Presentation of Alternatives

SPOOK HILL WATERSHED

MASTER DRAINAGE PLAN, PHASE I

April 25, 1985

Prepared for:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

Prepared by:

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INTRODUCTION

The purpose of this study is to develop a Master Plan for stormwater drainage within the watershed of Spook Hill and Signal Butte features of the Buckhorn - Mesa Watershed Protection Project (SCS). The Buckhorn - Mesa structures were planned to provide 100-year flood protection to areas in eastern Mesa downstream from the structures. 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 plan for stormwater drainage 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 the future 100-year floods.

BACKGROUND

Watershed

The Spook Hill Watershed is approximately 16 square miles in area located on the south and west slopes of the Usery Mountains. The location is shown on Figure 1. 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 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, storm runoff is characterized by 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 receeds 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

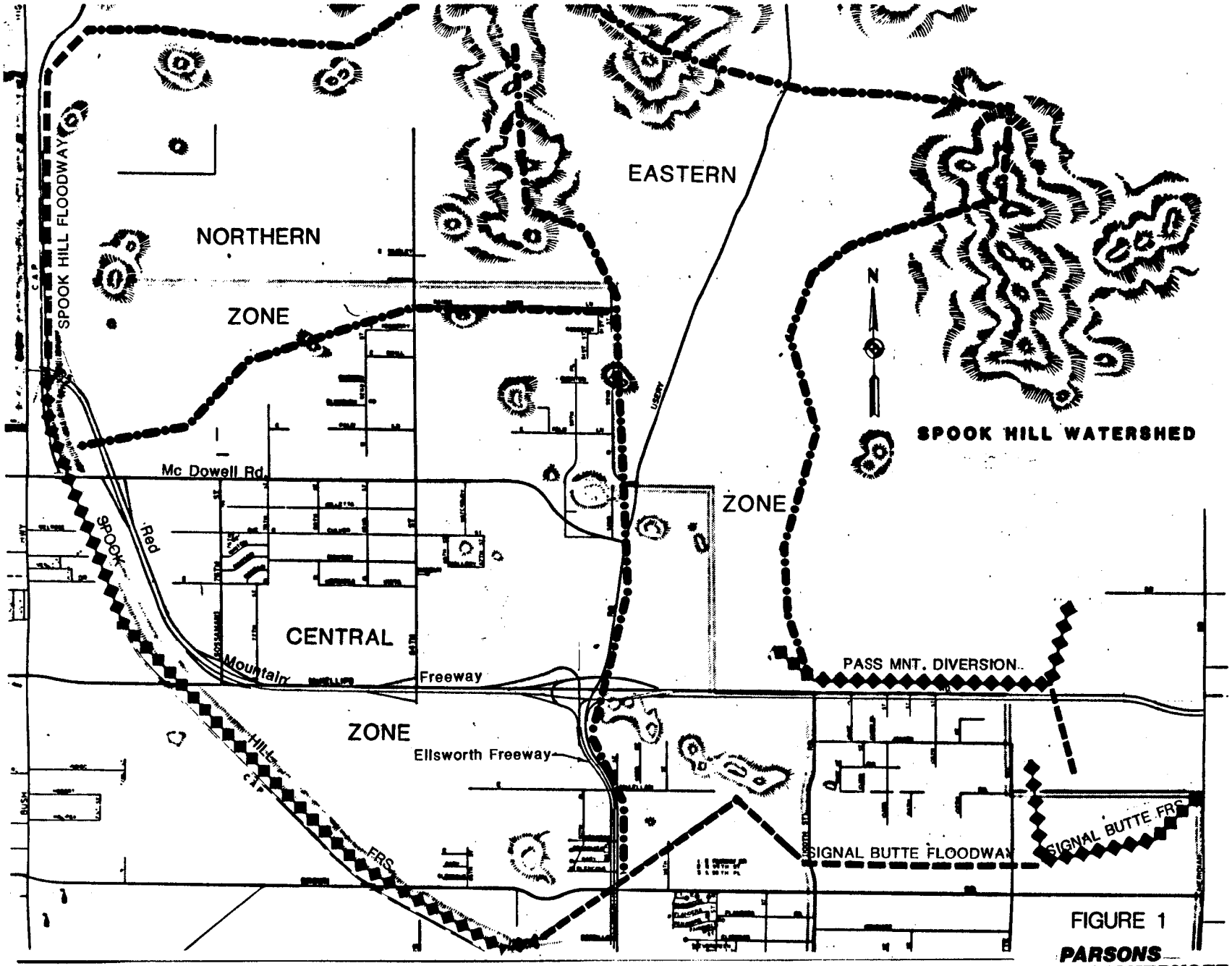

FIGURE 1

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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.

Buckhorn - Mesa Project

The purpose of the Buckhorn - Mesa Watershed Project is the prevention of floodwater and sediment damage to 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.

Because the Buckhorn - Mesa features operate as a system, it is essential to preserve the capability of each of the components to function as designed. At the same time, it is inevitable that development will occur within the watershed. The goal of this study is to determine how development can occur without compromising the Buckhorn - Mesa Watershed Project function.

Land Use

The pattern of current and future land uses across the watershed indicate three characteristic zones, each with unique impacts on development of a master drainage plan. It is convenient to consider the alternative plans and their implementation by zone and then to merge the best zone alternatives into an overall master plan. The zones are delineated on Figure 1.

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 -

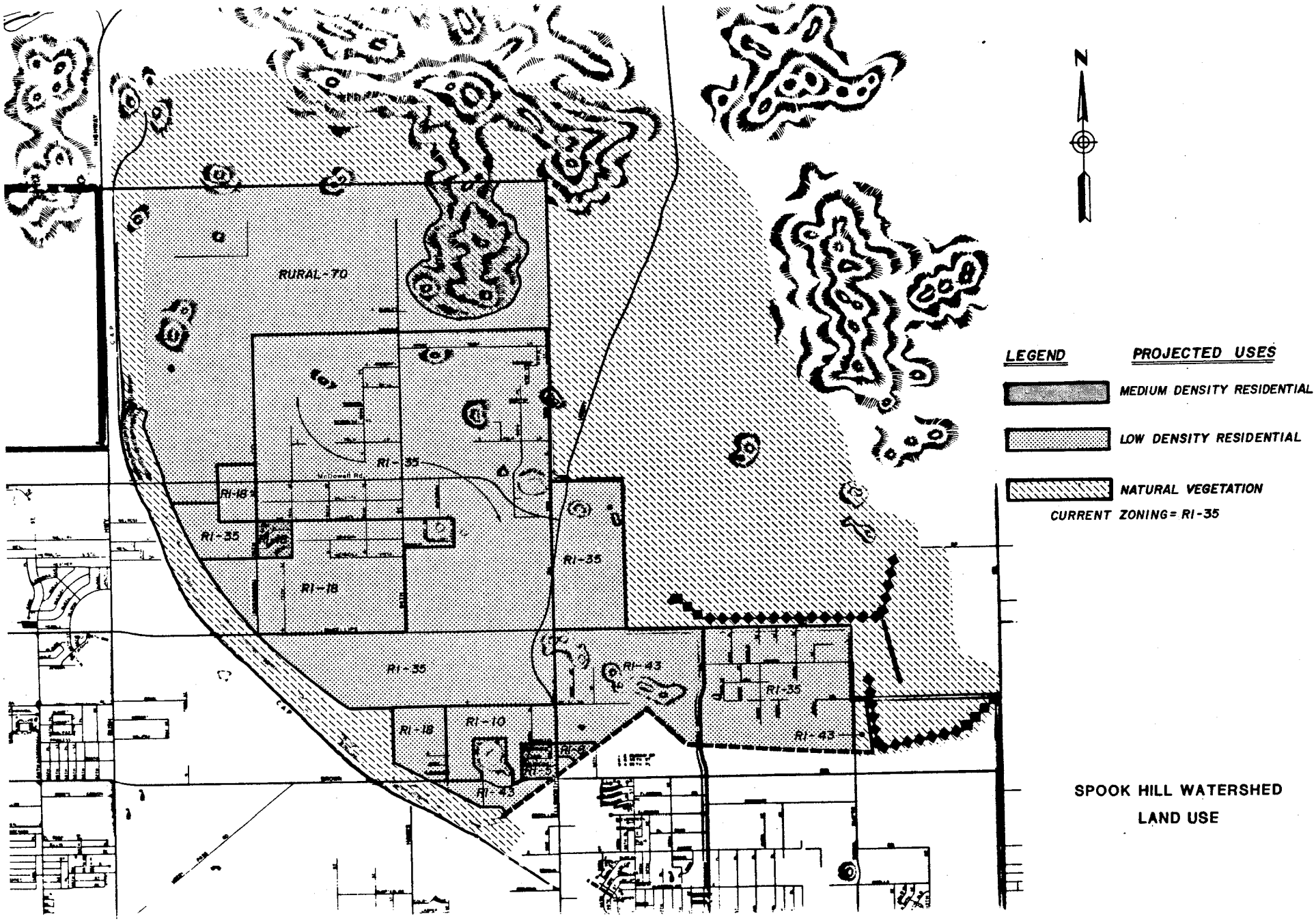
The area lying east of the extension of the Ellsworth Road section line is primarily public land. The Maricopa County Parks Department, the State of Arizona and the Bureau of Land Management (BLM) hold all land in this zone north of McKellips Road. South of McKellips Road are private acreages partially 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 can provide important protection for much of the developed area in the central zone, described in

