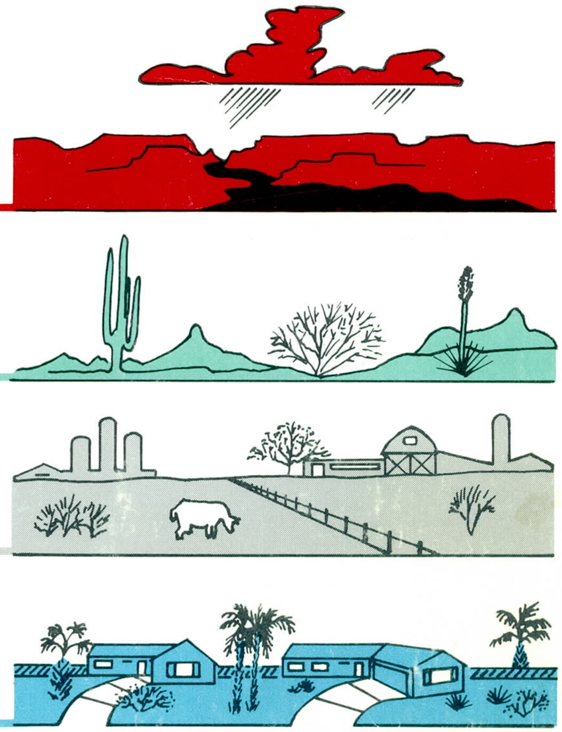

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

SPOOK HILL AREA DRAINAGE MASTER STUDY

(Master Drainage Plan for the Spook Hill FRS Watershed, Phase 1)

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

FLOOD CONTROL DISTRICT
of
Maricopa County

3335 West Durango Street • Phoenix, Arizona 85009
Telephone (602) 262-1501

D. E. Sagramoso, P.E., Chief Engineer and General Manager

JUL 13 1987

RE: **Spook Hill Area Drainage Master Study (ADMS)**

The attached report is the culmination of the initial phase of the **Spook Hill Area Drainage Master Study (ADMS)**, a study sponsored equally by the District, Maricopa County Highway Department, and the City of Mesa. The **ADMS** was performed by Parsons Brinckerhoff, Consulting Engineers, under contract to the District.

This **ADMS** evaluated existing and possible future hydrologic conditions in a 16-square mile area for purposes of defining area hydrology and providing a database framework for that area. This report summarizes hydrologic and related data and is to be used for information and as input for regulation. In the course of conducting the ADMS, a 100-year stormwater drainage system was considered as a potential **Area Drainage Master Plan (ADMP)**. That concept is described in this report.

NOTE THAT THE **ADMP** HAS NOT YET BEEN ADOPTED. HOWEVER, MUCH OF THE CONCEPT IS SUPPORTED BY BOTH THE DISTRICT AND THE CITY OF MESA. Users of this report should be alert for updates.

Questions may be addressed to me or Ms. Kebba Buckley, at the District, 262-1501, or to Mr. Keith Nath at the City of Mesa, 834-2512.

DESagramoso

D.E. Sagramoso, P.E.

SPOOK HILL AREA
DRAINAGE MASTER STUDY

(MASTER DRAINAGE PLAN FOR THE SPOOK HILL FRS WATERSHED, PHASE I)

February 1987

Submitted to

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
CITY OF MESA
MARICOPA COUNTY HIGHWAY DEPARTMENT

Submitted by

PARSONS BRINCKERHOFF QUADE & DOUGLAS, INC.
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Registered Professional Engineer (Civil)
CERTIFICATE
8976
B. R.
JOLLY
DATE SIGNED 1-31-87
Arizona U. S. A.

in Association with

SKIBITZKE & ASSOCIATES

Performed under Contract FCD 84-25

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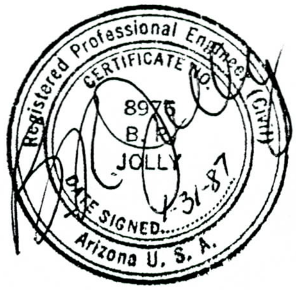

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PLANS AND PROFILES

I. INTRODUCTION

AREA DRAINAGE MASTER STUDY PROGRAM

This study, the Spook Hill Area Drainage Master Study (ADMS), began under the title of "Spook Hill FRS Watershed Master Drainage Plan." This study and the Eastern Maricopa County Drainage Master Plan, now known as the Eastern Maricopa County Area Drainage Master Study (ADMS), were prototype studies for what has evolved into the Flood Control District of Maricopa County Area Drainage Master Study Program [1]. Both of these studies began in August, 1984 and were cosponsored by the City of Mesa and the Maricopa County Highway Department, with the Flood Control District as the contracting agency.

PURPOSE

The purpose of this study is to develop a Master Plan for stormwater drainage within the watershed of the Spook Hill and Signal Butte features of the Buckhorn - Mesa Watershed Protection Project. The Buckhorn - Mesa structures were planned by the Soil Conservation Service (SCS) to provide 100-year flood protection to areas in eastern Mesa downstream from the structures. However, no flood protective measures were planned for the watershed area. Recent stormwater damages to existing properties and the strong potential for new development in the watershed point to a need for an integrated stormwater drainage plan within the watershed.

There are two major objectives of the study. The first is to develop a plan to control runoff to prevent flood damage within the watershed. The second is to manage the potential increase in runoff due to development in order to preserve the ability of the Buckhorn - Mesa Project to provide protection to lands downstream from future 100-year floods.

A significant feature of the study is consideration of the entire watershed as a unit irrespective of the jurisdictional boundaries. This allows implementation of drainage measures across the entire hydrologic unit without interruption of continuity by variation of codes and methods of stormwater management.

DEFINITION OF STUDY AREA

The area of study for the Spook Hill Area Drainage Master Study is comprised of the portions of the Buckhorn - Mesa Watershed Project drainage area which are directly tributary to the Spook Hill Floodway, Spook Hill FRS and the Signal Butte Floodway, shown in Figure 1. These three SCS flood control projects form the downstream boundary of the watershed and are the westerly and southerly limits of the study area. The northerly boundary lies along the crest of the Usery Mountains and crosses the saddle of Usery Pass. The easterly boundary follows the crest of Pass Mountain for a short distance, then lies along the westerly boundary of the Pass Mountain Diversion Watershed (SCS) to McKellips Road. The study area also contains an east "spur" bounded on the north by the Pass Mountain Diversion (proposed) and on the east by the Signal Butte FRS embankment. The total area is approximately 16 square miles.

HISTORY

The Spook Hill FRS Watershed lies in the Gila River Drainage Basin. Historically, flood flows from the Usery and Goldfield Mountains discharged onto the relatively flat slopes of the desert floor of the Eastern Salt River Valley. These flows spread across the desert valley in ill-defined washes or sheet flow areas. Runoff from small storms dissipated in the desert. Flows of larger magnitude collected into the swale later to become known as the Gila Drain, then followed the historic bed of Queen Creek and joined the Gila River near present-day St. Johns on the Gila River Indian Reservation.

As agricultural lands were developed in the East Valley, the majority of historic washes were leveled and raised irrigation canals were built. Flood flows then became a source of damage through breach of canals, erosion and sedimentation.

In 1963 the Buckhorn - Mesa Watershed Protection Project[2] was authorized by Congress as a SCS project to develop flood control and land treatment measures to curb damages to agricultural and urban land uses. The study area at that time was very sparsely populated desert. The principal thrust of the Buckhorn - Mesa Project was the protection of lands downstream of the Spook Hill and Signal Butte flood control structures. The concept of flood control which evolved was to build a series of

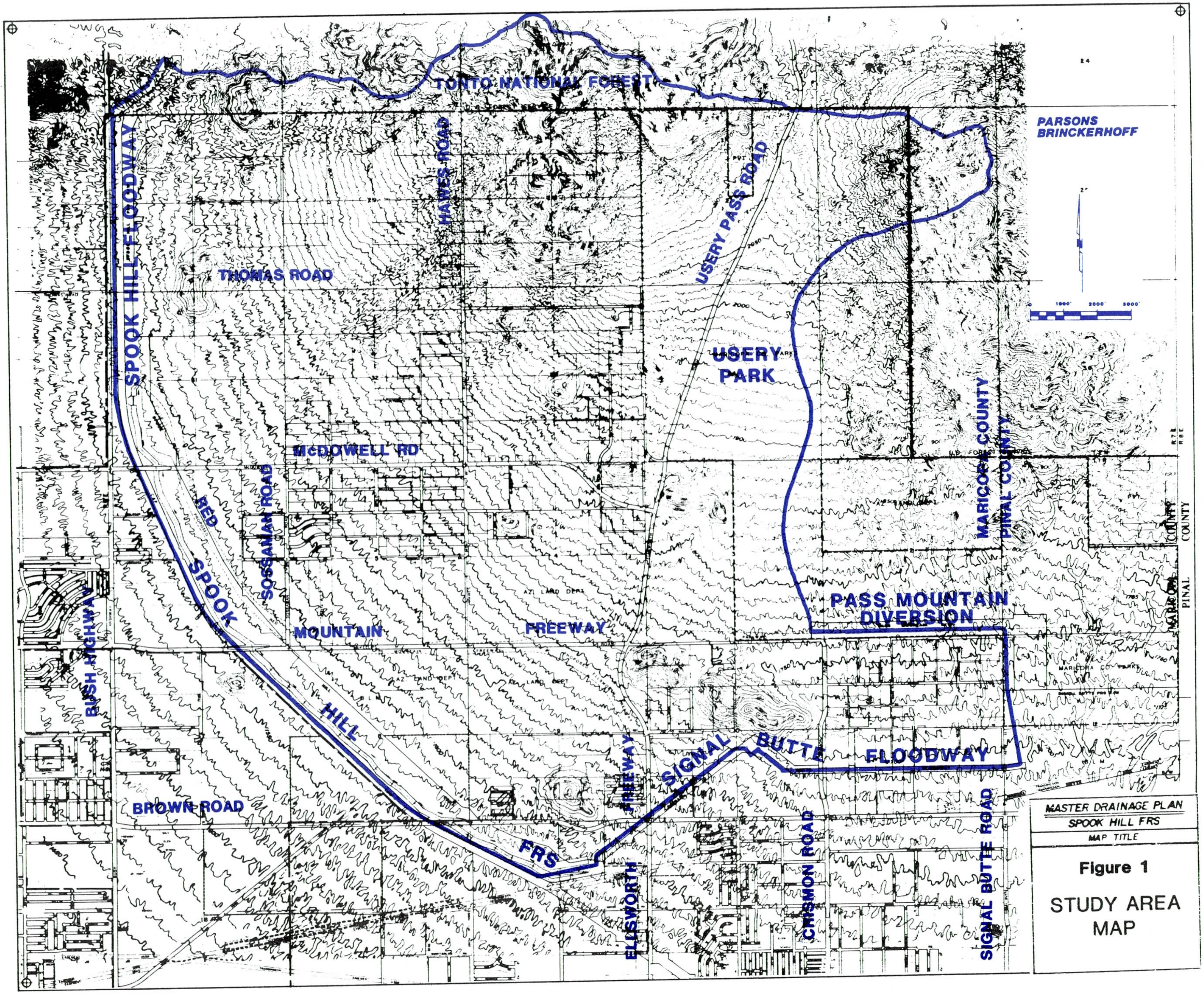


Figure 1

STUDY AREA MAP

structures which would retard flood flows from the mountainous areas of the watershed and divert the reduced outflow into the Salt River at Granite Reef Dam. Projections available at the time the Buckhorn-Mesa Watershed Plan was developed showed minimal low-density development expected above the Spook Hill FRS and Floodway and the Signal Butte Floodway.

Spook Hill FRS and Floodway were completed in 1979 and the Signal Butte Floodway was completed in 1985. Pass Mountain Diversion and Signal Butte FRS are currently under construction.

AREA DRAINAGE NEEDS

The recent upturn in the economy has fed urban expansion in the East Valley. With this surge comes the overwhelming likelihood of urban development in the study area in the immediate future. The sponsors of the Spook Hill Area Drainage Master Study have perceived the need to protect the urbanizing lands within the study area and simultaneously preclude any increase in storm runoff into the Buckhorn - Mesa flood control structures. The initiation of this study in August, 1984 allows these needs to be addressed in a timely manner.

In order to meet the two major objectives of the study, a master drainage plan must contain measures which provide for the following needs:

1. Control of runoff on the Spook Hill and Signal Butte watersheds in such a way as to limit runoff under fully developed watershed conditions to those design flows developed by SCS, or provision for modifications to the existing flood control structures to provide capacity to contain any increase in the future 100-year flood.

2. Mitigation of flood damages to existing residential areas.

3. Planning for drainage to meet the needs of future development.

4. Managing the discharge of sediment.

II. MASTER DRAINAGE PLAN SUMMARY

The watershed of Spook Hill FRS is somewhat unique among urbanizing areas in Maricopa County. Storm runoff from the Usery Mountains and surrounding alluvial fan is much more rapid than from the nearly-level valley floor which contains most of the urbanized land in the Phoenix metropolitan area. This rapid runoff also carries large amounts of sediment eroded from the upper reaches of the alluvial fan. Planning for control of storm runoff in the alluvial fan environment requires careful attention to both high peak flows and the high sediment load. Further, the effective implementation of a drainage plan within the process of urban development requires a sound administrative policy by which to govern engineering and construction.

The Spook Hill Area Drainage Master Plan presented in this report conforms very closely to the current City of Mesa drainage requirements in the Mesa City Code [3]. The Code requires that storage for the total volume of runoff from a 50-year 24-hour storm, effectively 2 to 3 inches of precipitation, be provided within each new subdivision and detained for a period of up to 36 hours. This is defined by the City of Mesa as "retention". This terminology has been adopted for the text of this report to differentiate the operation of these basins from "detention" as defined by other agencies within Maricopa County. The Master Drainage Plan, Figure 2, includes a series of retention basins for approximately each 160 acres of developed or developable land. The basins are sized to store the entire runoff from a 100-year 2-hour storm, or 3.08 inches of rainfall. Each basin discharges to a drainage pipe or channel which outfalls to the Spook Hill FRS, the Spook Hill Floodway or the Signal Butte Floodway. The basins are intended to completely drain within a 36-hour period. To manage the sediment load and preclude clogging of discharge pipes, each basin is designed to capture the sediment carried by sheet flooding and in collector channels. The discharge pipes will not be allowed to carry any sediment load from the basins, providing for a relatively maintenance-free operation. In the event that development precedes implementation of the Master Drainage Plan, onsite retention, designed by the developer in accordance with the Mesa City Code, may be allowed with corresponding adjustments applied to the Master Drainage Plan.

Within U.S. Forest Service and Maricopa County Parks Department lands, it is not permissible to build an array of retention basins. To control runoff from these public lands, a diversion dike along the west Usery Mountain Park boundary and a small dam

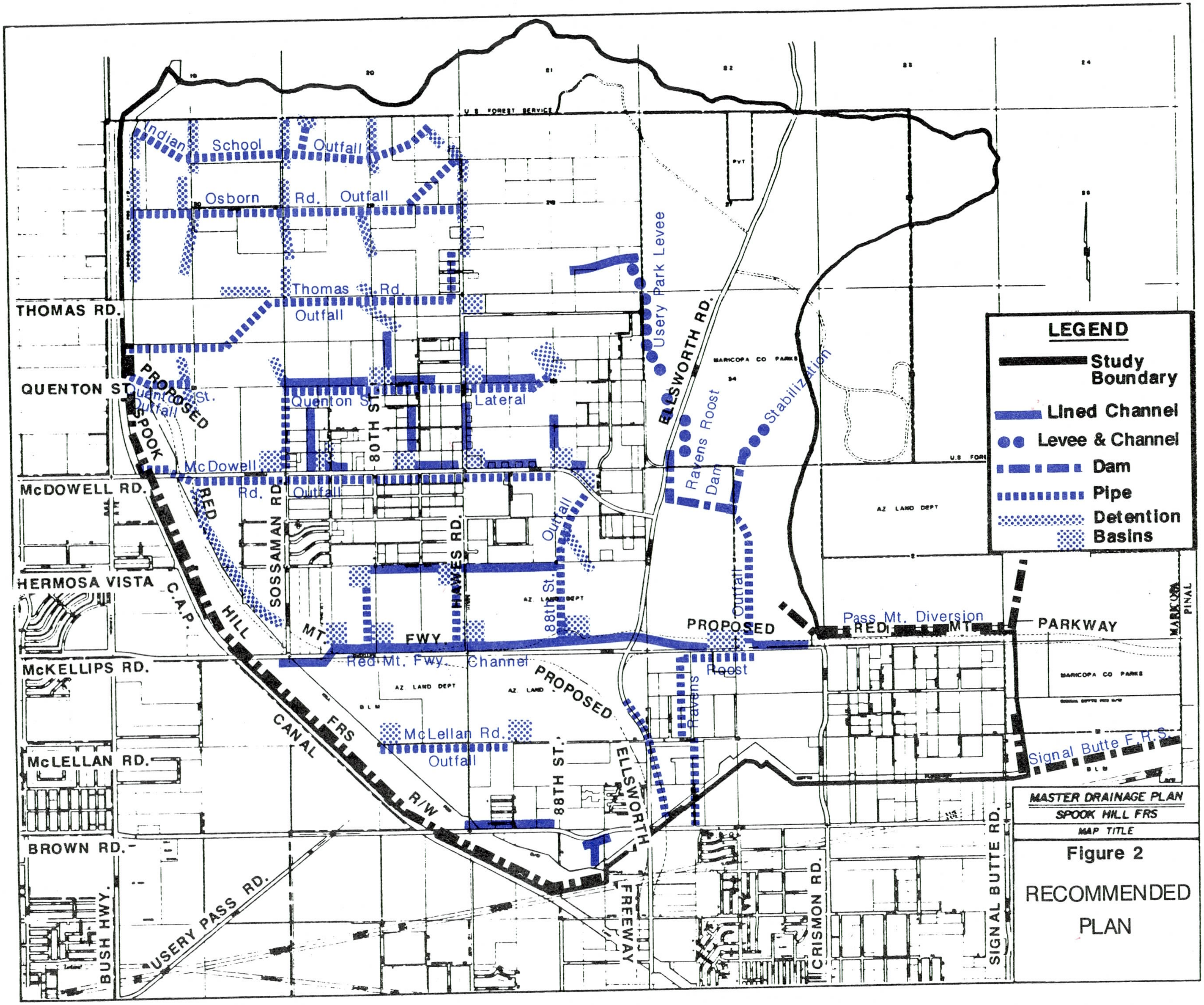


Figure 2
RECOMMENDED PLAN

southeast of the McDowell Road - Usery Pass Road intersection are provided. These function to eliminate major surface flows discharging onto developed and developable land south and west of the Park. These flows would otherwise require major channelization through developed and developable lands in the watershed in addition to the retention ponds required for future subdivision runoff within these lands. The design volume of the dam is drained to Signal Butte Floodway within a 72-hour period via an outlet structure and pipe.

Private lands adjacent to Signal Butte Floodway and adjacent to Spook Hill FRS south of McLellan do not have retention basins included in the Master Plan. These areas, when developed, can safely discharge post-development flows without damages being incurred downstream.

The estimated cost of the Master Drainage Plan is $39,366,000 with $14,674,000 projected as the construction cost and $24,692,000 as right-of-way cost. It is expected that costs for implementation of the Master Drainage Plan will be divided among private developers and public funding sources. Features of the plan projected for implementation by public agencies are identified in the "Implementation Program" section of Chapter VI. Various methods of funding for publicly implemented features are discussed in the "Financing Options" section of Chapter VI.

The effect of the Master Drainage Plan on Signal Butte Floodway and Spook Hill Floodway is a significant reduction in peak discharges from SCS design peak discharges. The Master Plan also significantly reduces the peak volume of runoff stored by Spook Hill FRS. The result is an increase in the level of protection afforded by these flood control structures and a reduction in the expected frequency of spillway discharges from Spook Hill FRS. Within the study area the Master Drainage Plan provides protection from the 100-year 2-hour event.

III. SUMMARY OF THE STUDY PROCESS

The Spook Hill Area Drainage Master Plan was developed in close coordination with the project sponsors. The following is a chronology of significant steps in the development.

August 20, 1984	Receipt of Notice-to-Proceed
August 28, 1984	Study kickoff meeting
September 17, 1984	Meeting to review initial findings with sponsors and refine the study concept.
September 18, 1984	Meeting of Study Teams with East Valley developers.
September 24, 1984	Meeting to review proposed hydrology methodology.
January 9, 1985	Progress meeting to review hydrology model.
January 14, 1985	Meeting to verify curve number values with SCS.
March 15, 1985	Authorization by District to modify hydrologic soils data in the model.
April 15, 1985	Completion of hydrology review by District.
April 25, 1985	Presentation of alternatives and recommended plan.
May 29, 1985	Meeting with sponsors for consensus on recommended plan.
June 11, 1985	Publication of Executive Summary.
June 12, 1985	30% Progress meeting.
June 28, 1985	60% Progess meeting.
August 28, 1985	90% Progress meeting and draft report submittal.

