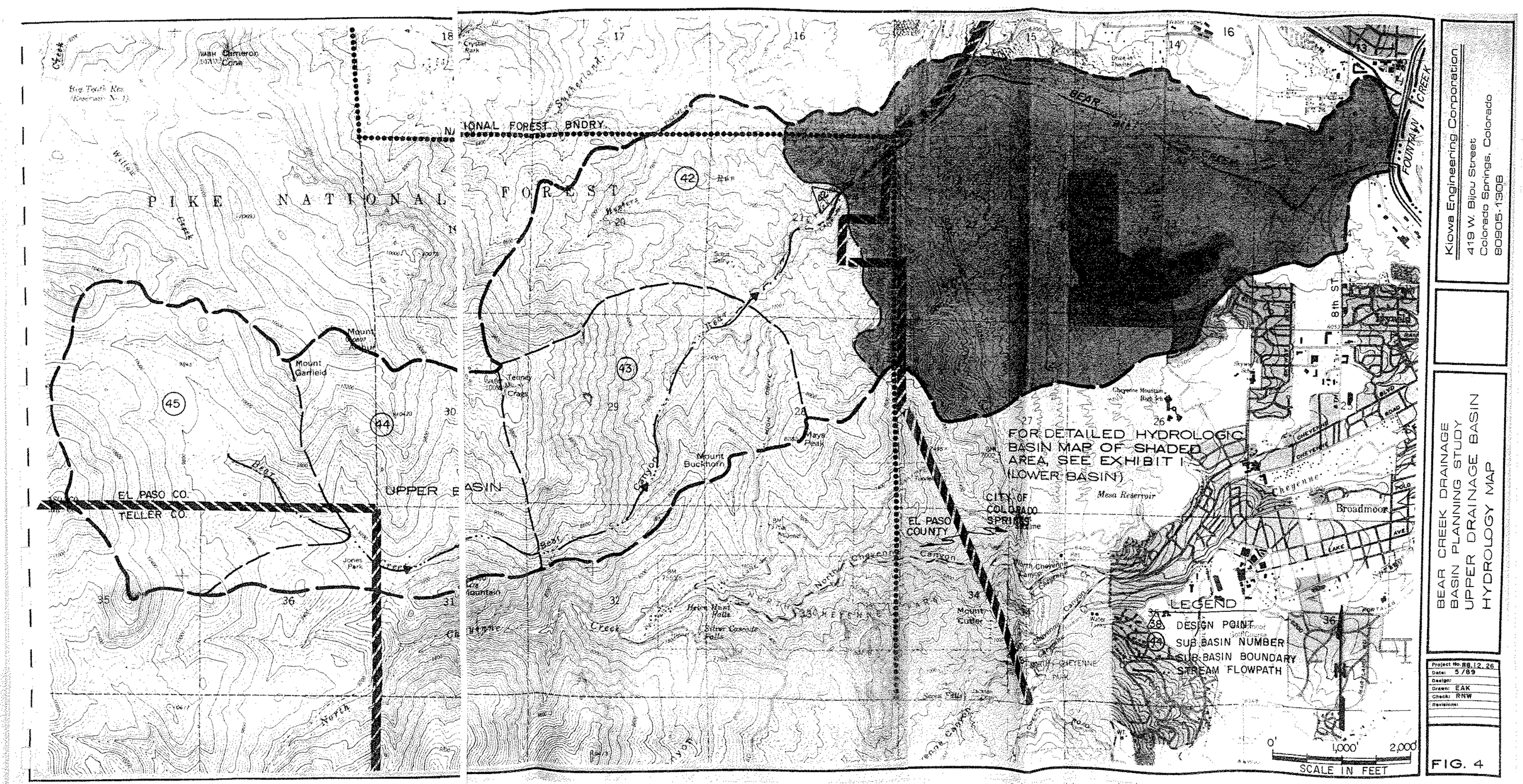
The runoff method used is the kinematic wave technique. This method allows for the uniform distribution of overland flow along the length of the main or lateral channels in a basin. This method was chosen because it accepts a higher level of detailed information (i.e., soil types, curve numbers, slopes, roughness, etc.) which was judged to be an advantage in the Bear Creek Basin.

Basin Characteristics

The study area covers approximately 10.7 square miles in which 60 percent is within the boundary of Pike National Forest;

15 percent is park land, 10 percent of land consists of residential and commercial development, and the remaining 15 percent of vacant land is to be developed. The basin encompasses areas within Teller and El Paso Counties and the City of Colorado Springs. Bear Creek flows in a southeasterly direction for approximately 2-1/2 miles from the head waters in the Pike National Forest and turns to a northeast direction for about 2.7 miles, and then flows southeast for 1.9 miles before discharging into Fountain Creek. Within the corporate limits the Bear Creek Basin is bounded on the north by 21st Street Basin, and two unstudied basins by the Southwest Area Basin on the south. The drainage basin and major features are shown on Figure 4 and Exhibit 1. The average channel slope between the upper basin boundary and Gold Camp Road is 22 percent and the remaining channel portion has a three to five percent slope. Due to the abrupt change of channel slope near the intersection of Bear Creek and Gold Camp Road, an alluvial fan was formed at the canyon mouth where the El Paso County Nature Center is located. Most of the Bear Creek channel section is heavily vegetated and the base flow is very low. Bear Creek becomes more incised just below Penrose Stadium where tributary channels convey more flow from the existing development within the upper basin. For analysis purposes, the lower basin area was further divided into nine sub-regional basins which included: (A) Lower Park Basin, (B) Upper Park Basin, (C) Skyway Basin, (D) Orion Drive North Basin, (E) Gardiner Gulch Basin, (F) Scorpio Gulch Basin, (G) Constellation Gulch Basin, (H) Gold Camp Road Basin, and (I) National Forest Basin. The lower basins are presented on Exhibit 1, contained in the map pocket. A total of 55 sub-basins were delineated within the study area for the purposes of determining flow rates and volumes at various key locations.

The existing flow patterns in the Gold Camp Road Basin are shown differently in this study than in the 1980 Bear Creek Master Plan. The field investigation conducted as part of this study revealed that all of the runoff from Basins 47 to 52 are directed to Gold Camp Road and then diverted northward in the



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BEAR CREEK DRAINAGE
BASIN PLANNING STUDY
UPPER DRAINAGE BASIN
HYDROLOGY MAP

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Revisions:	

FIG. 4

road section. The road has a 25-foot wide asphalt pavement section, with 6-inch to 12-inch high asphalt curb or bank. The street has no crown. The east edge of the road is 6-inches to 12-inches higher than the west side, causing the flow to concentrate along the west roadside ditch. Two locations exist along Gold Camp Road that allow water to cross the road and spill into the area east of Gold Camp Road. The first is at Bonnie Vista Road, where it was estimated that 50 percent of all flows are diverted into Basin 31 (Gardiner Gulch). The second is just below the downstream end of Basin 46, where the flows enter Basin 37. It is assumed that 100 percent of the flows enter Basin 37 at this location, (refer to Exhibit 1, in map pocket).

Field investigation revealed two additional areas that flow into the Bear Creek Basin that were not shown in the 1980 study. The first area is an area drained by a 48-inch RCP that diverts some flow from the northwest corner of the "Motor City Basin". This flow enters Bear Creek from the south, approximately 50 feet upstream of the Bear Creek box culvert under I-25. Flow from this basin is limited to the capacity of the 48-inch storm sewer. The second area covers approximately 75 acres, and drains into Bear Creek north of the Bear Creek culvert under I-25 (Sub-Basin 2). This area is bordered on the east by I-25, on the north by the bank of Fountain Creek. Sub-basin 2 includes the area between 8th Street and I-25, some area west of 8th Street. This area flows to the east towards I-25 and the highway embankment diverts the flow to the south, eventually entering Bear Creek. Discharges associated with a flood overflow from Fountain Creek into this area has not been considered in this hydrology of the Bear Creek Basin. Floodplains from Fountain Creek have been shown on the preliminary design plans.

Hydrologic Soils

Based on the 1981 El Paso County Soil Survey Report, 5 percent of the basin belongs to Type A soil, 70 percent of the basin is Type B soil, 10 percent of the basin is Type C soil, and 15 percent of the basin belongs to Type D soil. According to the

hydrologic soil classifications, Type A is sandy soil with higher infiltration rate and Type D is very clayey soil with lower infiltration rate. The basin hydrologic soil map is shown on Figure 5. Table 1 presents the geologic names of the soil groups within the Bear Creek Basin. For the purposes of modelling the future condition runoff, all sub-basins with Type A soils have been modelled assuming Type B soils in the developed condition, as per the City's Drainage Criteria Manual.

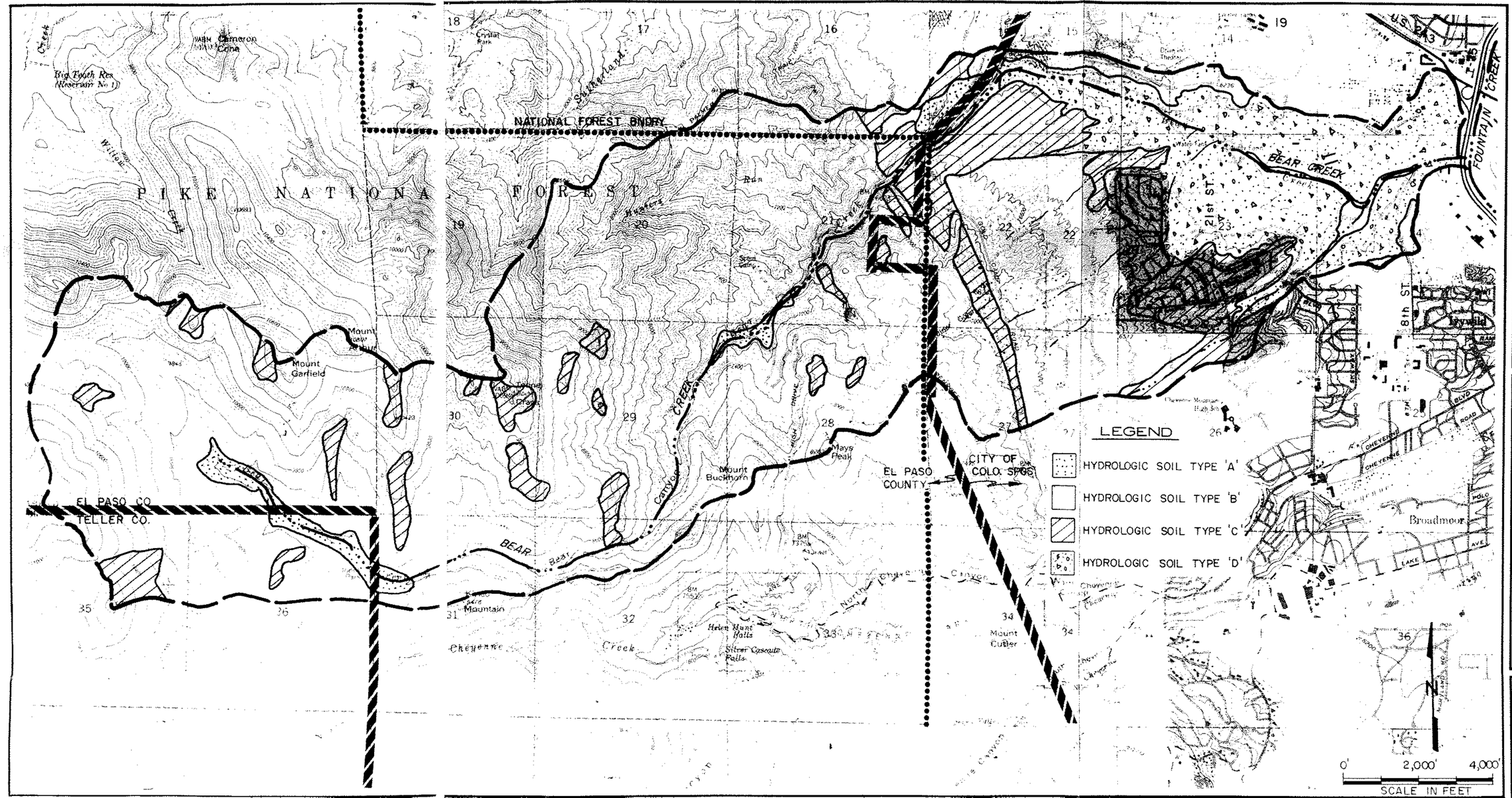
Geological Description

The upper portion of the Basin lies in the uplifted mountainous Pikes Peak granite consisting of exposed bedrock, with a soil profile formed from the weathered granites. This area is resistant to erosion where bedrock is exposed; however, the soil profile infiltration is relatively high.

The lower portion consists of uplifted sediments with the Pierre Shale outcropping as the uppermost sediment, overlain by Quaternary gravels and alluvium formed from the westerly mountainous granites. Runoff is higher where the Pierre Shale is exposed than in areas overlain by alluvium.

Primary faulting is evidenced along the base of the mountains in the vicinity of the Gold Camp Road where sediments to the east are abruptly terminated by the crystalline mountain mass to the west. Also, there is evidence of primary faulting along Bear Creek near the Bear Creek Nature Center where the Creek makes an abrupt 50 + or - degree meander to the east away from its upstream, northeasterly trend.

Generally, the westerly mountainous area is resistant to erosion with infiltration rates moderately low because of joint seepage. The intermediate foothill region is much less resistant to the erosion as characterized by the numerous gully washes in the relatively weak alluvium with increased infiltration. The easterly portion is again somewhat more erosion resistant, with runoff slightly greater and infiltration lower than the foothill region.



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BEAR CREEK DRAINAGE
BASIN PLANNING STUDY

HYDROLOGIC SOILS MAP

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FIG. 5

Table 1. Soils Types - Lower Basin.

Soil Description	Hydrologic Soil Type
Bresser Sandy Loam	B
Chaseville Gravelly Sand Loam	A
Chaseville-Midway Complex	A
Ellicott Loamy Coarse Sand	A
Fluvquentic Haplaquolls	B
Heldt Clay Loam	C
Jarre-Tecolote Complex	B
Kutler-Broadmoor Rock Outcrop	D
Pits, Gravel	A
Razor Stoney Clay Loam	A
Razor-Midway Complex	C
Ustic Torrifluvents	B

Previous Hydrologic Studies

Three basin studies related to the Bear Creek basin have been prepared. The first study was done by R. Keith Hook and Associates in 1972. The Hook study contains very detailed descriptions of individual sub-basin characteristics and existing drainage facilities, but revealed little information on the hydrological approaches with respect to storm distribution and depth, soil loss, and land use categories. A synthetic unit hydrograph method was utilized. The second study was completed by Lincoln DeVore, Inc., in 1980 which is an update of the 1972 Hook study. This study included a thorough review of past storm records and soil characteristics more from geologic point of view. The portion of the study area from east of Gold Camp Road to Fountain Creek was studied using orthophoto contoured maps (1" = 400' with a 2-foot contour interval). The 1980 study used the SCS method to define peak flow rates by averaging basin parameters for each of the design points. Rainfall information was based on the 1980 Areawide Runoff Manual adopted by Pikes Peak Regional Council. The third study related to the Bear Creek basin is the 1985 Flood Insurance Study (FIS), prepared by the Federal Emergency Management Agency (FEMA). Therein, the 10-, 50-, 100-, and 500-year peak discharges were calculated based on a synthetic unit hydrograph method, calibrated with the 1976 Technical Manual No. 1, Method for Estimating Flood Characteristics of Natural-Flow Streams in Colorado (TM-1).

