sea incorporated

Consulting Engineers

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June 15, 1987

Mr. James E. Attebery, P.E.
City Engineer
Mr. Jasper Hawkins
Mr. Vernon Schweigert
Citizens Against Reach Four
C/O City of Phoenix
Engineering Department
125 East Washington Street
Phoenix, Arizona 85004

Re: Cudia City Wash
Hydrologic Drainage Report

Gentlemen:

Attached is the first report for the above referenced project. Included in the Appendices are sufficient background material and supporting data, including computer runs of the model, to support the study and its conclusions.

On May 27, 1987, SEA, Inc. was commissioned by the City of Phoenix and the Citizens Against Reach Four to prepare an independent analysis to determine the peak flow from a 100 year 24 hour precipitation event occurring on the Cudia City Wash. The probable peak flow for the 100 year 24 hour precipitation of 3.80 inches over the Cudia City Wash drainage area is 6800 cfs. The peak flow could range from 5700 cfs to 7800 cfs depending upon characteristics.

SEA is pleased to have this opportunity to further serve the City on this critical project. If we can be of further assistance, please feel free to call on us.

Thank you.

Sincerely yours,

Registered Professional Engineer (Civil)
CERTIFICATE NO. 12477
HERBERT E. SKIBITZKE
Date Signed 6/15/87
ARIZONA, U.S.A.

Herbert E. Skibitzke, P.E.
Vice President
Project Manager

Roberta A. Bowen
Project Hydrologist

Attachment

HES:RAB/vs

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CUDIA CITY WASH

DRAINAGE STUDY

SUMMARY AND CONCLUSIONS

PREPARED BY:

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Introduction

On May 27, 1987, the City of Phoenix retained SEA, Inc. to determine the peak flow for Cudia City Wash from a 100-year, 24-hour storm event. This report outlines the method used to develop data for input to the hydrologic model and presents the results from this analysis of the watershed rainfall - runoff characteristics.

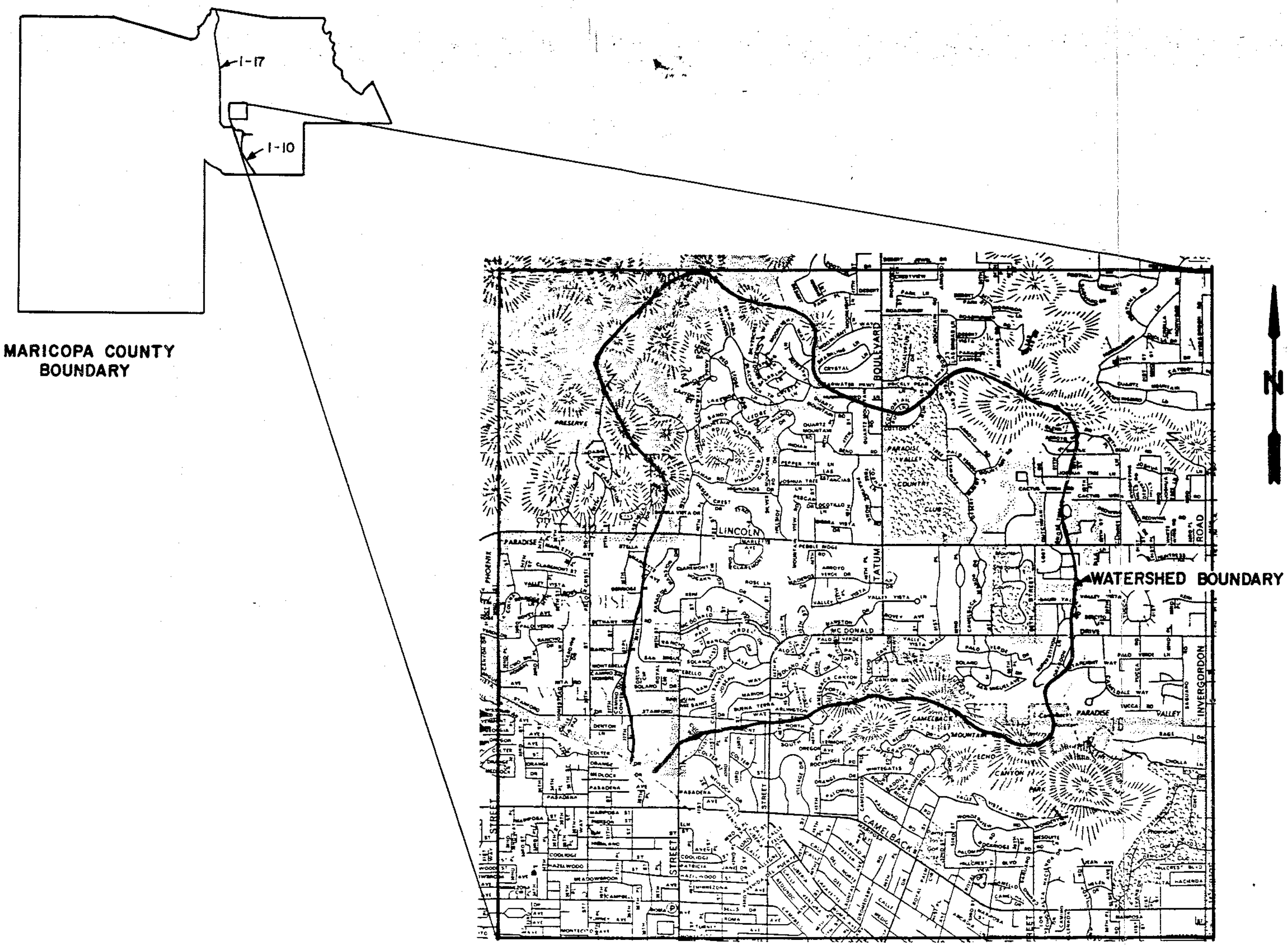
Although numerous studies had been performed prior to this, it was requested that SEA's study be an independent analysis. As a result, no attempt was made to access public agency or private consulting reports which had specifically calculated runoff from the Cudia City watershed. Those agencies contacted for information during the course of this study are listed in Appendix A.