DEFINITION OF PREVAILING CONDITIONS AND CONSTRAINTS IN THE STUDY AREA

The initial item of work was collection of data pertinent to succeeding phases of the study. Much of the watershed data was obtained from design documentation of the Buckhorn - Mesa Watershed Protection Project from SCS [4]. Additional insights were obtained from Flood Control District personnel and field reconnaisance. The following is a listing of agencies supplying data directly or through publications.

American Telephone and Telegraph - Communications (AT&T-C)
Bellamah Corporation
City of Mesa
Cooper Aerial Survey Company
Flood Control District of Maricopa County
Maricopa County Highway Department
Maricopa County Parks Department
Mountain Bell
National Oceanographic and Atmospheric Administration (NOAA)
U.S.D.A. Soil Conservation Service (SCS)
State of Arizona Land Department
University of Kentucky
U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC)
U.S. Bureau of Land Management (BLM)
U.S. Bureau of Reclamation
U.S. Forest Service (USFS)
U.S. Geological Survey (USGS)

Of primary importance was the definition of existing hydrologic conditions by development of a HEC-1 computer model. The existing watershed hydrology model was initially composed utilizing USGS Topographic Quadrangle Maps and April, 1984 aerial photographs by Cooper Aerial Survey Company. Adjustments were then made to match significant watershed boundaries utilized by SCS in the Buckhorn - Mesa Project design hydrology and to provide hydrographs at intermediate locations where engineering data would be needed for the alternatives analysis and preliminary engineering phases. An additional assumption was made that the master plan would contain measures to preclude future flows from discharging out of Usery Mountain Park north of McDowell along its west boundary. A subarea boundary was established to reflect this assumption in the existing watershed model. Hydrologic soil group distribution utilized by SCS was initially used for computation of runoff curve numbers for the subareas by the HYDPAR [5] computer program. The runoff for selected storm events was computed by the HEC-1 [5] computer program by two methods, the kinematic wave overland flow method and the SCS dimensionless hydrograph method. Through consultation with the Flood Control District, the kinematic wave overland flow method was chosen for futher hydrologic analysis.

Because of a wide disparity in the runoff curve numbers computed by HYDPAR and those used by SCS in the Buckhorn - Mesa Project Hydrology, discussions were held with SCS and the Flood Control District to determine the source of the disparity. Two new sources of data were located which would produce lower curve numbers. The first was a study report entitled "Runoff Curve Numbers for Semiarid Range and Forest Conditions"[6] which is used internally on a case by case basis by SCS. It is not an official SCS document, and the consultant opted not to base the hydrology for the project on an unofficial publication. The second source was the "Aguila - Carefree Soil Survey"[7] by SCS which is in the process of publication for public use. The soil survey served to modify hydrologic soil groups for the study area significantly. It was mutually decided by the consultant and the Flood Control District to modify the hydrologic soil group data input to HYDPAR and to model the hydrology using the resulting runoff curve numbers. This data was utilized in the hydrologic computations for the duration of the study.

Upon review of hydrology by the Flood Control District, analyses of sediment discharge for the 2-hour 2-year and 2-hour 100-year events were run using equations developed for the SEDIMOT II[8] computer program from the University of Kentucky. A detailed description of the existing watershed hydrology and sediment models is presented in Chapter IV, HYDROLOGY.

STUDY AND SELECTION OF DRAINAGE MEASURES

The Selected Alternative was achieved through consideration of three alternative drainage concepts. By contract, one alternative was specified to be a "channels" alternative. This alternative, "A", was a direct fit for the requirement that the initial hydrology model should not include any jurisdictional subdivision requirement for detention/retention. Other concepts considered included development of outfall facilities to serve the study area if development were regulated under the Maricopa County ordinance requiring detention, the City of Mesa ordinance requiring retention, a theorical compromise ordinance between Maricopa County and the City of Mesa and a plan utilizing regional retention basins. The second alternative, "B", selected for analysis was comprised of retention basins and outfall pipes and channels in accordance with the City of Mesa ordinance. The third alternative, "C", provided for two regional retention basins with the remainder of the watershed assumed to be developed in accordance with the Maricopa County ordinance with the required detention basins discharging to a series of channels. In Alternatives "B" and "C" the ordinances were not extended to County park or National Forest lands. Drainage facilities in each of the three alternatives were located along park boundaries. The alternatives were compared considering the following factors: cost, right-of-way, effect on Buckhorn - Mesa Structures, level of protection in the study area, environmental and social impacts, implementation factors, impact on infrastructure, and operation and maintenance.

As a result of the comparison of alternatives it was concluded that the area drainage needs were best satisfied by a combination of features of two alternatives. The alternative recommended by the consultant was a composite of Alternative "B" west of the Ellsworth Road alignment (extended) and Alternative "C" on the area to the east. The recommended alternative was approved as the Selected Alternative by consensus of the sponsors. The study and selection process is discussed in detail in the Chapter V, ALTERNATIVES ANALYSIS.

PRELIMINARY ENGINEERING

Once the recommended alternative was adopted as the Selected Alternative, a hydrologic analysis of the 100-year 2-hour event was made using the watershed parameters developed in the initial hydrology in a model with drainage sub-areas matched to the Selected Alternative features. The analysis incorporated routing through the retention basins, pipes, channels, the Raven's Roost Dam reservior and Spook Hill FRS to establish final capacity requirements for development of the Selected Alternative into the Master Drainage Plan. The Master Drainage Plan features were adjusted to match the hydrologic demands, and a final hydrology model of the plan was produced. Modifications to several of the sub-area runoff parameters were made by Flood Control District Staff to provide preliminary design hydrology for collector channels internal to these sub-areas.

The Master Drainage Plan was developed from the Selected Alternative and taken from conceptual stage to readiness for final design in the preliminary engineering stage. Pipe and channel profiles were prepared, retention basin volumes were finalized, the dam and spillway were positioned and sized and the overall plan layout was refined. In addition, recommended design criteria were finalized, quantity take-offs and cost estimates were prepared, right-of-way requirements were finalized and critical utility crossings were located. These details are discussed in Chapter VI, MASTER DRAINAGE PLAN.

STUDY CONCLUSIONS

The major conclusions of the study which influenced the recommendation of the Selected Alternative are as follows:

1. Full development in the watershed without measures to restrain the resulting additional runoff will cause design volume of Spook Hill FRS and design flow capabilities of Spook Hill Floodway and Signal Butte Floodway to be exceeded in a 100-year storm event.

2. The methodology of controlling runoff from the watershed using the retention concept equivalent to that contained in Mesa City Code has the greatest effect in reducing runoff, is least disruptive to the current land uses and infrastructure, and is equivalent in magnitude of costs when compared to the "channels-only" and combination of detention basins and channels concepts considered as alternatives in the study.

3. Because of the steep alluvial fan characteristics of the watershed, sedimentation is more severe than most Phoenix Metropolitan Area watersheds which are developed or developing. Sedimentation will be a major factor in design of the Master Drainage Plan facilities and their maintenance, particularly Raven's Roost Dam. Once the area is developed, the existing sediment yield from vacant lands will be reduced with a consequent reduction of sediment depositions in retention basins. However, the prevailing land slopes in the watershed will make it difficult to completely eliminate sediment production which is likely to occur from "desert lawns" and multi-acre residential lots.

4. The Master Drainage Plan meets the major objectives of the study. It will reduce the 100-year flow significantly throughout developable areas of the watershed and thereby eliminate major flood damage potential. It also manages the rate of runoff into the Buckhorn - Mesa Watershed Protection Project to preserve 100-year flood protection to areas downstream of the Buckhorn - Mesa Project.

IV. HYDROLOGY

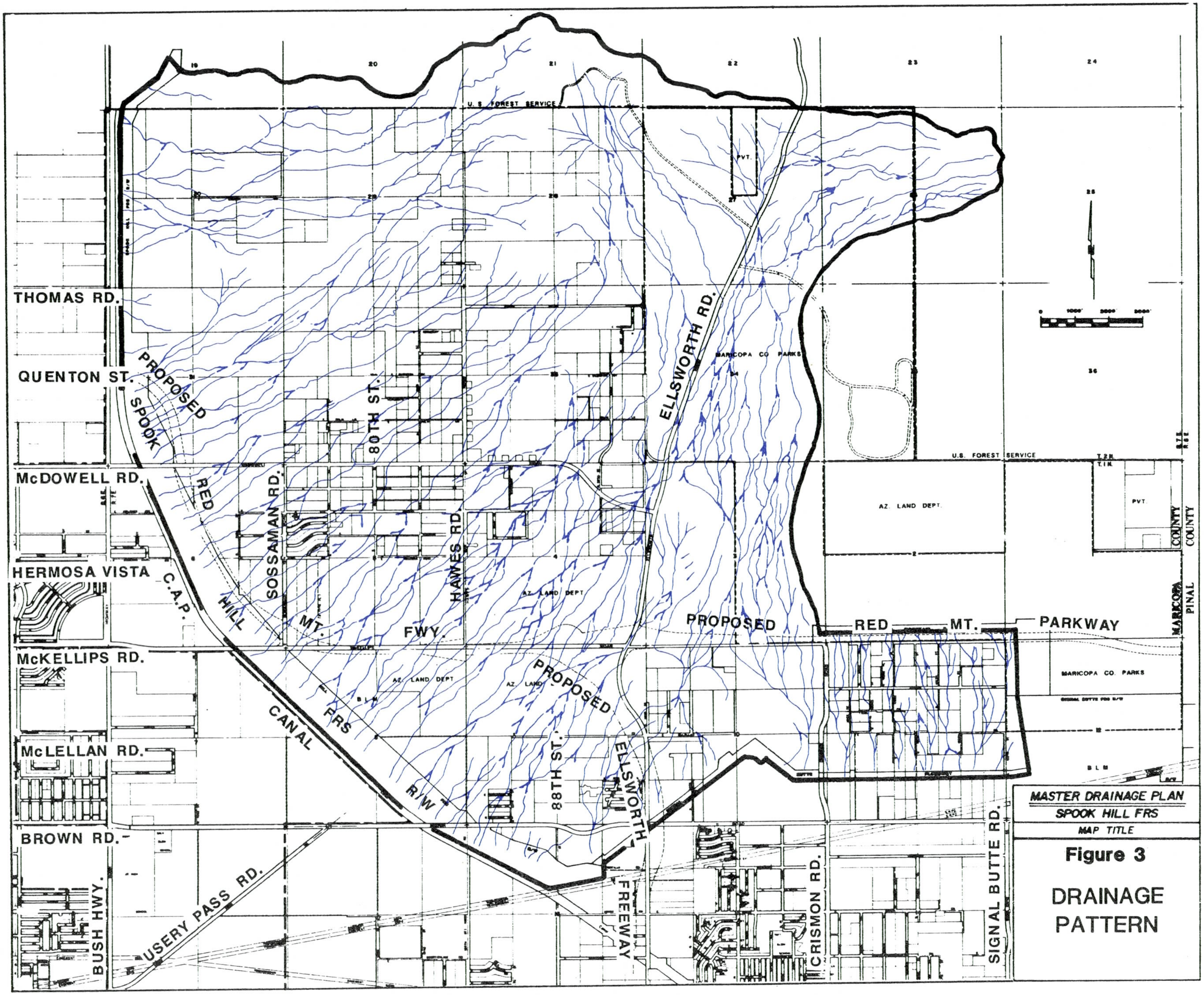
WATERSHED

The Spook Hill Watershed is approximately 16 square miles in area located on the south and west slopes of the Usery Mountains. The terrain, typical of desert alluvial fans, was formed by erosion of the Usery Mountains and Pass Mountain. Maximum slopes exceed 25% near the mountain crests, and minimum slopes of 2% occur at the location of Spook Hill Flood Retarding Structure (FRS). The alluvial fan is interrupted by a number of rock outcrops throughout the watershed.

The natural drainage pattern, shown in Figure 3, consists of incised channels on the upper slopes of the fan. Downstream the channels become shallow, poorly defined washes. In numerous areas these washes become braided or permanently split into divergent channels. As the channels become less distinct, the flow capacity is also reduced. In the event of a major storm, flows are not contained within the shallow natural washes and sheet flooding occurs. During major storms high volumes of sediment are transported down the fan and new flow patterns may be established which prevail until altered by a succeeding major storm.

Because of the steepness of the slopes and brevity of time of concentration, runoff from a storm with duration equal to time of concentration is characterized by a high peak and short duration of flow. Time of peak runoff from the watershed subareas in the hydrology model ranges from 1.5 to 2.5 hours after rainfall begins and recedes to 10% of the peak flow in four hours. As a result, the most severe damage potential within the watershed is from short duration, high intensity thundershowers. These are, typically, very localized events and may affect only a portion of the watershed. The sediment supply process remains very active in the areas of rock outcrop, and the transport of sediment down the alluvial fan is a significant factor in planning for storm drainage.

An essential element of the hydrology model is the inclusion of man-made features which influence or control drainage on the watershed. Because the Buckhorn - Mesa Project features form the downstream boundary of the watershed, they both control and are impacted by the runoff from the watershed under existing conditions and, as conditions are modified, by development. The purpose of the Buckhorn - Mesa Watershed Project is the prevention of floodwater and sediment damage to



MASTER DRAINAGE PLAN
SPOOK HILL FRS
MAP TITLE

Figure 3

DRAINAGE PATTERN

agricultural and urban lands and improvements along a front from Apache Junction to northeast Mesa. Spook Hill Floodway is the outfall for a series of dams and channels further east. It also directly intercepts runoff from the northerly portion of the Spook Hill Watershed and diverts these flows to the Salt River.

Spook Hill FRS controls runoff from the central part of the watershed by storing floodwaters for controlled release into Spook Hill Floodway. It also serves as conveyance for discharge from Signal Butte Floodway into Spook Hill Floodway.

Signal Butte Floodway intercepts runoff from the eastern part of the Spook Hill Watershed. It also conveys controlled releases from Signal Butte FRS into Spook Hill FRS.

GENERAL HYDROLOGIC PROCEDURE

The hydrologic modeling of Spook Hill watershed was initially done using the 1981 revised version of HEC-1[5]. Two of the approaches for modeling surface runoff in response to precipitation were used in the study, the kinematic wave overland flow method and the SCS dimensionless hydrograph.

Approach

The kinematic wave and SCS unit hydrograph methods require similar data on watershed characteristics These include the land slope, hydrologic soil type, curve number, stream length and land use. To facilitate use of HEC-1 when changes are to be made in the land use arrays, a grid cell data base is used, whereby the above described land use array plus the watershed designation are recorded by element. The data grid for Spook Hill was 100 elements by 90 elements. Each grid cell was 2.54 acres in size. This data base is then read by the program HYDPAR[5] which calculates lag time, watershed area, average land slope and average curve number for the watersheds. These data are then input to the HEC-1 program.

Soil Type

Hydrologic Soil Group "B" and "C" soils predominate in the watershed with some "D" group soils located prinicipally at rock outcrops. The soil types and resultant Hydrologic Soil Groups were taken from the Aguila-Carefree Soil Survey [7] manuscripts currently in publication by the Soil Conservation Service. Hydrologic Soils Group distribution is shown in Figure 4.

Land Slope

The average land slope was entered for every element in the grid cell data base. The topographic map of the area was overlain by the data base grid and the average slope in each element calculated. The elemental slopes were then averaged by HYDPAR to arrive at one average slope for the entire drainage subarea.

Land Use

Two land use arrays were used in this study, the current land use and the future land use. The current land use array was derived from the aerial photograph of the area. Areas of development on the photograph were outlined on a transparent overlay and this data transferred by grid location to the data base. The land use categories used in HYDPAR are as follows:

Natural Vegetation
Low Density Residential (less than six dwelling units per acre)
Medium Density Residential (6 - 10 dwelling units per acre)
High Density Residential (11 or more dwelling units per acre)
Developed Open Space

The future land use was based on current and probable future zoning in the area. Land use data was provided by the Maricopa County Department of Planning and Development [9] as the study area was not included in the City of Mesa Master Plan. The zoned regions are shown in Figure 5. All developable areas were coded to reflect development densities less than six dwelling units per acre, except areas zoned for R1-6 or R1-8 which were conservatively coded as six to ten units per acre. Because the future land use was delineated as large blocks and in many instances entire drainage subareas changed from natural vegetation to low density development, the land use array in the data base was not altered. Changes in the land use in the HEC-1 runs were reflected in the increased curve number.

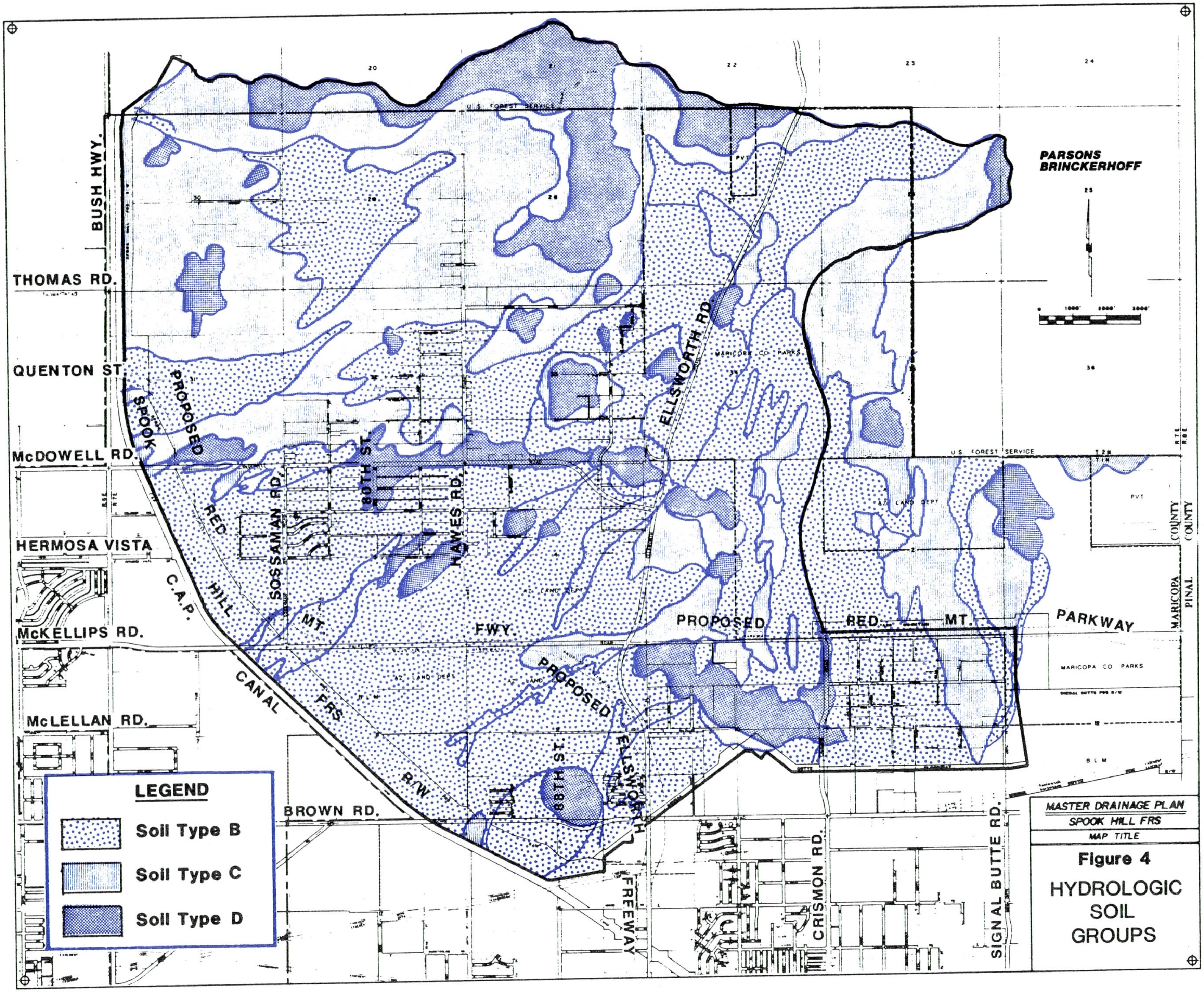
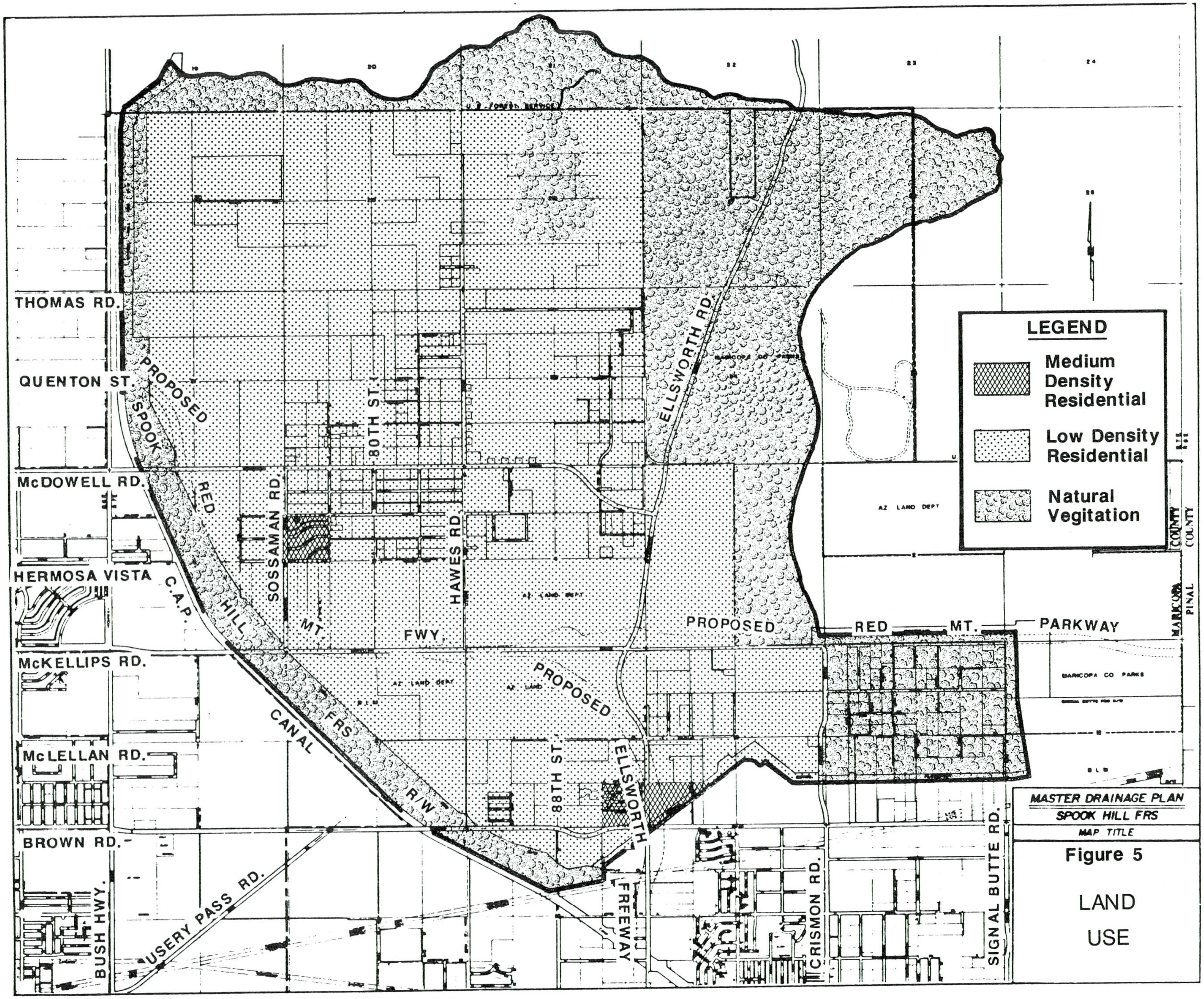