A publication by USGS dated 1988 entitled, "Evaluation of the Flood Hydrology in the Colorado Front Range Using Precipitation, Streamflow, and Paleoflood Data for the Big Thompson River Basin", was also referred to during the hydrologic analysis. This study focuses on the flood hydrology of foothill and mountain streams in the Front Range of Colorado (with emphasis on the Big Thompson River Basin). The precipitation, streamflow, and channel features of the foothills' streams were analyzed and a regression type hydrologic method developed.

Flow rates for the 100-year frequency storm from the previous studies are summarized on Table 2. Also shown on Table

Table 2. Comparison of Flow Rates from Previous Studies.

Location	100-Year Peak Discharge (cfs) 1972 Hook (2-Hr.Storm) ****	1980 Lincoln (6-Hr.Storm) ****	1985 FEMA	1988*** USGS
Canyon Mouth (at Gold Camp Road) (A = 7= sq. miles)	1049	2482	2700	600**
Confluence (Bear Creek and Fountain Creek) (A = 10.6= sq. miles)	2739	4008	6400*	1426**

* Area above 8000 feet was excluded. Technical Manual No. 1, Method for Estimating Flood Characteristics in Natural Flow Streams in Colorado, USGS, 1976.

** Area above 9000 feet was excluded.

*** 1988 USGS publication entitled "The Evaluation of the Flood Hydrology in the Colorado Front Range Using Precipitation, Streamflow, and Paleohydrology Flood Data from the Big Thompson Drainage."

****Future development condition.

2 is the 100-year peak flow obtained using the 1988 USGS publication.

The variations in peak discharges estimated in past studies are caused by several factors. In the case of the discharges contained in the Federal Emergency Management Agency (FEMA) study, Technical Manual No. 1 is a regression type analysis which in the case of Bear Creek, the major variables are area, and basin slope. This method does not account for the effect upon peak flows caused by basin shape or soils, channel routing, or preceding moisture conditions. In addition to this, the statistical data base used in developing the equations presented in TM-1 involved naturally-flowing streams, greater than 50-square miles. These comments also apply to the 1988 U. S. Geological Survey (USGS) Report mentioned above, however, the data base is more applicable to the Bear Creek watershed, since the study was developed for foothill/plains transition basins, however, no Arkansas River Basin watersheds were statistically represented. In the case of the R. Keith Hook study, the major reasons for the variation in flows for the future condition are the future land use assumptions, and procedure changes in the City's Drainage Criteria Manual since 1974. Both of these factors result in the higher curve number predictions reflected in this study and in the 1980 Lincoln/Devore basin plan.

Impervious Land Density

Land uses for existing and future basin conditions were determined from the available City zoning maps, aerial photographs, El Paso County park maps, and future development plans provided by the City Planning Division. The existing basin condition is defined as the present basin condition as of January 1989. Land use density and corresponding curve numbers were determined from the drainage criteria manual and from recommendations from the City Planning Department. Areas designated as open space (OS) within the existing park properties are currently zoned "R", residential, however in the future condition the zoning is anticipated to be zoned as "P", park

land. Figures 6 and 7 highlight the existing and future land uses assumed in the hydrologic analysis. Table 3 presents the percent of imperviousness assigned for each of the land use categories shown on Figures 6 and 7. Table 4 summarizes the curve numbers for both the existing and future conditions. For the purposes of this report, no hydrologic modelling of the basin was carried out for the totally undeveloped, or "historic" condition.

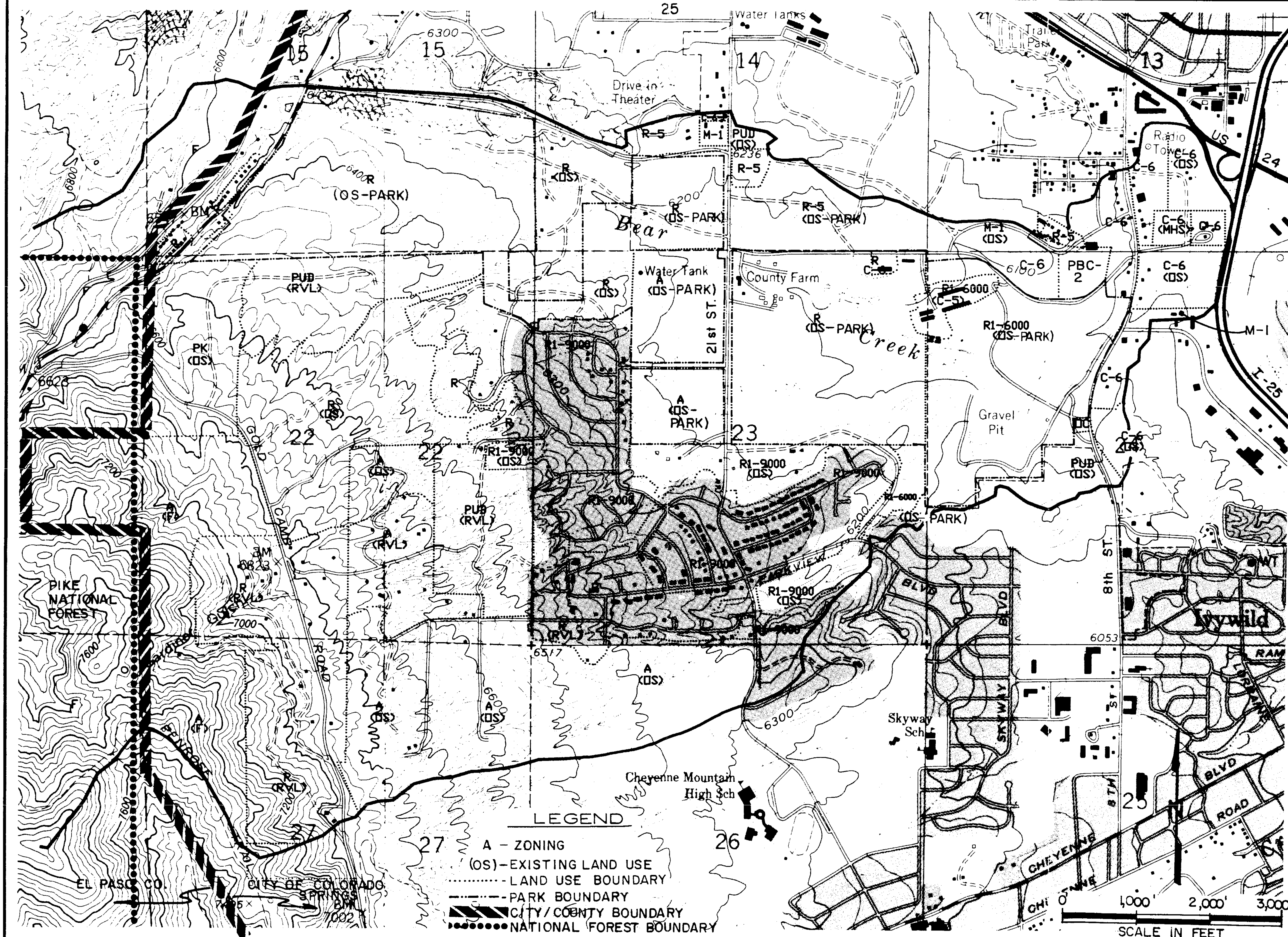
Design Rainfall

Two types of storm distributions were evaluated in order to determine a controlling storm for the sizing of drainage structures. The first type of storm is 24-hour, Type II-A storm with an antecedent moisture condition (AMC) of two (2). The second type of storm is a 2-hour distribution with an AMC of three (3). The rainfall data for the 10-year and 100-year recurrence intervals are required for this evaluation. Rainfall depths of the 24-hour storms are 4.7 inches and 3.2 inches for the 100-year and 10-year, respectively. Rainfall depths of the 2-hour storm are 2.7 inches, and 1.9 inches, for the 100-year and 10-year storm, respectively.

The 2-hour storm distribution is commonly applied in hydrologic modelling of small (less than five square miles) urban basins. The front range and particularly the foothills are prone to short duration thunderstorm events, capable of high intensities. Both storm durations were analyzed for the Bear Creek Basin. Since this study was initiated, the City of Colorado Springs is now recommending that the 2-hour storm distribution be analyzed assuming an antecedent moisture condition 2.

Results

The results of the hydrological analysis are presented in several formats. Exhibit 1 (contained in Map Pocket), the hydrologic basin map illustrates the basin boundary, channel



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BEAR CREEK DRAINAGE BASIN PLANNING STUDY

HYDROLOGIC LAND USE MAP - EXISTING CONDITION

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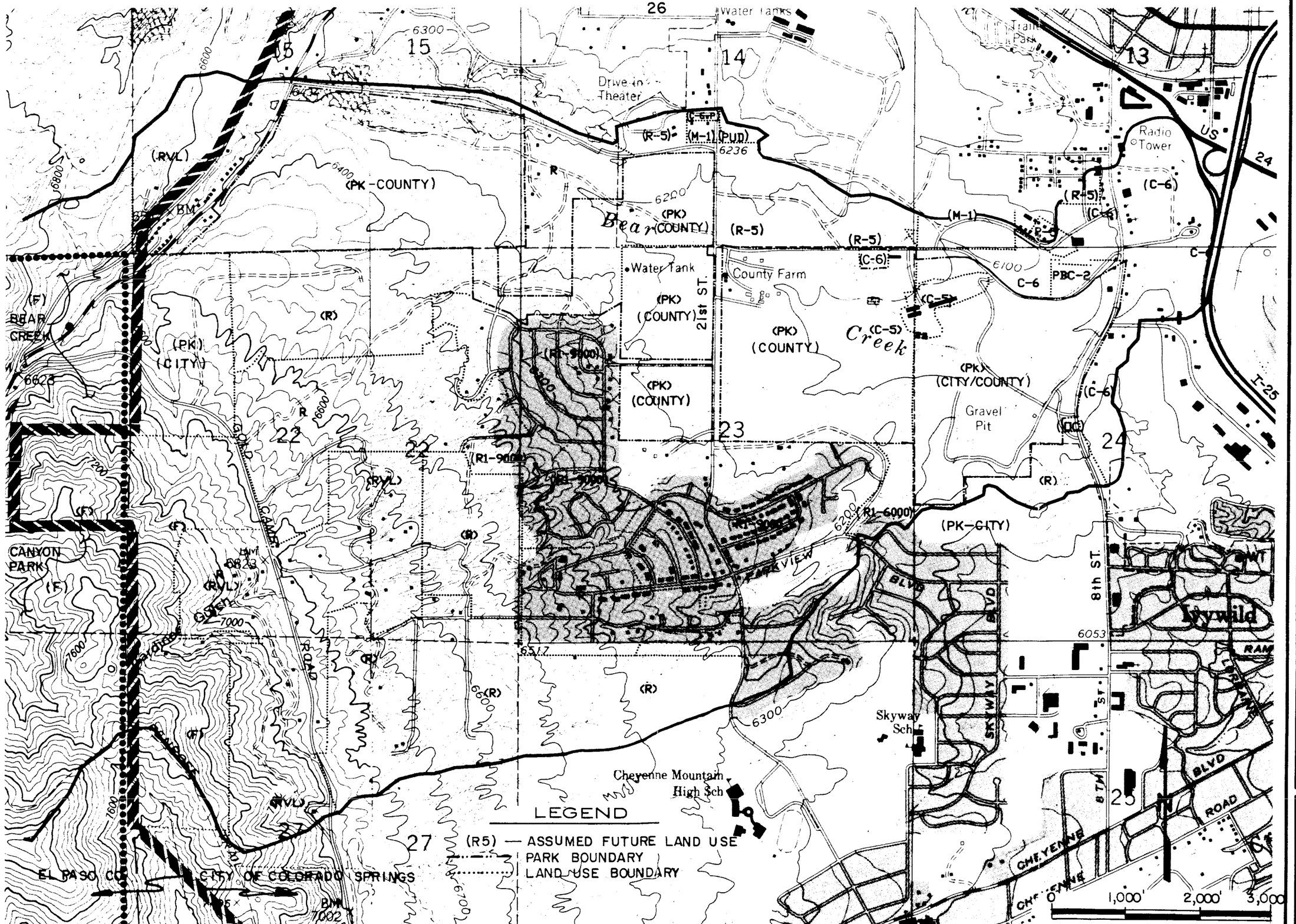
Revisions:	

FIG. 6



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BEAR CREEK DRAINAGE
BASIN PLANNING STUDY
HYDROLOGIC LAND USE
MAP—FUTURE CONDITION

Project No.	88.12.26
Date:	5/89
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Revisions:	

FIG. 7

Table 3. Percent of Imperviousness.

Zoning	Percent * Imperviousness	Land Use/Zoning Description	Remark
A	5	Agricultural	
PUD	70	Planned Unit Development	
R	20	Estate - Single-Family Residential (SFR)	1-2 Units/Acre
RVL	5	Residential Very Low	**
R-1-9000	40	9000 sq.ft./(SFR)	4-6 Units/Acre
R-1-6000	60	6000 sq.ft./(SFR)	6-8 Units/Acre
R-5	75	Multi-Family Residential	
MHP	60	Mobile Home Park	
MHS	50	Mobile Home Subdivision	
OC	75	Office Complex	
PBC	95	Planned Business Center No. 1 and 2	
C-5	85	Intermediate Business	
C-6	95	General Business	
M-1	95	Light Industrial	
PK	2	Park	**
OS	2	Open Space or Undeveloped	**
F	2	Forest	**

* Percent imperviousness determined from the City/County Drainage Criteria Manual, aerial photographs, mapping, and recommendations from the City Planning Department.