the following section. Within the park it is 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. Current zoning and projected land use are shown on Figure 2.



SPOOK HILL WATERSHED
LAND USE

FIGURE 2

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Drainage Regulations

The requirements for drainage imposed upon new developments have a permanent impact upon adjacent and downstream facilities. From one jurisdiction to the next the provisions of the local drainage ordinance can be quite different in what is required of a developer. In the Spook Hill Watershed much of the private land remains unincorporated and could be developed under Maricopa County regulations. Some of the land is certain to be annexed into the City of Mesa prior to development and would have to comply with the City's drainage criteria. A master drainage plan should have features sized and located to manage the storm runoff from the future fully-developed watershed. If there is a mix of drainage standards across the watershed, it will hinder the design and implementation of an efficient and economical drainage system. Application of one drainage standard for all future development within the watershed will promote cost effectiveness.

Maricopa County requires that the increase in runoff from a 100-year 2-hour design storm caused by the proposed development be detained within the site for release after passage of peak runoff. The maximum outflow rate from the site is the peak outflow rate for the design storm under predevelopment site conditions. The detention volume reduces the peak runoff rate for some smaller storms, but a 100-year storm can cause peak outflow equal to predevelopment conditions over a sustained period of time because the runoff volume is increased. However, actual runoff depends on the individual drainage design of each site. The potential maximum runoff must be addressed because Spook Hill FRS depends upon its storage volume to function as designed.

An increase in the volume of flow coming into Spook Hill FRS could compromise its intended 100-year flood control capability.

The City of Mesa requires that for new developments all the runoff generated onsite by a 50-year 24-hour storm, approximately three inches of precipitation, be retained on the site and released over a period not to exceed 36 hours. The result is storage of runoff from the first three inches of rainfall and a drastically reduced outflow for up to 1½ days. The effect is virtually 100-year flood control considering that the 100-year 2-hour storm for the watershed produces 3.09 inches of rainfall.

HYDROLOGY

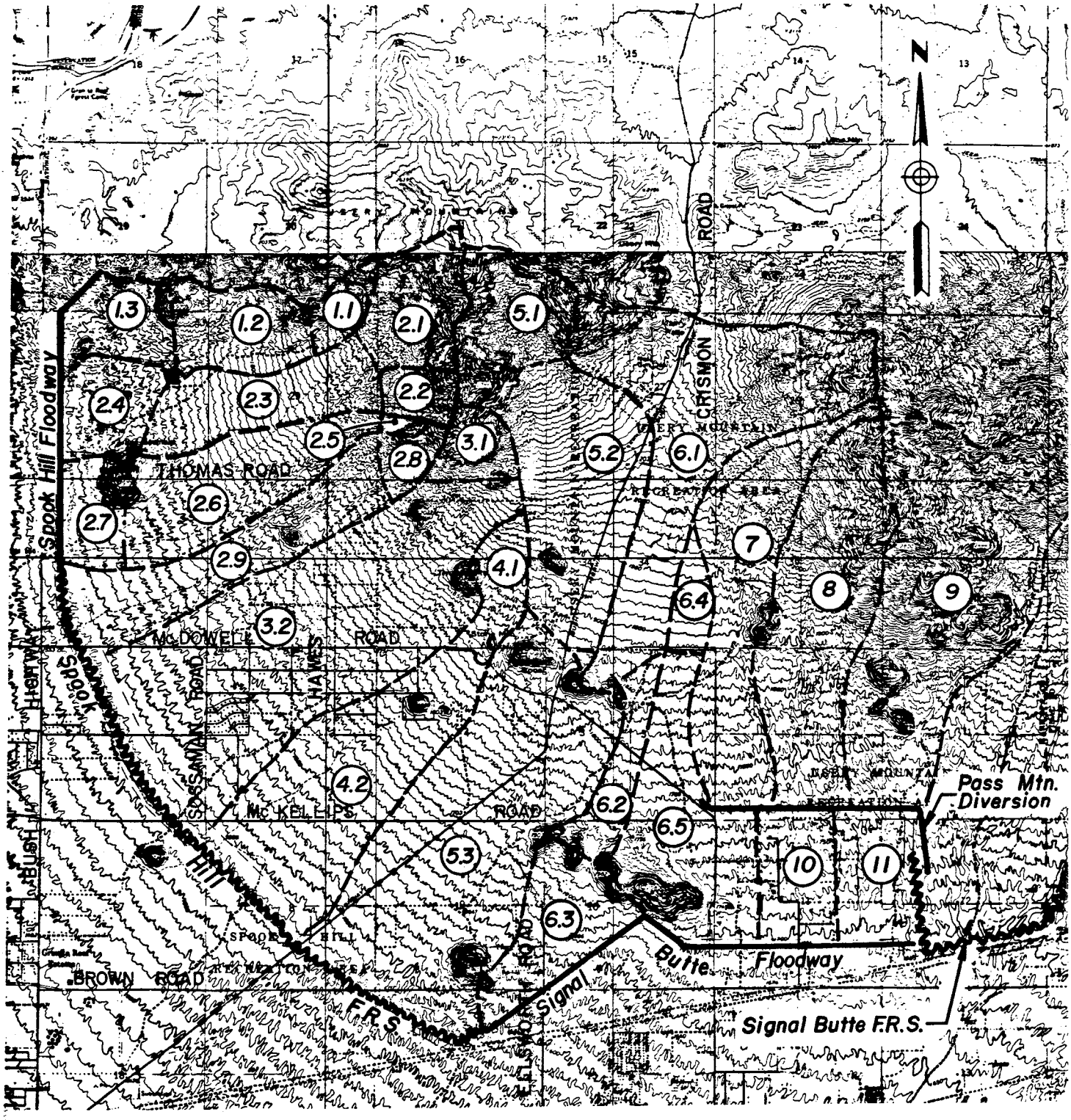
Hydrology for the watershed was modeled using the HEC-1 computer program. The first set of conditions assumed for the watershed were those which currently exist. The results are used as base hydrology with which to compare hydrology of the watershed under other sets of conditions.