Figure 4
HYDROLOGIC SOIL GROUPS



MASTER DRAINAGE PLAN

SPOOK HILL FRS

MAP TITLE

Figure 5

LAND USE

Curve Number

Curve numbers for the S ook Hill area were determined from Figures 9.5 and 9.6 showing curve numbers in the Western U S. from Chapter 7, Hydrologic Soil Groups, Section 4 of the SCS National Engineering Handbook (1972)[10].

A curve number based on cover and soil type was entered for each element of the data base. These curve numbers were then averaged by HYDPAR to arrive at one average curve number for each drainage subarea.

The average curve numbers for the 29 drainage subareas in the initial model shown in Figure 6 for both current and future land use are listed in Table A-1, Appendix A.

Only future land use curve numbers were used in the Master Drainage Plan model. Curve numbers for the 2-hour and 24-hour runs are the same.

Precipitation

Six precipitation events were used in the initial model, the 2, 5, 10, 50 and 100 year 2-hour precipitation and the 100 year 24-hour precipitation. As advised by hydrologists with the Flood Control District, the rainfall was assumed uniform over the entire watershed A hypothetical storm pattern was not used. The total precipitation was obtained from the NOAA Precipitation Atlas 2, Volume VIII[11] for Arizona. The time distribution was determined using the method contained in "HEC Training Document No. 15"[5]. The total precipitation volumes are listed in Table 1. In the Master Drainage Plan model, runoff was computed for the selected design event, the 100 year 2-hour storm.

TABLE 1

TOTAL PRECIPITATION VOLUMES

RECURRENCE INTERVAL	STORM DURATION	PRECIPITATION
2	2	1.10
5	2	1.50
10	2	2.00
50	2	2.47
100	2	3.08
100	24	4.09

COMPARISON TO SCS HYDROLOGIC PROCEDURES FOR BUCKHORN - MESA PROJECT

Because of the potential impact of the Master Drainage Plan on the Buckhorn - Mesa flood control structures it is important that the differences in the hydrologic methods between this study and the SCS Buckhorn - Mesa design hydrology be understood. SCS used a Type II, 24-hour event which has a time distribution of precipitation considered appropriate for Arizona as one basis for floodway design. The runoff curve number is a direct measure of runoff from a watershed related to total precipation without compensation for variation in precipitation intensity profile, so the curve number method incorporated in HEC-1 tends to predict higher runoff from long duration storms than direct observation will verify. The raw value for runoff curve number is, in fact, calibrated from recorded rainfall/runoff data for short duration storms of approximately one hour duration. To produce more realistic values for runoff, SCS used a curve number reduction technique calibrated against duration of precipitation, contained in a research paper entitled "Runoff Curve Numbers for Semiarid Range and Forest Conditions"[6]. The paper is not an official SCS document, but can be used by SCS, if justified for a specific case, as it was for portions of the Buckhorn - Mesa design hydrology. There is no reason to question the validity of the SCS hydrology based on these facts.

In contrast, the initial hydrology for this study utilized precipitation intensity distributions for 2-hour and 24-hour storms derived from methodology in "HEC Training Document No. 15"[5] from published data by NOAA[11]. The precipitation event was applied uniformly over the watershed to generate design runoff values for numerous facilities located throughout the watershed. This was done acknowledging the probability that storms producing the intensities of precipitation used for the study would be localized to the extent that uniform precipitation over the watershed would not occur in this climate and orography. Additionally, it was felt imprudent to utilize the curve number reduction technique for the 2-hour and 24-hour events in this study because the research paper is not yet in the public domain. Based on these facts, there is no reason not to use the study hydrology for preliminary engineering of individual features of the Master Drainage Plan.

In order to gage the precise impact of the Master Drainage Plan upon the design of the Buckhorn - Mesa flood control structures, additional hydrology would have to be performed using the SCS precipitation and curve number reductions, but with an additional adjustment of curve numbers upward for full development on the watershed. For the level of precision required in this study, the hydrology already produced is sufficient to determine that the Master Drainage Plan has a net effect toward significantly increasing the level of protection of the areas downstream of the Buckhorn - Mesa Project.

INITIAL HYDROLOGY MODEL

The initial hydrology computations were used to define current and fully developed future watershed conditions runoff for an array of storms. These runoff values were used to determine the potential impact of development within the watershed on the Buckhorn - Mesa flood control structures and to assist in the selection of the level of protection for which the alternative drainage plans would be sized. In order to establish a set of limiting hydrologic parameters, it was specified in the Scope of Work that the fully developed watershed would be considered without jurisdictional detention/retention requirements. Because the precipitation event was to be uniformly applied over the entire watershed, a two-hour storm was chosen to match predicted time-to-peak on the longest drainage subareas in the watershed. Storm frequency events of 2-year, 5-year, 10-year, 50-year and 100-year were specified for the model runs. In order to test the effect on the Spook Hill FRS storage volume, a run for the 100-year 24-hour storm was also included in the initial hydrology model.

Drainage Subarea Boundaries

An area of approximately 16 square miles was modeled in this study. The study area was divided into 14 drainage subareas based on elevation and drainage patterns as shown in Figure 6. The initial watershed boundaries were drawn based on the topography in the U.S.G.S. quadrangle maps for the area. These boundaries were then adjusted for apparent drainage patterns as shown on the Cooper Aerial Survey Company April, 1984 aerial photography for the region. Where disagreement in flow pattern or direction occurred between the topographic map and the photograph, the data was taken from the photograph. Drainage subarea boundaries were also adjusted so that they coincided with the major boundaries used by the Soil Conservation Service in the Signal Butte and Pass Mountain studies. Additionally, a line parallel to the west

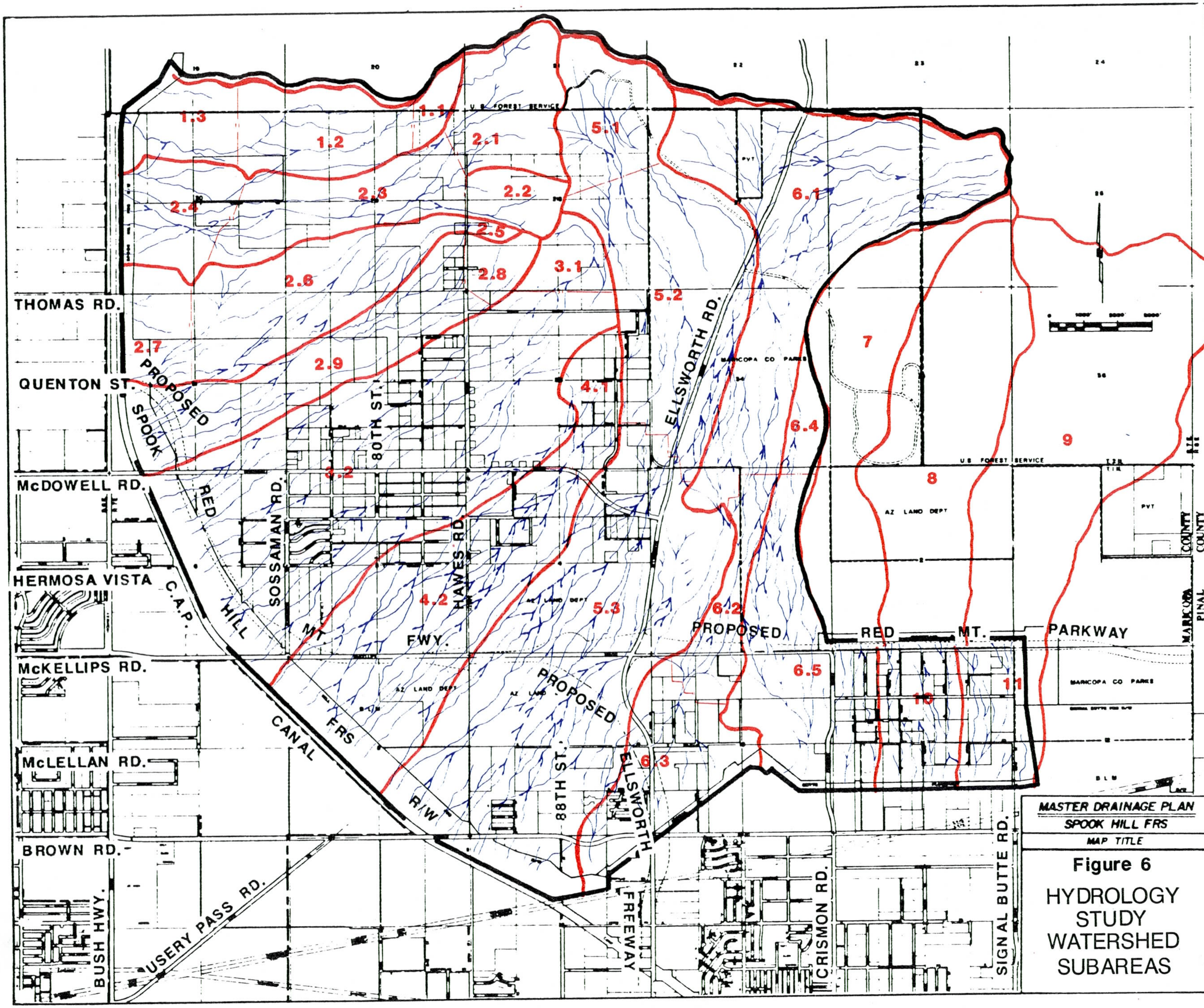


Figure 6
HYDROLOGY STUDY WATERSHED SUBAREAS

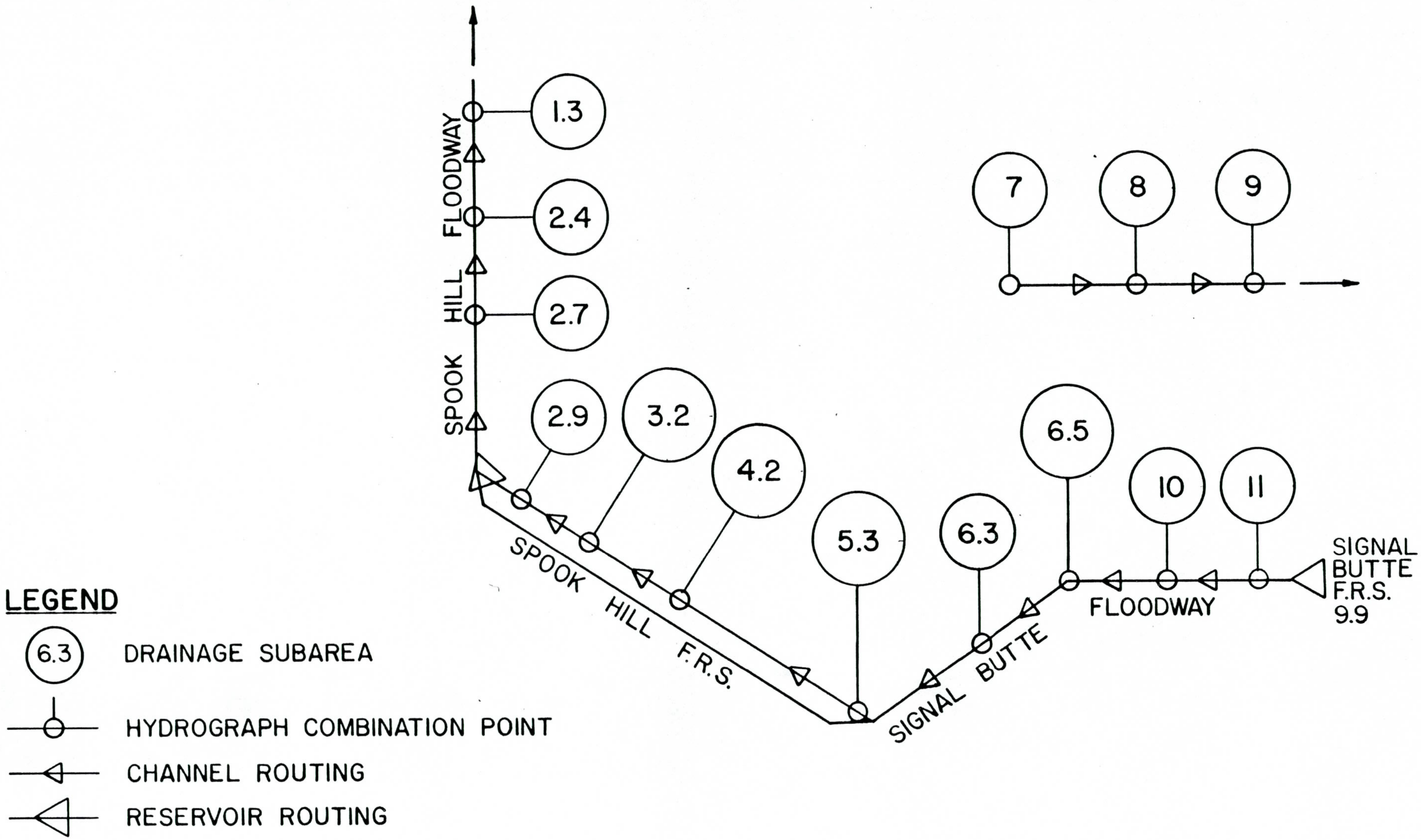
boundary of Usery Mountain Park was established as a drainage subarea boundary. The sheet flow/braided channel area in the northwest sector of the park was recognized early in the study as an area of very unstable flow pattern. It was determined that flows should be structurally deterred from leaving the park along this boundary in order to permanently establish a favorable flow pattern for any alternative plan concept. In sheet flow and braided wash areas continuous natural divides do not exist. In these areas, subarea boundaries were assumed but, in all cases, great care was taken to ensure minimal flow across the boundary. HEC-1 routing was provided for the 14 drainage subarea model. A schematic routing diagram is shown in Figure 7.

The routing assumed that Spook Hill FRS reservoir acts as a channel from the Signal Butte Floodway discharge point to the principal spillway outlet into Spook Hill Floodway. Reservoir routing into Spook Hill Floodway utilized the elevation-capacity curve for the entire Spook Hill FRS reservoir. The emergency spillway for Spook Hill FRS was ignored in order to determine the theoretical peak storage requirement for the FRS. This data would have been necessary if enlargement of the Spook Hill FRS storage volume were included in the Recommended Plan to contain a future 100-year flood below the spillway elevation.

The 14 drainage subareas were further divided into 29 drainage subareas to provide hydrographs at locations where flow modification (diversion, detention or retention) might be possible. The drainage subarea locations were selected based on engineering feasibility rather than hydrologic considerations. The 29 drainage subarea model was not routed.

In each model, three drainage subareas tributary to Pass Mountain Diversion, which do not directly contribute runoff to the study area, were included, in case diversion to or from Pass Mountain Diversion proved viable as an alternative drainage plan feature. These subareas remain in the initial model only as a matter of interest since no such diversion was proposed in any alternative.

Complete model input and output details are contained in the computer tape and hard copy model runs supplied to the Flood Control District. Summaries of the computer output comparing current conditions and future conditions hydrology are presented in Appendix A for the 2-hour 100-year storm on the 29 drainage subarea model unrouted, the 2-hour 100-year storm on the 14 drainage subarea model routed and the 24-hour 100-year storm on the 14 drainage subarea model routed in Tables A-2, A-3 and A-4 respectively.



SCHEMATIC ROUTING DIAGRAM
OF INITIAL HYDROLOGY MODEL

FIGURE 7

Parsons Brinckerhoff

MASTER DRAINAGE PLAN HYDROLOGY MODEL

The Master Drainage Plan hydrology model was used to confirm the operation of the plan under the 100-year 2-hour design event and to make final adjustments in the capacities of the features of the plan. Because of the approximation of the Master Drainage Plan to the City of Mesa subdivision criteria, the watershed was assumed to be fully developed. Runoff curve numbers reflect the conditions under which the future fully developed watershed was modeled in the initial hydrology model. A comparison between the initial hydrology model results for future watershed conditions and the Master Drainage Plan Hydrology Model was used to assess impacts on the Buckhorn - Mesa flood control structures for the 100-year 2-hour event.

Drainage Subarea Boundaries

The study area was divided into 58 drainage subareas based on flow pattern through the undeveloped portions of the watershed and street patterns through areas of development or established street right-of-way. Subarea delineation is shown in Figure 8.

Routing

The Master Drainage Plan hydrology model utilizes reservoir and channel routing capabilities of HEC-1 to a great degree. In general, the model consists of computations of drainage subarea runoff, routing of the flow through a retention basin by the reservoir routing routine, routing the retention basin outflow through a reach of pipe or channel by the channel routing routine and combining hydrographs at junction points. At outfall points to the Buckhorn - Mesa flood control structures the hydrographs are combined and routed downstream by the channel routing routine. As in the initial model routing, Spook Hill FRS reservoir is considered as a channel until flow reaches the principal spillway where it is routed into Spook Hill Floodway by reservoir routing. The routing diagram is shown in Figure 9.