** Land use types created for this report are for hydrologic modelling purposes only.

Table 4: Summary of curve numbers

KIOWA ENGINEERING CORPORATION

HEC-1 CURVE # CALCULATION SPREADSHEET

DATE: 11-May-89

NOTE: SOIL GROUP A = 1 SOIL GROUP C = 3
SOIL GROUP B = 2 SOIL GROUP D = 4

PROJECT: BEAR CREEK DRAINAGE BASIN PLANNING STUDY

<-------- S-O-I-L G-R-O-U-P I-N-F-O-R-M-A-T-I-O-N -------->									** ANTECEDENT MOISTURE CONDITION = 2 **								** AMC = 3 **	
	** FIRST GROUP **		** SECOND GROUP **		** THIRD GROUP **				EXISTING CONDITIONS				FUTURE CONDITIONS				EXISTING	FUTURE
BASIN ID NUMBER	GROUP NUMBER	PERCENT OF GROUP	GROUP NUMBER	PERCENT OF GROUP	GROUP NUMBER	PERCENT OF GROUP	% IMP. EXISTING	% IMP. FUTURE	1ST GROUP CURVE #	2ND GROUP CURVE #	3RD GROUP CURVE #	WEIGHTED CURVE	1ST GROUP CURVE #	2ND GROUP CURVE #	3RD GROUP CURVE #	WEIGHTED CURVE	COMPUTED CURVE #	COMPUTED CURVE #
1	4	100					19	95	83.9	0.0	0.0	84	96.8	0.0	0.0	97	93	95
2	4	100					50	94	89.2	0.0	0.0	89	96.7	0.0	0.0	97	95	95
3	2	4	4	96			8	54	2.6	78.8	0.0	81	3.2	86.3	0.0	89	92	95
4	2	55	4	45			45	95	42.5	39.8	0.0	82	52.4	43.6	0.0	96	92	95
5	2	23	4	77			2	2	14.2	62.4	0.0	77	14.2	62.4	0.0	77	89	89
6	4	100					23	26	84.6	0.0	0.0	85	85.1	0.0	0.0	85	94	94
7	2	49	4	51			2	2	30.3	41.3	0.0	72	30.3	41.3	0.0	72	86	86
8	2	20	4	81			6	36	12.6	66.2	0.0	79	14.8	70.3	0.0	85	90	94
9	2	9	4	91			21	21	6.2	76.7	0.0	83	6.2	76.7	0.0	83	93	93
10	3	16	4	84			7	13	12.2	68.8	0.0	81	12.4	69.6	0.0	82	92	92
11	4	100					2	2	81.0	0.0	0.0	81	81.0	0.0	0.0	81	92	92
12	4	19	3	81			40	40	16.6	67.8	0.0	84	16.6	67.8	0.0	84	93	93
13	4	31	3	69			25	38	26.3	55.4	0.0	82	27.0	57.5	0.0	84	92	93
14	2	46	3	54			13	22	30.2	41.9	0.0	72	31.7	43.0	0.0	75	86	88
15	3	28	2	72			2	21	21.0	44.5	0.0	65	22.2	49.4	0.0	72	82	86
16	4	70	3	30			8	21	57.4	22.9	0.0	80	59.0	23.8	0.0	83	91	93
17	4	100					2	3	81.0	0.0	0.0	81	81.2	0.0	0.0	81	92	92
18	3	9	2	24	4	67	8	26	6.9	15.4	55.0	77	7.2	16.9	57.0	81	89	92
19	2	30	4	70			20	74	20.5	58.9	0.0	79	26.3	65.3	0.0	92	90	95
20	3	16	4	84			5	5	12.1	68.5	0.0	81	12.1	68.5	0.0	81	92	92
21	2	13	4	54	3	33	2	6	8.0	43.8	24.8	77	8.2	44.1	25.1	77	89	89
22	3	41	4	59			3	11	30.8	47.9	0.0	79	31.6	48.7	0.0	80	90	91
23	3	36	4	64			29	33	29.2	54.8	0.0	84	29.6	55.2	0.0	85	93	94
24	4	30	2	70			40	40	26.2	52.8	0.0	79	26.2	52.8	0.0	79	90	90
25	2	100					8	22	64.0	0.0	0.0	64	69.0	0.0	0.0	69	81	84
26	3	4	2	96			12	22	3.1	62.8	0.0	66	3.2	66.2	0.0	69	83	84
27	4	5	3	23	2	72	3	16	4.1	17.3	44.8	66	4.2	18.0	48.1	70	83	85
28	2	100					3	13	62.2	0.0	0.0	62	65.8	0.0	0.0	66	80	83

Table 4 cont'd: Summary of curve numbers

KIOWA ENGINEERING CORPORATION

HEC-1 CURVE # CALCULATION SPREADSHEET

DATE: 11-May-89

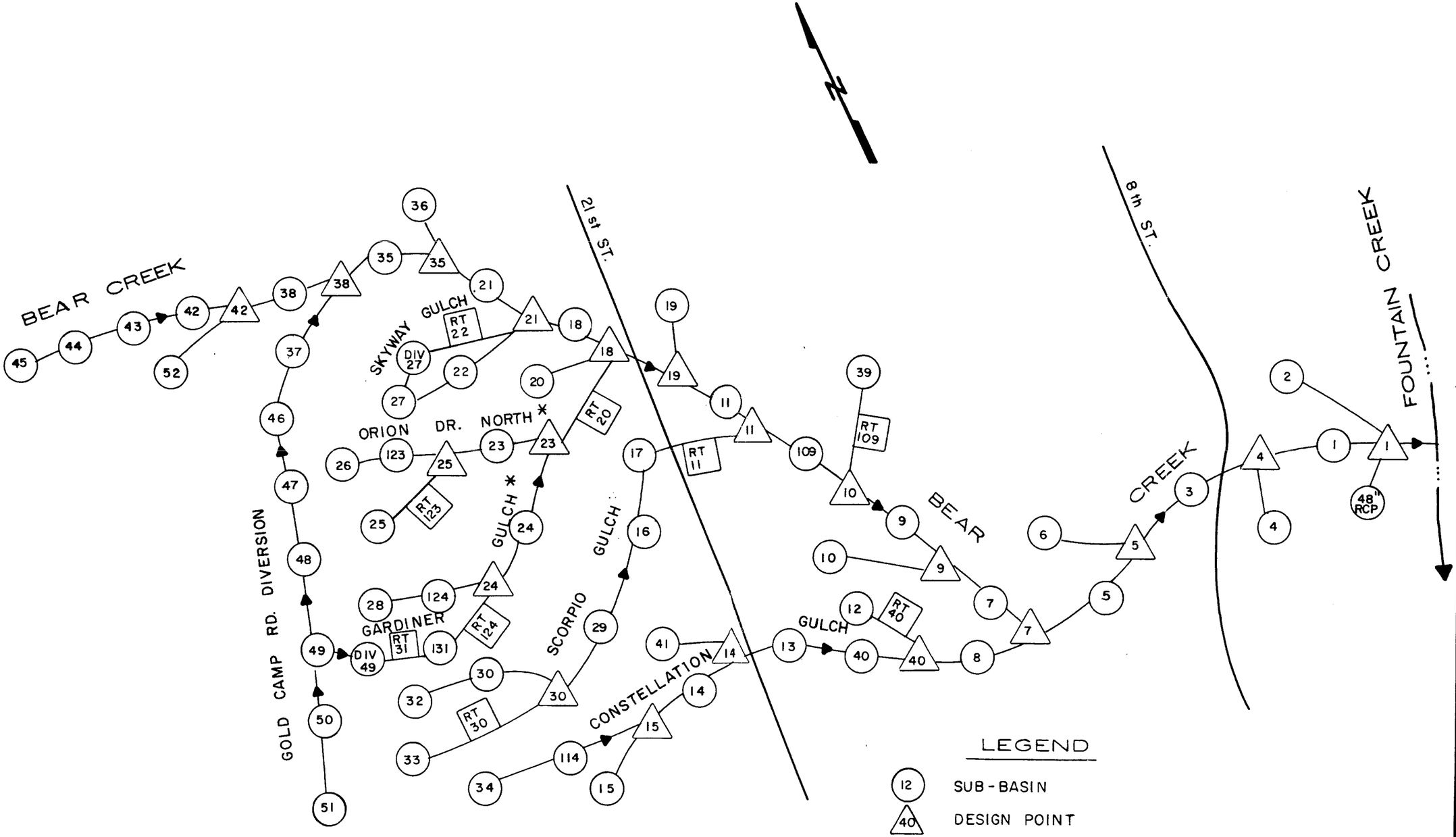
NOTE: SOIL GROUP A = 1 SOIL GROUP C = 3
SOIL GROUP B = 2 SOIL GROUP D = 4

PROJECT: BEAR CREEK DRAINAGE BASIN PLANNING STUDY

<-------- S-O-I-L G-R-O-U-P I-N-F-O-R-M-A-T-I-O-N -------->									** ANTECEDENT MOISTURE CONDITION = 2 **								** AMC = 3 **	
	** FIRST GROUP **		** SECOND GROUP **		** THIRD GROUP **				EXISTING CONDITIONS				FUTURE CONDITIONS				EXISTING	FUTURE
BASIN ID NUMBER	GROUP NUMBER	PERCENT OF GROUP	GROUP NUMBER	PERCENT OF GROUP	GROUP NUMBER	PERCENT OF GROUP	% IMP. EXISTING	% IMP. FUTURE	1ST GROUP CURVE #	2ND GROUP CURVE #	3RD GROUP CURVE #	WEIGHTED CURVE	1ST GROUP CURVE #	2ND GROUP CURVE #	3RD GROUP CURVE #	WEIGHTED CURVE	COMPUTED CURVE #	COMPUTED CURVE #
29	3	55	2	45			35	34	45.4	33.2	0.0	79	45.3	33.0	0.0	78	90	90
30	3	7	2	93			17	27	5.5	62.5	0.0	68	5.7	65.8	0.0	71	84	86
31	2	100					5	11	62.9	0.0	0.0	63	65.0	0.0	0.0	65	80	82
32	2	100					5	12	62.9	0.0	0.0	63	65.4	0.0	0.0	65	80	82
33	2	100					4	15	62.5	0.0	0.0	63	66.5	0.0	0.0	66	80	83
34	2	100					2	18	61.8	0.0	0.0	62	67.6	0.0	0.0	68	80	84
35	2	21	3	79			2	2	13.0	59.3	0.0	72	13.0	59.3	0.0	72	86	86
36	1	37	2	18	3	45	2	5	14.8	11.1	33.8	60	23.3	11.3	34.1	69	78	84
37	3	100					2	2	75.0	0.0	0.0	75	75.0	0.0	0.0	75	88	88
38	2	13	3	87			2	2	8.0	65.3	0.0	73	8.0	65.3	0.0	73	87	87
39	2	8	4	92			2	75	4.9	74.5	0.0	79	7.0	86.0	0.0	93	90	95
40	4	100					10	10	82.4	0.0	0.0	82	82.4	0.0	0.0	82	92	92
41	2	15	3	85			27	32	10.6	68.6	0.0	79	10.9	69.6	0.0	81	90	92
42	3	1	2	99			2	2	0.8	61.2	0.0	62	0.8	61.2	0.0	62	80	80
43	3	8	2	92			2	2	6.0	56.9	0.0	63	6.0	56.9	0.0	63	80	80
44	1	8	3	10	2	82	2	2	3.2	7.5	50.7	61	4.9	7.5	50.7	63	79	80
45	1	4	3	9	2	87	2	2	1.6	6.8	53.8	62	2.5	6.8	53.8	63	80	80
46	3	13	2	87			2	2	9.8	53.8	0.0	64	9.8	53.8	0.0	64	81	81
47	1	26	3	56	2	18	2	2	10.4	42.0	11.1	64	16.1	42.0	11.1	69	81	84
48	3	45	2	55			2	2	33.8	34.0	0.0	68	33.8	34.0	0.0	68	84	84
49	3	16	2	84			2	2	12.0	51.9	0.0	64	12.0	51.9	0.0	64	81	81
50	3	13	2	87			2	2	9.8	53.8	0.0	64	9.8	53.8	0.0	64	81	81
51	3	6	2	94			2	2	4.5	58.1	0.0	63	4.5	58.1	0.0	63	80	80
52	3	14	2	86			2	2	10.5	53.1	0.0	64	10.5	53.1	0.0	64	81	81
109	4	90	2	10			2	2	72.9	6.2	0.0	79	72.9	6.2	0.0	79	90	90
114	2	95	3	5			13	20	62.5	3.9	0.0	66	64.9	4.0	0.0	69	83	84
123	3	75	4	25			29	33	60.9	21.4	0.0	82	61.6	21.6	0.0	83	92	93
124	2	95	4	5			26	32	66.9	4.3	0.0	71	69.0	4.3	0.0	73	86	87

routing scheme, sub-basin locations, and design points. A HEC-1 flow diagram for the entire basin is shown on Figure 8. A summary of flow rates for the key design points for both the 24-hour and 2-hour storm patterns is presented on Table 5. Sub-basin discharges are shown on Table 6. In general, this study shows very similar flow rates between the existing and future basin conditions due to the fact that the future developable land within the basin is a relatively small portion of the total study area (15 percent). Both the existing and future basin flows were obtained by assuming the existing stream section and drainage patterns. No attenuation due to detention was modelled in the hydrologic analysis, however several small on-site ponds exist in the Skyway Heights Subdivision. For the future development condition, the proposed Orion Drive storm sewer was modelled in the routing scheme. The variance in the peak flows obtained using the 2-hour and 24-hour storm distribution is significant. The difference is probably because of the length of the basin, which would allow a shorter duration peak runoff to move out of the basin prior to the peak from the upper basin entering the lower reach of Bear Creek. The 24-hour storm pattern yields a more conservative peak flow rate from the standpoint of drainage structure sizing. As a result of the review of the hydrologic analysis and results, the 24-hour storm with antecedent moisture condition 2 is recommended for purposes of further defining the drainage plan for the basin. Figures 9 through 11 are storm hydrographs generated at selected design points, for the 100-year existing and future basin conditions. Complete HEC-1 input and output data are contained within the Technical Addendum (Volume II) of this report.

The hydrologic results recommended herein should be used for planning purposes only. Peak discharges to be applied in the final design of drainage facilities within the Bear Creek Basin must be verified. Actual drainage basin characteristics may vary for specific areas and locations within the Bear Creek Basin.



LEGEND

- 12 — SUB-BASIN
- 40 — DESIGN POINT
- RT 40 — ROUTE THROUGH SUB-BASIN 40
- FLOW DIRECTION

*PROPOSED ORION DRIVE NORTH & GARDINER GULCH STORM SEWER PROJECT REFLECTED IN FUTURE CONDITION ROUTING.

Kiowa Engineering Corporation
419 W. Bijou Street
Colorado Springs, Colorado
80905-1308

BEAR CREEK DRAINAGE
BASIN PLANNING STUDY

HEC-1 SCHEMATIC
EXISTING DRAINAGE CONDITION

Project No.	88.12.26
Date:	5/89
Design:	BJH
Drawn:	EAK
Check:	
Revisions:	

FIG. 8

TABLE 5: SUMMARY OF PEAK FLOW RATES FOR KEY DESIGN POINTS

DESIGN POINT	LOCATION	AREA SQ. MI	100 YR. 24 HR. (1 EXIST	100 YR. 24 HR. (1 FUTURE	100 YR. 2 HR. (2 EXIST	100 YR. 2 HR. (2 FUTURE	10 YR. 24 HR. (1 EXIST	10 YR. 24 HR. (1 FUTURE	10 YR. 2 HR.(2) EXIST	10 YR. 2 HR.(2) FUTURE
1	FOUNTAIN CREEK	10.71	4140	4540	3880	3990	1140	1460	1780	1850
4	8TH STREET	10.57	3940	4390	3800	3930	1060	1340	1750	1820
5		10.39	3850	4260	3730	3850	1030	1250	1710	1770
7	CONSTELLATION GULCH @ BEAR CREEK	10.33	3790	4200	3700	3820	1000	1200	1690	1760
9		9.58	3340	3670	3390	3480	770	950	1550	1590
10		9.34	3260	3570	3280	3370	730	890	1490	1540
11		9.25	3240	3510	3240	3340	700	850	1470	1520
14	CONSTEL. GULCH & CRESTA	0.46	230	340	200	260	60	100	90	130
15		0.35	140	220	140	190	30	70	60	90
18	21ST STREET	8.87	2980	3210	3070	3150	580	690	1390	1430
19		8.91	3000	3250	3090	3170	590	720	1400	1440
21		8.23	2580	2740	2770	2840	440	490	1250	1280
23	ORION DRIVE NORTH	0.47	580	660	510	550	210	250	210	250
24	ORION DRIVE SOUTH	0.18	240	270	170	190	80	100	70	80
25		0.2	230	280	240	260	80	100	90	100
30		0.14	120	140	130	150	30	50	40	60
35	BEAR CK NAT CENTER	7.7	2540	2740	2560	2630	400	450	1150	1170
38		7.51	2590	2720	2510	2570	390	430	1120	1140
40		0.59	470	580	380	460	190	240	160	210
42	UPPER BASIN OUTFALL	6.83	2270	2410	2290	2340	340	380	1020	1040
43	OUTLET OF CONSTELLATION GULCH	0.72	680	800	520	650	290	350	220	310
37	OUTLET OF GOLD CAMP DIVERSION	0.51	200	205	150	155	55	60	70	70

NOTES: (1) 24-HOUR DURATION STORM, ANTECEDENT MOISTURE CONDITION II. 24-HOUR STORM SELECTED FOR USE IN THE BEAR CREEK BASIN FOR PLANNING AND DESIGN OF FACILITIES.