The second set of conditions assumed that all developable lands were completely built-out at projected density with no retention or detention of storm runoff. These results yield the most severe conditions of runoff from a storm of given density.

Each of these conditions were used to determine hydrology for storms of 2, 5, 10, 50 and 100-year intensities. A map of the watershed, Figure 3, shows how the watershed was divided into hydrologic subareas.

Results

The results presented here are for the 100-year storms only. The 100-year hydrology is particularly significant because of the 100-year frequency design of the Buckhorn - Mesa Project and because the retention of runoff from a 50-year 24-hour storm per Mesa's ordinance would amount to control of 100-year storm on this watershed.



SPOOK HILL WATERSHED

SUBAREA BOUNDARIES

FIGURE 3

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Table I gives a summary of the 100-year 2-hour hydrology for each subarea under current and future watershed conditions. Tables II and III present respectively the routing of the 100-year 2-hour and 24-hour flood peaks downstream for current and future watershed conditions.

A comparison of future conditions to current conditions shown on Tables I - III indicates that without retention or detention within the watershed, subarea peak outflows will increase by amounts up to 77% at buildout (Table I). Spook Hill Reservoir, denoted "RES" in Tables II and III, has its spillway crest at elevation 1582. Spook Hill is able to contain the runoff from the current and future 100-year 2-hour event. Under both current and future conditions for the 100-year 24-hour event, flow over the spillway would occur in the model. There are, however, differences between the methodology of the hydrology for this study and Soil Conservation Service design hydrology which partially explain the higher runoff values for this study. These are technical in nature and will be addressed in the final report.

Within the northern zone the effects of future development on the hydrology can be mitigated by detention, retention or preservation of adequate drainageways through the length of the watershed.

Direct discharge downstream via drainage channels without some measure of detention would cause inflows to Spook Hill Floodway to exceed its capacity. Enlargement of the floodway or provision of an attenuation basin at the floodway might be required.

Table I: Summary, 100 Year 2 Hour Storm Subarea Hydrolgy

Current Conditions

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	Vol. A-Ft.	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA
HYDROGRAPH AT	SB 7	491.	2.00	56	112.	71.	71.	.90
HYDROGRAPH AT	SB 8	1157.	1.67	93	187.	118.	118.	1.29
HYDROGRAPH AT	SB 9	1962.	1.50	137	276.	174.	174.	1.92
HYDROGRAPH AT	SB11	182.	2.00	20	40.	26.	26.	.36
HYDROGRAPH AT	SB10	234.	1.83	27	52.	34.	34.	.38
HYDROGRAPH AT	SB6.4	60.	2.00	7	15.	10.	10.	.15
HYDROGRAPH AT	SB6.5	377.	2.00	53	103.	67.	67.	.85
HYDROGRAPH AT	SB6.1	776.	2.00	106	209.	135.	135.	1.68
HYDROGRAPH AT	SB6.2	171.	1.83	19	38.	25.	25.	.29
HYDROGRAPH AT	SB6.3	280.	1.83	34	68.	44.	44.	.53
HYDROGRAPH AT	SB5.1	791.	1.50	38	76.	48.	48.	.42
HYDROGRAPH AT	SB5.2	384.	2.17	55	109.	70.	70.	1.07
HYDROGRAPH AT	SB5.3	551.	2.33	124	239.	158.	158.	2.26
HYDROGRAPH AT	SB4.1	170.	1.67	16	32.	20.	20.	.24
HYDROGRAPH AT	SB4.2	304.	2.33	66	127.	84.	84.	1.26
HYDROGRAPH AT	SB3.1	333.	1.50	16	33.	21.	21.	.20
HYDROGRAPH AT	SB3.2	764.	2.33	166	320.	211.	211.	2.56
HYDROGRAPH AT	SB2.8	169.	1.33	8	17.	11.	11.	.11
HYDROGRAPH AT	SB2.9	283.	2.17	47	92.	60.	60.	.77
HYDROGRAPH AT	SB2.5	50.	1.33	2	4.	2.	2.	.02
HYDROGRAPH AT	SB2.6	326.	2.00	44	86.	56.	56.	.67
HYDROGRAPH AT	SB2.7	412.	1.50	21	43.	27.	27.	.26
HYDROGRAPH AT	SB2.1	857.	1.50	39	78.	49.	49.	.46
HYDROGRAPH AT	SB2.2	230.	1.33	11	22.	14.	14.	.14
HYDROGRAPH AT	SB2.3	235.	2.00	31	61.	40.	40.	.55
HYDROGRAPH AT	SB2.4	331.	1.50	26	53.	34.	34.	.34
HYDROGRAPH AT	SB1.1	153.	1.50	8	15.	10.	10.	.10
HYDROGRAPH AT	SB1.2	284.	1.50	26	52.	33.	33.	.35
HYDROGRAPH AT	SB1.3	352.	1.50	24	47.	30.	30.	.30

*** NORMAL END OF HEC-1 ***

Future Conditions

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	Vol. A-Ft.	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	% of Current Peak
HYDROGRAPH AT	SB 7	491.	2.00	56	112.	71.	71.	.90	100
HYDROGRAPH AT	SB 8	1157.	1.67	93	187.	118.	118.	1.29	100
HYDROGRAPH AT	SB 9	1962.	1.50	137	276.	174.	174.	1.92	100
HYDROGRAPH AT	SB11	282.	1.67	29	57.	37.	37.	.36	155
HYDROGRAPH AT	SB10	369.	1.67	36	71.	46.	46.	.38	158
HYDROGRAPH AT	SB6.4	60.	2.00	7	15.	10.	10.	.15	100
HYDROGRAPH AT	SB6.5	509.	2.00	64	127.	82.	82.	.85	135
HYDROGRAPH AT	SB6.1	816.	2.00	109	216.	139.	139.	1.68	105
HYDROGRAPH AT	SB6.2	248.	1.67	24	48.	31.	31.	.29	145
HYDROGRAPH AT	SB6.3	429.	1.67	47	94.	60.	60.	.53	153
HYDROGRAPH AT	SB5.1	832.	1.50	41	82.	52.	52.	.42	105
HYDROGRAPH AT	SB5.2	436.	2.17	61	120.	77.	77.	1.07	114
HYDROGRAPH AT	SB5.3	946.	2.17	175	340.	223.	223.	2.26	172
HYDROGRAPH AT	SB4.1	245.	1.50	22	43.	27.	27.	.24	144
HYDROGRAPH AT	SB4.2	537.	2.17	95	184.	121.	121.	1.26	177
HYDROGRAPH AT	SB3.1	394.	1.33	19	38.	24.	24.	.20	118
HYDROGRAPH AT	SB3.2	1192.	2.17	220	427.	280.	280.	2.56	156
HYDROGRAPH AT	SB2.8	251.	1.33	11	22.	14.	14.	.11	149
HYDROGRAPH AT	SB2.9	447.	2.00	65	128.	83.	83.	.77	158
HYDROGRAPH AT	SB2.5	46.	1.33	2	4.	2.	2.	.02	92
HYDROGRAPH AT	SB2.6	536.	1.83	60	119.	76.	76.	.67	164
HYDROGRAPH AT	SB2.7	519.	1.50	26	52.	33.	33.	.26	126
HYDROGRAPH AT	SB2.1	903.	1.50	43	86.	55.	55.	.46	105
HYDROGRAPH AT	SB2.2	278.	1.33	12	25.	16.	16.	.14	121
HYDROGRAPH AT	SB2.3	379.	1.83	45	89.	58.	58.	.55	161
HYDROGRAPH AT	SB2.4	514.	1.50	34	67.	43.	43.	.34	155
HYDROGRAPH AT	SB1.1	189.	1.33	9	18.	11.	11.	.10	124
HYDROGRAPH AT	SB1.2	433.	1.50	33	66.	42.	42.	.35	152
HYDROGRAPH AT	SB1.3	493.	1.50	29	57.	36.	36.	.30	140