Location

Located in northern Maricopa County, the Cudia City Wash drainage area is roughly bounded by 58th Street on the east, 36th Street on the west, Stanford Drive on the south and Roadrunner Road on the north, Figure 1. Approximately 80 percent of the watershed is in the town of Paradise Valley, with the remainder in the City of Phoenix. The main wash flows from northeast to southwest with the outlet north of the Arizona Canal in the vicinity of 40th Street.

The goal of this study was the development of a rainfall-runoff relationship and a resulting peak flow using a hydrologic runoff model. The type of hydrologic model used is determined by watershed characteristics, such as the degree of urbanization, the land surface slopes, and the mechanism of flow. As the data were collected and analyzed in the early stages of the study, the U.S. Army Corps of Engineers (COE) HEC-1 program, specifically the kinematic wave portion was selected as the most appropriate model. This decision was based upon the extent of urbanization, the highly variable land slopes, the complexity of the drainage pattern, the size of the subwatersheds, and the presence of overland flow conditions in much of the area.

Two sources of data are available. Some background information can be accessed in either agency files or as published reports or maps (i.e., soils and topographic data). Other data such as the information used to define the channel characteristics, must be collected on site. Four site visits were made to the watershed to determine channel widths, sediment size, and roughness coefficients and to define channel courses when these were indeterminate from either aerial photographs or the topographic map of the area.



LOCATION MAP OF CUDIA CITY
WASH DRAINAGE AREA

0 MILE 1

FIGURE 1

Geology

Cudia City Wash occupies a broad, low-relief graben valley. The wash and its tributaries drain adjacent steep, rugged horst blocks marked by the Phoenix, Mummy and Camelback Mountains. The main wash trends southwesterly between the three ranges.

Mummy Mountain is usually considered part of the Phoenix Mountains. This report treats them separately based on their separation by a narrow valley (probably due to a unique fracture system), lithologic variations, and independent drainage patterns.

The mountain ranges are rugged, resistant, fault-bound horsts flanked by concomitant graben valleys. These sharp features are typical of Basin and Range extensional, brittle tectonism. Direction, trend, and detrital composition of the washes appear to be entirely dependant upon local geologic and geomorphologic characteristics.

In the study area, the Phoenix and Mummy Mountains are comprised primarily of Precambrian schist and gneiss. Isolated gneissic outcrops form hills between the two ranges. Clast compositions in tributaries draining the two ranges are largely muscovite schist, dark green (hornblend?), quartz-rich gneiss, and vein-quartz fragments.