(2) 2-HOUR DURATION STORM, ANTECEDENT MOISTURE CONDITION III (FOR INFORMATION ONLY).

TABLE 6: SUMMARY OF PEAK FLOW RATES FOR SUBBASINS

SUB-BASIN NO.	AREA SQ. MI	100 YR. 24 HR. (1 EXIST	100 YR. 24 HR. (1 FUTURE	100 YR. 2 HR. (2 EXIST	100 YR. 2 HR. (2 FUTURE	10 YR. 24 HR. (1 EXIST	10 YR. 24 HR. (1 FUTURE	10 YR. 2 HR.(2) EXIST	10 YR. 2 HR.(2) FUTURE
1	0.02	30	50	20	40	20	40	10	20
2	0.13	260	440	140	310	110	290	70	190
3	0.13	160	280	150	180	70	160	70	90
4	0.04	60	150	50	120	30	100	30	70
5	0.01	20	20	20	20	10	10	10	10
6	0.05	130	130	70	70	60	60	40	40
7	0.02	30	30	30	30	10	10	10	10
8	0.13	210	220	140	190	100	110	60	100
9	0.06	80	80	60	60	30	30	30	30
10	0.18	130	160	100	100	50	50	50	50
11	0.02	30	30	30	30	20	20	20	20
12	0.05	100	100	100	100	60	60	50	50
13	0.08	140	150	150	160	70	80	70	80
14	0.05	50	60	50	50	20	20	20	20
15	0.13	60	140	60	80	10	30	30	40
16	0.11	170	190	100	120	60	80	50	60
17	0.04	70	70	50	50	20	20	20	20
18	0.13	180	220	110	150	60	80	50	70
19	0.03	50	110	40	80	30	70	20	40
20	0.04	70	70	40	40	30	30	20	20
21	0.27	230	390	190	310	90	120	80	100
22	0.06	130	130	120	130	60	60	60	70
23	0.06	120	120	100	110	60	70	50	60
24	0.03	60	60	40	40	30	30	20	20
25	0.09	80	110	90	110	20	30	30	40
26	0.09	100	120	110	110	30	40	50	50
27	0.2	170	240	150	150	60	80	60	70
28	0.06	50	70	50	70	10	20	20	20
29	0.03	70	70	70	70	30	30	30	30
30	0.05	70	80	70	80	20	30	20	30
31	0.04	40	50	40	50	10	10	10	20
32	0.04	20	20	20	30	5	10	10	10
33	0.05	50	60	50	60	10	20	10	20
34	0.16	90	140	110	160	20	40	30	60
35	0.07	100	100	100	100	40	40	50	50
36	0.12	40	110	40	70	10	20	20	30
37	0.03	60	60	40	40	20	20	20	20
38	0.17	190	190	120	120	40	40	60	60
39	0.05	80	150	50	130	30	90	20	70
40	0.01	20	20	20	20	10	10	10	10
41	0.06	80	80	50	60	30	30	20	30
42	1.93	1210	1210	970	970	150	150	370	370
43	1.69	680	680	630	630	110	110	270	270
44	1.45	500	630	550	590	80	110	240	260
45	1.69	400	450	590	590	80	90	260	260
46	0.13	110	110	110	110	30	30	30	30

TABLE 6: SUMMARY OF PEAK FLOW RATES FOR SUBBASINS

SUB-BASIN NO.	AREA SQ. MI	100 YR. 24 HR. (1 EXIST	100 YR. 24 HR. (1 FUTURE	100 YR. 2 HR. (2 EXIST	100 YR. 2 HR. (2 FUTURE	10 YR. 24 HR. (1 EXIST	10 YR. 24 HR. (1 FUTURE	10 YR. 2 HR.(2) EXIST	10 YR. 2 HR.(2) FUTURE
47	0.02	20	20	10	20	3	10	5	10
48	0.04	40	40	20	20	10	10	10	10
49	0.14	100	100	60	60	10	10	30	30
50	0.11	40	40	50	50	10	10	20	20
51	0.04	30	30	30	30	10	10	10	10
52	0.06	50	50	40	40	10	10	20	20
109	0.04	40	40	30	30	20	20	10	10
114	0.05	20	30	20	30	10	10	10	10
123	0.03	70	70	60	60	30	40	30	30
124	0.08	150	170	150	160	70	70	70	70

NOTES: (1) 24-HOUR DURATION STORM, ANTECEDENT MOISTURE CONDITION II (FOR DESIGN).

(2) 2-HOUR DURATION STORM, ANTECEDENT MOISTURE CONDITION III (FOR INFORMATION ONLY).

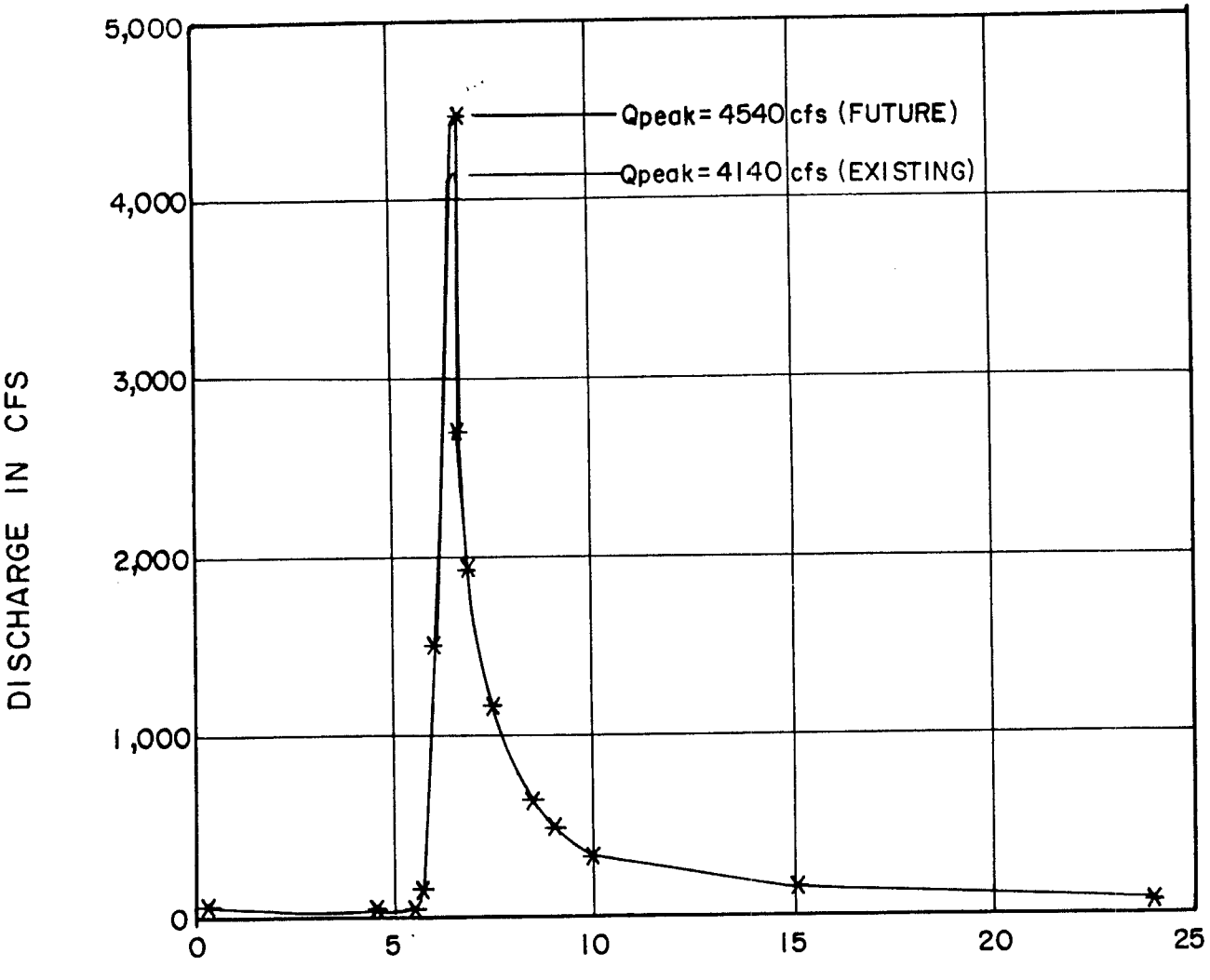


FIGURE 9
100-YR. FLOOD HYDROGRAPH
BEAR CREEK at FOUNTAIN CREEK

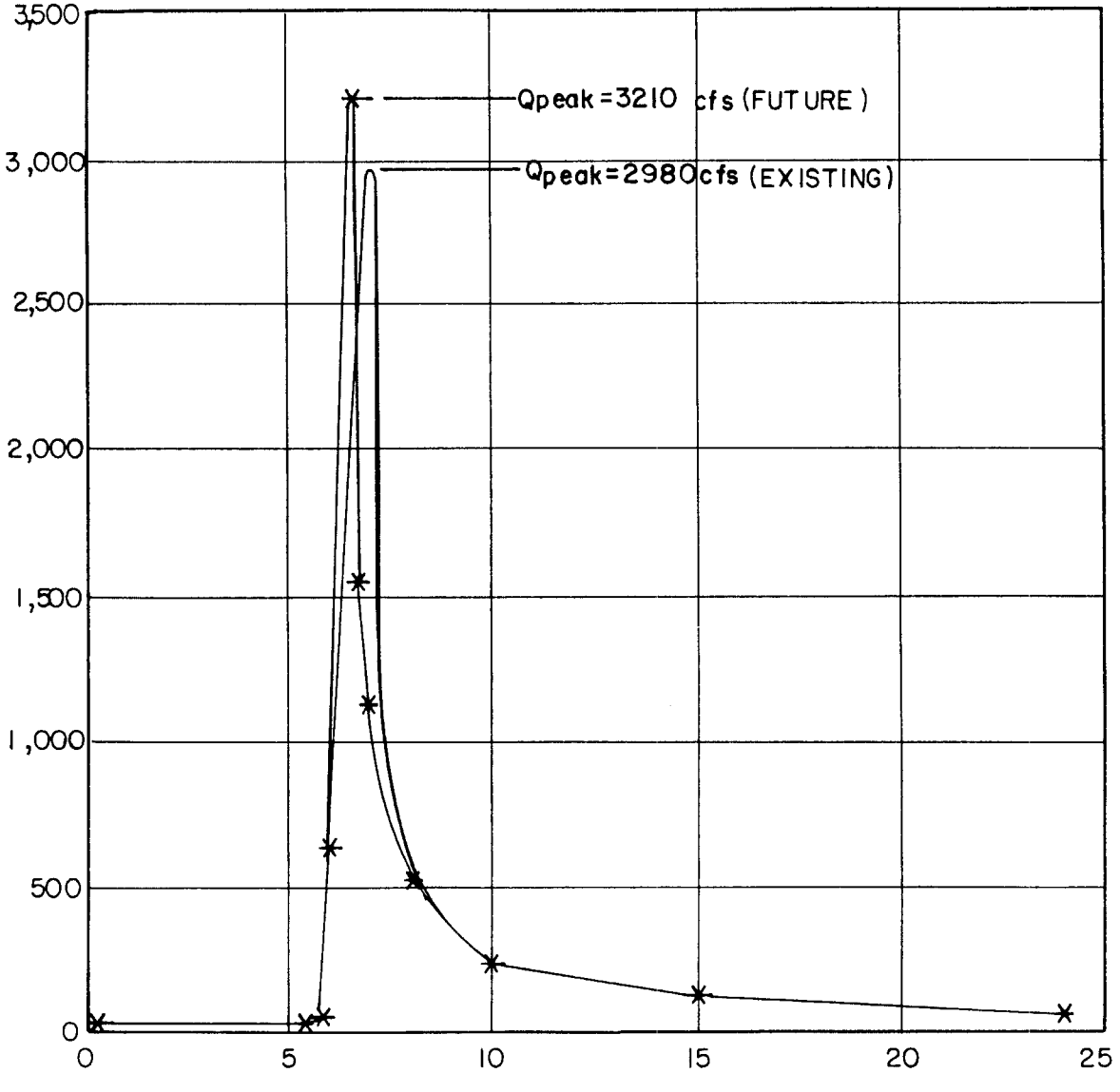
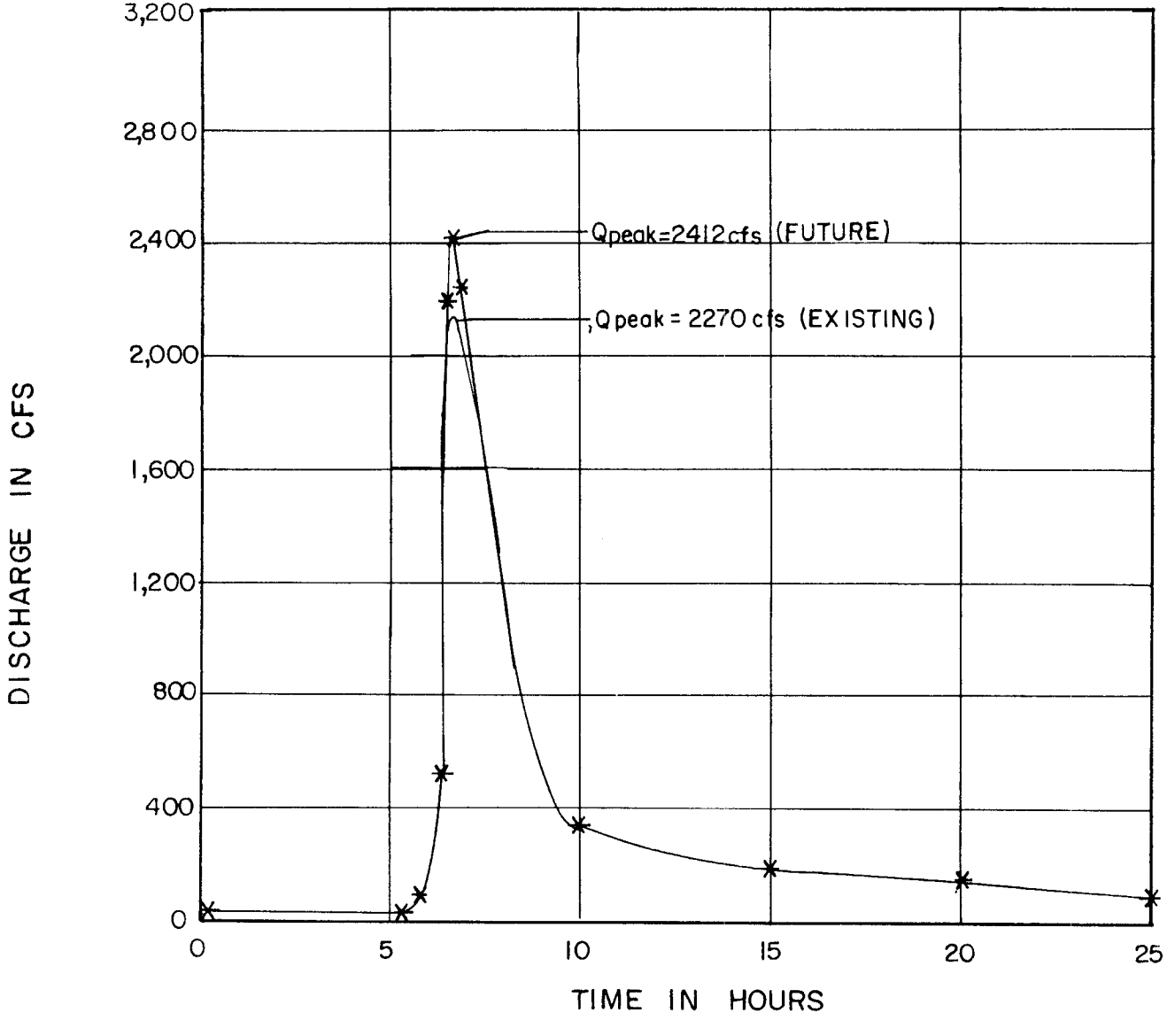