*** NORMAL END OF HEC-1 ***

Table II: 100 Year, 2 Hour Routing

Current Conditions

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	SB 7	491.	2.00	112.	71.	71.	.90		
ROUTED TO	RT7B	483.	2.17	112.	71.	71.	.90		
HYDROGRAPH AT	SB 8	1157.	1.67	187.	118.	118.	1.29		
2 COMBINED AT	C87B	1457.	1.67	299.	189.	189.	2.19		
ROUTED TO	RT89	1428.	1.83	299.	189.	189.	2.19		
HYDROGRAPH AT	SB 9	1962.	1.50	276.	174.	174.	1.92		
2 COMBINED AT	C889	3090.	1.50	575.	363.	363.	4.11		
HYDROGRAPH AT	SB99	154.	1.33	156.	135.	135.	1.92		
HYDROGRAPH AT	SB11	340.	1.83	195.	159.	159.	2.28		
HYDROGRAPH AT	SB10	557.	1.83	241.	188.	188.	2.66		
HYDROGRAPH AT	SB6.5	821.	2.17	348.	257.	257.	3.66		
HYDROGRAPH AT	SB4.3	1313.	2.33	622.	445.	445.	6.16		
HYDROGRAPH AT	SB5.3	1805.	2.33	969.	688.	688.	9.91		
HYDROGRAPH AT	SB4.2	2111.	2.33	1119.	789.	789.	11.41		
HYDROGRAPH AT	SB3.2	2796.	2.33	1455.	1014.	1014.	14.17		
HYDROGRAPH AT	SB2.9	3073.	2.33	1560.	1083.	1083.	15.05		
ROUTED TO	RES	503.	7.33	466.	317.	317.	15.05	1580.67	7.33
HYDROGRAPH AT	SB2.7	515.	7.17	487.	386.	386.	16.00		
HYDROGRAPH AT	SB2.4	807.	2.17	620.	506.	506.	17.49		
HYDROGRAPH AT	SB1.3	1165.	2.17	712.	570.	570.	18.24		

*** NORMAL END OF HEC-1 ***

Future Conditions

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	SB 7	491.	2.00	112.	71.	71.	.90		
ROUTED TO	RT7B	483.	2.17	112.	71.	71.	.90		
HYDROGRAPH AT	SB 8	1157.	1.67	187.	118.	118.	1.29		
2 COMBINED AT	C87B	1457.	1.67	299.	189.	189.	2.19		
ROUTED TO	RT89	1428.	1.83	299.	189.	189.	2.19		
HYDROGRAPH AT	SB 9	1962.	1.50	276.	174.	174.	1.92		
2 COMBINED AT	C889	3090.	1.50	575.	363.	363.	4.11		
HYDROGRAPH AT	SB99	154.	1.33	156.	135.	135.	1.92		
HYDROGRAPH AT	SB11	442.	1.67	207.	167.	167.	2.28		
HYDROGRAPH AT	SB10	737.	1.83	270.	208.	208.	2.66		
HYDROGRAPH AT	SB6.5	1097.	2.17	413.	299.	299.	3.66		
HYDROGRAPH AT	SB4.3	1672.	2.17	722.	509.	509.	6.16		
HYDROGRAPH AT	SB5.3	2385.	2.17	1181.	826.	826.	9.91		
HYDROGRAPH AT	SB4.2	2924.	2.17	1399.	971.	971.	11.41		
HYDROGRAPH AT	SB3.2	3974.	2.17	1842.	1267.	1267.	14.17		
HYDROGRAPH AT	SB2.9	4413.	2.17	1986.	1361.	1361.	15.05		
ROUTED TO	RES	660.	6.67	625.	438.	438.	15.05	1581.37	6.67
HYDROGRAPH AT	SB2.7	679.	6.33	651.	532.	532.	16.00		
HYDROGRAPH AT	SB2.4	1166.	2.17	845.	686.	686.	17.49		
HYDROGRAPH AT	SB1.3	1637.	2.00	964.	765.	765.	18.24		

*** NORMAL END OF HEC-1 ***

Table III: 100 Year, 24 Hour Routing

Current Conditions

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	SB 7	629.	12.67	185.	50.	50.	.90		
ROUTED TO	RT78	585.	13.00	186.	50.	50.	.90		
HYDROGRAPH AT	SB 8	1433.	12.33	299.	81.	81.	1.29		
2 COMBINED AT	CB78	1856.	12.33	484.	131.	131.	2.19		
ROUTED TO	RT89	1658.	12.67	482.	131.	131.	2.19		
HYDROGRAPH AT	SB 9	2201.	12.33	442.	120.	120.	1.92		
2 COMBINED AT	CB89	3802.	12.33	924.	251.	251.	4.11		
HYDROGRAPH AT	SB99	156.	2.67	156.	139.	139.	1.92		
HYDROGRAPH AT	SB11	472.	12.67	222.	157.	157.	2.28		
HYDROGRAPH AT	SB10	917.	12.67	312.	181.	181.	2.66		
HYDROGRAPH AT	SB6.5	1162.	13.00	492.	233.	233.	3.66		
HYDROGRAPH AT	SB6.3	1952.	13.00	944.	348.	348.	6.16		
HYDROGRAPH AT	SB5.3	2749.	13.00	1532.	551.	551.	9.91		
HYDROGRAPH AT	SB4.2	3247.	13.00	1777.	623.	623.	11.41		
HYDROGRAPH AT	SB3.2	4314.	13.00	2299.	778.	778.	14.17		
HYDROGRAPH AT	SB2.9	4757.	13.00	2467.	826.	826.	15.05		
ROUTED TO	RES.	940.	17.67	907.	360.	360.	15.05	1582.51	17.67
HYDROGRAPH AT	SB2.7	983.	17.33	948.	408.	408.	16.00		
HYDROGRAPH AT	SB2.4	1290.	13.00	1139.	491.	491.	17.49		
HYDROGRAPH AT	SB1.3	1713.	13.00	1275.	534.	534.	18.24		

NORMAL END OF HEC-1 ***

Future Conditions

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	SB 7	629.	12.67	185.	50.	50.	.90		
ROUTED TO	RT78	585.	13.00	186.	50.	50.	.90		
HYDROGRAPH AT	SB 8	1433.	12.33	299.	81.	81.	1.29		
2 COMBINED AT	CB78	1856.	12.33	484.	131.	131.	2.19		
ROUTED TO	RT89	1658.	12.67	482.	131.	131.	2.19		
HYDROGRAPH AT	SB 9	2201.	12.33	442.	120.	120.	1.92		
2 COMBINED AT	CB89	3802.	12.33	924.	251.	251.	4.11		
HYDROGRAPH AT	SB99	156.	2.67	156.	139.	139.	1.92		
HYDROGRAPH AT	SB11	671.	12.67	245.	163.	163.	2.28		
HYDROGRAPH AT	SB10	1186.	12.67	351.	191.	191.	2.66		
HYDROGRAPH AT	SB6.5	1490.	13.00	569.	254.	254.	3.66		
HYDROGRAPH AT	SB4.3	2410.	13.00	1063.	400.	400.	6.16		
HYDROGRAPH AT	SB5.3	3531.	13.00	1780.	620.	620.	9.91		
HYDROGRAPH AT	SB4.2	4350.	13.00	2112.	716.	716.	11.41		
HYDROGRAPH AT	SB3.2	5901.	13.00	2772.	908.	908.	14.17		
HYDROGRAPH AT	SB2.9	6423.	13.00	2981.	968.	968.	15.05		
ROUTED TO	RES	1144.	17.33	1099.	442.	442.	15.05	1583.25	17.33
HYDROGRAPH AT	SB2.7	1197.	17.00	1151.	503.	503.	16.00		
HYDROGRAPH AT	SB2.4	1762.	13.00	1416.	602.	602.	17.49		
HYDROGRAPH AT	SB1.3	2404.	12.67	1585.	653.	653.	18.24		

*** NORMAL END OF HEC-1 ***

The central zone has areas of chronic flooding. These areas will continue to be subject to flooding under future conditions without retention or detention. Where there are roads on a grid system, much of the flow concentrates in depressed reaches of roadway and leaves erosion damage or sediment as a chronic maintenance item. Past development was not required to retard flow but allowed existing storm runoff to flow through the site along with increased runoff from the site. As a result the development of other lands within this zone must accommodate the "flow-through" condition in addition to detention of the increase in site runoff. Storm runoff also temporarily interferes with surface travel because of the predominance of dip crossings and diversion of washes down intersecting streets.