Output

The Master Drainage Plan hydrology model for the design event is voluminous and complex. The entire design model has been presented to the Flood Control District and the City of Mesa on tape and hard copy. A summary of the computations is

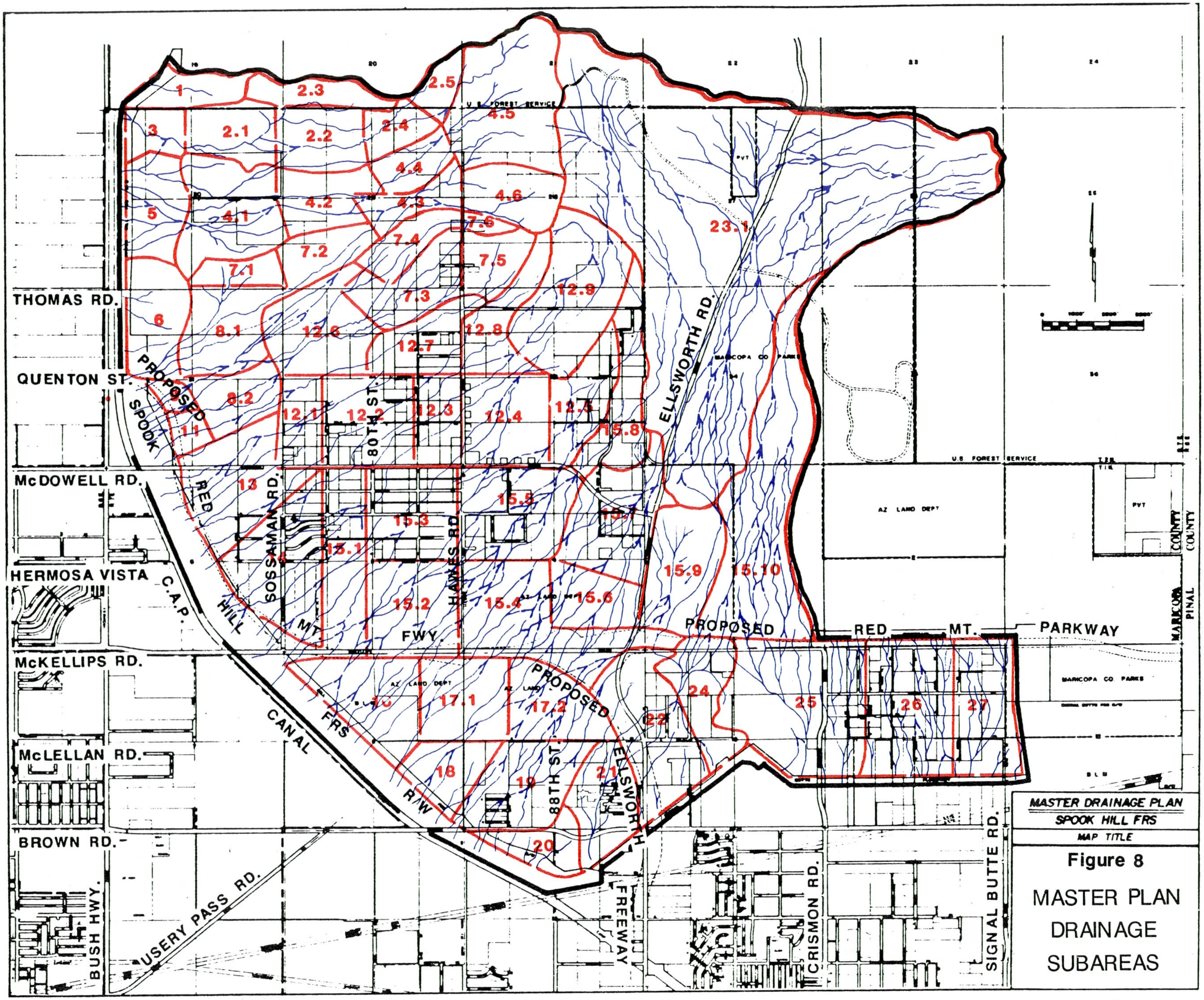
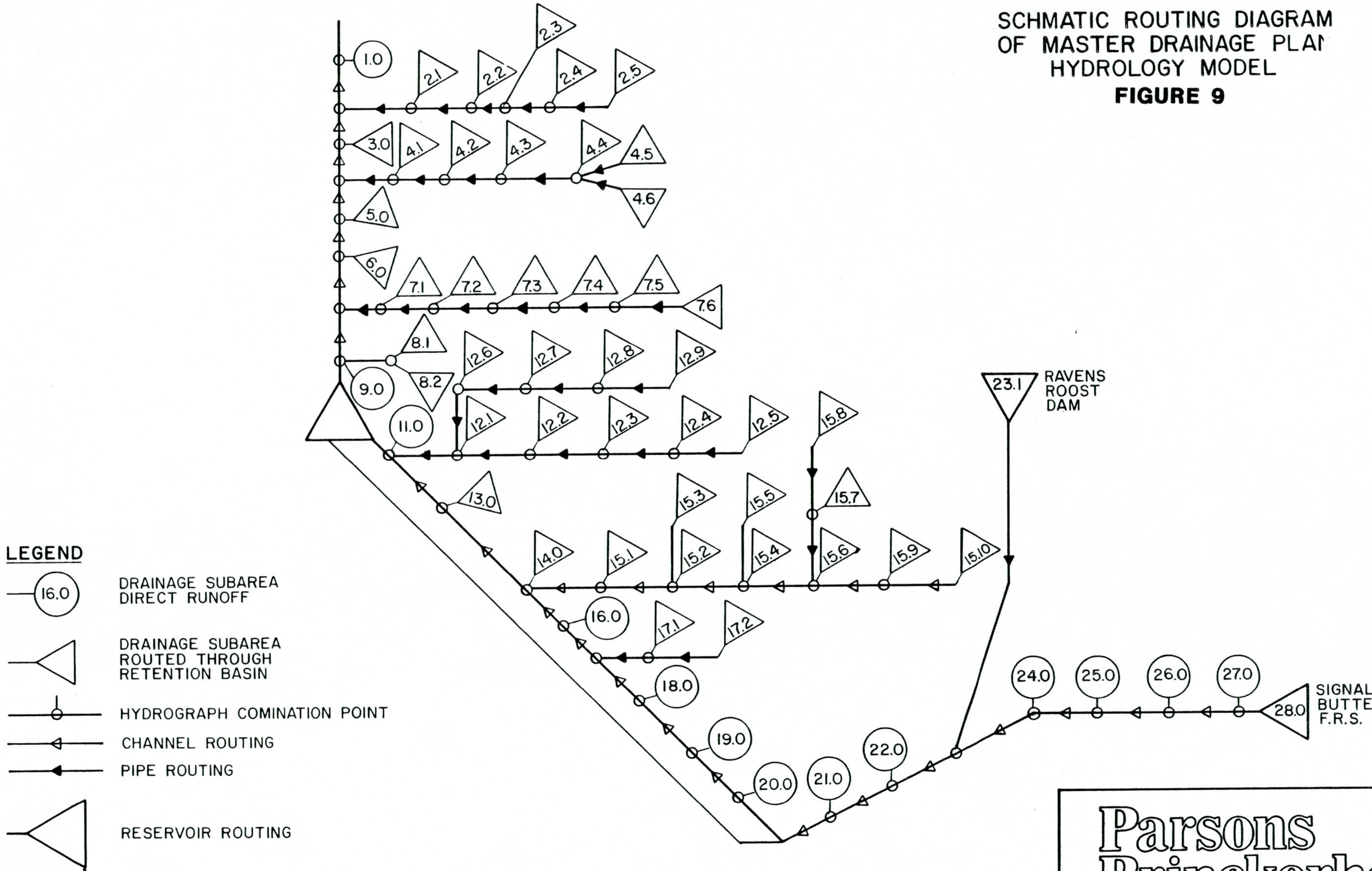


Figure 8

MASTER PLAN DRAINAGE SUBAREAS

SCHMATIC ROUTING DIAGRAM OF MASTER DRAINAGE PLAN HYDROLOGY MODEL

FIGURE 9



Parsons Brinckerhoff

presented in Table A-5 of Appendix A. The model was run for a 24-hour duration event. At the end of 24 hours, Spook Hill FRS had not reached a peak storage or outflow. However, the inflow and outflow rates for Spook Hill FRS were slowly converging with inflow at 370 cfs and falling and outflow at 358 cfs and increasing. Storage volume at 24-hours was 472 acre-feet. Projection of peak values at approximately 27 hours results in discharge of 365 cfs and storage of 480 acre-feet.

EFFECT OF THE MASTER DRAINAGE PLAN ON THE BUCKHORN - MESA FLOOD CONTROL STRUCTURES

The effect of the Master Plan on the Buckhorn - Mesa flood control structures is best illustrated by a comparison of peak flow rates at various floodway locations and peak volume stored in Spook Hill FRS between the initial hydrology model and the Master Plan hydrology model from the 100-year 2-hour storm on the future fully developed watershed. These results are presented in Table 2.

TABLE 2
COMPARISON OF FUTURE CONDITIONS HYDROLOGY WITH AND WITHOUT THE MASTER DRAINAGE PLAN
100-Year 2-Hour Storm Runoff

	INITIAL MODEL		MASTER PLAN MODEL	
LOCATION	CONC. PT.	PEAK FLOW RATE (cfs)	CONC. PT.	PEAK FLOW RATE (cfs)
Bend, Signal Butte Floodway	6.5	1097	25	1027
End, Signal Butte Floodway	6.3	1672	21	1422
Discharge Spook Hill FRS	2.9	660	10	365*
Thomas Road, Spook Hill Floodway	2.7	679	6	398*
End, Spook Hill Floodway	1.3	1166	1	458*
Spook Hill FRS Peak Volume (Acre-feet)		767		480*

* Projected value, did not peak in 24-hours.

As is evident, the Master Drainage Plan serves to reduce peak flows at each point. More significantly, the peak storage in Spook Hill FRS is substantially reduced by the plan, creating capacity within the reservoir for a substantially greater runoff than the 100-year event without spillway flow occurring. Note that the 100-year 2-hour event did not result in a spillway flow for future conditions in the initial model, either.

SEDIMENT MODEL

The sediment yield routine from A Hydrology and Sedimentology Watershed Model, Part 1: Modeling Techniques[8] was used to calculate sediment yield for the drainage subareas of the initial hydrology model, as per Figure 5, for the 100-year 2-hour and 2-year 2-hour storms. Sediment yields are presented in Table A-6 of Appendix A. The input parameters for each drainage subarea are runoff volume in acre-feet, peak discharge in cubic feet per second, length, and slope all taken from the initial hydrology input/output; the soil erodibility parameter, estimated from the soil classifications, Map 6; and the control practice parameters, assumed as unity. The small upstream drainage subareas in Figure 8 are primarily rock outcrop and were considered non-erodible. The sediment yield calculated for these areas is essentially zero.

Typical values of sediment yield are represented by drainage subarea 24, corresponding to a quarter-section drainage subarea. The 100-year 2-hour storm sediment yield of 2420 tons corresponds to approximately 1195 cubic yards of sediment or 0.74 acre-feet which would be trapped in a retention basin if stabilization of erosion by development is ignored. It is evident that if sedimentation continues on this order of magnitude that periodic sediment removal is important.

For the Raven's Roost Dam Watershed, the 100-year 2-hour storm aggregate sediment yield from drainage subareas 5.1, 5.2 and 6.1 is 30,000 tons. This converts to 14,815 cubic yards or 9.2 acre-feet. It is evident that the reservoir capacity is sufficient to handle the sediment yield from a single major storm. However, periodic sediment removal here is also important.

Because of the slope of the alluvial fan comprising the watershed and the prevailing granular nature of the soil surface, sediment yields is naturally high. Sediment production may be reduced significantly as development provides nonerodible cover, but the potential for erosion of any exposed natural desert during a major storm will always exist.

V. ALTERNATIVES ANALYSIS

GENERAL CONSIDERATIONS

Three alternatives (Alternatives A, B, and C) were prepared as part of this study. Each alternative was sized to accommodate the runoff from a 100-year storm. A prime reason for this decision was that future development would most likely be under the City of Mesa's retention ordinance which requires retention of the runoff from a 3-inch rainfall. This would approximately correspond to either a 24-hour 50-year storm or a 2-hour 100-year storm. Alternative B assumes retention in accordance with the City of Mesa's regulations. Likewise, Alternative C assumed uniform application of the Maricopa County detention ordinance over developable lands. This would require some detention, but would allow release of flows at a rate equivalent to the pre-development 100-year flows. This would amount to a 100-year flow with the bed load sediment removed.

A third rationale for 100-year design was a need to control inflows to the Buckhorn - Mesa flood control system to assure that its 100-year design is preserved. It was considered imperative that no emergency spillway flows occur from Spook Hill FRS for an event of intensity less than or equal to a 100-year storm.

Existing development within the study area is primarily one acre and larger parcels. Because of the existing private improvements and infrastructure, it was desirable to minimize upstream flows into the developed area. All three alternatives included features which divert approaching flows away from of the existing development except where proposed SCS flood control structures will provide this diversion. For all alternatives, features proposed for Usery Mountain Park were located along its boundary to the greatest extent possible.

CHARACTERISTIC ZONES

The pattern of current and future land uses across the watershed indicated three characteristic zones, each with unique impacts on development of a master drainage plan. The alternative plans and their implementation were considered by zone and then the best zone alternatives were merged into an overall master plan. The zones are delineated on Figure 10.

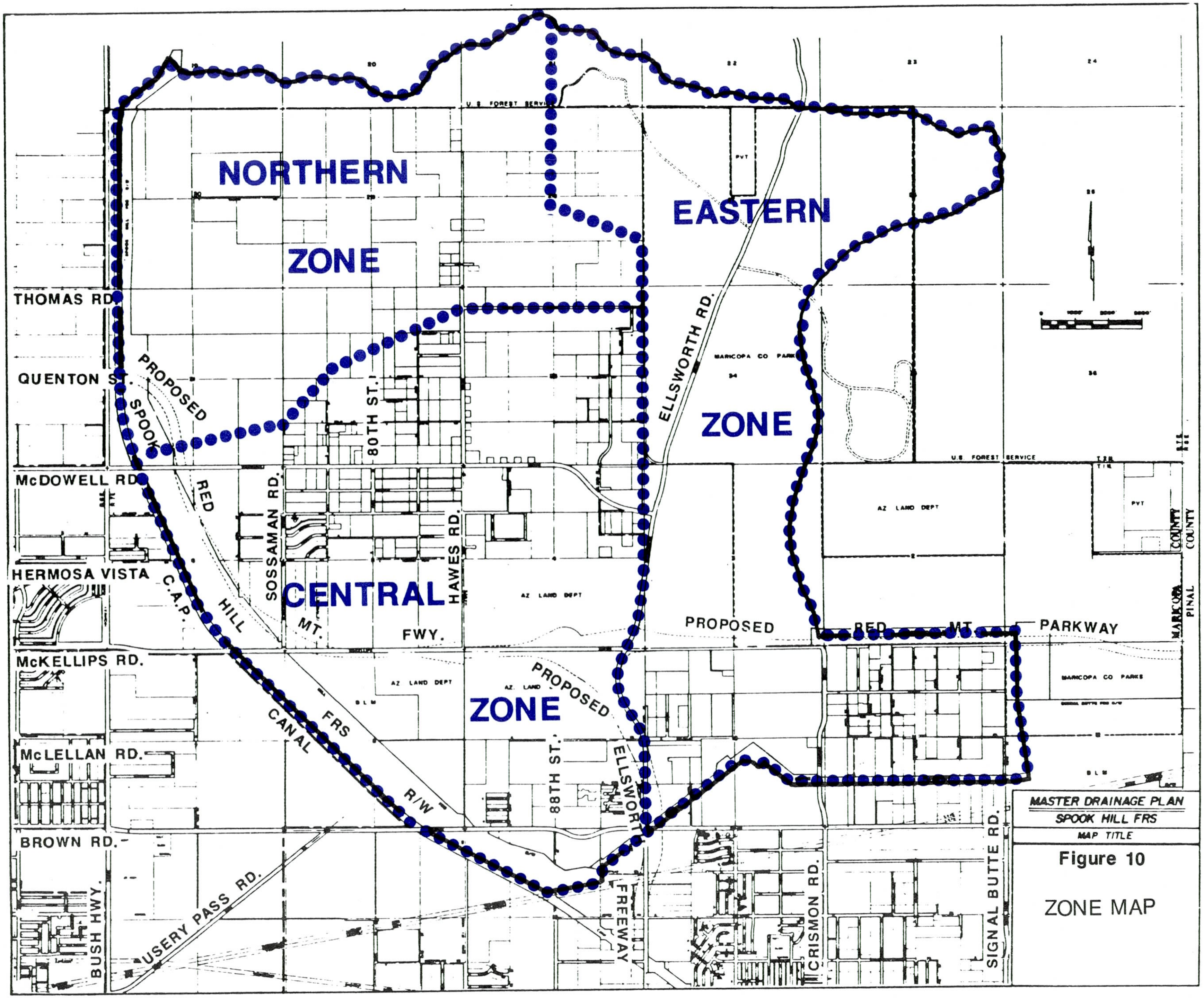


Figure 10

ZONE MAP

Northern Zone

The watershed area tributary to Spook Hill Floodway in the northwest quadrant of the watershed is undeveloped private land. Flood damage potential will be non-existent until development occurs. At the time of development, future drainage needs can be provided through existing or modified ordinance requirements.

Eastern Zone

The area lying east of the extension of the Ellsworth Road section line is primarily public land. The Maricopa County Parks Department, and the State of Arizona have extensive holdings in this zone north of McKellips Road. South of McKellips Road are private acreages partially developed into "desert ranches". The majority of eastern zone runoff is generated within or flows through Usery Mountain Park. The mountain slopes tributary to the park represent the highest elevations and steepest slopes in the entire Spook Hill Watershed. Location of drainage control features within and along the park boundary would provide important protection for much of the developed area in the central zone, described in the following section. Within the park it was essential to propose only construction of features with minimal impact to the native desert environment.

Central Zone

The large wedge-shaped area between the northern and eastern zones contains most of the developed land in the watershed. The entire zone is developable land in private, State, or BLM ownership. The street and utility network is partially completed and represents a major constraint to drainage planning within this zone compared to the northern and eastern zones. Maintenance of access to properties and division of ownership into numerous small parcels will add tremendously to the cost of providing for drainage within the central zone.

Projections of land use by Maricopa County are for low-density residential use (less than six dwelling units per acre) for private, State and BLM lands within the Spook Hill Watershed. Maricopa County Parks Department and National Forest lands will remain perpetually undeveloped. The following is the analysis of alternatives.

CRITERIA FOR DEVELOPMENT OF ALTERNATIVE FEATURES

Channels

Channel Type	Max. Velocity	Max. Side Slope	Min. Freeboard
Earth-lined	4 fps or by soil test	4:1	1.5'
Natural with Levees	6 fps if bed load supply maintained	3:1 (Riprap)	1.5'
Riprap-lined	Combination of depth and velocity for Factor of Safety 1.5 for max. D_{50} = 12" at 3:1 side slopes		
Soil Cement	12 fps	3:1	1.5'
Concrete	12 fps	vert.	1.5'

Channels will not be designed to flow at Froude Number within ± 20% of critical (F = 1.0). Channel exits will have a riprap-lined stilling basin or apron.

Channels are to be non-erodible at design conditions. The maximum allowable velocity is 12 fps for safety.

Pipes

Pipes are to be designed for open channel flow, with maximum depth of flow of 0.7 of the pipe diameter. Velocity will be limited to 20 feet per second for open channel flow. Pipes will be sized so that at the design flow rate the calculated full pipe velocity is limited to 10 feet per second*. Pipes will be used only for discharges which contain no bed load sediment. Manholes will be located on approximately 500' centers, and the base of the manhole will be shaped to match the lower half of the pipe cross section. Pipe outfalls will be made using Bureau of Reclamation impact-type stilling basins.

* This criterion may be omitted.

Retention Basins

Retention basins will be excavated, with design maximum water surface elevation at natural ground. The City of Mesa has no freeboard requirement. Where a basin intercepts a wash, the wash may be filled to contain the basin. The fill will be engineered to assure suitable compaction and water-tightness. At these locations a freeboard of 1.5 feet will be provided across the wash, and flow of water will be directed away from the fill. In lieu of natural ground, a retention basin may be contained by an engineered road fill with full-width pavement. Each basin will be provided with an outlet structure designed to retain bed load sediment within the basin.

Dams

Dam embankments will be engineered zoned earth-fill. Reservoir volume will contain two 100-year events below the emergency spillway elevation. The emergency spillway capacity and dam freeboard will be in accordance with Soil Conservation Service practice. The principal outlet will be sized to evacuate the volume of one 100-year event within 72 hours. The outlet system will be piped downstream to a release point in one of the Buckhorn - Mesa facilities to preclude erosion of channels by the clear water.

ALTERNATIVE A

Alternative A consists of a series of channels sized to convey the runoff from a 100-year 2-hour storm under future conditions. No retention or detention of runoff in the watershed is provided under this alternative. Alternative A is shown in Figure 11.

The channels are of two basic types: "natural" channels and lined channels. The term "natural channels", as used in this report, refers to a wash with low berms or levees constructed on each bank. The slope of the berms inside the channel would be lined with riprap extending from 2 feet below the bottom of the channel to 1.5 feet above the calculated high water level. Since natural channels would conform to the existing ground slope, the channel bottom width would be chosen to keep velocities below 6 feet per second. Vegetation would be permitted to grow within the natural channels.