Camelback Mountain is comprised of Precambrian granite (the camel's "body") unconformably overlain by Early Miocene red fanglomerate named the Camel Head Formation (the camel's "head").

Streams draining this range carry detritus rich in granitic components. These sediments are markedly pink in color and consist of whole potassium feldspar crystals, angular quartz grains, and subrounded granitic pebbles (some muscovite-rich).

Angularity of detrital grains increases with proximity to high relief areas of provenance. Subangular and subrounded grains are seen in the low lying, low relief areas away from the base of the mountain ranges.

Finer grain sizes are seen in the lower reaches of the streams. Conversely, coarser sizes usually occur near the headwaters with one exception: coarse particles do appear downstream when there is a confluence of two washes. This phenomenon disrupts the otherwise normal fining-downstream particle distribution.

Topography

The first step in a runoff model is to delineate the major watershed boundary and then further subdivide this area into smaller areas each having similar characteristics of slope, soil type and drainage pattern.

The first data needed were the U.S. Geological Survey 7.5 minute Quadrangle Sheets for Sunnyslope and Paradise Valley. These maps, photorevised in 1982, with a contour interval of 20 feet, contained the only topographic information available for the entire area. To facilitate data entry and analysis, the two quadrangle maps were spliced together and enlarged to a scale of 1 inch equals 1,000 feet. This allowed the study team to delineate the major watershed for Cudia City Wash in greater detail than might otherwise have been possible, and to further subdivide the watershed into smaller areas each having similar characteristics. Achieving this degree of detail required the use of aerial photographs obtained from Kenney Aerial Mapping. Twelve photographs taken in April 1987, at a scale of 1 inch to 1,800 feet, provided stereo coverage of the watershed. In addition, Kenney provided a photo mylar at the same 1 inch to 1,000 feet scale of the topographic map.

The topographic map was also used to calculate slopes and the areas of the subwatersheds, and to measure the lengths of individual tributary washes. These data are contained in Table 1.

<u>Precipitation</u>

The 100-year, 24-hour and 6-hour storms generate 3.80 inches and 3.15 inches of precipitation, respectively, as indicated by data obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 2, Precipitation Frequency Atlas of the Western United States, Volume VIII, Arizona. The modeling procedure used in SEA's analysis requires that the total rainfall be distributed in some fashion over the duration of the storm. Developing this storm pattern requires the determination of the one-hour, 100-year storm using equation (1) below in conjunction with the 6-hour and 24-hour storms.

$$Y1 = 0.494 + 0.755 [(X6)(X6/X24)] \qquad (1)$$

Where Y1 is the 100-year, 1-hour storm, X6 is the 100-year, 6-Hour storm and X24 is the 100-year, 24-hour storm. Using the one-hour ratios for calculating the 5-, 10-, 15- and 30-minute rainfall intensities developed by the National Weather Service for the western United States, the peak 15-minute intensity was calculated as 1.40 inches/hour. The rainfall rates for the 24-, 6- and 1-hour events, in addition to the 5-, 10-, 15- and 30-minute rates calculated above, were plotted on log-log paper and the incremental rainfall at 15- minute intervals determined. The net rainfall for each period was arranged with the highest rainfall occurring in the 15-minute period following the midpoint of the storm.