Storm flows within the eastern zone do not increase under future conditions within Usery Mountain Park and Tonto National Forest which comprise most of the zone. future developments of vacant lands in the eastern and central zones and the drainage systems for the proposed Red Mountain Freeway will have to contend with large discharges from these public lands if the master drainage plan does not do so.

Most of the large acreage developments south of McKellips Road and east of Ellsworth Road will be protected by Pass Mountain Diversion. This is an area of fairly well-defined washes which can adequately drain the existing land use or some future more dense development.

Two existing subdivisions along Ellsworth Road just north of Signal Butte Floodway have existing channels for offsite flows. The subdivision west of Ellsworth Road is several years old and has channels of considerably less than 100-year capacity.

The proposed Red Mountain Freeway is aligned such that it will intercept flow from approximately 80% of the Spook Hill Watershed. Along this alignment, the washes are very shallow and have very low capacity before sheet flow begins. Flows from the existing or future conditions 100-year storm would have a major impact on the cost for right-of-way and construction of the proposed freeway.

Under existing conditions, sediment deposition is an additional problem caused by major flooding. Within this watershed, however, the gravel-sized granite bed load is very important to the stability of the watershed. The bed load tumbles along the wash bottom with the flow. Flowing water has a specific "appetite" for bed load depending on flow depth and velocity among other variables. If bed load is removed from flow in a natural wash, the water will erode any material it can dislodge to replenish its bed load capacity. If the amount of flow is increased, the "appetite" for bed load is increased. Future development without some control on flows promises to eliminate much of the source for bed load and, simultaneously, increase flows. Severe erosion would be the result. Use of natural washes for drainage of "clear water" flows should be avoided, as should use of earth lined channels within that part of the watershed where slopes are 2 percent or greater.

ALTERNATIVES

General Considerations

Three alternatives (Alternatives A, B, and C) have been prepared as part of this study. Each alternative has been sized to accommodate the runoff from a 100-year storm. A prime reason for this decision is that future development will most likely be under the City of Mesa's retention ordinance which requires retention of the runoff form a 3-inch rainfall. This corresponds to a 24-hour 50-year storm or also to a 2-hour 100-year storm. Alternative B assumes retention in accordance with the City of Mesa's regulations. Likewise, Alternative C assumes uniform application of the Maricopa County detention ordinance over developable lands. This requires some detention, but allows release of flows at a rate equivalent to the 100-year flows as undeveloped conditions. This amounts to a 100-year flow with the bed load sediment removed.

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

Much of the central zone has been subdivided and is partially built out in one acre and larger parcels. Because of the existing private improvements and infrastructure, it is desirable to minimize upstream flows into the developed area. All three alternatives include features which divert

approaching flows to the north or east of the existing development. For all alternatives, features proposed for Usery Mountain Park have been located along its boundary to the greatest extent possible.

Design Criteria

Channel Type	Max. Velocity	Side Slope	Min. Freeboard
Earth-lined	4 fps or by soil test	4:1	1.5'
Natural with Levees	6 fps only with 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 depths within $\pm$ 20% of critical depth. Channel exits will have a riprap-lined stilling basin for any velocity exceeding 6 fps.

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

Pipes

Pipes are to be designed for open channel flow, approximately one-half full. Velocity will be limited to 20 fps for open channel flow. Pipes will be sized so that at the design flow rate the calculated full pipe velocity is limited to 10 fps. 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 Reclaimation impact-type stilling basins.

Retention Basins

Retention basins will be excavated with maximum water surface elevation at natural ground. 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. A freeboard of 1.5' 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.

Each of the alternative plans is presented on a figure located in the attached envelope. An overlay of the watershed topography is also enclosed to allow a better understanding of how each plan fits with the hydrology model and with the topography.

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 5.

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, as shown in Figure 4. The inboard side of the berms 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 ft/sec. Vegetation would be permitted to grow within the natural channels.

Lined channels, also shown in Figure 4, 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 ft/sec, 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 ft/sec. 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 cfs. 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 -

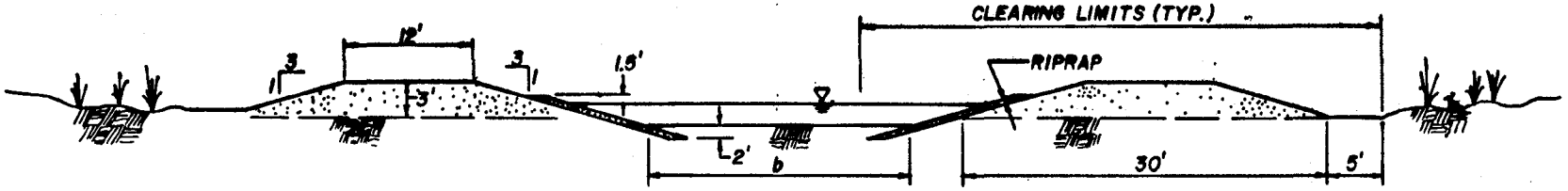
In contrast to the northern zone, drainage channels within the central zone would consist almost exclusively of lined channels paralleling Quenton Street, McDowell Road and Hermosa Vista Drive. One natural channel would be constructed from the intersection of Hermosa Vista Drive and 88th Street northeast 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.

SPOOKHILL WATERSHED
ALTERNATIVE CROSS-SECTIONS



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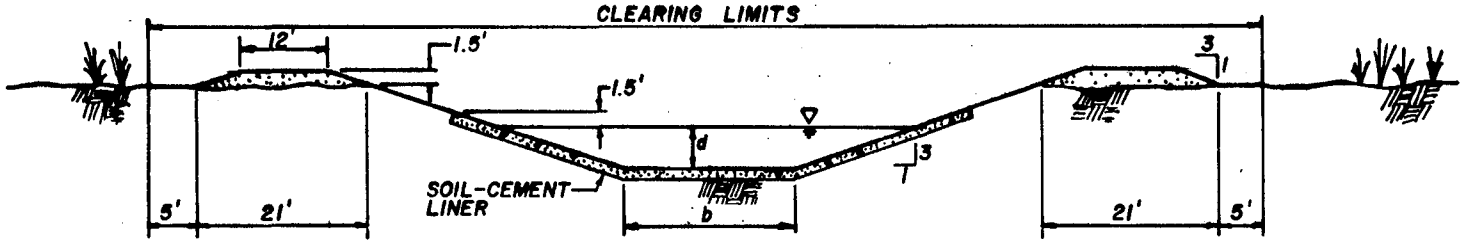
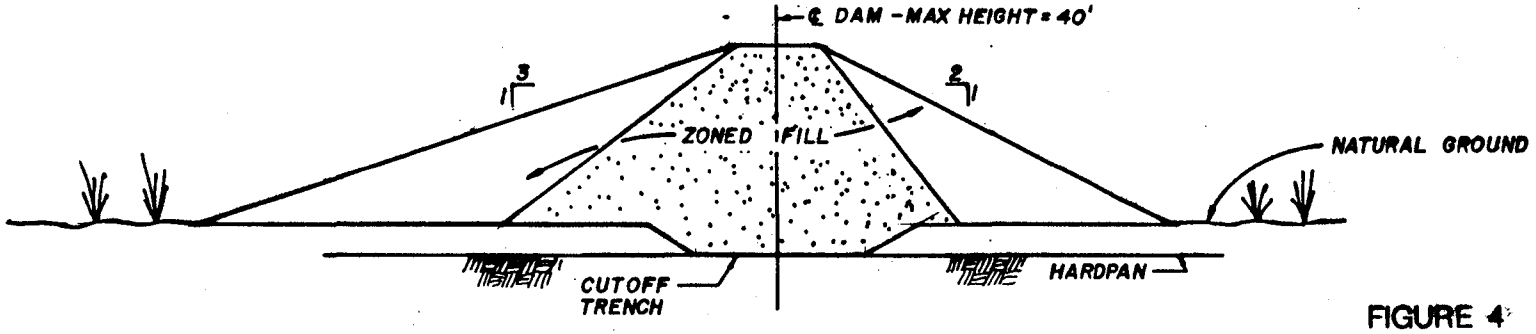