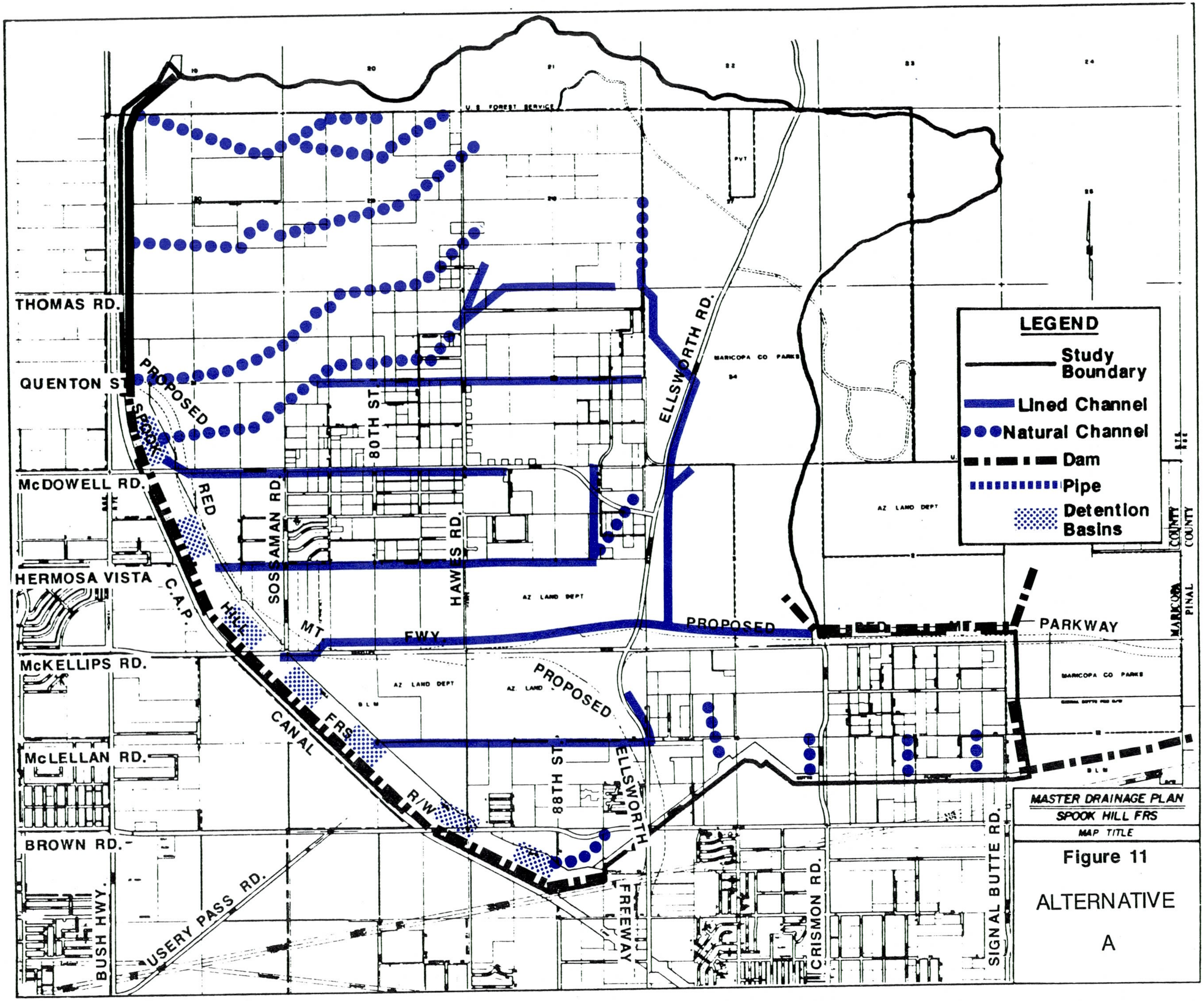


Figure 11

ALTERNATIVE A

Lined channels would have a soil-cement liner across the channel bottom and sides extending 1.5 feet above the calculated high water elevation. The liner would permit velocities of up to 12 feet per second, thus allowing narrower channel bottom widths than natural channels. Each side of the channel would have a low berm and 3:1 side slopes.

Lined channels would often have to be constructed at slopes less than that of the natural ground in order to keep bottom widths in the range of 6 to 12 feet while maintaining an upper velocity limit of 12 feet per second. This would require construction of drop structures periodically along the length of the channel. The drop structures would be constructed of reinforced concrete or grouted riprap.

Northern Zone

Under Alternative A, channels in the northern zone would consist primarily of natural channels, with a few lined channels carrying flows up to 400 cubic feet per second. Because this zone is largely undeveloped, the number of roads crossing the channels can be minimized by careful planning, thus reducing costs for bridges and culverts.

Central Zone

In contrast to the northern zone, drainage channels within the central zone would consist almost exclusively of lined channels paralleling Quenton Street, McDowell Road and Hermosa Vista Drive. One natural channel would be constructed from the intersection of Hermosa Vista Drive and 88th Street northeast to the north side of McDowell Road and 90th Street. Extensive use of drop structures would be required in this zone.

The lined channels in the central zone would be approximately 40 to 50 feet wide at the top of the berm. Since they would parallel existing roads the lined channels width would cut off access to adjacent properties unless a frontage road parallel to the channel were provided. For the purpose of this report, it is assumed that the frontage road would be accessible from the main road every quarter mile; bridges over the channel would be constructed at these points.

Eastern Zone

The main drainage channels in the eastern zone would consist of three lined channels, with five small natural channels in the southern part of this zone. The largest lined channel would parallel the proposed Red Mountain Freeway eastward from the Spook Hill FRS to approximately 100th Street. The Red Mountain Freeway channel would be joined at Ellsworth Road by another lined channel extending approximately two miles to the north. This second channel would be designed to intercept flows from the Usery Mountain Recreation Area. The last major lined channel in this zone would parallel McLellan Road.

Alternative A is a rather straightforward structural approach to flood control and is noted for its relative simplicity. This alternative is most adaptable to the northern zone due to the complete lack of development there. Construction of this alternative within the central and eastern zones would presumably require acquisition of right of way for access roads and may require acquisition and demolition of existing structures.

In any case, it must be noted that Alternative A greatly increases the peak discharge to the Spook Hill Floodway and Spook Hill FRS. Both of these facilities would have to be enlarged or otherwise modified to accommodate the increased flows.

ALTERNATIVE B

Alternative B is shown on Figure 12. This alternative includes provision of a retention basin for approximately each quarter-section to store the volume of the future conditions 100-year 2-hour (3.09 inch) rainfall. Each basin discharges via a pipeline sized to empty the basin within 36 hours.

Northern Zone

Within the Northern Zone this concept is intended to be adapted to serve the drainage requirements of a master-planned development. The assumption is that runoff would be delivered to the retention basin sites by future subdivision streets or drains in accordance with the City of Mesa Procedures Manual. The basins could either remain private or be dedicated for purposes of this plan, but positive provisions for removal of sediment are required. The piped outlet systems should be located within public right-of-way.

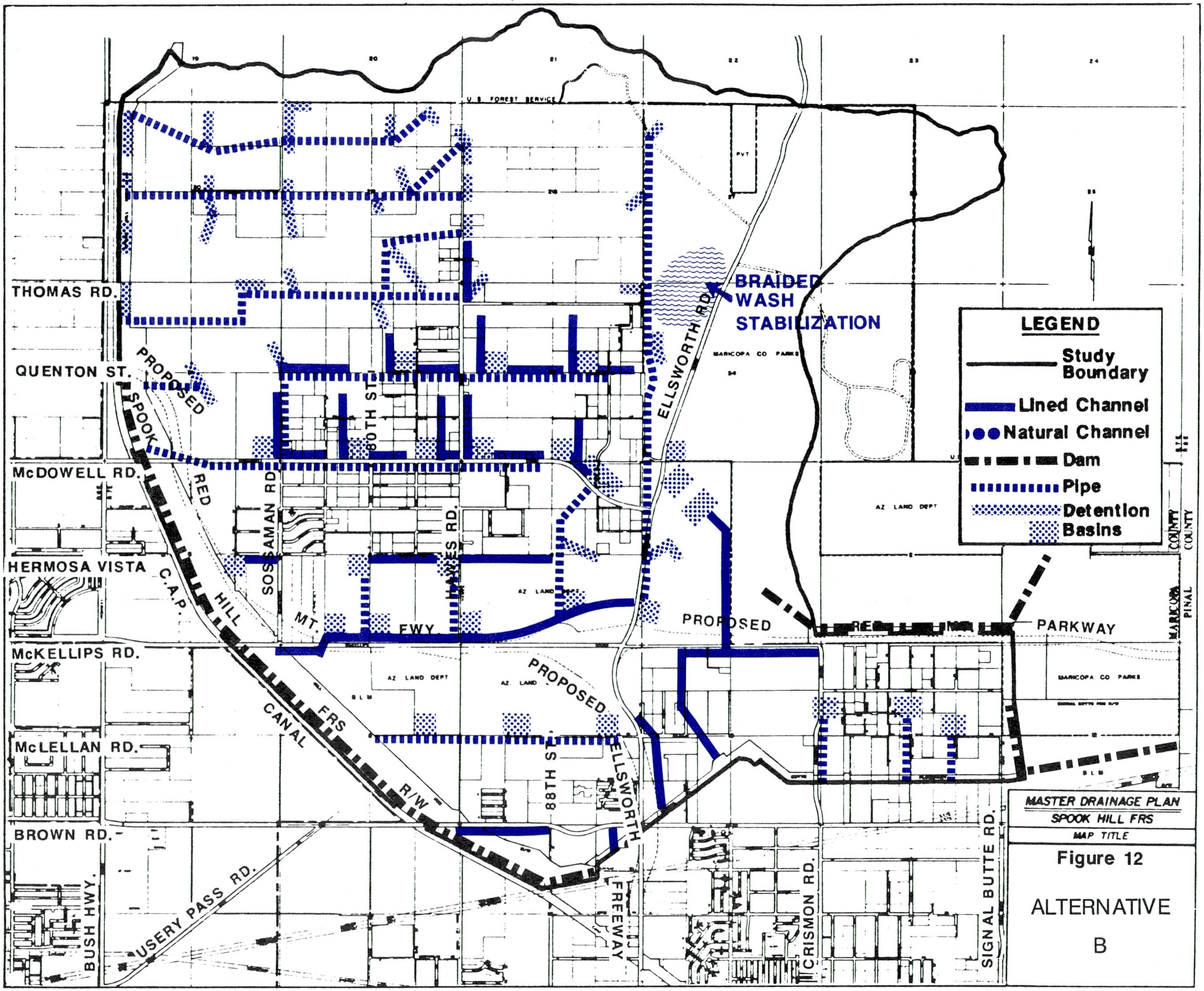


Figure 12

ALTERNATIVE B

Basin capacities range from 5 to 25 acre-feet. Pipe sizes are 30" diameter or less. Soil-cement lined channels are used in two locations to divert flows from the south face of Usery Mountain into retention basins.

The future conditions hydrology which causes increased runoff does not occur until the land is developed. Therefore, the alternative can generally wait for land development before most of the features are needed.

Cost and right-of-way are expected to be requirements of the developer in general. In the vicinity of the Hawes Road and Thomas Road intersection, the two lined channels and two retention basins are needed for reduction of flow into the developed area of the central zone and can not be expected to be provided by a developer.

Central Zone

Alternative B within the central zone is a combination of concepts. For some undeveloped portions the alternative is similar to the developer-installed concept described for the northern zone. For the most part the alternative is a retrofit of the City of Mesa's current drainage standard over a developed area which has no coordinated drainage system. Throughout the central zone the layout of retention basins, channels and outlet pipes is constrained by a grid pattern of dedicated streets and division of ownerships into small acreages. The plan is workable because a substantial number of the acreages which will be needed for retention ponds remain vacant. The number of pond locations will be limited, so runoff will have to be diverted to the pond sites.

The most difficult area for implementation of this alternative is the one mile wide strip immediately north of McDowell Road. The natural drainage pattern is southwest at an approximate 45 degree angle with the existing street grid. Runoff will be collected into ditches parallel to or within the streets. It may be possible to use the existing roadside swale along McDowell Road and the depressed cross-section of Quenton Street and the north-south dirt roads to convey the collected flows. However, it is assumed that the ditches shown on the Alternative B plan are lined. A paved shoulder ditch or inverted-crown curbed street section is a possible compromise to placing a formal channel within additional right-of-way.

The Alternative B features shown south of Hermosa Vista Drive generally avoid developed parcels. The channels and pipes follow the half-mile grid because of some splits in ownership and because of the proposed Red Mountain Freeway along the McKellips Road alignment. Retention basins as shown are in a workable arrangement. Other layouts may be possible if a developer chooses to master plan a portion of the area.

The system within the 1/2 mile strip north of the Red Mountain Freeway has the combined functions of future subdivision drainage and freeway protection. Discharge to Spook Hill FRS is via a small channel adjacent to the freeway. The resulting reduction in flow at Red Mountain Freeway attributable to Alternative B represents a substantial savings to the freeway project compared with existing conditions and Alternatives A and C.

A small system of retention basins and channels along McLellan Road and outfall channels along Brown Road and south from 90th Street (extended) at Brown Road provide drainage for the area of the Central Zone south of the Red Mountain Freeway.

Basin capacities range from 12 to 25 acre-feet. Maximum pipe diameter is 42 inches.

Eastern Zone

Within the eastern zone the concept of retention and piped outfall is workable only along the west boundary of Usery Mountain Park and south along Ellsworth Road. The system serves to divert flows away from development within the central zone and to discharge metered flows at the Red Mountain Freeway. Some watershed stabilization for braided washes in Usery Mountain Park north of the Quenton Street alignment will be required to assure permanent diversion of these washes away from developed land.

Two retention basins are shown just south of the McDowell Road alignment and east of Ellsworth Road. These basins are sized for less than the 100-year 2-hour runoff volume and act as attenuation basins. The peak rate runoff flowing through these basins is reduced by approximately 50% but outflow remains too large for a pipe installation. The channel discharges to the Signal Butte Floodway and collects flows enroute from another channel paralleling the Red Mountain Parkway from Crismon Road west 3/4 mile. A small drainage channel parallels the east side of the Ellsworth Freeway from Signal Butte Floodway north 3/4 miles to protect that segment of freeway.

Basins and outlet pipes are shown in the "desert ranch" area south of the Red Mountain Freeway between the Ellsworth Freeway and Signal Butte Road. The system would be needed only in the event of redevelopment of this area into urban land use. Drainage is reasonably adequate given the current land-use and density.

ALTERNATIVE C

Alternative C, shown in Figure 13, consists of dams, channels, and storm drains to detain and convey runoff generated by a 100-year 2-hour storm under existing conditions. It has been assumed under this alternative that future developments would be allowed to release flows up to the pre-development peak in accordance with the current Maricopa County ordinance. Some on-site detention or other mitigating measures would therefore be required.

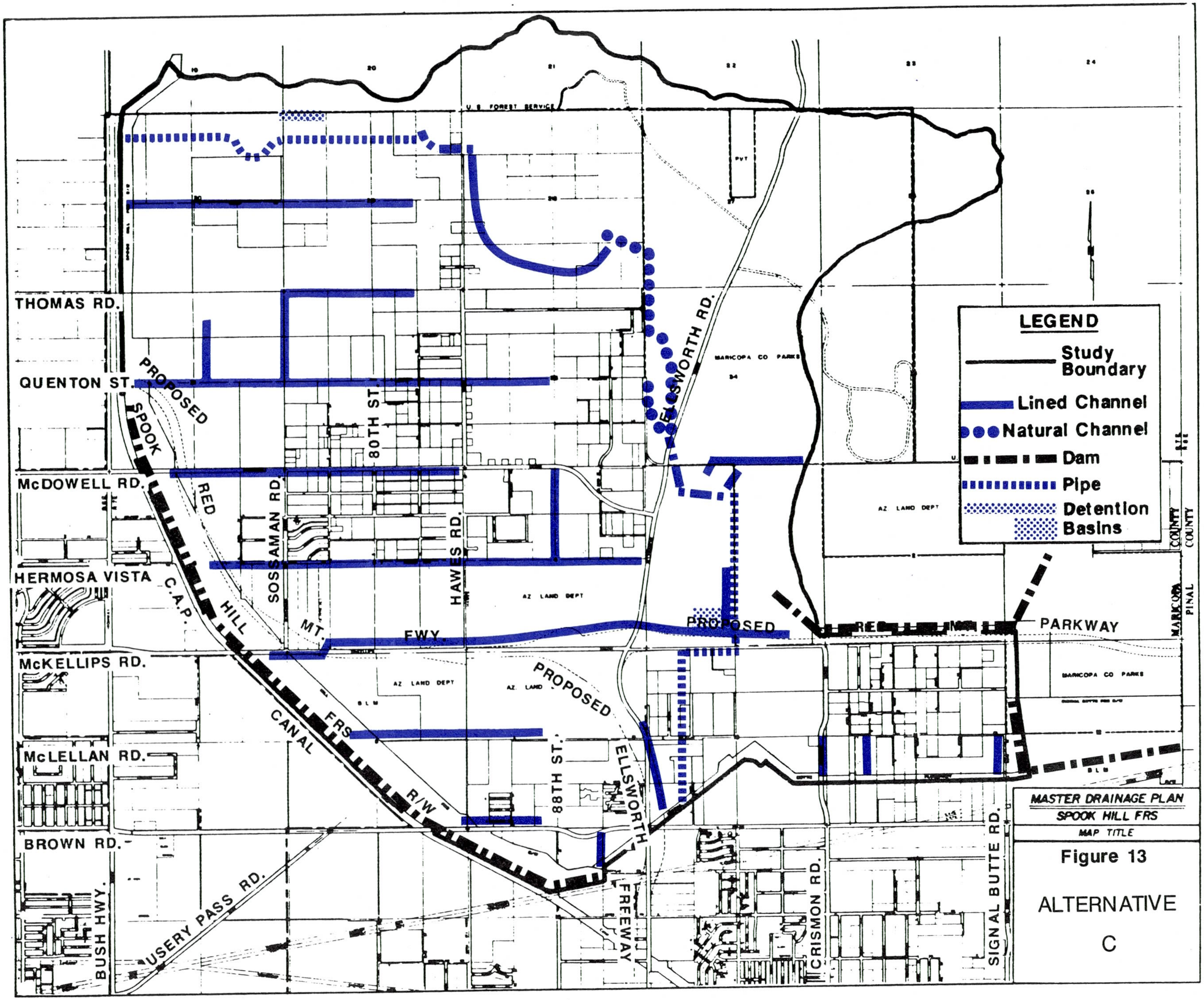
Northern Zone

The northern zone features an earth dam designed to store runoff from the southern end of the Usery Mountains. Runoff from the mountains would be intercepted by a lined channel and conveyed to the storage area behind the dam. Stored runoff would be released through a storm drain constructed westward from the dam along the national forest boundary and discharging to the Spook Hill Floodway.

Other drainage channels along in the northern zone would be lined channels along the alignments of Osborn Road, Thomas Road, and Quenton Street. Since the northern zone is largely undeveloped at present, it is assumed that there would be few bridges over the channels and that frontage roads along channels would not be extensive.

Central Zone

Drainage facilities in the central zone would consist of lined channels along Quenton Street, McDowell Road, and Hermosa Vista Drive similar to the lined channels proposed under Alternative A. The Alternative C channels, however, are generally



MASTER DRAINAGE PLAN
SPOOK HILL FRS
MAP TITLE

Figure 13

ALTERNATIVE C

smaller since flows under Alternative C are less than under Alternative A. This results in fewer drop structures in this zone. Another consequence of the smaller flows and channels of Alternative C is that many channel crossings may be made with box culverts, especially in the upper reaches. Frontage roads would still be required under this alternative.

Eastern Zone

Major drainage features in the eastern zone include lined channels along the Red Mountain Freeway alignment, McLellan Road, and Ellsworth Road, a dam between three low hills east of Ravens Roost and a flow diversion levee along the western boundary of the Usery Mountain Recreation Area. The levee would run from the southern end of the Usery Mountains to Ellsworth Road approximately 1/4 mile northeast of Ravens Roost, and would keep runoff from the recreation area from flowing onto developed or developable lands to the west. Flow along the levee would flow east under Ellsworth Road through a multibarrel box culvert and into the storage area behind the eastern zone dam.

Stored runoff behind the dam would be released through a storm drain. The storm drain would not discharge to the drainage channel along the proposed Red Mountain Freeway but rather to the Signal Butte Floodway approximately 3/4 mile to the south.

The combined effect of the dams and the requirement not to exceed predevelopment flows is to maintain the peak flow delivered to the Spook Hill Floodway within design limits. Alternative A, on the other hand, increases the peak flow in the floodway. Compared to Alternative B, Alternative C would allow more land to be developed by virtue of the fact that no large retention facilities would be required within each quarter section. There would, however, be some land lost to channels and frontage roads under Alternative C.

Summary evaluations of the three alternatives as they affect each zone are presented in Table 3 (northern zone), Table 4 (central zone) and Table 5 (eastern zone).