TABLE 1
SUBWATERSHED CHARACTERISTICS

WATERSHED	AREA (sq mi)	STREAM LENGTH (ft)	SLOPE (ft/ft)	LOSS RATE (in/hr)	PERCENT IMPERVIOUS
Upper 6B	0.094	2000	0.100	1.0	0
Middle 6B	0.188	2000	0.016	2.6	5
Lower 6B	0.562	2000	0.011	2.6	5
Upper 6A	0.036	1500	0.250	1.9	0
Middle 6A	0.096	1500	0.100	1.9	5
Lower 6A	0.085	1500	0.030	5.7	1
Upper 6D	0.012	500	0.008	2.7	10
Upper 6C	0.060	1600	0.100	1.0	0
Middle 6C	0.065	1700	0.030	2.6	5
Lower 6C	0.065	1700	0.020	2.6	5
Lower 6D	0.038	1200	0.020	2.6	10
Upper 5A	0.049	1250	0.100	1.0	0
Middle 5A	0.049	1250	0.040	2.6	5
Middle 5A	0.049	1250	0.025	2.6	5
Lower 5A	0.049	1250	0.020	2.6	4
Upper 5B	0.084	1500	0.100	1.0	0
Middle 5B	0.083	1500	0.022	2.6	3
Lower 5B	0.040	1500	0.0125	2.6	1
Upper 5C	0.030	1000	0.010	1.9	5
Middle 5C	0.036	1500	0.060	2.6	5
Lower 5C	0.036	1500	0.025	2.6	5
Lower 5C	0.035	1500	0.014	2.6	3
Upper 7A	0.050	1000	0.200	1.0	0
Middle 7A	0.090	1500	0.050	1.9	4
Lower 7A	0.090	1500	0.030	1.9	4
4	0.192	700	0.006	3.5	5
Upper 7B	0.025	1500	0.100	1.0	0
Lower 7B	0.040	1500	0.040	1.9	5
Upper 3A	0.070	1500	0.250	1.0	0
Upper 3A	0.070	1500	0.250	1.0	0
Middle 3A	0.166	2000	0.050	1.9	4
Lower 3A	0.070	1500	0.050	1.9	4
Lower 3A	0.050	1000	0.020	1.9	4
3B	0.179	6500	0.023	2.6	5
Upper 2A	0.033	1000	0.250	1.9	0
Upper 2A	0.033	1000	0.100	1.9	5
Upper 2A	0.034	1000	0.050	1.9	5
Upper 2A	0.033	1000	0.250	1.9	0
Upper 2A	0.033	1000	0.100	1.9	5
Upper 2A	0.034	1000	0.050	1.9	5
Lower 2A	0.011	1000	0.050	1.9	5
2C	0.160	3000	0.040	2.6	3
2B	0.178	1800	0.020	3.5	5
Upper 7C	0.028	1000	0.250	1.0	0
Lower 7C	0.042	1500	0.160	2.6	1
Upper 7C	0.028	1000	0.250	1.0	0
Lower 7C	0.042	1500	0.160	2.6	1

TABLE 1
Continued

WATERSHED	AREA (sq mi)	STREAM LENGTH (ft)	SLOPE (ft/ft)	LOSS RATE (in/hr)	PERCENT IMPERVIOUS
Lower 7C	0.060	1500	0.030	3.7	5
8A	0.218	2500	0.010	3.7	5
8B	0.263	2000	0.005	3.7	5
Upper 1A	0.313	4000	0.100	1.0	0
Lower 1A	0.055	3800	0.030	2.6	1
Upper 1B	0.096	4000	0.030	3.7	2
Upper 1C	0.044	1900	0.017	3.7	5
Lower 1C	0.036	1900	0.017	3.7	5
9A	0.152	4500	0.007	4.8	4
9B	0.059	2000	0.0125	4.8	5

The procedure used to develop the storm pattern nests the one-hour storm within the six-hour storm which is in turn nested within the 24-hour storm. This allows expansion of a point precipitation measurement into a mathematical representation of the entire storm.

Soils

Soil types and infiltration rates were obtained from the Soil Survey for Eastern Maricopa and Northern Pinal Counties Area, Arizona, published in 1974 by the U.S. Soil Conservation Service (SCS). The soils map for this watershed is included as Figure 2. In addition, Table 2 lists the major soil types, the hydrologic soil groups and their permeabilities.

Degree of Urbanization

The type and extent of development in the watershed determines how much of the area available for runoff is impervious to infiltration. Past and present conditions are readily available from aerial photographs. Figure 3 is one of the April 1987 aerial photographs which shows the extent of present urbanization in the watershed. Actual percent impervious was calculated for a few watersheds from these photographs by calculating the areas covered by pavement and structures. This result was then extrapolated to the remainder of the subwatersheds by comparison with similar calculated areas.
Future conditions were estimated using the current aerial photographs and the Maricopa Association of Governments (MAG) study titled "Update of the Population and Socioeconomic Database for Maricopa County, Arizona", released in May, 1987. The MAG study divided the area into large zones which encompassed not only the Cudia City Wash but also adjacent areas. Although the MAG study indicated that population density in the zones of interest may double by the year 2015, current zoning and patterns of development indicate that such increases are unlikely in those portions of the MAG study contained in the watershed.