SECTION - LINED CHANNEL
Not to Scale



SECTION - DAM
Not to Scale

FIGURE 4

PARSONS BRINCKERHOFF
April, 1985

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 6. 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.

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 cause 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 conditons 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 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. This work is not shown on Figure 6.

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 miles. 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 7, 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 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 recreaction area from flowing onto developed or developable lands to the west. Flow along the levee would flow east under Ellsworth road (Bush Highway) 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.

One 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 effect each zone are presented in Table IV (northern zone), Table V (central zone) and Table VI (eastern zone).

Table IV

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	
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 V

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 VI

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 IV, V, and VI, 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 8. The estimated cost and right-of-way requirements are summarized in Table VII.

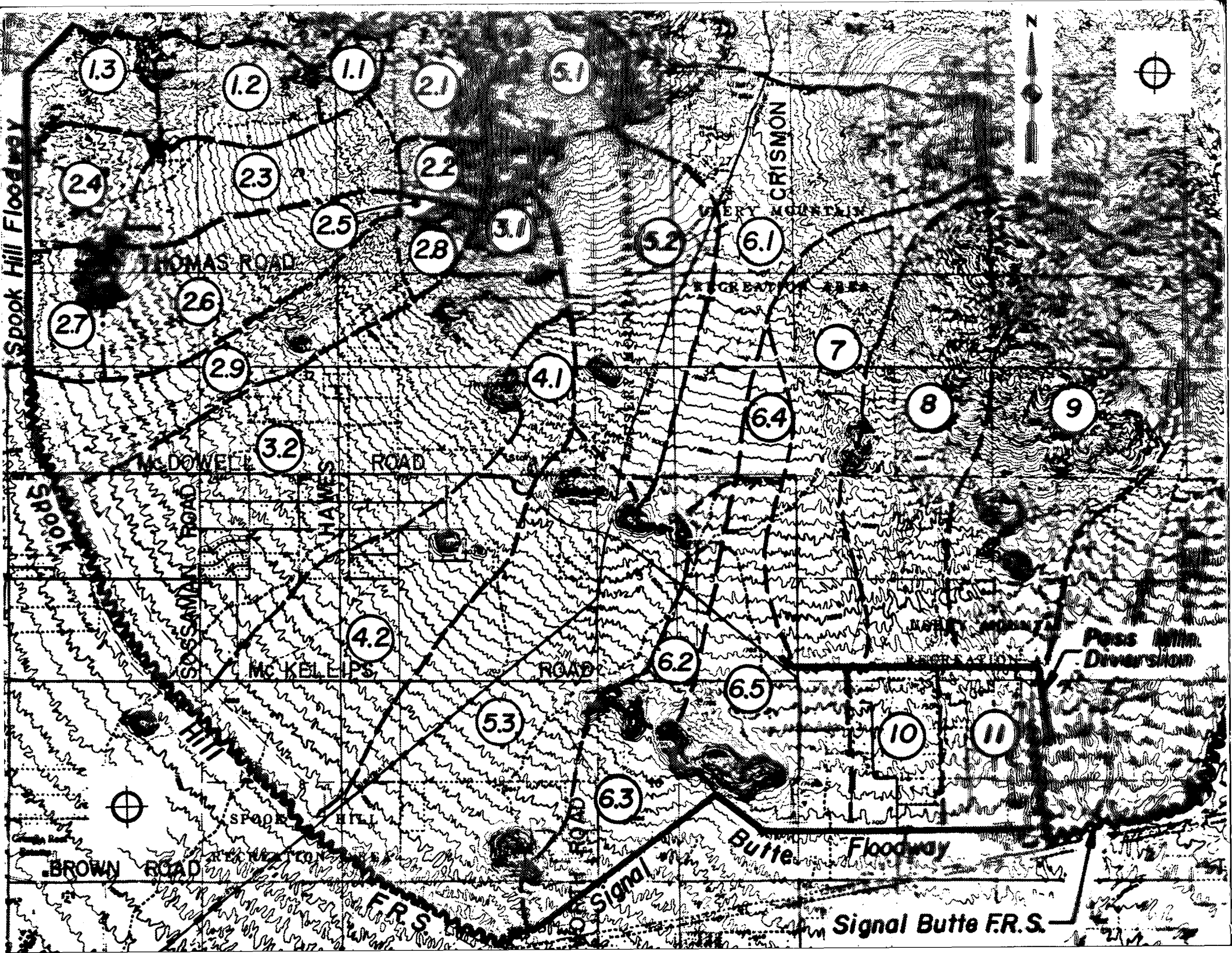
VII. Recommended Plan Summary

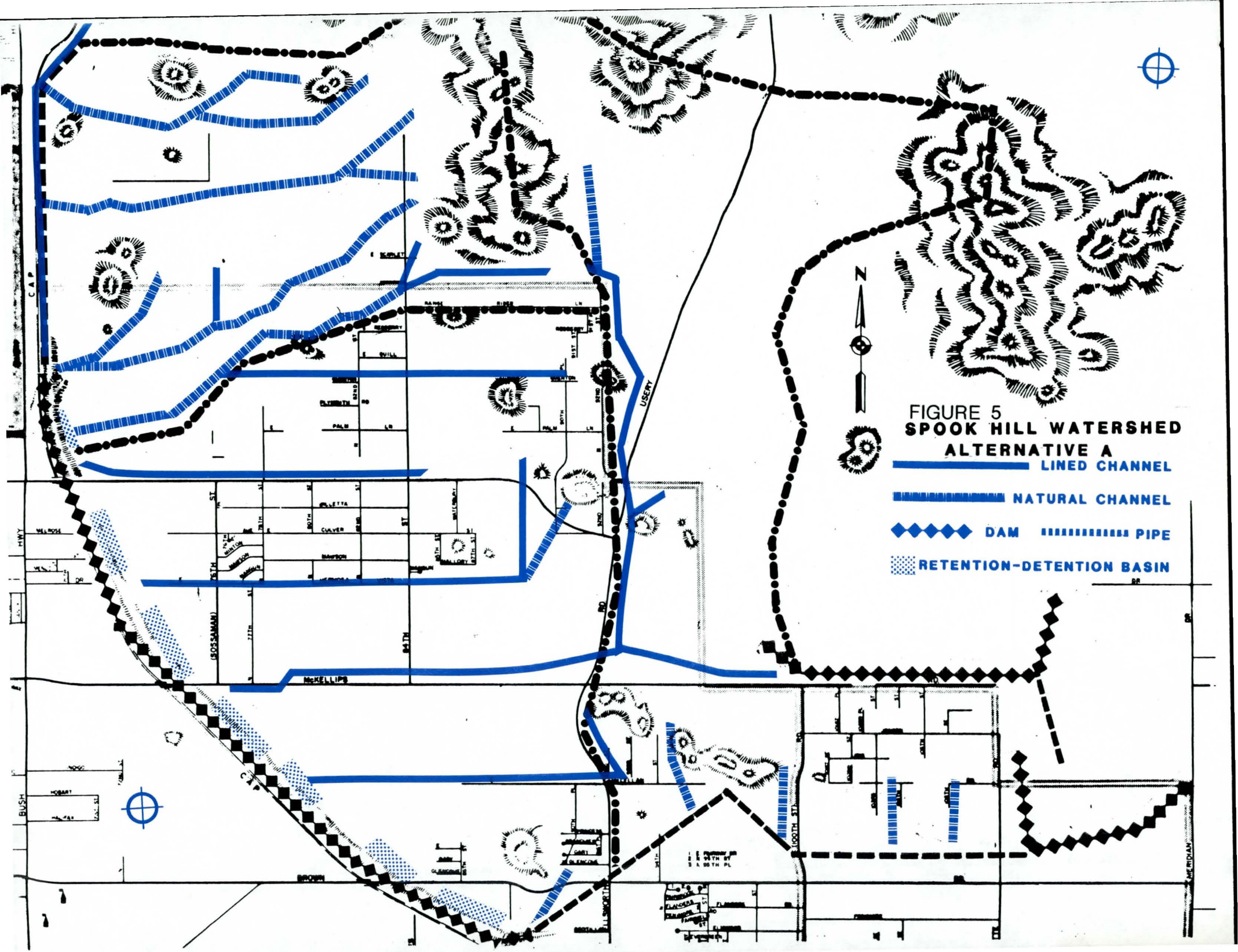
Zone	Recommended Alternative	Estimated Cost, $ million	Right-of-Way, acres
Northern	B	4.1	109
Central	B	8.5	248
Eastern	C	7.4	180
	Totals	**20.0**	**537**