FIGURE 10
100-YR. FLOOD HYDROGRAPH
BEAR CREEK at 21st ST



FUTURE

EXISTING

24-HR. DURATION

AMC-II

DESIGN PT. 42

FIGURE 11

100-YR. HYDROGRAPH

BEAR CREEK at GOLD CAMP RD

IV. HYDRAULIC ANALYSIS AND FLOODPLAIN DELINEATION

A hydraulic analysis along the major drainageways was conducted to establish the flow capacities of existing structures, and to identify areas of flooding. The major drainageways were divided into reaches in order to better organize the planning effort. Presented on Table 7 are the stream reaches. The reaches were selected based upon their particular drainageway characteristics and/or problems. Brief descriptions of each reach are included. The 100-year floodplain for future basin conditions is presented in the preliminary design drawings.

Structure Inventory

As part of the field investigation, the existing drainage facilities were evaluated and inventoried. The size, type, and condition was recorded for all the bridges, culverts, channels, inlets, pipes, and miscellaneous drainage features in the basin. Hydraulic capacity was estimated for the larger existing culverts and bridges for use in the hydrologic routing and the floodplain evaluation. In general, all of the major roadway crossings over Bear Creek are of insufficient capacity to convey the 100-year existing condition peak runoff with the exception of the existing culvert under I-25 at the outfall of the basin. The inventory of structures is presented in Appendix B. This inventory follows a standard format developed by the City/County. Maps showing the drainage structures inventoried have been provided to the City and correlated to the City Utility Department Plat Maps.

Existing Channel and Floodplain Description and Condition

Reach 1 Bear Creek, STA 0+00 to 21+00: Assuming limited blockage, the culvert at I-25 has adequate capacity to present the 100-year flow from overtopping I-25. The I-25 road embankment is high enough to direct any deep ponded flow to the south, into the southwest area basin. This reach has a 10- to 20-foot bottom width and a 2:1 riprap embankment on the north bank. The south bank is mainly 3:1 grass with patches of riprap.

Table 7. Planning Reaches.

Reach No.	Location	Station (1)
	BEAR CREEK CHANNEL	
1	I-25 to 8th Street	STA 0+00 to 21+00
2	8th Street to Penrose Stadium	STA 21+00 to 54+00
3	Penrose Stadium to 21st Street	STA 54+00 to 85+50
4	21st Street to the Bear Creek Nature Center	STA 85+50 to 155+00
5	Bear Creek Nature Center to Gold Camp Road	STA 155+00 to 190+00
	CONSTELLATION GULCH	
6	Bear Creek to Cresta Road (21st Street)	STA 0+00 to 55+00
7	Constellation Gulch (and tributaries) above Cresta	
	SCORPIO GULCH	
8	From Bear Creek to Gold Camp Road	
	ORION DRIVE PLANNING AREA	
9	Outfall System - Bear Creek to Orion Drive	
10	Gardiner Gulch - Orion Drive to Gold Camp Road	
11	Orion Drive North - Orion Drive West to Gold Camp Road	
	SKYWAY GULCH	
12	From Bear Creek to Gold Camp Road	
	GOLD CAMP ROAD BASIN	
13	From Bear Creek to the South Basin Boundary (along Gold Camp Road)	

(1) Stations refer to the preliminary design drawings.

The invert is rocked through the lower one-half of the reach, and sandy in the upper one-half of the reach. Willows line the invert for the majority of the reach. The floodplain has split flow due to overtopping of the culvert at 8th Street. This causes flow to move along the north overbank, approximately 250 foot wide. Depths of one to two feet and velocities of three to five feet per second are estimated on the overbank. Replacement of the 8th Street culvert would allow the flow to remain in the existing channel. Flow depths range from six- to eight-feet and velocities from 11 to 13 feet per second. The 8th Street twin corrugated steel culverts do not have pedestrian access and is poorly aligned. The poor alignment has the potential to cause erosion of the north bank at the outlet. In the middle of this reach is a eight-foot high concrete spillway/drop structure.

Reach 2 Bear Creek, STA 21+00 to 54+00: The backwater upstream of 8th Street creates a 500-foot wide floodplain adjacent to the road. The channel (STA 21+00 to 26+00) is deeply cut with steep, unprotected eroding banks. Many large cottonwoods line the edge of the low flow channel. The floodplain is approximately 40- to 100-feet wide. It is 9-feet deep and velocities range from 9 to 12 feet per second. The channel has sufficient capacity to carry the 100-year flow, but further bank and invert erosion could occur. Bedrock outcrops have been noted in several locations, which has halted the degradation of the invert.

The channel section from STA 26+00 to 51+00 is narrow, deep and with unvegetated eroding banks. The floodplain is split in this segment with overflows moving east along the historic channel path through the stadium parking lot. When flood depths exceed eight-feet at STA 51+00 overtopping occurs and the overflow drains down the historic flow path. This results in a shallow 15- to 40-foot wide floodplain. The floodplain along the primary channel is 30- to 50-feet wide, nine to ten-feet deep, and 12 feet per second average velocity. Further erosion could

occur in this reach as the channel invert drops due to low flow degradation.

From STA 51+00 to 54+00 the construction of the stables at the Penrose Stadium has filled into the north bank of the creek, constricting the flow. The floodplain in this heavily vegetated area is 40- to 80-feet wide, four feet deep and a ten feet per second average velocity.

Reach 3 Bear Creek, STA 54+00 to 85+50: The lower portions of Reach 3 (from STA 54+00 to 78+00) is an undisturbed wide channel, lined with a moderate number of cottonwoods and other vegetation. The floodplain is 80- to 200-feet wide, flowing four to seven-feet deep, and has velocities ranging from 8 to 11 feet per second. In the upper portion of this reach (from STA 78+00 to 85+50) a split flow occurs causing a wide floodplain through the Park area. The inadequate culvert capacity at 21st Street causes the 100-year flow to overtop the roadway and split, with a portion of the flow continuing east along the drainageway and a portion of the flow moving south along 21st Street to a low point and then into the Park. The main channel has been narrowed to a very small section and lined with a vertical concrete wall and rocks. The southern portion of this split flow includes flow from Scorpio Gulch (Reach 8). The existing floodplain is about 150- to 800-feet wide flowing two- to eight-feet deep and 4 to 11 feet per second. The County Park Building first floor is more than one-foot above the 100-year water surface. A tree located at the outlet of the north bay of the box culvert under 21st Street creates a blockage which reduces the capacity of the already undersized culvert. A trail crossing exists in the north bay of the culvert. Bank and invert erosion exists at the outlet of the 21st Street culvert, and along the low flow areas of the creek east of Creek Crossing Road.

Reach 4 Bear Creek, STA 85+50 to 155+00: This reach is a natural, undisturbed reach of Bear Creek flowing through predominantly Bear Creek Regional Park. A few low flow trail and

road crossings are located in this reach. The vegetation in the channel is heavy. The floodplain is 30- to 150-feet wide and flows three- to six-feet deep and seven to ten feet per second. Due to the heavy vegetation in this reach, stream bank erosion would be minimal. The twin box culvert at 21st Street is under capacity which causes an 800-foot wide backwater flow over 21st Street. No habitable structures are within the 100-year floodplain.

Reach 5 Bear Creek, STA 155+00 to 190+00: This reach is more typical of a mountain stream. It is in a steep, narrow rocky canyon with a two-lane paved street located on the north bank of the channel (Bear Creek Road). It appears the road is encroaching into the historic drainageway. Several private wood bridges span the creek, and are all generally less than 100-year capacity. The floodplain ranges from 30- to 15-feet wide and has depths from four- to five-feet deep, and velocities of seven to ten feet per second. The channel slope is about 4.5 percent. Both the roadway and several private residences could be damaged in a 100-year event. The culverts at the intersection of Bear Creek Road and Upper/Lower Gold Camp Road are in good condition, however, they are of insufficient capacity to pass the existing condition 100-year flow.

Reach 6 Constellation Gulch, STA 0+00 to 55+00: The existing channel is a natural drainageway. The upper 3000 feet and the bottom 1000 feet are steep, narrow, unvegetated, eroding channels. The middle 1500 feet is a wide, flat and well-vegetated drainageway. The floodplain is 20- to 250-feet wide with depths from 0.5 to five-feet and velocities of four to nine feet per second. The lower two sections (approximately 2500 lineal feet) are located in the County Park. Low flows have caused erosion of the invert, and bank sloughing, particularly the outlet of storm sewers. The condition of the existing channel is particularly degraded downstream of the Cresta Drive and Parkview Boulevard crossings.

Reach 7 Constellation Gulch, STA 55+00 to Gold Camp Road: This reach of Constellation Gulch is from Cresta Road along Constellation Drive to Gold Camp Road. In the lower one-third of this reach, from Cresta Drive to Taurus Road, the road forms the invert of the drainageway. The roadway has a 24-foot asphalt mat with 2 to 1 side slopes, and has a slope ranging from six to ten percent. Most of the residences abutting Constellation Drive have been constructed below street grade. Sediment and runoff in amounts greater than the street section capacity will move overland through private lots. Structural damage is not expected to occur, however, damage to landscaping and roadside ditches could occur.

Reach 8 Scorpio Gulch: This reach begins at Bear Creek STA 79+00, and crosses through Bear Creek Park in a southwesterly direction. South of the park boundary Scorpio Gulch crosses Orion Drive and onto Scorpio Drive. At the intersection of Scorpio Drive and Polaris Drive, Scorpio Gulch is confined by a steep ravine passing through the Skyway Heights Subdivision. No storm drainage systems exist. The upper ravine is moderately vegetated, and invert degradation has occurred.

Reach 9: The Orion Drive outfall system runs from Bear Creek (STA 90+00), southwest through the park along the existing diversion channel to the low point in Orion Drive. This system is constructed with an 84-inch reinforced concrete pipe (RCP) and replaces the existing riprap channel. Local storm drainage has overtopped the existing ditch, and has caused debris and siltation within Bear Creek Park.

Reach 10: Gardiner Gulch runs from Orion Drive to Gold Camp Road. This reach includes the Orion Drive south storm sewer system. At the terminus of the storm sewer system, Gardiner Gulch is within a steep ravine similar to Scorpio Gulch. Bank and invert degradation has occurred in this segment. Several

detention ponds exist on Gardiner Gulch within the Skyway Heights Subdivision. These ponds are of small capacity, and impacted by frequent siltation. The storm sewer within Orion Drive are of sufficient capacity to contain the 100-year flows.

Reach 11: Orion Drive North runs from Orion Drive west to Gold Camp Road. A proposed storm sewer within Orion Drive running west to Southern Cross will collect storm runoff from the Skyway Heights Subdivision. The upper portions of this reach are within steep ravines, densely to moderately vegetated.

Reach 12: Skyway Gulch runs from Bear Creek (STA 103+00) westerly up through 2200 feet of 60-inch and 72-inch CMP to the east boundary of the Skyway Northwest Subdivision. Surface overflows would follow the historic drainage path which passes through the County Park and private undeveloped land. Above the storm sewer system, Skyway Gulch is a series of steep ravines. Sediment deposition has caused local damages near residences within the Skyway Subdivision.

Reach 13: This reach is the Gold Camp Road diversion. It begins at Bear Creek (STA 180+00) and runs south through a narrow steep rocky drainageway at an 11 percent slope for about 1800 feet. This first segment is located within the Bear Creek City Park (Subbasin 37). After crossing under Gold Camp Road a natural depression created by the Gold Camp Road embankment can store approximately ten acre feet until the road would be overtopped. (The effect of this storage was not modelled in the hydrologic analysis.) The effect of this storage will not exist upon construction of an outlet culvert. Upstream of this area runoff flows along Gold Camp Road for about 6400 feet, terminating at the south basin boundary. This diversion was modelled in the hydrologic analysis. At Gold Camp Road and Bonnie Vista Drive a flow split was identified which causes approximately 50 percent of the 100-year flow to be conveyed east, along the historic path. Information from the City Street

Division indicates that flow has overtopped the roadway at this location in the past. Debris and sedimentation has occurred along Bonnie Vista Drive.

Flood History

No recorded flood events exist for Bear Creek or its tributaries. Flooding caused by heavy rainfall in the lower basin has caused the 21st Street culvert to be overtopped, as well as several of the bridges within Bear Creek Park West of 21st Street. The floodplain adjacent to Bear Creek Road (Reach 5) is predicted to spread across the road and possibly cause shallow flooding to residential structures, however, there is no record of this ever occurring.

The Orion Drive storm sewer was designed to collect local runoff from the Top of Skyway Subdivision, and is currently under construction. Heavy thunderstorms in the past have caused runoff to exceed the street section along Orion Drive, particularly the north/south segment of Orion Drive west of Bear Creek Park. Shallow flooding has impacted residences along Orion Drive, and also caused damages related to erosion and debris deposition within Bear Creek Park. The outfall pipe has been sized to collect the 100-year peak flow, and convey it underground to Bear Creek.