Calibration Data

In addition to collecting data to model current and future conditions, it was necessary to calibrate the hydrologic model so that the model input adequately described the watershed runoff process. Any agency which might have monitored flows on Cudia City Wash was contacted, and it was found that the U.S. Geological Survey (USGS) had in fact estimated runoff from a June 22, 1972 storm. The information obtained from the USGS is contained in Appendix B. The analysis by the USGS used high water marks to calculate a peak flow of approximately 3,000 cfs from the easternmost 2.16 square miles of the watershed. This information is critical to the development of a reasonable hydrologic model. The prediction of the model can only be as good as the input data, and the most poorly defined input data

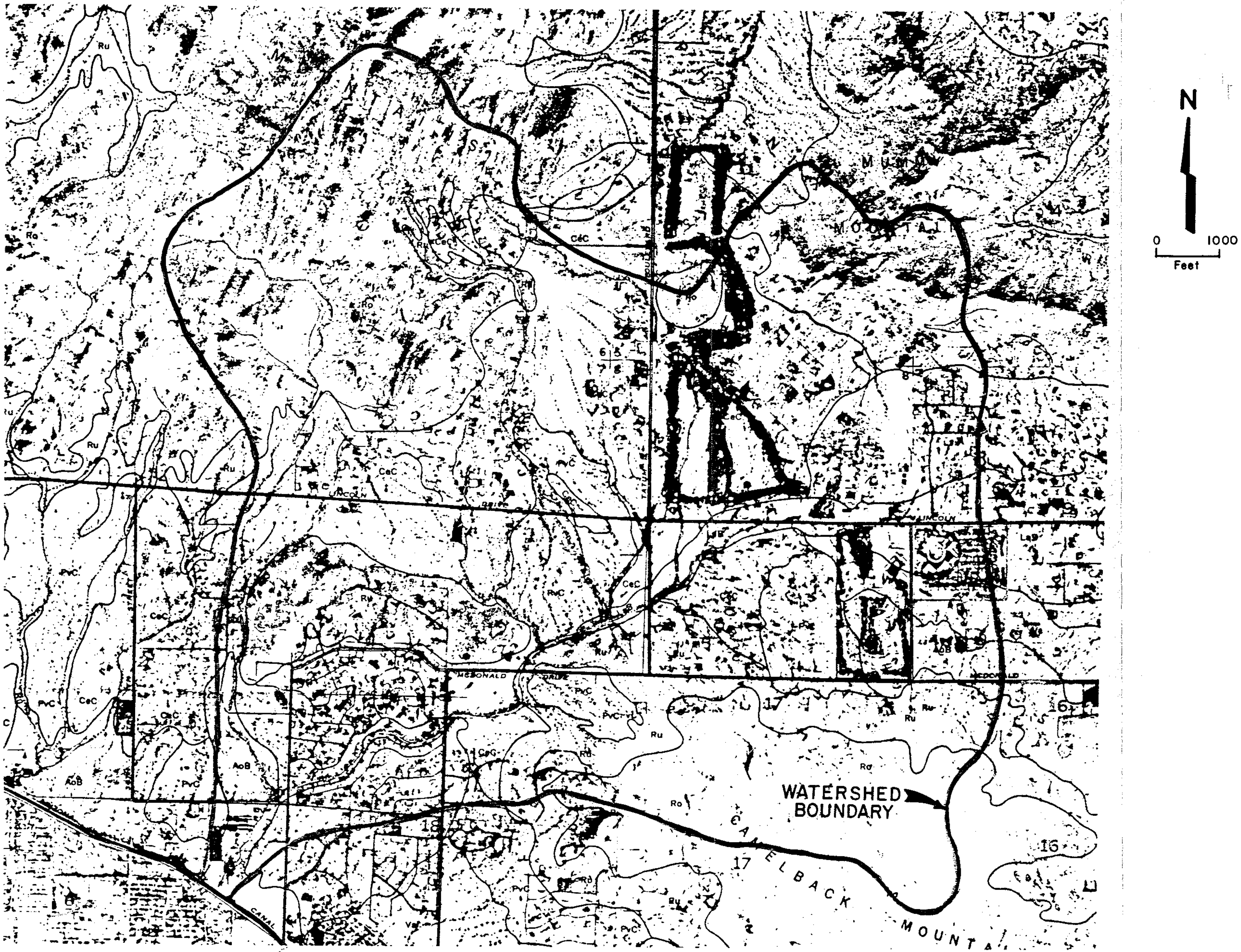


FIGURE 2:

SOILS MAP OF CUDIA CITY WASH DRAINAGE STUDY AREA SHOWING WATERSHED BOUNDARY

TABLE 2

SOIL CHARACTERISTICS

SOIL TYPE	SOIL DESCRIPTION	ESTI-MATED SLOPE %	RUNOFF	HYDRO-LOGIC SOIL GROUP	LOSS RATE (IN/HR)
RO	50%-70% Rock Outcrop		Rapid	NE	NA
RU	Rough Broken Land	5-60	Rapid	NE	NA
AOB	Antho Gravelly Sandy Loam	1-3	Slow to Medium	B	2.0-6.3
CEC	Cavelt Gravelly Loam	1-5	Slow to Medium	D	0.63-2.0
LaB	Laveen Loam	1-3	Slow to Medium	B	0.63-2.0
PVC	Pinamt Gravelly Loam	3-5	Medium	B	0.20-0.63
TrB	Tremant Gravelly Loam	1-3	Slow to	B	0.63-2.0
Va	Valencia Sandy Loam	0-1.5	Slow	B	2.0-6.3

NE = Not Estimated
NA = Not Available

From: USDA Soil Conservation Service, 1974, Soil Survey Eastern Maricopa and Northern Pinal Counties Area, Arizona.

FIGURE 3:

AERIAL PHOTOGRAPH OF CUDIA CITY WASH DRAINAGE AREA for the watershed are the loss rates. The loss rate is defined as the quantity of water which will infiltrate rather than run off. In order to assure the reasonableness of the loss rates used, they were varied until the precipitation measured on June 22, 1972, produced a response in the model which was equivalent to the calculated June 22, 1972 peak flow.

In addition to the peak flow estimate, two rain gage measurements were available for the area. The USGS had a gage at 34th Street and Coolidge which measured 4.46 inches of rain and the National Weather Service had a gage at Mummy Mountain which recorded 2.9 inches of rain on June 22, 1972. The location of these gages is shown on Figure 4. The large range in precipitation volumes measured at gages approximately 5 miles apart is not unusual for summer thunderstorms in the Phoenix area. A difficulty arises, though, when trying to determine not only what precipitation caused the runoff on June 22, but was what the duration of the precipitation. The only rainfall data available for the Cudia City Wash area are daily totals, but hourly precipitation values are available for the Phoenix Weather Service Office at Sky Harbor Airport, a distance of some 7 miles from the watershed. These data show that the storm may have been a six-hour storm with the peak rainfall volume occurring in a one-hour period. Given this pattern, the volume of rain still needs to be determined. Thunderstorms in Arizona can be highly localized, resulting in one station showing large volumes of rain while nearby stations record little rain. This is illustrated by Figure 5, a map showing total precipitation on June 22, 1972, for the gages in the Phoenix metropolitan area.

Since there is no rainfall gage within the watershed, it was necessary to estimate the precipitation which caused the documented June 22, 1972, runoff. The Mummy Mountain gage (2.98") and the 34th Street and Coolidge gage (4.46") are approximately equidistant from the watershed boundary. However, the main body of the watershed is closer to the Mummy Mountain gage. In addition, rainfall on June 22 had already wetted the area, meaning that loss rates would be lower than under dry conditions. The model loss rates were calibrated using precipitation values of 2.9, 3.1, 3.35 and 3.68 inches. The results of these calibrations indicate that reasonable loss rates are only achieved if precipitation values closer to the Mummy Mountain reading of 2.9 inches are used.

Model Development

The HEC-1 computer program containing the kinematic wave routing option was used to model the Cudia City Wash drainage area. The program is described extensively by the COE in the user's manual for HEC-1 and in their Training Document Number 10, "Introduction and Application of Kinematic Wave Techniques Using HEC-1". Briefly, the model requires that subwatersheds be divided into a main channel, a typical collector channel and