Table 3

NORTHERN ZONE	ALTERNATIVE A	ALTERNATIVE B	ALTERNATIVE C
COST (WITHOUT RIGHT-OF-WAY)	$4.4 million does not include (*)	$4.1 million	$7.7 million does not include (**)
RIGHT-OF-WAY	133 acres dedicated	109 acres dedicated	70 acres dedicated
EFFECT ON BUCKHORN-MESA FLOOD STRUCTURES	Exceeds channel capacity of Spook Hill Floodway by 80% ±. *Requires enlarged channel or attenuation basin, no cost included.	Reduces peak flow in Spook Hill Floodway by approximately 50% including design discharge out of Spook Hill FRS.	Maintains discharge approximately at channel capacity of Spook Hill Floodway.
LEVEL OF PROTECTION ON WATERSHED	100-year	100-year	100-year
ENVIRONMENTAL/SOCIAL IMPACTS	Some natural washes remain. Open channel require restriction of public use during flows. Increase of discharge into sedimentation basin and habitat at Salt River	Assumes environment will be altered by development. Exposure of public to open channel flow is minimized.	Assumes environment will be altered by development. High velocity open channel flows eliminate possibility of public use.** Detention basins are required within development.
IMPLEMENTATION FACTORS	Can be by developer. May require variance by County or City from current drainage standards.	Can be by developer. Meets City of Mesa's current drainage standards.	Can be by developer. Meets Maricopa County's current drainage standards.
IMPACT ON INFRASTRUCTURE	*Roads will require several major channel crossings with future development	Compatible with future development. Flexible pipe/basin locations. Can be done without major road crossings of channels required in future.	**Roads will require several major channel crossings with future development.
OPERATION & MAINTENANCE	Predominantly natural channel bed may tend to scour under increased flow. Bed load supply from Usery Mountains is vital to stability. Local damage will require maintenance after major flows. Flow=6 hrs.	Requires sediment removal from basins after major flows, but development may eliminate much sedimentation. Basins evacuate within 36 hours.	Soil cement channels expected to be durable. Sediment will tend to collect in drop structures somewhat. Flow duration less than 8 hours.

Table 4

CENTRAL ZONE	ALTERNATIVE A	ALTERNATIVE B	ALTERNATIVE C
COST (WITHOUT RIGHT-OF-WAY)	$10.5 Million does not include (*)	$ 8.5 Million	$6.9 Million does not include (**)
RIGHT-OF-WAY	109 Acres	248 Acres	86 acres
EFFECT ON BUCKHORN-MESA FLOOD STRUCTURES	* Requires excavation of additional volume in Spook Hill FRS to preserve 100-year capacity	Reduces peak flow into Spook Hill FRS by approximately 80%. Metered release reduces maximum instanteous storage in Spook Hill FRS, Increases FRS capacity significantly above 100-year.	Increase in volume of runoff with development discharge to Spook Hill FRS.** Some increase in storage volume is likely to be required.
LEVEL OF PROTECTION ON WATERSHED	100-year	100-year	100-year
ENVIRONMENTAL/SOCIAL IMPACTS	High velocity open channels not for public use. Visual impact in developed area. Severs frontage access on major roads, requires frontage roads.	Locates retention ponds throughout developed area. Can be implemented without permanent change in existing parcel access.	High velocity open channels not for public use. Visual impact in developed area. Severs frontage access on major roads, requires frontage roads.
IMPLEMENTATION FACTORS	Right-of-way acquisition across numerous small parcels, possible total taking. Slight probability of significant developer participation in some areas.	Right-of-Way acquisition of undeveloped parcels. Pipe easements on developed parcels or in street ROW. Slight probability of developer participation in some areas.	Right-of-Way acquisition across numerous small parcels, possible total taking. Slight probability of developer participation in some areas.
IMPACT ON INFRASTRUCTURE	Considerable disruption to access on channel frontages. Some relocation of utilities necessary. Limits future road widening along channels.	Temporary disruption of access. Some relocation of utilities. No impairment of future road widening.	Some relocation of utilities necessary. Limits future road widening along channels.
OPERATION & MAINTENANCE	Soil cement channels expected to be durable. Some sediment and refuse collection expected in drop structures. Flow= 4 hrs.	Requires sediment removal from basins after major flows. Current land use will continue to generate some sediment. Basins evacuate in 36 hours.	Soil cement channels expected to be durable. Some sediment and refuse collection expected in drop structures. Flow = 8 hours.

Table 5

EASTERN ZONE	ALTERNATIVE A	ALTERNATIVE B	ALTERNATIVE C
COST (WITHOUT RIGHT-OF-WAY)	$4.0 million plus significant cost impact in Central Zone Alts. B & C . Does not include (*)	$5.0 million	$7.4 million
RIGHT-OF-WAY	98 acres	248 acres	180 acres
EFFECT ON BUCKHORN-MESA FLOOD STRUCTURES	Contributes to accelerated peak storage in Spook Hill FRS. *Requires excavation in Spook Hill FRS to maintain 100-year volume.	Reduces peak discharge to Signal Butte Floodway approximately 30%. Retards flow into Spook Hill FRS slightly. Improves Spook Hill FRS protection slightly.	Reduces peak discharge to Signal Butte Floodway by approximately 50%. Considerable reduction in peak storage of Spook Hill FRS. Considerable increase in Spook Hill FRS capacity over 100-year.
LEVEL OF PROTECTION ON WATERSHED	100-year	100-year	100-year, most positive control of public lands runoff of three alternatives.
ENVIRONMENTAL/SOCIAL IMPACTS	Soil cement channel in edge of Usery Mountain Park. Protects development to west.	Permanent retention ponds in edge of Usery Mountain Park. Pipeline scar after construction along boundary. Stabilize braids in Usery Park.	Levee construction along Usery Mountain Park Boundary, optional channel in Park on McDowell alignment control of 50% of sediment source on watershed.
IMPLEMENTATION FACTORS	Requires Maricopa County Parks Board approval, BLM approved.	Maricopa County Parks Board and BLM approval. Major channel through desert ranch area east of Ellsworth.	Requires Maricopa County Parks Board and BLM approval.
IMPACT ON INFRASTRUCTURE	Slight chance of utility conflicts. Some temporary impairment of access.	Slight chance of utility conflicts. Temporary impairment of access.	Slight chance of utility conflicts. Some temporary impairment of access
OPERATION & MAINTENANCE	Considerable sediment discharge, frequent removal at channel inlet sites required. Flow=4 hrs.	Sediment removal from basins after major flows. Soil cement channels expected to be durable. Some sediment collection in drop structures expected. Flow = 36 hrs.	Eliminates most of sediment removal downstream of dam. Occasional removal of sediment at dam. Flow= 72 hrs.

RECOMMENDED PLAN

Based on the information and evaluations summarized in Tables 3, 4, and 5, the recommended plan is as follows:

Northern Zone:	Alternative B
Central Zone :	Alternative B
Eastern Zone :	Alternative C (modified)

The recommended plan is shown in Figure 2. The estimated construction cost and right-of-way requirements are summarized in Table 6.

TABLE 6

RECOMMENDED PLAN SUMMARY

Zone	Recommended Alternative	Estimated Construction Cost, $ million	Right-of-Way, acres
Northern	B	4.1	109
Central	B	8.5	248
Eastern	C	7.4	180
	Totals	**20.0**	**537**

* These figures reflect estimates made in the Alternative Analysis Phase of the study. Refined estimates were subsequently developed in the Preliminary Engineering Phase.

Under the recommended plan, Alternative C as applied to the eastern zone would be modified slightly to include a detention basin near the intersection of the proposed Red Mountain Parkway and the extension of 96th Street.

The detention basin would discharge a metered flow to the channel on the north side of the proposed Red Mountain Parkway, a concept consistent with that recommended for the central zone. No additional cost for this detention basin has been included in the cost estimate presented in Table 6, above, since the reduction in flow is assumed to produce cost savings in downstream channel construction that would offset the additional cost of the detention basin.

VI. MASTER DRAINAGE PLAN

The Master Drainage Plan for the Spook Hill FRS Watershed is based on several sound concepts. First, the Master Drainage Plan is developed for an entire watershed area. This allows development of a plan which does not depend on upstream flows from an uncontrolled area of another watershed and does not discharge flows uncontrolled into a downstream watershed. The Master Drainage Plan considers land use, particularly the division between lands which are developable and lands which are designated as permanent public open space. The plan incorporates features to protect developable land from uncontrolled runoff from public lands. The Master Plan features within the developable land areas may, in many cases, be implemented directly as a function of subdivision process as the land develops. The effect of the plan is to place all developable land in the watershed under a single ordinance administered by a single agency which is familiar with the application of the ordinance. At the same time, this ordinance requires the same subdivision drainage procedure as is required in other parts of the City of Mesa in order to be fair to land owners in the watershed. Finally, the Master Drainage Plan is flexible. Because the retention basins proposed for developable land are intended to meet the City of Mesa development ordinance requirements, the basins may be incorporated in an entirely different arrangement to match subdivision needs. The major restriction is that the effect on drainage of such a subdivision under any development master plan be the same as the effect of those Master Drainage Plan features which have been replaced.

The effect of the Master Drainage Plan is to provide 100-year 2-hour storm runoff protection to the watershed. In addition, the Master Drainage Plan reduces peak inflows from the watershed into the Buckhorn - Mesa flood control structures. This reduction of peak inflows increases the level of protection to lands downstream of the Buckhorn - Mesa project. Finally, the Master Drainage Plan manages the sedimentation and erosion potential within the study area.

The Master Drainage Plan, shown in Figure 2, is further defined by an accompanying series of 30" x 36" maps and 24" x 36" profile and detail drawings.

PRELIMINARY ENGINEERING AND DESIGN CRITERIA

Retention Basins - Each retention basin is sized to contain the entire volume of the runoff from a 100-year 2-hour storm of 3.08 inches of precipitation from its drainage subarea. Retention basins have a maximum depth of 3.5 feet and maximum side slopes of 6:1. Each basin is drained by a discharge structure fitted with an orifice or series of orifices 8 inches square. The orificies are positioned vertically to produce an elevation discharge relationship capable of draining the basin by gravity within a 36 hour period. The bed of the basin in the vicinity of the discharge structure is essentially level to preclude movement of bed load sediment to the discharge structure. The discharge structure is connected to the outfall pipe or channel by pipe 12 to 24 inches in diameter laid on sufficient grade to produce open channel flow with a maximum depth of 70% of the pipe diameter at maximum design discharge. In accordance with City of Mesa procedures, no freeboard is provided along fully entrenched banks. Where banks are constructed of fill material, 1.5 feet of freeboard is provided.

Outfall Pipes - Each outfall pipe is designed to carry the maximum aggregate flow from upstream retention basins in open channel (partially full) flow with a maximum depth of 70% of the pipe diameter. The maximum allowable velocity is 20 feet per second. The outfall pipes are to be used exclusively for flows from which bed load sediment has been removed, i.e. flows which have passed through a retention basin. No street or overland flow collection facilities should be designed to connect directly into the outfall pipe system. Such facilities should be designed to discharge into a retention basin to assure bed load sediment removal. The outfall pipes are intended to be located within the right-of-way of existing or future streets. These pipes should be designed for traffic and burial depth by determination of the pipe D-load for each reach. Junction of outfall pipes or connection of retention basin discharge pipes are accomplished at manholes. Manhole covers are to be sealed and bolted down. Manholes are provided at approximately 500 foot intervals.

Ellsworth Freeway Outfall Pipe - The outfall pipe along the east side of Ellsworth Freeway between Red Mountain Freeway and Signal Butte Floodway will receive sediment discharge because it is designed as a storm drain intended for several catch basins through its length. It has been oversized and set on a relatively steep slope to carry sediment through. However, the pipe is seen as a feature of the freeway rather than of the Master Drainage Plan, and may be designed as an outfall channel during freeway design.

Outfall Structures - Each outfall pipe of 24 inch diameter or greater discharges through a stilling basin designed in accordance with Section 6 of Hydraulic Design of Stilling Basins and Energy Dissipators [12] by the U.S Bureau of Reclamation and set flush with the bed of the respective floodway or Spook Hill FRS low flow channel.

Outfall Channel - The outfall channel along Red Mountain Freeway is a soil-cement-lined trapezoidal channel with 3:1 side slopes and bed width as specified on the profile sheet. The lining on the bed and side slopes is approximately 12 inches thick. Maximum allowable velocity is 12 feet per second. Channel grade is set to produce either subcritical flow with maximum Froude number of 0.8 or supercritical flow with minimum Froude number of 1.2. Change in flow regime from supercritical to subcritical accomplished at a stilling basin 40 to 50 feet in length with bed elevation set a minimum of 1.5 feet below the outlet channel grade. The stilling basin is also soil-cement lined. The stilling basin is drained by a vee-notch in the bed of the downstream channel set on a level grade to the downstream "daylight" point.

Other Channels - The existing channel extending along the north side of Brown Road for one-half mile east from the Spook Hill FRS and the wash running south from Brown Road immediately west of Ellsworth Road require no improvement.

Raven's Roost Dam - Storage volume for the dam below the spillway elevation of 1867 is equivalent to twice the total storm runoff from the 100-year 2-hour event or 386 acre-feet. This will accommodate the runoff and the sediment volume trapped during a storm significantly in excess of the 100-year event without spillway flow. The spillway is an excavated 100 foot wide channel flanking the easterly embankment. The spillway crest is a poured concrete sill for the full 100 feet width of the spillway with the spillway channel upstream and downstream of the crest sloping away from the crest at a 1% slope. The spillway design hydrograph, with a volume of 3.37 inches of runoff from the entire Raven's Roost Dam watershed, is prorated from the S.C.S. spillway design hydrograph for Spook Hill FRS based on the ratio of watershed areas. Maximum spillway design discharge is 450 cubic feet per second at elevation 1868.5. The dam freeboard design hydrograph with a volume of 10.27 inches of runoff from the watershed, is similarly prorated from the Spook Hill FRS freeboard design hydrograph. Maximum freeboard design discharge through the spillway is 4,100 cubic feet per second at elevation 1872.6. These discharges and water-surface elevations result from routing the respective hydrographs through the Raven's Roost reservoir. Allowing for some wave action, the top of embankments is set at elevation 1876.0. The embankments are zoned-earthfill with a core of low-permeability material which will resist damaging seepage rates for the duration of the freeboard design event outflow. The easterly embankment would be subject to adjacent spillway flow during the freeboard design event and requires riprap protection along the downstream face and along a portion of the upstream face. The reservoir volume below spillway elevation is drained through a discharge structure and outfall pipe. The discharge structure is fitted with an orifice $20\frac{1}{4}$ inches square with centerline at elevation 1847.0 designed to discharge the 386 acre-foot volume within 72 hours. The discharge structure is fitted with a trashrack to prevent clogging of the orifice and outfall pipe by debris.

Diversion Levee - The levee along the west boundary of Usery Park is riprap lined on each face. It has a maximum height of $3\frac{1}{2}$ feet, a 14 foot top width and 4:1 side slopes. Where necessary to provide unobstructed flowage along the east side of the levee, high ground will be cut to $3\frac{1}{2}$ feet below the top of the levee profile for a width of 10 feet at the north end and increasing to 40 feet at Usery Pass Road.

Culverts - Culverts are required for the Red Mountain Freeway outfall channel crossings of Ellsworth Road and McKellips Road and the Usery Park levee crossing of Usery Pass Road. The Ellsworth Road and McKellips Road crossings are sized for hydraulic capacity only. The Usery Pass Road Crossing is a four barrel 8 foot x 4 foot concrete box culvert to allow freeboard for debris and passage of bed-load sediment through the culvert. During final design grates should be considered to preclude public access, depending on adjacent land uses. The City of Mesa installs grates where required for safety, but not merely to handle debris.

Runoff in Excess of Design Capacity - In an event exceeding the 100-year 2-hour design event, retention basins would overflow at a location protected from the potential for breach of the basin bank. Generally this is accomplished by depressing the full depth of the basin below existing ground. Basins which are partially contained by fill are provided with 1.5 feet of freeboard at the fill section to cause overflow to occur where the basin is fully depressed and where the outflow is directed away from the fill. Raven's Roost Dam is sized larger than the 100-year 2-hour event to avoid spillway flows except in extreme events. Channel and levee cross-sections are provided with freeboard which allow for some excess flows to be contained. A significant exceedence of the design event would cause overtopping with localized flooding downstream. The use of a 100-year design event, in itself, makes exceedence of design capacity rare.

Stabilizing Dip Crossings - Because the Master Drainage Plan does not eliminate any roadway dips, there will continue to be road dip crossings of wash areas until and unless all roads in the study area are fully improved, i.e. the City of Mesa presently requires street improvements to provide a culvert capacity for the 10-year storm. It is recommended that future road improvements by City, County, or developers adhere to this City of Mesa standard. Local scour may continue in major storms where significant drainage area is tributary to the dip crossing. However, the division of the study areas into small watersheds by the Master Drainage Plan minimizes flow at most wash locations. The provisions in the plan not to release clearwater flows into natural terrain also precludes much of the potential for scour of dip crossings. There are two primary causes of scour at roadway dip crossings observed on the watershed. The first is the failure to build a solid road bed slightly below the natural sediment level. The second is borrow of material from wash beds, particularly upstream of the dip. The borrow hole allows bed load sediment to drop from the flow. The flowing water immediately begins to satisfy its "appetite" for sediment by eroding the bed and banks of the wash, lowering the wash profile for a distance downstream. One solution to such erosion at the dip crossing is to place cobble-size rock in the wash bed downstream. The rock, if too large to move with the storm flow, will transfer erosion downstream. Additional rock may have to be added several times before the wash becomes stable. The rock serves as a non-erodible surface to protect the downstream edge of the roadway while having the flexibility to adjust to periodic lowering of the downstream bed due to erosion. Implementation of the Master Drainage Plan will also serve to reduce major erosive flow concentrations.

RIGHT-OF-WAY

The Master Drainage Plan requires an estimated 412 acres of right-of-way and 70,500 lineal feet of 15 to 20 foot wide pipeline easement. The projected cost for right-of-way is $24,692,000. The right-of-way and easement requirements are shown on the Master Drainage Plan, Map 3 and are listed in Table B-1, Appendix B. Several opportunities exist whereby acquisition of the right-of-way may be expedited. The outfall pipes are shown requiring only underground easements. The intent of the Master Drainage Plan is that pipes be located ultimately in street right-of-way. Several pipe routes extend along existing roads such as McDowell Road. The intention here is to utilize existing roadway right-of-way. In undeveloped areas, pipe locations should be modified as necessary in the subdivision process to follow proposed streets. Not only will dual use of the right-of-way save in acquisition costs, but access for maintenance will be facilitated.

Similarly, retention basins within undeveloped areas should be treated as a function of the usual development process, either dedicated to the City of Mesa as multiple-use parks or retained by the developer as open space areas required in development.

The Red Mountain Freeway Channel right-of-way would be logically acquired with right-of-way for the freeway. A single acquisition is more economical than successive right-of-way takings.

Other rights-of-way for construction of the Master Drainage Plan will certainly have to follow traditional agency negotiated purchase or eminent domain proceedings, but early acquisition prior to major land development in the study area will result in lower overall right-of-way cost.

CRITICAL UTILITY INTERFERENCE

Although the Spook Hill Watershed is still sparsely developed, there are existing utilities that may have to be relocated or protected due to construction of the elements of the recommended plan. Other utilities proposed for construction in the future may also require relocation or protection depending on their construction schedule with respect to proposed drainage facilities. In most cases, however, the drainage facilities can be located to avoid any major utilities. The impact of the recommended plan on existing utilities and on important proposed utilities is discussed more fully in the following sections.

Water

Major existing water lines that may be impacted by construction of outfalls parallel to their alignment include 8-inch and 6-inch diameter mains in McDowell Road, 16-inch and 8-inch diameter mains in McLellan Road and an 8-inch diameter main in Hawes Road between Scarlett Road and Thomas Road (extended). Potential right angle crossings between outfalls and water mains occur at the intersections of Ellsworth Road and McLellan Road, Hawes Road and Quenton Street, and 94th Street and McLellan Road. In addition, there is a 500,000 gallon water storage tank near the outlet of the proposed McLellan Road Outfall. In all cases it is assumed that the proposed drainage facilities can be designed to avoid the existing water utilities.

Telephone

Underground Mountain Bell telephone lines that would parallel proposed outfalls are located in Hawes Road between Hermosa Vista Drive and McKellips Road in Ellsworth Road between McLellan Road and the extension of Jensen Road and in McKellips Road. (The latter two telephone lines will probably be affected more by construction of the proposed Red Mountain and Ellsworth Freeways than by the recommended drainage plan.) Right angle crossings between outfalls and telephone lines will occur at the intersections of 94th Street and McLellan Road, McDowell Road and Waterbury Road (86th Street), and McDowell Road and the extension of 87th Street. Most of these potential conflicts can be avoided by careful outfall alignment selection. However, two segments of an existing telephone line in Usery Pass Road will have to be relocated during construction of culverts at the Red Mountain Freeway Outfall Channel and at the Usery Park Levee.