Other local flooding problems exist within the Scorpio Gulch, Constellation Gulch, and Gardiner Gulch. At Orion Drive and Hercules, an unimproved portion of Scorpio Gulch begins. Drainage from areas above this location have caused street flooding on Orion Drive. Stormwater has caused severe degradation to the natural drainageway. At Cresta Drive and Constellation Gulch, runoff from the areas above this point has caused street flooding on Cresta Drive, and degradation of the existing roadway embankment and the drainageway. Further downstream, at Constellation Gulch and Parkview Boulevard, the roadway has in the past been overtopped. The outlet drainageway and road embankment is severely eroded.

The Federal Emergency Management Agency (FEMA) developed a 100-year floodplain and floodway for Bear Creek in 1986. This floodplain is based upon a higher peak 100-year discharge than estimated in this report. Because of the steepness and narrowness of the main channel, the areal extent of the 100-year floodplain between the FEMA study and floodplains developed in this report do not vary significantly. Base flood elevations range from one to two feet lower in this report, as compared to the FEMA study.

Water Quality

Water quality within the Bear Creek Basin is currently good, with the major impact to water quality coming from sediment entering the major drainageway from tributaries. Industrial and commercial development is expected to occur in the lower portion of the basin, and pollutants associated with this type of urban development would not be expected to greatly degrade the quality of the base flow. The disturbance of areas in the basin are the result of land development construction activities which present the greatest threat to water quality in the basin, and to the receiving waters of Fountain Creek. The highly-erodible nature of the decomposed granite found on hillsides and within the drainageways has caused sediment to move into streets and storm sewers. This is particularly true in the upper portions of the basin, within the Skyway Heights and Top of Skyway Subdivisions. The lining of drainageways above will not retard the rate of erosion from areas disturbed by construction. Adherence to, and enforcement of, erosion control standards for disturbed sites is essential in the Bear Creek Basin if the drainageways are not to be adversely impacted. Check and drop structures, and selective riprap-lined swales is required to prevent bank sloughing due to invert degradation created by the high flow velocities.

V. DEVELOPMENT OF ALTERNATIVE PLANS

Introduction

Alternative drainageway improvement concepts have been examined that address the existing and future stormwater management needs of the basin. Alternatives have been identified for each reach of the drainageway on a conceptual level. Quantitative and qualitative comparisons are presented, and a recommendation made as to which plan is most feasible to advance to preliminary design and eventually implementation.

The general planning goals followed during the alternative plan development phase were:

1. Identify stormwater facilities which will reduce existing floodplains and flooding problems within urbanized areas;

2. Provide stormwater management within developing areas of the basin in order to reduce the detrimental effects of runoff and sedimentation from disturbed areas;

3. Provide stormwater facilities which preserve and/or enhance the existing drainageway and areas adjacent to the drainageway which provide an environmental resource in the area;

4. Identify facilities which will minimize future operations and maintenance costs; and

5. Provide stormwater management facilities which will at least maintain and/or enhance the water quality characteristics of the basin.

The City/County Drainage Criteria Manual was used to estimate rates of runoff and size facilities. Other planning goals were developed through the coordination process, and common or mutual goals of the interested agencies identified prior to the initiation of the alternative development phase.

Evaluation Parameters

Coordination meetings were held throughout the study to address overall goals and specific concerns of those governmental agencies, individuals, and private community groups asked to participate in the study. One result of this coordination effort

was the development of the following list of parameters which were considered when evaluating an alternative.

- Flood Control
- Erosion Control
- Operation and Maintenance
- Water Quality
- Wildlife Habitat
- Construction Cost
- Preserve Existing Vegetation
- Administration and Implementation
- Open Space
- Land Use
- Constructability
- Recreation
- Aesthetics
- Transportation (Trails)

The list of evaluation parameters was sent out to the persons on the mailing list, and each person was asked to rank their top seven to eight parameters, based upon the technical information presented to date, and from their own point of view.

The review of the rankings received from the interested agencies and individuals revealed that preservation of existing vegetation, flood control, land use and open space, and erosion control were the more important parameters within the Bear Creek Basin. These parameters reflect the existence of the Bear Creek Park, and the importance of maintaining the creek to complement or enhance the park setting to the most practicable extent possible. In a field meeting with representatives from the U.S. Army Corps of Engineers (COE), the Environmental Protection Agency (EPA), and the Colorado Division of Wildlife, subsequent to the evaluation parameter ranking, the importance of the park setting and the riparian areas was again verified. Creek stabilization and floodplain preservation were identified as possible alternatives within the Bear Creek Park. Within the urban areas, a higher ranking of erosion and flood control was indicated in the evaluation parameter ranking. This is primarily because of the erosive soils in the undeveloped upper reaches, which have caused existing residences to be impacted by sediment being forced out of the street section and onto private property. Erosion control and local storm sewer systems would probably be effective in addressing these types of problems.

Preliminary Matrix of Alternatives

The alternative planning process began with the evaluation of general drainageway planning alternatives. Alternatives which are generally available in the majority of urban drainage basins include:

1. Floodplain preservation,
2. Channelization,
3. Detention, on-site or regional,
4. Diversion between sub-basins, and
5. Closed conduits.
6. Combinations of the above.

These concepts were evaluated for each reach of the basin. The results are summarized on Table 8.

Drainage System Alternates

Based upon the technical work, field visits, and meetings with the interested agencies and individuals, alternative drainage improvements have been developed. Alternatives for channel sections, detention facilities, storm drain systems, and diversions have been developed and are discussed below.

Channels: Shown on Figure 12 are conceptual channel sections for Reaches 1 through 5 of Bear Creek. Within Reaches 1 and 5, selectively applied the benched section employing a riprap low flow area appears to be a reasonable solution to the existing bank sloughing, flooding and maintenance access problems which currently exist, while limiting disturbances to native vegetation. Low flow linings will limit invert degradation in combination with selectively sited drop/check structures. Within Reach 2 through 4, a stabilized section utilizing selective riprap bank lining and grade control structures is recommended as the preferred alternative.

Presented on Figure 13 is a stabilized channel section for use in the steep ravines within Reaches 7 through 12. Storm sewers and improvements to the street section such that flows can be handled within the street right-of-way will prevent runoff from impacting residences lying below the street grade. The

TABLE 8: MATRIX OF ALTERNATIVE DRAINAGE CONCEPTS
BEAR CREEK DRAINAGE BASIN PLANNING STUDY

REACH	CONCEPTUAL PLANNING ALTERNATIVES EVALUATED					
	FLOOD PLAIN PRESERVATION	DETENTION		CHANNELIZATION		DIVERSION
		ON-SITE	REGIONAL	STABILIZED LOW FLOW SECTION WITH FLOODPLAIN PRESERVATION	TRAPEZOIDAL 100-YEAR SECTION	
BEAR CREEK						
1	OVERFLOW AT 8TH STREET IMPACTS PRIVATE PROPERTY. EXISTING RIPRAP CHANNEL HAS ADEQUATE CAPACITY TO CONVEY 100-YEAR DISCHARGE.	ONSITE PONDS IN THIS REACH WOULD HAVE NEGLIGIBLE AFFECT ON PEAK FLOWS.	REGIONAL DETENTION IN UPPER REACHES (4 OR 5) COULD REDUCE OVERFLOW AT 8TH STREET AND PRESSURE FLOW AT THE I-25 CULVERT. NO REGIONAL SITES AVAILABLE IN REACH 1.	EXISTING INVERT STABLE. ONE ADDITIONAL CHECK MAY ENHANCE PRESERVATION OF EXISTING INVERT VEGETATION. SOUTH BANK IN NEED OF RIPRAP TO 10-YEAR CHANNEL DEPTH.	SOUTH BANK IN NEED OF RIPRAP. RIPRAP ON NORTH BANK COULD BE SHIFTED TO SOUTH BANK FOR MORE SYMMETRIC CHANNEL SECTION. DROP AND CHANNELIZATION NEEDED AT OUTLET OF I-25 CULVERT.	NO OPPORTUNITY TO DIVERT IN THIS REACH. LOCAL DIVERSIONS IN UPPER BASIN WOULD HAVE NEGLIGIBLE IMPACT ON CHANNEL SIZE IN THIS REACH.
2	EXISTING CHANNEL CAPACITY CAUSES 100-YEAR FLOW TO SPLIT THROUGH STADIUM PARKING LOT. 100-YR FLOODPLAIN COULD IMPACT POWER LINES AND OTHER PARK FACILITIES.	ONSITE DETENTION FOR AREAS ADJACENT TO THIS REACH WOULD HAVE SMALL AFFECT ON CHANNEL SECTION(S) REQUIRED IN THIS REACH OR IN REACH 1.	SAME AS REACH 1. NO REGIONAL DETENTION SITES AVAILABLE IN THIS REACH.	EXISTING INVERT DEEP IN "OX-BOW" SOUTH OF THE EXISTING STADIUM PARKING AREA. DROP STRUCTURES REQUIRED TO REDUCE EARTHWORK ASSOCIATED WITH BANK STABILIZATION.	100-YEAR SECTION WOULD REQUIRE REMOVAL OF TREES IN THIS REACH. BENCHED SECTION MORE FEASIBLE IN THIS REACH.	DIVERSION OF 100-YEAR FLOW TO HISTORIC PATH THROUGH STADUIM PARKING AREA COULD REDUCE MAINTENANCE IN THIS REACH, HOWEVER UTILITY RELOCATION COSTS WOULD BE HIGH.
3	CHANNEL BANK WELL STABILZED BY EXISTING VEGETATION. GRADE CONTROL COULD REDUCE LOCAL BANK SLOUGHING AND DETERIORATION OF PARK FACILITIES.	SAME AS REACH 2.	REGIONAL DETENTION SITE UNAVAILABLE IN THIS REACH. DETENTION IN REACH 4 OR 5 COULD REDUCE REQUIRED ROADWAY CROSSING SIZE AT 21ST STREET. REGIONAL DETENTION UPSTREAM OF THIS REACH WILL EXTEND PERIODS OF LOW FLOW.	GRADE CONTROL AND CLEARING OF DEAD VEGETATION WOULD FURTHER STABILIZE THE LOW FLOW AREAS OF THE CREEK ADJACENT TO PARK PICNIC AREAS.	SECTION VERY IRREGULAR. TRAPEZIODAL CHANNEL CONSTRUCTION WOULD REQUIRE REMOVAL OF LARGE TREES AND WILLOWS WHICH NOW ACT TO PREVENT BANK SLOUGHING.	SAME AS REACH 1
4	NO STRUCTURES ARE CURRENTLY ADVERSELY IMPACTED BY 100-YEAR FLOOD PLAIN.	AREAS TRIBUTARY TO THIS REACH NOT SUBJECT TO EXTENSIVE DEVELOPMENT. ON-SITE POND WOULD HAVE LIMITED IMPACT ON MAJOR DRAINAGEWAY FLOW RATES.	POTENTIAL SITE UPSTREAM OF 21ST STREET. CONSTRUCTION OF POND WOULD REQUIRE REMOVAL OF OVERGROWTH AND LARGE TREES WITHIN DETENTION BASIN.	GRADE STABILIZATION AT OUTFALLS STORM SEWERS AND SIDE DRAINAGES INTO BEAR CREEK DROP AND CHECK STRUCTURES WOULD STABILIZE AREAS.	PINELLO PROPERTY LIMITS POSSIBILITY OF CONTIGUOUS CHANNEL IMPROVEMENTS THROUGH REACH 4, UNLESS THE PROPERTY IS DEVELOPED.	SAME AS REACH 1
5	100-YEAR FLOODPLAIN OVERTOPS BEAR CREEK ROAD. LOSS OF ROAD AND PRIVATE BRIDGES POSSIBLE. SEVERAL SINGLE-FAMILY RESIDENCES IMPACTED BY FLOOD PLAIN.	SAME AS REACH 4	DETENTION TO DECREASE PEAK 100-YEAR FLOW TO MEET EXISTING CHANNEL CAPACITY WOULD HAVE TO BE SITED WITHIN NATIONAL FOREST. NO SITES CAPABLE OF STORING SUFFICIENT VOLUME OF RUNOFF TO DECREASE FLOW IN DOWNSTREAM REACHES.	INVERT IN ITS EXISTING CONDITION IS STABLE. OVERGROWTH COULD BE CLEARED TO GAIN ADDITIONAL CHANNEL CAPACITY. ROAD SURFACE COULD ALSO BE RAISED.	DRAINAGEWAY TO NARROW FOR THE CONSTRUCTION OF 100-YEAR RIPRAP CHANNEL. LINING OF BANK ALONG ROAD SUGGESTED TO PROTECT ROADWAY EMBANKMENT IN THIS REACH.	SAME AS REACH 1. GOLD CAMP ROAD DIVERSION WILL NOT ADVERSELY AFFECT THE MAJOR DRAINAGEWAY RECEIVING THE DIVERTED RUNOFF.

TABLE 8: MATRIX OF ALTERNATIVE DRAINAGE CONCEPTS
BEAR CREEK DRAINAGE BASIN PLANNING STUDY

REACH	FLOOD PLAIN PRESERVATION	CONCEPTUAL PLANNING ALTERNATIVES EVALUATED				
		DETENTION		CHANNELIZATION		DIVERSION
		ON-SITE	REGIONAL	STABILIZED LOW FLOW SECTION WITH FLOODPLAIN PRESERVATION	TRAPEZOIDAL 100-YEAR SECTION	
CONSTELLATION GULCH						
6	FLOOD PLAIN NARROW AND NOT IMPACTING ANY RESIDENTIAL STRUCTURES.	ONSITE DETENTION WOULD HAVE LITTLE IMPACT ON FLOOD PLAIN REDUCTION IN THIS REACH, OR ALONG BEAR CREEK.	NO SITES AVAILABLE IN UPPER AREAS OF GULCH.	INVERT NEEDS STABILIZATION USING DROPS AND/OR CHECKS DOWNSTREAM OF CRESTA DRIVE. PIPED SYSTEM ALSO FEASIBLE BETWEEN CRESTA AND PARKVIEW.	SELECTIVE BANK LINING IS SUFFICIENT IN THIS REACH, UP TO THE 10-YEAR WATER DEPTH, MINIMUM. 100-YEAR LININGS NEEDED AT BENDS.	NO UPSTREAM DIVERSION OF FLOWS TRIBUTARY TO THE GULCH IS PRACTICAL.
7	SHALLOW FLOODING ALONG CONSTELLATION DRIVE IS UNCONFINED. MANY HOUSES HAVE BEEN CONSTRUCTED BELOW STREET GRADE.	ONSITE DETENTION WOULD HAVE TO BE SITED IN UPPER AREAS ADJACENT TO ROADWAYS. MAINTENANCE OF ONSITE DETENTION AREAS WOULD BE INTENSIVE BECAUSE OF ERODABLE SOILS ALONG DRAINAGE PATHS.	NO SITES AVAILABLE IN THIS REACH.	STABILIZATION IN UPPER BASINS WOULD LESSEN SEDIMENTATION IMPACTS TO RESIDENTIAL AREAS AND PROTECT RECEIVING DRAINAGEWAYS.	RIPRAP LINING OF BANKS IMPRACTICAL WITHIN UPPER REACH. STORM SEWER WITHIN CONSTELLATION DRIVE COULD MITIGATE LOCAL DRAINAGE PROBLEMS.	SAME AS REACH 6.
SCORPIO GULCH						
8	SHALLOW FLOODING WITHIN RESIDENTIAL AREAS UNCONFINED AND HARD TO CONTROL.	ONSITE DETENTION WOULD HAVE MINIMAL IMPACT UPON FLOW REDUCTION TO DOWNSTREAM REACHES. EXISTING PONDS THIS REACH ARE CURRENTLY SILTED IN AND NOT FUNCTIONING PROPERLY.	NO SITES AVAILABLE WITHIN THIS REACH.	SAME AS REACH 7.	RIPRAP LINING WIHTIN STEEP SECTIONS OF SCORPIO GULCH WOULD BE IMPRACTICAL BECAUSE OF POOR CONSTRUCTION ACCESS AND ASSOCIATED DISTURBANCES TO ERODABLE SOILS.	DIVERSION OF GOLD CAMP ROAD BASIN FLOWS WOULD DECREASE SIZE OF CONVEYANCES IN SCORPIO GULCH.
ORION DRIVE BASIN/GRADINER GULCH BASIN						
9-11	FLOODPLAINS IN THIS REACH RELATIVELY NARROW AND SHALLOW AND CONTAINED WITHIN PLATTED PRESERVATION EASMENTS.	ONSITE DETENTION SUBJECT TO HIGH MAINTENANCE AND WOULD HAVE SMALL IMPACT UPON DECREASING PEAK FLOWS TO DOWNSTREAM AREAS.	NO SITES AVAILABLE WITHIN THIS REACH. EXISTING PONDS HAVE LITTLE IMPACT ON DOWNSTREAM FLOWS, HOWEVER THEY DO PROVIDE SOME EROSION AND SEDIMENT CONTROL.	ORION DRIVE STORM SEWER WILL REDUCE THE NEED FOR CHANNEL STABILIZATION IN THE LOWER SEGMENT OF THIS REACH. STABILIZATION OF UPPER REACH WILL REDUCE SEDIMENTATION NOW IMPACTING	SAME AS REACH 8. FORMAL CHANNEL LININGS NOT CONSISTENT WITH SHAPE OF USE INTENDED FOR PRESEVATION ADJACENT TO DEVELOPED AREAS.	SAME AS REACH 8 DEEP GULCHES AND RAVINES MAKES DIVERSION IMPRACTICAL.