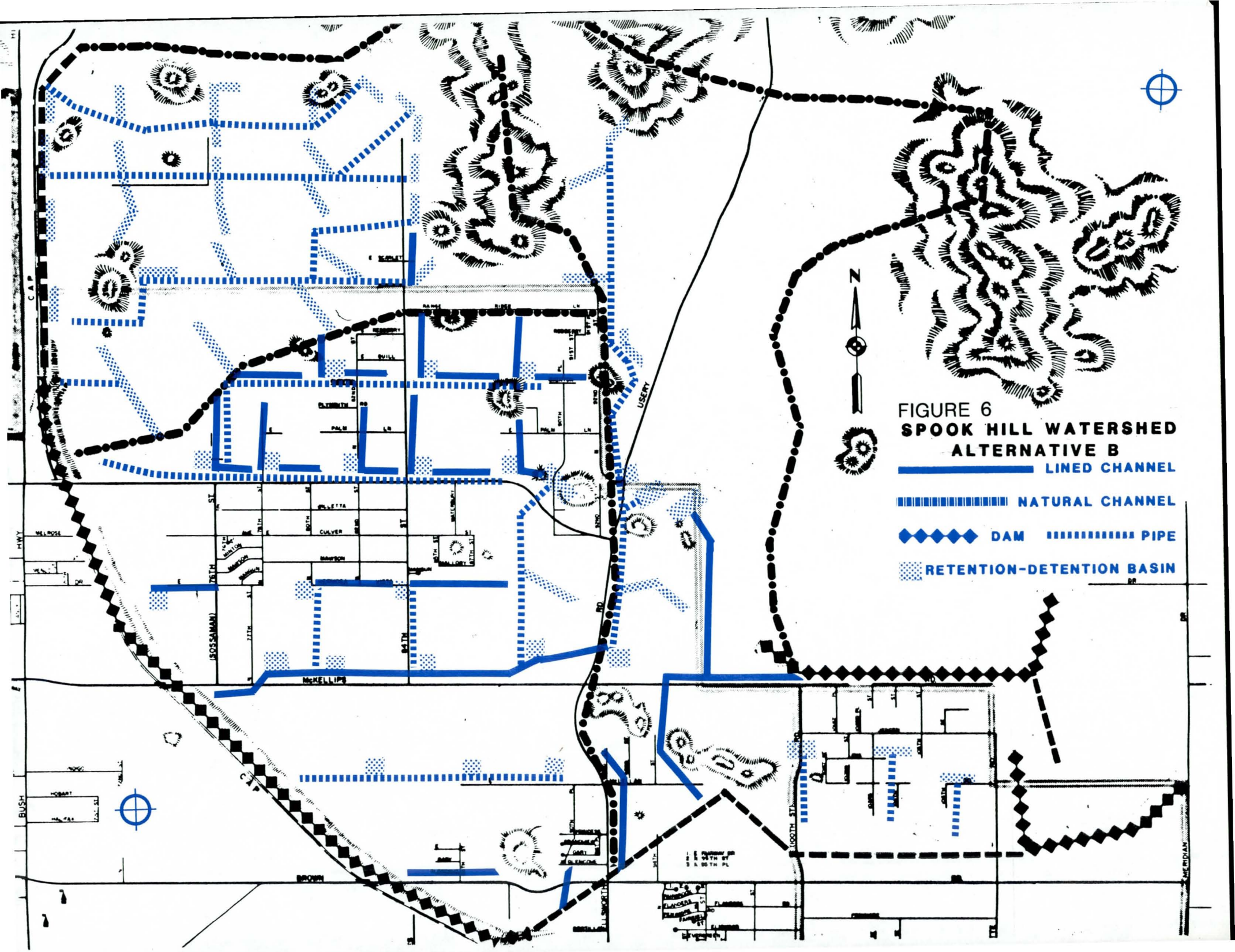
Under the recommended plan, Alternative C as applied to the eastern zone would be modified slightly to include a detention basin near the intersection of the proposed Red Mountain Parkway and the extension of 96th Street.