One telephone facility under construction that will need to be protected is a transcontinental fiber-optic cable owned by American Telephone and Telegraph Communications (AT&T-C). This cable will be located under the west embankment of the proposed Raven's Roost Dam. Seepage cutoffs will be required to protect the dam in this location. The outfall from the dam will also parallel the fiber-optic cable for approximately 1 mile; sufficient horizontal and vertical separation of these two facilities will be required to avoid relocation of the cable.

Gas

The only gas pipeline within the watershed is a 2-inch diameter City of Mesa line along McLellan Road between the Spook Hill FRS and 93rd Street. The proposed McLellan Road outfall would be located to avoid this gas facility while the proposed Ellsworth Road Outfall would pass under the gas line at right angles. Adjustment of the gas line may be required.

Sanitary Sewer

There are no sanitary sewer facilities that would be impacted by the proposed drainage systems.

Electric Power

Electric power facilities in the study are are owned and operated by the Salt River Project (S.R.P.). Nearly all the facilities are overhead power lines, located primarily along McDowell Road, McLellan Road, Ellsworth Road and McKellips Road (east of Ellsworth Road). Other overhead power lines serve small subdivisions and individual parcels.

Only the McDowell Road Outfall and the McLellan Road Outfall may have any impact on existing electric power facilities. These impacts may be mitigated or avoided by careful selection of the outfall alignments.

Cable TV

Two cable TV companies have facilities in the study area: Golden Hills Cablevision and DCA Cable. At present, neither company has facilities that would be affected by the recommended plan.

OPERATION AND MAINTENANCE

The Master Drainage Plan is designed to operate by gravity. The primary operation required during storm runoff is to assure that retention basin discharge structures are not clogged and that debris is removed from the open channels, culverts, and Raven's Roost Dam outlet. The plan is designed for all-weather access to facilities, including an access road across Raven's Roost Dam.

Maintenance activity will be principally the removal of sediment from the retention basins and dam after major storm flows have been discharged. Because of the granitic basis of the study area, the trapped sediment may have some value as landscape material. Pipe outfalls and channel stilling basins should also be inspected after major storms to assure that they remain clear. It is also imperative that direct connection of storm drains to the outfall system be permanently avoided because the outfall system design has only capacity for metered outflow from retention basins.

Introduction of additional flows and the potential clogging due to sediment from direct connections could cause the system to operate in pressure flow at high hydraulic head. The results could be damage to the pipe system and back-flow through retention basin discharge structures.

QUANTITIES AND COST ESTIMATES

Estimated quantities and construction costs for each drainage system within the recommended plan are shown in Table B-2 in Appendix B. Storm drain construction includes costs for trench excavation, pipe bedding, trench backfill and compaction, reinforced concrete pipe, and manholes. Manholes were assumed to be spaced approximately every 500 feet. Detention basin construction includes cost for clearing and grubbing, excavation, embankments, grading, compaction and landscaping. Unit prices for construction items were derived from several sources including recent Arizona Department of Transportation bid tabulations, site work cost data manuals, and prices quoted by local suppliers. A 20 percent contingency factor has been applied to the total cost to cover unanticipated costs and unexpected complexities encountered in final design and construction. All costs are based on 1985 prices and will probably increase in future years due to inflation.

Estimated easement and right-of-way requirements for each drainage system and their costs are shown in Table B-1 in Appendix B. Easements for storm drains are assumed to be 15 feet wide unless otherwise noted. Right-of-way for fee title is assumed to cost $60,000 per acre; easements are assumed to have no cost.

Costs to implement each of the drainage systems in the recommended plan are shown in Table 7. Estimated design fees have been derived by estimating the number of drawings to be produced for each drainage system and adding estimated costs for surveying, soils investigations and specifications preparation. In the case of Raven's Roost Dam, additional costs for an environmental assessment and for regulatory agency licensing have also been included. Design fee is included in the estimated construction cost, but are shown as a separate item because design occurs in an earlier budget year than construction for each facility in the implementation program.

TABLE 7

MASTER DRAINAGE PLAN COSTS

DRAINAGE SYSTEM	EST. CONSTRUCTION COST, X $1,000*	EST. DESIGN FEE X $1,000	EST. R.O.W. COST, X $1,000	EST. TOTAL COST, $1,000
Indian School Road Outfall	1,019	54	1,560	2,579
Floodway Basins 1, 2, and 3	205	12	660	865
Osborn Road Outfall	1,450	76	2,340	3,790
Thomas Road Outfall	1,256	65	1,980	3,236
Quenton Street Outfall	350	18	660	1,010
McDowell Road Outfall east of Sossaman Road	858 [5]	45 [3]	1,380 [4]	2,238
McDowell Road Outfall West of Sossaman Road	534 [4]	28 [2]	300 [3]	834
Quenton Street Lateral	1,104 [4]	58 [2]	1,800 [3]	2,904
Red Mountain Freeway Outfall Channel	2,382	124 [4]	4,560	6,942
80th Street Outfall	239	12	600	839
Hawes Road Outfall	312	16	720	1,032
88th Street Outfall	536	24	960	1,496
Freeway Basin 1	175	9 [5]	540	715
Freeway Basin 2	175	9 [5]	540	715
McLellan Road Outfall	492	26	720	1,212
Ellsworth Road Outfall	603	31	12	615
Usery Park Levee	414 [2/3]	22 [1]	-	414
Raven's Roost Dam and Outfall	1,581 [2/3]	136 [1]	3,960 [1]	5,541
Quenton Street Collector Channel	368	17	435	803
McDowell Road Collector Channel	345	23	615	960
Hermosa Vista Collector Channel	276	25	350	626
TOTAL	**14,674**	**820**	**24,692**	**39,366**

* Includes 20% contingency, 15% engineering and administration.

Superscripts indicate year of implementation program.

RECOMMENDED IMPLEMENTATION PROGRAM

The Scope of Work calls for a five-year implementation program. Some of the features such as Raven's Roost Dam are essential to other Master Plan features and there is a logical sequence toward implementation of these necessary elements. Other features such as the basin and outfall systems in the northern section are only needed as development proceeds. These features are also relatively independent of effects on other systems and should only be implemented with land development. A third category are features which protect proposed public construction projects such as the freeway basins and outfall systems in the central zone that could be implemented by the public or by developers depending on when needs arise. A fourth category are features that collect and deliver flows to retention basins within the central zone where development has defined a system of streets which cross drainage patterns at an angle and divert some flows. These features, such as collector channels, will be needed only when and if development occurs which increases the densities beyond the existing acre and multi-acre lot sizes within this zone. The five-year program presented here specifically addresses the first and third categories. The program is shown graphically in Figure 14.

YEAR 1 - Design of Raven's Roost Dam and Outfall and of Usery Park Levee, Right-of-way acquisition for these features.

YEAR TOTAL COST $4,118,000

YEAR 2
- Design of Quenton Street Lateral and Retention Basins
- Design of McDowell Road Outfall from Spook Hill FRS to Sossaman Road.
- Construct Raven's Roost Dam and Outfall and Usery Park Levee (2 years).

YEAR TOTAL COST $1,083,500

YEAR 3
- Design McDowell Road Outfall and Basins east of Sossaman Road
- Acquire right-of-way for Quenton Street Lateral and Basins and McDowell Road Outfall west of Sossman Road
- Complete Raven's Roost Dam and Outfall and Usery Park Levee and McDowell Road Outfall from Spook Hill FRS to Sossaman Road

YEAR TOTAL COST $3,142,500

SPOOK HILL WATERSHED MASTER DRAINAGE PLAN

Figure 14

5 YEAR IMPLEMENTATION PROGRAM FEATURES NOT DIRECTLY RELATED TO LAND DEVELOPMENT

Year	1	2	3	4	5
Raven's Roost Dam & Outfall, Usery Park Levee	Design; Aquisition of Right-of-Way	Construction	Construction		
McDowell Rd. Outfall & Detention Basin West of Sossaman Rd.		Design	Aquisition of Right-of-Way	Construction	
Quenton Street Lateral & Detention Basins		Design	Aquisition of Right-of-Way	Construction	
McDowell Rd. Outfall & Detention Basins East of Sossaman Rd.			Design	Aquisition of Right-of-Way	Construction
Red Mountain Freeway Outfall Channel				Design	
Red Mountain Freeway Detention Basins					Design
TOTAL BUDGET	$4,118,00	$1,083,500	$3,142,500	$3,142,000	$876,000

Legend: Design — Aquisition of Right-of-Way — Construction

YEAR 4 - Construct Quenton Street Lateral and Basins and McDowell Road Outfall from Spook Hill FRS to Sossaman Road

- Acquire right-of-way for McDowell Road Outfall and Basins east of Sossaman Road

- Design Red Mountain Freeway Outfall Channel for "as needed" construction

YEAR TOTAL COST $3,142,000

YEAR 5 - Construct McDowell Road Outfall and Basins east of Sossaman Road

- Design Freeway Basins for "as needed" construction

YEAR TOTAL COST $ 876,000

The remainder of the Master Drainage Plan features may either be constructed by concurrent development or await public construction of Red Mountain Freeway and Ellsworth Freeway. Outfall channels should be constructed beginning at the downstream end. The pattern of land development may dictate that a developer construct an entire outfall through undeveloped land or await construction of the outfall by his downhill neighbor. Some public agency support of right-of-way acquisition for developer-installed features may result in earlier implementation of privately constructed features, and hence, earlier attainment of the benefits of the Master Drainage Plan.

FINANCING OPTIONS

Several methods are available to distribute costs among public and private beneficiaries. Those which appear most viable are presented here.

Developer Implementation - In those areas where large parcels of land are developed, the intent of the Master Drainage Plan is to allow the developer to construct the plan as presented or as he choses in accordance with current City of Mesa subdivision regulations, such that the effect of the Master Drainage Plan is carried out. These are developer costs, as in any other area of the City of Mesa.

Where a developer constructs a complete system, but subsequent developments benefit by being able to discharge retention basins to the system, the costs may be prorated with the subsequent developer being assessed his prorata share for reimbursement of the developer who constructed the system.

Public Financing - For major features such as the Raven's Roost Dam and appurtenances, the public agencies may choose to jointly fund the construction as a public project without attempting to define and assess private benefits.

For other facilities, such as the Red Mountain Freeway Outfall Channel, one public agency (ADOT) may reimburse cost savings to another agency (FCD, Mesa) for actual construction cost or a portion of the estimated cost savings realized due to the implementation of the Master Drainage Plan. The cost sharing may take other forms such as acquisition of right-of-way in lieu of reimbursement or early construction of roadway segments utilizing retention basin excavation as borrow material.

Public/Private Cost Sharing - It may be feasible in the case of Raven's Roost Dam, the Quenton Street Lateral and McDowell Road Outfall to determine relative benefits to owners of existing developed property and future development. Costs could be allocated between the public and private sectors through an improvement district or special assessment district for payback of allocated costs by installment. In most cases where a public agency decided in favor of front-ending costs for facilities, say the Red Mountain Freeway retention basins, which directly served identifible developable properties, it is expected that costs would be assessed against future development and collected as a portion of the development fees during the subdivision process. The public/private cost sharing concept is particularly well-adapted for future developments of smaller parcels, i.e. 80 acres or less which are tributary with other lands to a retention basin or outfall system.

FINAL DESIGN

The Master Drainage Plan is defined sufficiently for final design of any feature of the plan to begin. As seen the in the Master Drainage Plan hydrology model, the Master Plan functions well in the configuration presented. The Master Plan allows for flexibility, however, in that development in adherence to the City of Mesa subdivision regulations is generally adaptable to the function of the plan.

The major features, such as Usery Park Levee, Raven's Roost Dam and Outfall Pipe, and the Red Mountain Freeway Channel have been located to provide specific major benefits, and relocation to any degree should be in consideration of their function.

For each feature, site-specific hydrology and geotechnical exploration are essential. In addition, a common survey datum for the entire Master Drainage Plan should be established early-on and all facilities surveyed and designed to that datum. Because profiles for the plan were taken from USGS Quadrangle Maps, some adjustments of profiles to surveyed topographic conditions will be needed. In such cases, adherence to the design criteria will assure that the adjusted system design will function as planned. Specific necessities are: final establishment of Raven's Roost spillway and top-of-dam elevations through hydrologic analysis of site-specific spillway and freeboard storm hydrology; location of suitable impervious core and stable embankment materials by geotechnical exploration and establishment of zoned-fill slopes by embankment stability analysis of these soils under dry and dam-full conditions; determination of cutoff trench depth and spillway profile by site borings and analysis; determination of suitable riprap sources and production methods for riprap sized to meet specific hydraulic conditions at the dam embankment, levee face and at outfall structures; determination of suitable sources and mix designs for the soil-cement channels; final culvert structural designs; hydraulic design of basin and dam outlet structures and debris-proofing design; pipe final hydraulic analysis and "D" load design; junction structure design.

Costs will be a major factor in implementing the Master Drainage Plan, particularly in budgeting of public funds. Cost savings may be investigated in reducing retention basin right-of-way by deepening the basins beyond the 3½ foot maximum depth allowed in the Master Drainage Plan and increasing or "stepping" the side slopes.

Much of the runoff collection will be via the street system. In areas where existing unpaved streets exist, consideration should be given to paving and installing curb and gutter. For major public street projects such as the proposed McDowell Road improvements, catch basins outfalling to retention basins should be built in addition to curb and gutter construction.

In any modifications of land use, consideration should be given to development of street patterns, landscape slopes and treatments which minimize the production of sediment to reduce the ultimate maintenance expense for the Master Drainage Plan.

FUTURE DEVELOPMENT CONSIDERATIONS

The Master Drainage Plan addresses hydrology based on drainage subareas of finite size, generally 160 acres. Retention basins have been located at the low corner or edge of the subareas. These locations are the logical collection points for retention of runoff, however, consideration of specific basin sites and collection systems for undeveloped areas is a function of subdivision planning and design. The following is a listing of considerations in establishing internal drainage within the drainage subareas during implementation.

1. Each subarea should be modeled hydrologically in the final design process to establish a design volume for the retention basins. The model should be based on the proposed development pattern or, within partially-developed zones, the existing drainage pattern.

2. The layout of street patterns may be used as a series of laterals to collect runoff and direct flows toward the retention basin or internal drainage system. Where streets are used as a major element in the delivery of accummulated lateral flows to the retention basin, care should be taken to limit depths of flow to City of Mesa standards using a normal crown street cross-section. Excess flows should be carried via channels or piped storm drains.

3. In some developed areas a more practical option may be to provide the aggregate subarea retention volume in a series of smaller retention ponds located throughout the subarea. A piped discharge system extended from the outfall pipe or channel will be required. Sediment-laden flows should not be introduced into these pipes.

4. The Master Drainage Plan model is based on a land use for future development of up to six residential units per acre based on Maricopa County projections [9]. This appears to be a good "average" value for 160 acre subareas. However, the Plan should be viewed as flexible to accommodate future zoning changes.

5. Some of the landowners in the central zone, where existing densities are between one to ten acres per dwelling unit, have expressed the intention to maintain this low density environment for the foreseeable future. In these areas it may be advisable to acquire retention sites against the potential for infilling of vacant lands by developed at higher densities, but to delay acquisition and construction of collector channels until they are required to handle increased runoff from developments.

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TABLE A-1

AVERAGE CURVE NUMBERS FOR DRAINAGE SUBAREAS

WATERSHED	CURRENT LAND USE	FUTURE LAND USE
1.1	81.7	85.4
1.2	82.2	87.3
1.3	83.4	87.6
2.1	84.2	85.9
2.2	82.7	85.3
2.3	76.7	84.4
2.4	83.1	88.5
2.5	87.0	85.2
2.6	79.6	86.2
2.7	83.0	88.1
2.8	81.9	87.5
2.9	78.7	85.1
3.1	83.4	86.7
3.2	80.1	85.9
4.1	79.8	86.4
4.2	75.8	83.0
5.1	85.3	87.0
5.2	75.1	76.8
5.3	76.9	83.6
6.1	76.9	83.6
6.1	78.9	79.5
6.2	79.8	84.4
6.3	79.3	86.3
6.4	74.3	74.3
6.5	79.1	83.1
10	81.8	87.7
11	76.8	83.8

TABLE A-2
100-YEAR 2-HOUR STORM SUBAREA HYDROLOGY

STATION	CURRENT WATERSHED CONDITIONS PEAK FLOW cfs	TIME PEAK hours	VOLUME ac-ft.	FUTURE WATERSHED CONDITIONS PEAK FLOW cfs	TIME PEAK hours	VOLUME ac-ft.
PASS MOUNTAIN DIVERSION WATERSHED						
SB 7	491	2.00	56	491	2.00	56
SB 8	1157	1.67	93	1157	1.67	93
SB 9	1962	1.50	137	1962	1.50	137
SPOOK HILL WATERSHED MODEL						
SB11	182	2.00	20	282	1.67	29
SB10	234	1.83	27	369	1.67	36
SB 6.4	60	2.00	7	60	2.00	7
SB 6.5	377	2.00	53	509	2.00	64
SB 6.1	776	2.00	106	816	2.00	109
SB 6.2	171	1.83	19	248	1.67	24
SB 6.3	280	1.83	34	429	1.67	47
SB 5.1	791	1.50	38	832	1.50	41
SB 5.2	384	2.17	55	436	2.17	61
SB 5.3	551	2.33	124	946	2.17	175
SB 4.1	170	1.67	16	245	1.50	22
SB 4.2	304	2.33	66	537	2.17	95
SB 3.1	333	1.50	16	394	1.33	19
SB 3.2	764	2.33	166	1192	2.17	220
SB 2.8	169	1.33	8	251	1.33	11
SB 2.9	283	2.17	47	447	2.00	65
SB 2.5	50	1.33	2	46	1.33	2
SB 2.6	326	2.00	44	536	1.83	60
SB 2.7	412	1.50	21	519	1.50	26
SB 2.1	857	1.50	39	903	1.50	43
SB 2.2	230	1.33	11	278	1.33	12
SB 2.3	235	2.00	31	379	1.83	45
SB 2.4	331	1.50	26	514	1.50	34
SB 1.1	153	1.50	8	189	1.33	9
SB 1.2	284	1.50	26	433	1.50	33
SB 1.3	352	1.50	24	493	1.50	29

TABLE A-3

100-YEAR 2-HOUR STORM ROUTED HYDROLOGY

	CURRENT WATERSHED CONDITIONS				**FUTURE WATERSHED CONDITIONS**			
STATION	**PEAK FLOW** cfs	**TIME PEAK** hours	**MAX. STAGE** feet	**TIME MAX. STAGE** hours	**PEAK FLOW** cfs	**TIME PEAK** hours	**MAX. STAGE** feet	**TIME OF STAGE** hours
PASS MOUNTAIN DIVERSION WATERSHED								
SB 7	491	2.00			491	2.00		
SB 8	1157	1.67			1157	1.67		
RT89	1428	1.83						
SB 9	1962	1.50			1962	1.50		
CB89	3090	1.50			3090	1.50		
SPOOK HILL WATERSHED MODEL								
SIGNAL BUTTE FRS DISCHARGE	156	1.33			156	1.33		
SB11	340	1.83			442	1.67		
SB10	557	1.83			737	1.83		
SB 6.5	821	2.17			1097	2.17		
SB 6.3	1313	2.33			1672	2.17		
SB 5.3	1805	2.33			2385	2.17		
SB 4.2	2111	2.33			2924	2.17		
SB 3.2	2796	2.33			3974	2.17		
SB 2.9	3073	2.33			4413	2.17		
FRS RES	503	7.33	1580.67	7.33	660	6.67	1581.37	6.67
SB 2.7	515	7.17			679	6.33		
SB 2.4	807	2.17			1166	2.17		
SB 1.3	1135	2.17			1637	2.00		

TABLE A-4

100-YEAR 24-HOUR STORM ROUTED HYDROLOGY

	CURRENT WATERSHED CONDITIONS				**FUTURE WATERSHED CONDITIONS**			
STATION	**PEAK FLOW** cfs	**TIME PEAK** hours	**MAX. STAGE** feet	**TIME MAX. STAGE** hours	**PEAK FLOW** cfs	**TIME PEAK** hours	**MAX. STAGE** feet	**TIME MAX. STAGE** hours
PASS MOUNTAIN DIVERSION WATERSHED								
SB 7	629	12.67			629	12.67		
SB 8	1433	12.33			1433	12.33		
CB78	1856	12.33			1856	12.33		
SB 9	2201	12.33			2201	12.33		
CB89	3802	12.33			3802	12.33		
SPOOK HILL WATERSHED MODEL								
SIGNAL BUTTE FRS DISCHARGE	156	2.67			156	2.67		
SB11	472	12.67			671	12.67		
SB10	917	12.67			1186	12.67		
SB 6.5	1162	13.00			1490	13.00		
SB 6.3	1952	13.00			2410	13.00		
SB 5.3	2749	13.00			3531	13.00		
SB 4.2	3247	13.00			4350	13.00		
SB 3.2	4314	13.00			5901	13.00		
SB 2.9	4757	13.00			6423	13.00		
SPOOK HILL FRS RES	940	17.67	1582.51	17.67	1144	17.33	1583.25	17.33
SB 2.7	983	17.33			1197	17.00		
SB 2.4	1290	13.00			1762	13.00		
SB 1.3	1713	13.00			2404	12.67		

TABLE A-5

MASTER DRAINAGE PLAN HYDROLOGY MODEL SUMMARY

KEY TO SYMBOLS

SB - Calculate runoff from drainage subareas.
CB - Combine hydrographs in Buckhorn - Mesa flood control structure.
RT - Route flows through Buckhorn - Mesa flood control structure.
PR - Routing through pipe.
PJ - Combine hydrographs at a pipe junction.
RR - Reservoir routing.
RB - Retention basin routing.
CR - Channel routing.
CJ - Combine hydrographs at a channel junction point.