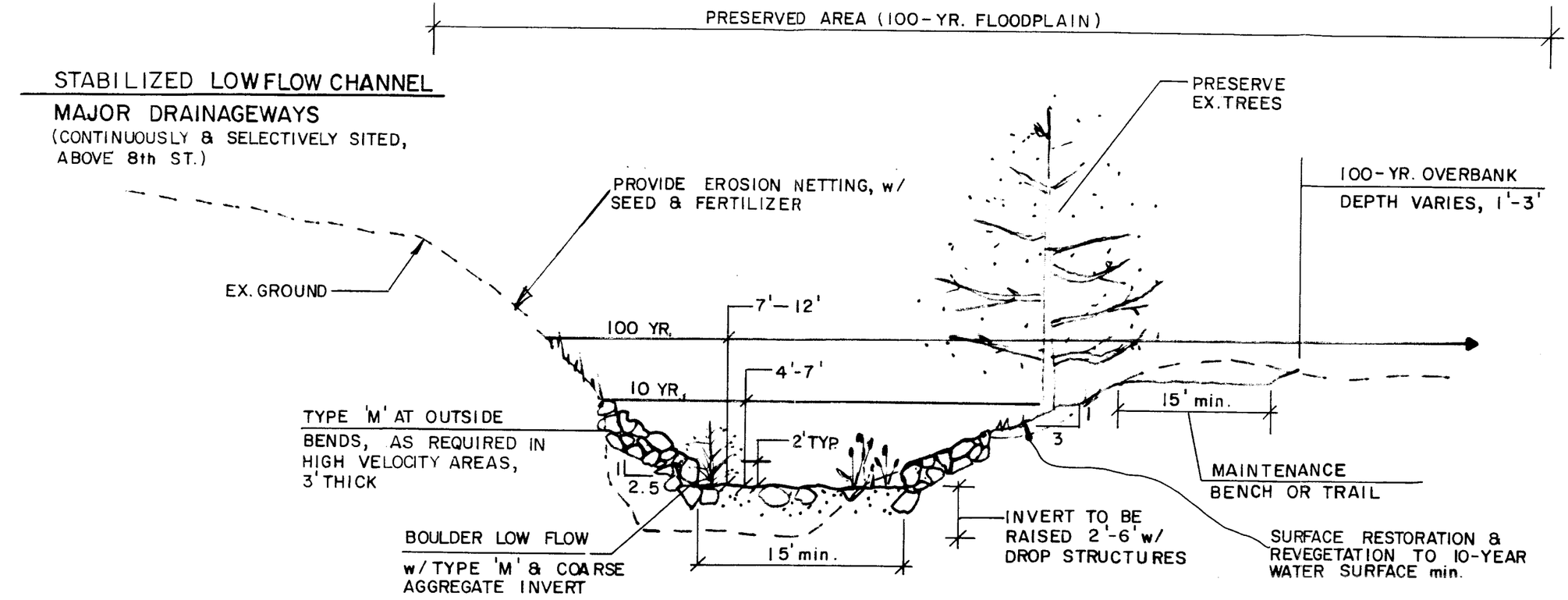
TABLE 8: MATRIX OF ALTERNATIVE DRAINAGE CONCEPTS
BEAR CREEK DRAINAGE BASIN PLANNING STUDY

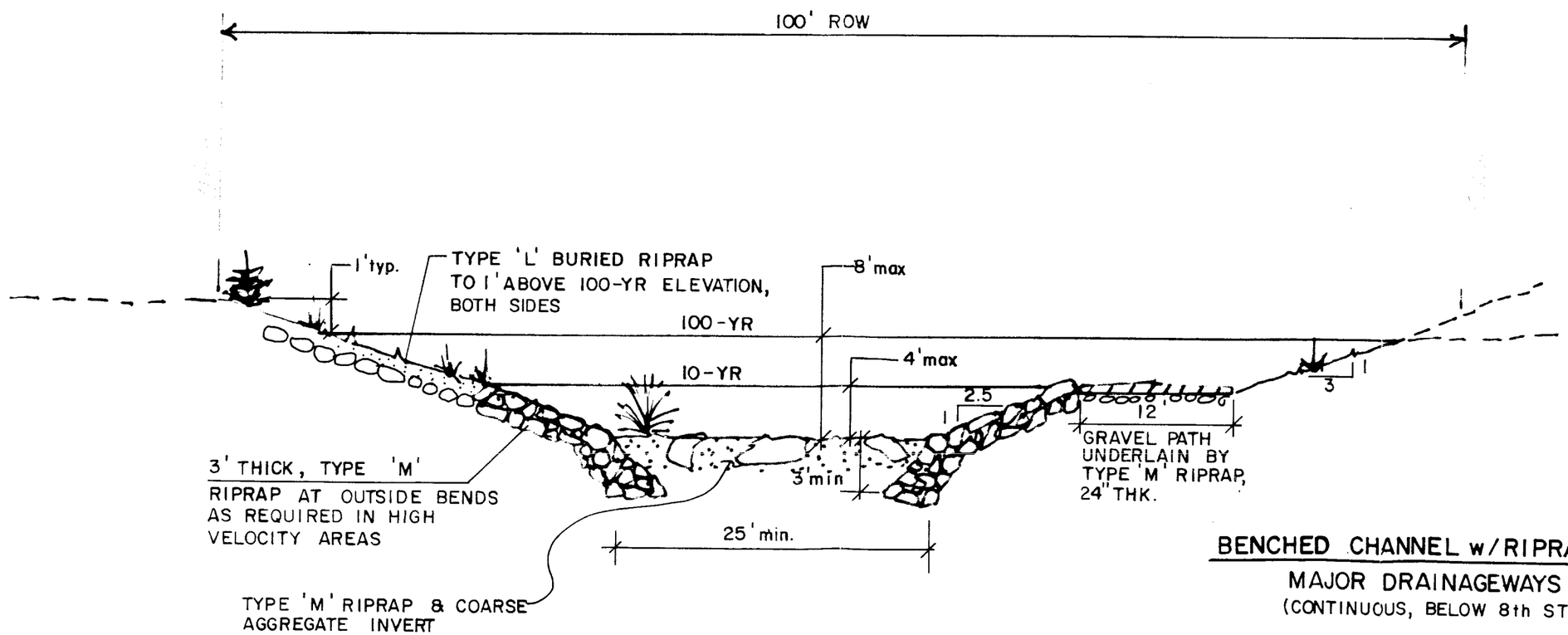
REACH	FLOOD PLAIN PRESERVATION	CONCEPTUAL PLANNING ALTERNATIVES EVALUATED: DETENTION ON-SITE	DETENTION REGIONAL	CHANNELIZATION STABILIZED LOW FLOW SECTION WITH FLOODPLAIN PRESERVATION	CHANNELIZATION TRAPEZOIDAL 100-YEAR SECTION	DIVERSION
				PRIVATE RESIDENCES.		
SKYWAY GULCH						
12	FLOOD PLAIN UNDEFINED WITHIN THIS REACH.	NO SITES AVAILABLE IN THIS REACH.	NO SITES AVAILABLE IN THIS REACH.	STABILIZATION IN UPPER REACH WILL REDUCE SEDIMENTATION NOW EFFECTING PRIVATE RESIDENCES.	TRAPEZOIDAL SECTION FEASIBLE BELOW ORION DRIVE AND ABOVE BEAR CREEK PARK. TRAPEZOIDAL SECTION WOULD NOT BE PRACTICAL THROUGH PARK SINCE LIMITED STRUCTURES ARE IMPACTED BY FLOODING.	DIVERSION OF GOLD CAMP ROAD FLOW ABOVE SKYWAY GULCH BASIN WOULD HAVE POSITIVE IMPACT IN THIS REACH.
GOLD CAMP ROAD BASIN						
13	SAME AS REACH 12.	HILLSIDES LIMIT THE SITING OF SMALL DETENTION PONDS.	NO SITES AVAILABLE IN THIS REACH WHICH COULD REDUCE PEAK DISCHARGES TO DOWNSTREAM REACHES.	ROADSIDE DITCHES ALONG WEST SIDE OF GOLD CAMP ROAD WILL REDUCE POSSIBILITIES OF FLOW MOVING ACROSS GOLD CAMP ROAD.	SELECTIVE RIPRAPPING OF ROADSIDE DITCHES PRACTICAL IN SEGMENTS WHICH ARE STEEP.	DIVERSION OF FLOWS ALONG GOLD CAMP ROAD MAY REDUCE SIZES OF DRAINAGE CONVEYANCES WITHIN REACHES 8 THROUGH 12.

STABILIZED LOW FLOW CHANNEL

MAJOR DRAINAGEWAYS

(CONTINUOUSLY & SELECTIVELY SITED, ABOVE 8th ST.)





BENCHED CHANNEL w/ RIPRAP LOWFLOW

MAJOR DRAINAGEWAYS

(CONTINUOUS, BELOW 8th ST.)

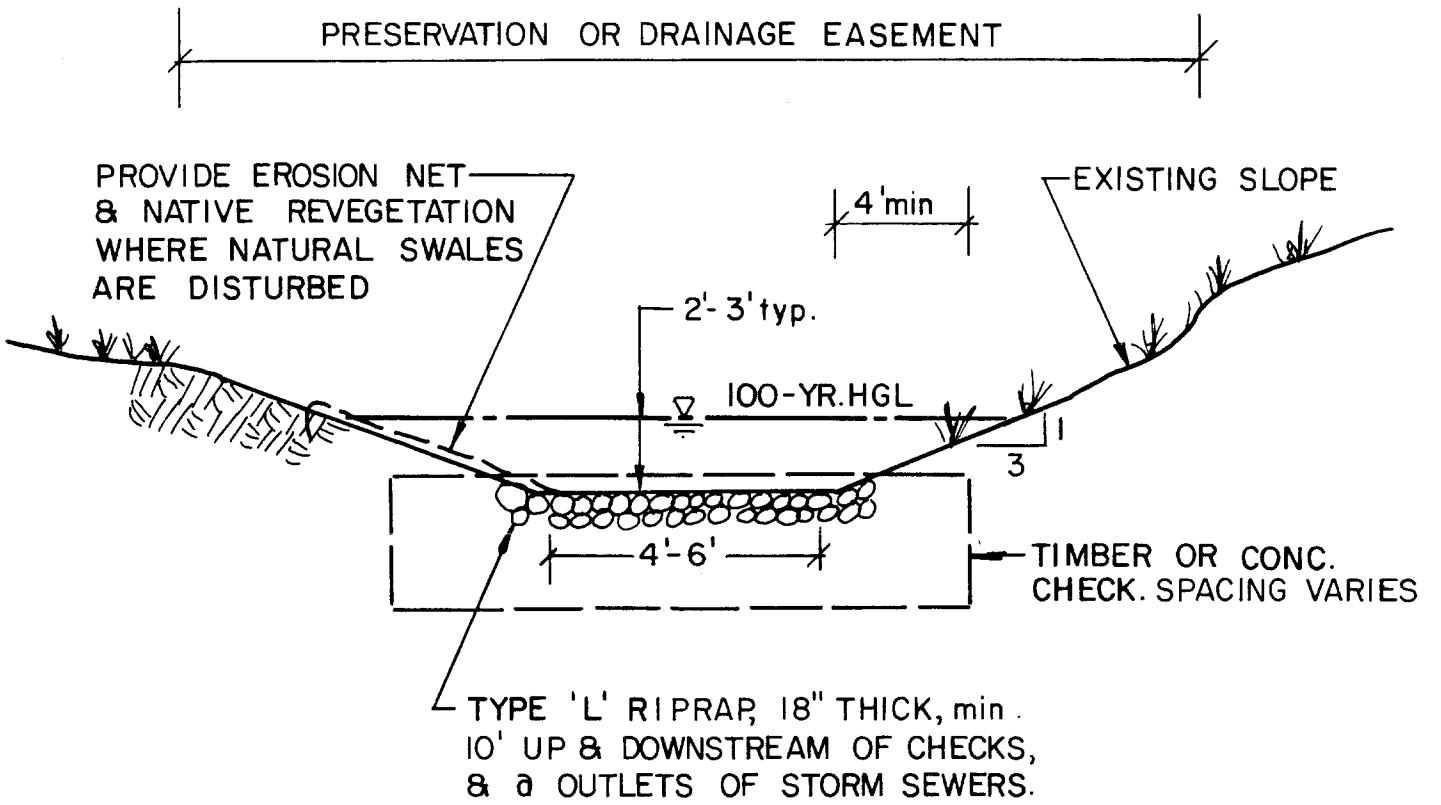
Kiowa Engineering Corporation
419 W. Bijou Street
Colorado Springs, Colorado
80905-1308

BEAR CREEK DRAINAGE BASIN PLANNING STUDY

ALTERNATE CHANNEL SECTIONS

Project No.	88.12.26
Date:	10/89
Design:	RNW
Drawn:	RNW
Check:	RNW
Revisions:	

FIG. 12



THIS SECTION TO BE USED WITHIN THE PRIVATELY MAINTAINED PRESERVATION EASEMENTS.