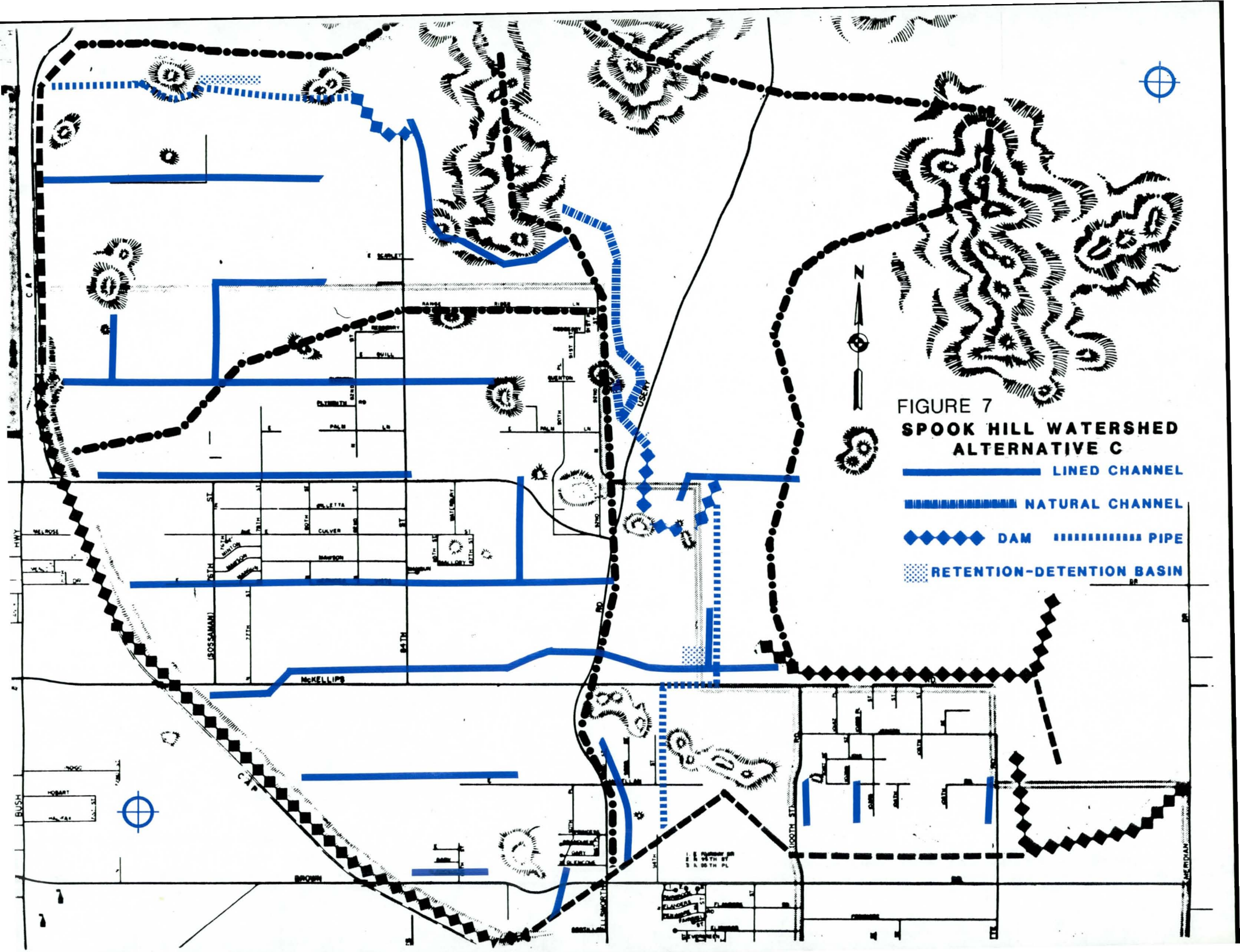
The detention basin would discharge a metered flow to the channel on the north side of the proposed Red Mountain Parkway, a concept consistent with that recommended for the central zone. No additional cost for this

detention basin has been included in the cost estimate presented in Table VII 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.


Spook Hill Floodway
1.3
1.2
1.1
2.1
3.1
2.4
2.3
2.2
2.5
2.8
3.1
5.2
6.1
THOMAS ROAD
2.6
2.7
2.9
4.1
7
6.4
8
9
3.2
McDOWELL ROAD
Spook Hill
4.2
McKELLIPS ROAD
6.2
6.5
5.3
10
11
6.3
Pass Mtn. Diversion
Signal Butte Floodway
BROWN ROAD
F.R.S.
Signal Butte F.R.S.
CRISMON


N
USERY
McKELLIPS
CAP
BUSH
HOBART
BROWN
ELLSWORTH
MERIDIAN
FIGURE 5
SPOOK HILL WATERSHED
ALTERNATIVE A
LINED CHANNEL
NATURAL CHANNEL
DAM
PIPE
RETENTION-DETENTION BASIN


N
USERY
CAP
HWY
BUSH
McKELLIPS
BROWN
84TH
ROSSMAN
MERIDIAN
FIGURE 6
SPOOK HILL WATERSHED
ALTERNATIVE B
LINED CHANNEL
NATURAL CHANNEL
DAM
PIPE
RETENTION-DETENTION BASIN


N
FIGURE 7
SPOOK HILL WATERSHED
ALTERNATIVE C
LINED CHANNEL
NATURAL CHANNEL
DAM
PIPE
RETENTION-DETENTION BASIN
CAP
HWY
BUSH
McKELLIPS
(SOSSAMAN)
84TH
100TH ST
USERY
BROWN
HOBART
MERIDIAN

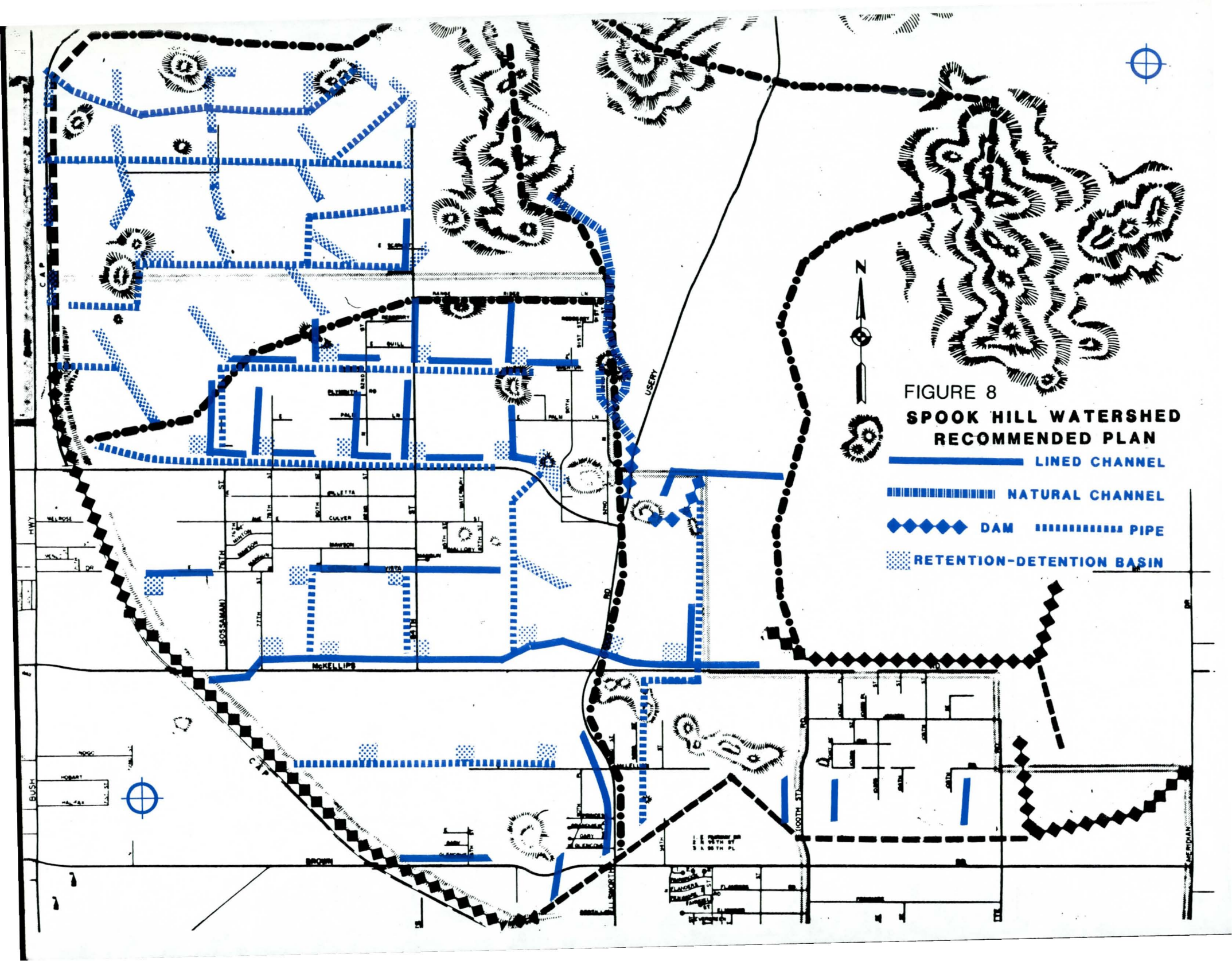

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FIGURE 8
SPOOK HILL WATERSHED
RECOMMENDED PLAN
LINED CHANNEL
NATURAL CHANNEL
DAM
PIPE
RETENTION-DETENTION BASIN
USERY
McKELLIPS
BROWN
BUSH
CAP