	STATION	**PEAK FLOW** cfs	**TIME OF PEAK** hours	**MAXIMUM STAGE** feet	**TIME OF MAX STAGE** hours
Inflow from					
Signal Butte	28	156	1.33		
SB-CB-RT	27	442	1.67		
SB-CB-RT	26	737	1.83		
SB-CB-RT	25	1027	2.00		
SB-CB-RT	24	1106	2.00		
SB	23.1	1397	2.00		
RR					
(Raven's Roost)	23.1	58	5.83	1861.40	5.83
PR	23.1	58	6.00		
CB	23.1	1143	2.00		
SB-CB-RT	22	1308	2.00		
SB-CB-RT	21	1422	2.00		
SB-CB-RT	20	1471	2.00		
SB-CB-RT	19	1617	1.83		
SB-CB-RT	18	1686	1.83		
SB	17.2	158	1.50		
RB	17.2	6	4.17		
PR	17.2	6	4.17		

TABLE A-5
(Continued)

MASTER DRAINAGE PLAN HYDROLOGY MODEL SUMMARY

	STATION	PEAK FLOW cfs	TIME OF PEAK hours	MAXIMUM STAGE feet	TIME OF MAX STAGE hours
SB	17.1	191	1.50		
RB	17.1	9	3.67	102.42	3.83
PJ	17.1	14	3.83		
PR	17.1	14	4.00		
CB	17.1	1698	1.83		
RT	17.1	1697	1.83		
SB	15.10	161	2.33		
RB	15.10	14	6.67		
CR	15.10	14	6.83		
SB	15.9	331	1.50		
RB	15.9	10	3.83	102.87	3.83
CJ	15.9	24	5.83		
CR	15.9	24	6.00		
SB	15.8	128	1.83		
RB	15.8	8	4.50	102.29	4.50
PR	15.8	8	4.50		
SB	15.7	588	1.50		
RB	15.7	11	3.50	103.44	3.50
PJ	15.7	19	4.17		
PR	15.7	19	4.17		
SB	15.6	142	1.50		
RB	15.6	5	3.67	102.76	3.83
CJ	15.6	48	5.17		
CR	15.6	48	5.17		
SB	15.5	513	1.50		
RB	15.5	15	3.67		
PR	15.5	15	3.67		
SB	15.4	322	1.67		

TABLE A-5

(Continued)

MASTER DRAINAGE PLAN HYDROLOGY MODEL SUMMARY

	STATION	PEAK FLOW cfs	TIME OF PEAK hours	MAXIMUM STAGE feet	TIME OF MAX STAGE hours
RB	15.4	12	4.17	102.92	4.17
CJ	15.4	75	4.83		
CR	15.4	75	4.83		
SB	15.3	353	1.50		
RB	15.3	11	3.83	102.72	4.00
PR	15.3	11	4.00		
SB	15.2	199	1.67		
RB	15.2	9	4.17	102.90	4.17
CJ	15.2	95	4.67		
CR	15.2	95	4.67		
SB	15.1	397	1.50		
RB	15.1	9	2.83	103.17	2.83
CJ	15.1	104	4.67		
CR	15.1	104	4.67		
CB	15	1918	1.83		
SB	14	192	1.83		
RB	14	192	1.83	102.52	4.50
CB	14	1926	1.83		
RT	14	1926	1.83		
SB	13	266	1.50		
RB	13	10	4.17	102.92	4.17
CB	13	1934	1.83		
RT	13	1934	1.83		
SB	12.5	195	1.50		
RB	12.5	6	4.00		
PR	12.5	6	4.00		
SB	12.5	6	4.00		

TABLE A-5

(Continued)

MASTER DRAINAGE PLAN HYDROLOGY MODEL SUMMARY

	STATION	PEAK FLOW cfs	TIME OF PEAK hours	MAXIMUM STAGE feet	TIME OF MAX STAGE hours
RB	12.4	9	3.33	103.02	3.33
SB	12.3	219	1.50		
RB	12.3	5	3.33	103.21	3.33
PJ	12.3	20	3.50		
PR	12.3	20	3.50		
SB	12.2	223	1.50		
RB	12.2	9	4.00	102.96	4.00
PJ	12.2	29	3.67		
PR	12.2	29	3.83		
SB	12.9	538	1.50		
RB	12.9	14	3.50	102.85	3.50
PR	12.9	14	3.67		
SB	12.8	319	1.50		
RB	12.8	6	3.33	103.09	3.50
PJ	12.8	20	3.50		
PR	12.7	165	1.50		
RB	12.7	5	3.67	102.94	3.83
PJ	12.7	25	3.67		
PR	12.7	25	3.67		
SB	12.6	519	1.50		
RB	12.6	10	3.33	103.08	3.50
PJ	12.6	36	3.67		
PR	12.6	36	3.67		
SB	12.1	263	1.50		
RB	12.1	5	3.33	102.66	3.33
PJ	12.1	70	3.67		
PR	12.1	70	3.83		

TABLE A-5

(Continued)

MASTER DRAINAGE PLAN HYDROLOGY MODEL SUMMARY

	STATION	PEAK FLOW cfs	TIME OF PEAK hours	MAXIMUM STAGE feet	TIME OF MAX STAGE hours
CB	12	1992	1.83		
SB-CB	11	2015	1.83		
RR	FRS	356	23.83	1579.98	23.83
CB	9	356	23.83		
SB	8.1	346	1.50		
RB	8.1	9	3.50	103.13	3.50
SB	8.2	140	1.50		
RB	8.2	5	3.83	102.86	4.00
PJ	8	14	3.67		
PR	8	14	3.67		
CB	7	367	23.87		
SB	7.6	50	1.33		
RB	7.6	2	2.33	101.19	2.33
PR	7.6	2	2.50		
SB	7.5	229	1.33		
RB	7.5	5	2.83	1202.96	2.83
PJ	7.5	7	2.50		
PR	7.5	7	2.50		
PR	7.5	7	2.67		
SB	7.4	192	1.50		
RB	7.4	5	1.50	103.22	3.50
PJ	7.4	12	2.83		
PR	7.4	12	2.83		
SB	7.3	297	1.50		
RB	7.3	9	3.33	102.55	3.33
PJ	7.3	21	3.00		
PR	7.3	21	3.00		
SB	7.2	101	1.50		

TABLE A-5

(Continued)

MASTER DRAINAGE PLAN HYDROLOGY MODEL SUMMARY

	STATION	PEAK FLOW cfs	TIME OF PEAK hours	MAXIMUM STAGE feet	TIME OF MAX STAGE hours
RB	7.2	4	3.67	102.44	3.67
PJ	7.2	25	3.17		
PR	7.2	25	3.17		
CB	7	386	23.50		
SB	6	390	1.50		
RB	6	9	2.83	103.05	3.00
CB	6	392	23.50		
RT	6	392	23.67		
SB	5	327	1.50		
RB	5	9	3.00		
CB	5	398	23.67		
RT	5	398	23.67		
SB	4.6	333	1.33		
RB	4.6	6	2.83	103.19	2.83
PR	4.6	6	2.83		
SB	4.5	706	1.50		
RB	4.5	15	3.00	103.19	3.17
PR	4.5	15	3.17		
PJ	4.5	21	3.00		
SB	4.4	201	1.50		
RB	4.4	5	3.17	103.08	3.17
PJ	4.4	25	3.17		
PR	4.4	25	3.17		
SB	4.3	205	1.50		
RB	4.3	5	3.17	103.11	3.17
PJ	4.3	30	3.17		
PR	4.3	30	3.17		
SB	4.2	252	1.50		

TABLE A-5
(Continued)

MASTER DRAINAGE PLAN HYDROLOGY MODEL SUMMARY

	STATION	PEAK FLOW cfs	TIME OF PEAK hours	MAXIMUM STAGE feet	TIME OF MAX STAGE hours
RB	4.2	5	3.33	103.12	3.50
PJ	4.2	35	3.17		
PR	4.2	35	3.33		
SB	4.1	597	1.50		
RB	4.1	11	3.50	102.94	3.50
PJ	4.1	46	3.33		
PR	4.1	46	3.33		
PR	4.1	46	3.33		
CB	4.0	434	23.67		
RT	4.0	434	1.50		
RB	3.0	4	2.83	102.50	3.00
CB	3.0	437	23.67		
RT	3.0	437	23.67		
SB	2.5	141	1.33		
RB	2.5	4	2.67		
PR	2.5	4	2.67		
SB	2.4	193	1.33		
RB	2.4	5	2.83		
PJ	2.4	9	2.83		
PR	2.4	9	2.83		
SB	2.3	227	1.50		
RB	2.3	5	3.17		
PJ	2.3	14	3.00		
PR	2.3	14	3.00		
SB	2.2	364	1.33		
RB	2.2	9	2.83		
PJ	2.2	23	3.00		
PR	2.2	23	3.00		
SB	2.1	338	1.33		
RB	2.1	9	2.83		
PJ	2.1	32	3.00		

TABLE A-5

(Continued)

MASTER DRAINAGE PLAN HYDROLOGY MODEL SUMMARY

	STATION	PEAK FLOW cfs	TIME OF PEAK hours	MAXIMUM STAGE feet	TIME OF MAX STAGE hours
PR	2.1	32	3.00		
CB	2.1	459	23.50		
RT	2.1	458	23.50		
SB	1	170	1.50		
CB	1	458	23.50		

TABLE A-6

SEDIMENT YIELD FOR THE 100-YEAR 2-HOUR AND 2-YEAR 2-HOUR STORMS

	100-YEAR 2-HOUR		2-YEAR 2-HOUR	
DRAINAGE SUBAREA	SEDIMENT YIELD (TONS)	SEDIMENT YIELD (INCHES)	SEDIMENT YIELD (TONS)	SEDIMENT YIELD (INCHES)
1.1	--	--	--	--
1.2	8,527	.15	701	.013
1.3	3,257	.07	257	.006
2.1	--	--	--	--
2.2	--	--	--	--
2.3	10,902	.14	567	.007
2.4	2,420	.05	229	.002
2.5	--	--	--	--
2.6	7,019	.07	430	.003
2.7	2,255	.06	169	.001
2.8	--	--	--	--
2.9	5,216	.05	252	.002
3.1	--	--	--	--
3.2	26,466	.07	1214	.008
4.1	3,236	.09	244	.007
4.2	11,384	.06	378	.002
5.1	--	--	--	--
5.2	16,494	.11	203	.001
5.3	19,875	.06	671	.002
6.1	13,505	.06	287	.001
6.2	2,196	.05	126	.003
6.3	5,164	.07	332	.004
6.4	559	.03	--	--
6.5	7,219	.06	288	.002
7	7,739	.06	402	.003
8	12,521	.07	915	.005
9	--	--	--	--
10	2,434	.04	177	.003
11	2,248	.04	109	.002

TABLE B-1

ESTIMATED EASEMENT AND RIGHT-OF-WAY REQUIREMENTS

DRAINAGE SYSTEM	RIGHT-OF-WAY (ACRES) CHANNEL	BASIN	TOTAL	EASEMENT LINEAL FT.[a]	RIGHT-OF-WAY COST $ THOUSANDS
Indian School Road Outfall	-	26	26	9,000	$1,560
Floodway Basins 1,2, and 3	-	11	11	--	660
Osborn Road	-	39	39	12,200	2,340
Thomas Road Outfall	-	33	33	11,800	1,980
Quenton Street Outfall	-	11	11	2,300	660
McDowell Road Outfall east of Sossaman Road	-	23	23	--	1,380
McDowell Road Outfall west of Sossaman Road	-	5	5	--	300
Quenton Street Lateral	-	30	30	9,000	1,800
Red Mountain Freeway Outfall Channel	25	51	76	--	4,560
80th Street Outfall	-	10	10	2,000	600
Hawes Road Outfall	-	12	12	2,000	720
88th Street Outfall	-	16	16	4,700	960
Freeway Basin 1	-	9	9	--	540
Freeway Basin 2	-	9	9	--	540
McLellan Road Outfall	-	12	12	4,500	720
Ellsworth Road Outfall	0.2	-	0.2	3,400[b]	12
Usery Park Levee	--	-	--	--	--
Raven's Roost Dam and Outfall	--	66	66	9,600	3,960
Quenton Street Collector Channel	7.2	-	7.2		435
McDowell Road Collector Channel	10.3	-	10.3		615
Hermoso Vista Collector Channel	5.8	-	5.8		350
TOTALS	**48.5**	**363**	**411.5**	**67,100** **3,400[b]**	**24,692**

[a] 15 feet wide easement unless otherwise noted.

[b] 20 feet wide easement.

TABLE B-2

ESTIMATED QUANTITIES AND CONSTRUCTION COSTS

Drainage System	Item Description	Quantity	Units	$ Thousand	$ Thousand
Indian School	30" Pipe	0.4	mi	246	98
Road Outfall	24" Pipe	0.6	mi	220	132
	18" Pipe	1.1	mi	188	207
	Retention Basins	5	LS	--	281
	Outlet Structure	1	ea	20	20
	Continency	20%			148
	Estimated Cost				$ 886
Floodway	Retention Basins	3	LS	--	118
Basins 1, 2	Outfall and Outlet				
	Structures	3	ea	10	30
and 3	Contingency	20%	—	--	30
	Estimated Cost				$ 178
Osborn Road	36" Pipe	0.4	mi	330	132
Outfall	30" Pipe	0.5	mi	246	123
	27" Pipe	0.6	mi	233	140
	24" Pipe	0.5	mi	220	110
	18" Pipe	0.5	mi	188	94
	Retention Basins	6	LS	--	432
	Outlet Structure	1	ea	20	20
	Continency	20%			210
	Estimated Cost				$1,261

TABLE B-2

(Continued)

ESTIMATED QUANTITIES AND CONSTRUCTION COSTS

Drainage System	Item Description	Quantity	Units	$ Thousand	$ Thousand
Thomas Road	30" Pipe	1.3	mi	246	320
Outfall	24" Pipe	0.7	mi	220	154
	18" Pipe	0.3	mi	188	56
	Retention Basins	7	LS	--	359
	Outlet Structure	1	ea	20	20
	Contingency	20%			182
	Estimated Cost				$1,091
Quenton Street	24" Pipe	0.5	mi	220	110
Outfall	Retention basins	2	LS	--	123
	Outlet Structure	1	ea	20	20
	Contingency	20%			51
	Estimated Cost				$ 304
McDowell Road	30" Pipe	0.3	mi	246	74
Outfall east of	27" Pipe	0.4	mi	233	93
Sossaman Road	24" Pipe	0.4	mi	220	88
	18" Pipe	0.6	mi	188	113
	Retention Basins	4	LS	--	254
	Contingency	20%	-	--	124
	Estimated Cost				$ 746
McDowell Road	42" Pipe	0.75	mi	414	311
Outfall west of	Retention Basins	1	LS	--	55
Sossaman Road	Outlet Structure	1	ea	20	20
	Contingency	20%	—	--	78
	Estimated Cost				$ 464

TABLE B-2
(continued)

ESTIMATED QUANTITIES AND CONSTRUCTION COSTS

Drainage System	Item Description	Quantity	Units	$ Thousand	$ Thousand
Quenton Street	36" Pipe	0.3	mi	330	99
	30" Pipe	0.5	mi	246	123
	27" Pipe	0.25	mi	233	58
	24" Pipe	0.5	mi	220	110
	18" Pipe	0.4	mi	188	75
	Retention Basins	4	LS	--	335
	Contingency	20%	-	--	160
	Estimated Cost				$ 960
Red Mountain Freeway Outfall Channel	Lined Channel	3.0	mi	350	1,050
	Stilling Basins	5	ea	15	75
	Concrete box culvert	1	ea	15	15
	Retention Basins	6	LS	--	566
	Outlet Structure	1	ea	20	20
	Contingency	20%			345
	Estimated Cost				$2,071
80th Street Outfall	24" Pipe	0.15	mi	220	33
	21" Pipe	0.25	mi	204	51
	Retention Basin	1	LS	--	114
	Outlet Structure	1	ea	10	10
	Contingency	20%	-	--	42
	Estimated Cost				$ 208

TABLE B-2
(continued)

ESTIMATED QUANTITIES AND CONSTRUCTION COSTS

Drainage System	Item Description	Quantity	Units	$ Thousand	$ Thousand
Hawes Road	21" Pipe	0.4	mi	204	82
Outfall	Retention Basins	1	LS	--	134
	Outlet Structure	1	ea	10	10
	Contingency	20% -	--	45	
	Estimated Cost				$ 271
88th Street	27" Pipe	0.4	mi	233	93
Outfall	24" Pipe	0.5	mi	220	110
	Retention Basins	2	LS	--	175
	Outlet Structure	1	ea	10	10
	Contingency	20%	-	--	78
	Estimated Cost				$ 466
Freeway Basin 1	18" Pipe	0.1	mi	188	19
	Retention Basin	1	LS	--	98
	Outlet Structure	1	ea	10	10
	Contingency	20%	-	--	25
	Estimated Cost				$ 152
Freeway Basin 2	18" Pipe	0.1	mi	188	19
	Retention Basin	1	LS	--	98
	Outlet Structure	1	ea	10	10
	Contingency	20%	-	--	25
	Estimated Cost				$ 152

TABLE B-2
(continued)

ESTIMATED QUANTITIES AND CONSTRUCTION COSTS

Drainage System	Item Description	Quantity	Units	$ Thousand	$ Thousand
McLellan Road	30" Pipe	0.1	mi	246	25
Outfall	27" Pipe	0.1	mi	233	23
	24" Pipe	0.7	mi	220	154
	Retention Basins	2	L.S.	--	135
	Outlet Structures	1	ea	20	20
	Contingency	20%	-	--	71
	Estimated Cost				$ 428
Ellsworth Road	54" Pipe	0.7	mi	582	407
	Outlet Structure	1	ea	30	30
	Contingency	20%	-	--	87
	Estimated Cost				$ 524
Usery Park	Lined channel	0.3	mi	350	104
Levee	Levee	1.1	mi	110	121
	Concrete box culvert	1	ea	75	75
	Contingency	20%	-	--	60
	Estimated Cost				$ 360
Raven's Roost	Clear and grub	10	ac	1	10
Dam and Outfall	Embankment	46	10^3cy	6.5	299
	Unclassified excavation	60	10^3cy	1.5	90
	Rock excavation	2.4	10^3cy	20.0	48
	Levee	0.2	mi	110	22
	Dam Outlet	1	ea	20	20
	Spillway	1	ea	10	10
	36" Pipe	1.9	mi	330	627
	Pipe Outlet Structure	1	mi	20	20
	Contingency	-	-	--	229
	Estimated Cost				$1,375

TABLE B-2
(continued)

ESTIMATED QUANTITIES AND CONSTRUCTION COSTS

Drainage System	Item Description	Quantity	Units	$ Thousand	$ Thousand
Hermosa Vista Collector Channel	Channel clear, grub	5.8	ac	1.5	9
	Channel excavation	24	10^3cy	1.5	36
	Channel lining	19	10^3sy	5	95
	Stilling basins	8	ea	15	120
	Concrete box culvert	1	ea	15	15
	Contingency				45
	Estimated cost				320
McDowell Road Collector Channel	Channel clear, grub	10.2	ac	1.5	15
	Channel excavation	30	10^3cy	1.5	45
	Channel lining	24	10^3sy	5	145
	Stilling basins	8	ea	15	120
	Concrete box culvert	3	ea	15	45
	Contingency				50
	Estimated cost				300

TABLE B-2

(continued)

ESTIMATED QUANTITIES AND CONSTRUCTION COSTS

Drainage System	Item Description	Quantity	Units	$ Thousand	$ Thousand
Quenton Street Collector Channel	Channel clear, grub	6.7	ac	1.5	10
	Channel excavation	23	10^3cy	1.5	35
	Channel lining	22	10^3sy	5	110
	Stilling basins	2	ea	15	30
	Concrete box culvert	1	ea	15	15
	Contingency				40
	Estimated cost				240
	GRAND TOTAL				**12,757**