TYPICAL SECTION
REACHES 7-12

FIGURE 13

selection of the stabilized section shown on Figure 13 has been based primarily on the need to protect the flow invert where highly erosive soils exist. Checks and riprap can provide this type of stabilization, and thereby reduce the occurrence of bank failures which destroy the scrub-juniper vegetation. Storm sewers within Constellation Drive and within the Gardiner Gulch flow path will be further refined in the preliminary design phase.

The selection of the channel sections within Reaches 1 through 5 was primarily driven by the need to provide better maintenance access, and to minimize the construction and flow impacts upon the existing park riparian areas to the greatest practical extent. Maintenance access to these reaches of Bear Creek can be provided by the existing trail system, or at selective locations along the drainageway near a specific structure such as a culvert or drop structure. At many locations within Bear Creek Regional Park, access to the low flow area of Bear Creek is adequate without the introduction of a formal maintenance trail. Segments with adequate maintenance access would be maintained by the City. Channel grade control structures will be needed in combination with either the benched or stabilized flow section in order to restore the invert to a higher elevation. This will reduce the amount of bank regrading and improve the visual appearance of the stream, and enhance the maintenance and recreational access to the base flow area of the Creek. Above design point 42, the channel is natural, generally stable and in little need of maintenance at this time. Maintenance at culverts after high flow events may be required to clear vegetation which might accumulate because of high flows.

Detention Facilities: On site facilities have been constructed in the Skyway Heights and Top of Skyway Subdivisions. In general, these ponds are ineffectual in reducing peak discharges to the downstream areas because of their small volume, and in general, are mostly filled with sediment. For these reasons, the establishment of additional on-site storage areas

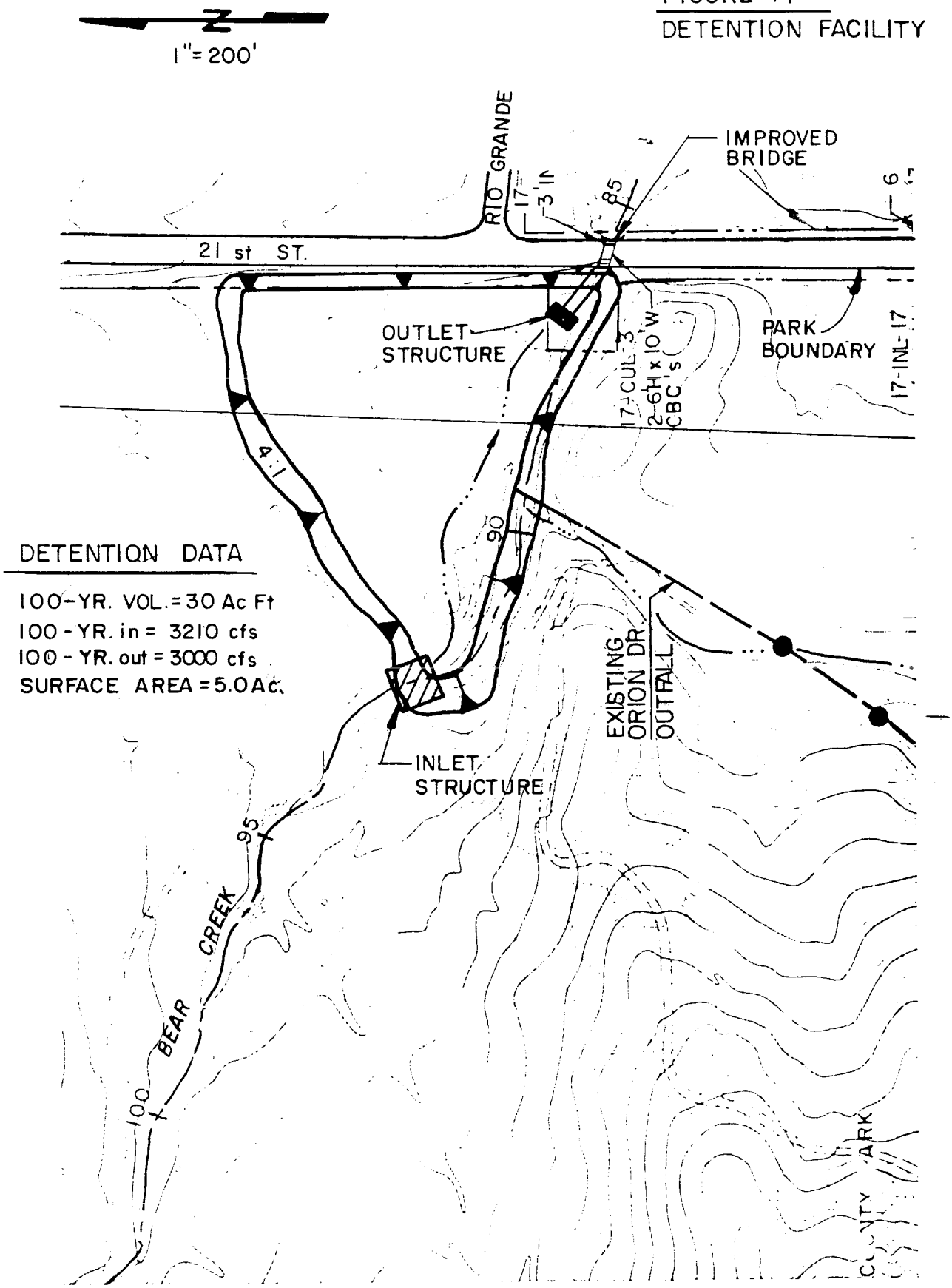
was not considered to be advantageous for future drainage planning within Reaches 6 through 13.

Regional detention is physically possible in Reach 4 of Bear Creek. A detention site with a storage capacity of approximately five acre-feet was identified upstream of 21st Street within Bear Creek Regional Park. This facility was sized to reduce the 100-year flow rate so that the road crossings at 8th and 21st Streets could be made smaller, and so that peak discharges could be maintained at existing (current) basin conditions. This concept is of marginal importance, since both the 8th and 21st Streets roadway crossings would still need replacement in order to reduce backwater effects, and to accommodate trail crossings within the bridge opening. Detention ponding will have no effect on reducing the low flows which cause the majority of the bank and invert degradation, which presently occurs at many locations along Bear Creek. Additionally, disturbance to the existing riparian areas within the proposed detention facility would be significant. Regional detention is not viewed as a benefit to the overall Bear Creek drainage plan. The conceptual layout of the proposed detention facility is presented on Figure 14.

Letter of Permission Submittal Summary

A Letter of Permission (LOP), submittal was made to the U.S. Army Corps of Engineers as part of the basin planning process. The LOP is a process whereby certain catagories of routine drainageway construction and maintenance activities can be generally permitted without the need for an individual 404 permit, as long as the activity has been identified in the drainage basin planning study. Contained within Volume III of this report is the LOP submittal documents along with relevant coordination received by the Corps and the City during the LOP review process. At this time a list of catagories has not been received by the City pertaining to the Bear Creek basin.

FIGURE 14
DETENTION FACILITY



VI. PRELIMINARY DESIGN

The results of the preliminary design analysis are summarized in this section. The alternative improvements have been quantitatively and qualitatively evaluated, and presented to the City of Colorado Springs and other interested agencies and individuals. Field review of specific areas of concern have been conducted in order to refine the channel treatments suggested for use along Bear Creek and its major tributaries. The preliminary plan for the preferred alternative is shown on the drawings contained within Appendix A of this report.

Criteria

The City of Colorado Springs, El Paso County Drainage Criteria Manual was used in the development of the typical sections and plans for the major drainageways within the Bear Creek Basin. The City/County manual was supplemented by various criteria manuals with more specific application. These were:

1. Hydraulic Engineering Circular 15 (HEC-15), Design of Flexible Linings for Roadside Channels, prepared by the Federal Highway Administration, 1987.
2. "Design Guidelines and Criteria for Channels and Hydraulic Structures on Sandy Soils," prepared by Simons, Li & Associates, Inc., 1981.
3. "Arapahoe County Erosion Control Manual," prepared by Kiowa Engineering Corporation, 1989.

Various design plans and subdivision reports were used to better locate drainage facilities within the basin. Design plans for the 8th Street and the 21st Street improvement projects have also been incorporated into the plans.

Hydrology

Presented on Table 9 is the selected hydrologic data to be used for the sizing of local and major drainageway improvements. The sizing of local systems should be verified using the methods outlined in the City/County Drainage Criteria Manual during final designing analyses. The rational method should be used to check

TABLE 9: SUMMARY OF PEAK FLOW RATES
SELECTED PRELIMINARY DESIGN PLAN
BEAR CREEK DRAINAGE BASIN PLANNING STUDY

DESIGN POINT	LOCATION	DRAINAGE AREA (SQ. MI.)	100-YEAR DISCHARGE (CFS) (1)	10-YEAR DISCHARGE (CFS) (1)
1	FOUNTAIN CREEK	10.71	4540	1460
4	8TH STREET	10.57	4390	1340
5		10.39	4260	1250
7	CONSTELLATION GULCH & BEAR CREEK	10.33	4200	1200
9		9.58	3670	950
10		9.34	3570	890
11		9.25	3510	850
14	CONSTELLATION GULCH & CRESTA DRIVE	0.46	340	100
15		0.35	220	70
18	21ST STREET	8.87	3210	690
19		8.91	3250	720
21		8.23	2740	490
23	ORION DRIVE NORTH	0.47	660	250
24	ORION DRIVE SOUTH	0.18	270	100
25		0.2	280	100
30		0.14	140	50
35	BEAR CREEK NATURE CENTER	7.7	2740	450
38		7.51	2720	430
40		0.59	580	240
42	UPPER BASIN OUTFALL	6.83	2410	380
43	OUTLET OF CONSTELLATION GULCH	0.72	800	350

NOTES: (1) 24-HOUR DURATION STORM, ANTECEDENT MOISTURE CONDITION II. 24-HOUR STORM SELECTED FOR USE IN THE BEAR CREEK BASIN FOR PLANNING AND DESIGN OF FACILITIES HAS BEEN DEVELOPED. ASSUMING FUTURE DEVELOPMENT CONDITIONS.

(2) HYDROLOGY RECOMMENDED IN THIS REPORT IS FOR PLANNING PURPOSES ONLY. PEAK DISCHARGES MUST BE VERIFIED DURING THE FINAL DESIGN OF STORM DRAINAGE FACILITIES WITHIN THE THE BEAR CREEK BASIN.

(3) FOR SUB-BASIN DATA REFER TO TABLE 6 AND VOLUME II OF THIS REPORT.

the peak flow rates presented on Table 9 for all tributary areas less than 100 acres in size.

Channels

In general, selective riprap banks and invert improvements are recommended along the main Bear Creek drainageway. Below 8th Street a trapezoidal riprap section has been selected with drop structures to stabilize the invert at a higher elevation. Between 8th Street and 21st Street, a "stabilized" section has been selected. Riprap low flow areas should be provided to protect the adjacent land from damages due to bank sloughing during a 10-year frequency event. Trickle channels should be constructed to present erosion caused by the stream's base flow. Drop structures have been specified to selectively raise the invert from three- to six-feet in order to enhance the visual impact of the creek through the park area. Construction of bank and invert improvements should be conducted so as to maintain the existing vegetation and channel cross-section as much as possible. Above 21st Street only limited bank improvements have been identified, in combination with the construction of check structures across the existing low flow areas. The existing channel is well vegetated and stable except at confluences with side drainages. West of the Bear Creek Nature Center, riprap lining and channel clearing is recommended to increase the channel capacity and protect the roadway from being damaged in a 100-year event. The banks adjacent to private bridges should be protected using riprap lining on the approach and downstream banks. More analysis is required in this area of Bear Creek in order to better define the extent of the floodplain and the location of riprap bank linings.

A riprap stabilized channel section with drop structures has been recommended for Constellation Gulch below Cresta Road. Should the land adjacent to the gulch upstream of Parkview Boulevard be developed, a 100-year capacity storm sewer would be required within the platted roadway (Capricorn Court). Temporary stabilization at the outlet of the existing drainage structure at

21st Street should be considered in order to slow the degradation at the invert. Above Cresta Drive, storm sewer systems has been proposed to collect runoff within Constellation Drive and Parkview Boulevard.

Within the existing residential areas below Gold Camp Road (Skyway and Top of Skyway), channel check structures and localized channel riprap protection have been specified, particularly in the vicinity of Electra Drive. Outlet structures have been suggested in order to limit scouring at the outlets of culverts. A typical outlet detail is presented in the preliminary design drawings. In general, timber check structures should be constructed across the low flow area of the natural drainage paths downstream of each storm sewer or side drainage outfall point. The timber checks have been designed to be installed and maintained by the private land owners. Any area disturbed by home or road building activities adjacent to a drainage path should be immediately stabilized using erosion control methods suitable to the soils and vegetation at a particular site. Checks should be required for all future development in this area.

A stabilized roadside channel has been suggested for the Gold Camp Road basin. The channel section will vary from grasslined to riprap-lined trapezoidal sections, depending upon the slope of the adjacent roadway. Concrete checks should be constructed downstream of inflow points, and at 400-foot intervals for all segments with slopes exceeding two percent. Erosion netting should be used initially in all grasslined or buried riprap sections to further stabilize the roadside channel while vegetation is being established.

Since the predominant soil in the upper Gardiner Gulch, Scorpio, and Constellation Gulch basins is highly erodible, the natural swales and ravines will be greatly affected by point discharges. The erosion caused by a point discharge will eventually be deposited along the "preservation areas", and may cause damage to private landscaping of homes abutting such easements. It is suggested that the local homeowners' group(s)

collectively fund the construction of the localized checks sited on the plans. Erosion control measures should be required during the construction of homes abutting the preservation easements, no matter how small the disturbance. Since no easement exists for the City to access to the natural ravines and swales, maintenance of checks and natural vegetation by the homeowner (or homeowners' association) is a critical need so that the degradation of these preserved areas do not negatively affect private property in the area. Access easements should be obtained for City access to the outlet of roadway culverts and detention areas.

For the forest areas above Bear Creek Road (i.e., the Upper Bear Creek Basin), no improvements have been suggested. During the field inventory process, the natural drainageway is relatively stable and not in need of substantial modification. Wherever culverts are replaced along the roadway through Bear Creek Canyon Park, a riprap stabilization at the outlets is suggested so that the natural vegetation is not negatively impacted. Bank improvements, where required, should be constructed using rock and vegetation indigenous of this area.

Drop Structures and Check Structures

Drop structures have been sited along Bear Creek and Constellation Gulch, in order to slow the channel velocity, reduce the physical depth of the channel invert where degradation has occurred, and to protect the channel from headcutting over a long period of time. Through the park areas, drops have been sited where the most severe invert degradation has occurred. The drop height has been limited to three-feet maximum. In some cases, the construction of a drop(s) in combination with localized riprap bank and low flow improvements may be sufficient to stabilize the channel for a considerable distance upstream of the drop(s).

Check structures have been specified along the major drainageways. The check structures will act to maintain the current invert upstream of the checks. Over time this will help to prevent bank sloughing due to invert degradation, and will