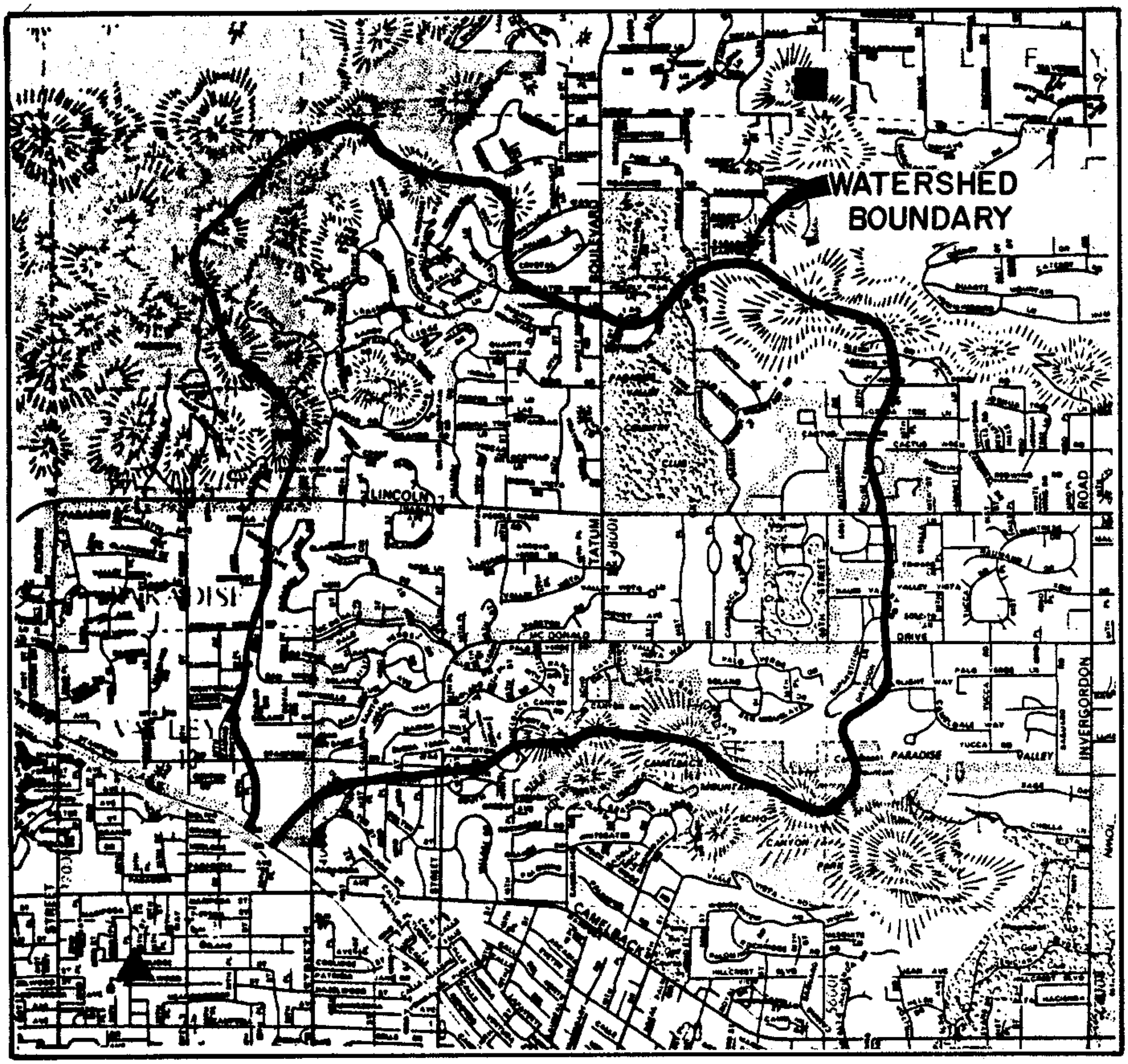
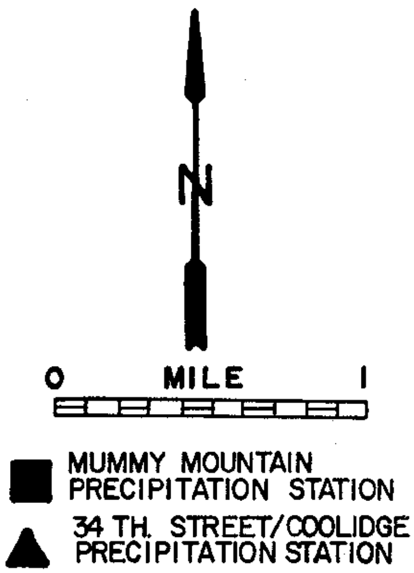


FIGURE 4:

LOCATION OF PRECIPITATION GAGE STATIONS IN VICINITY OF STUDY AREA



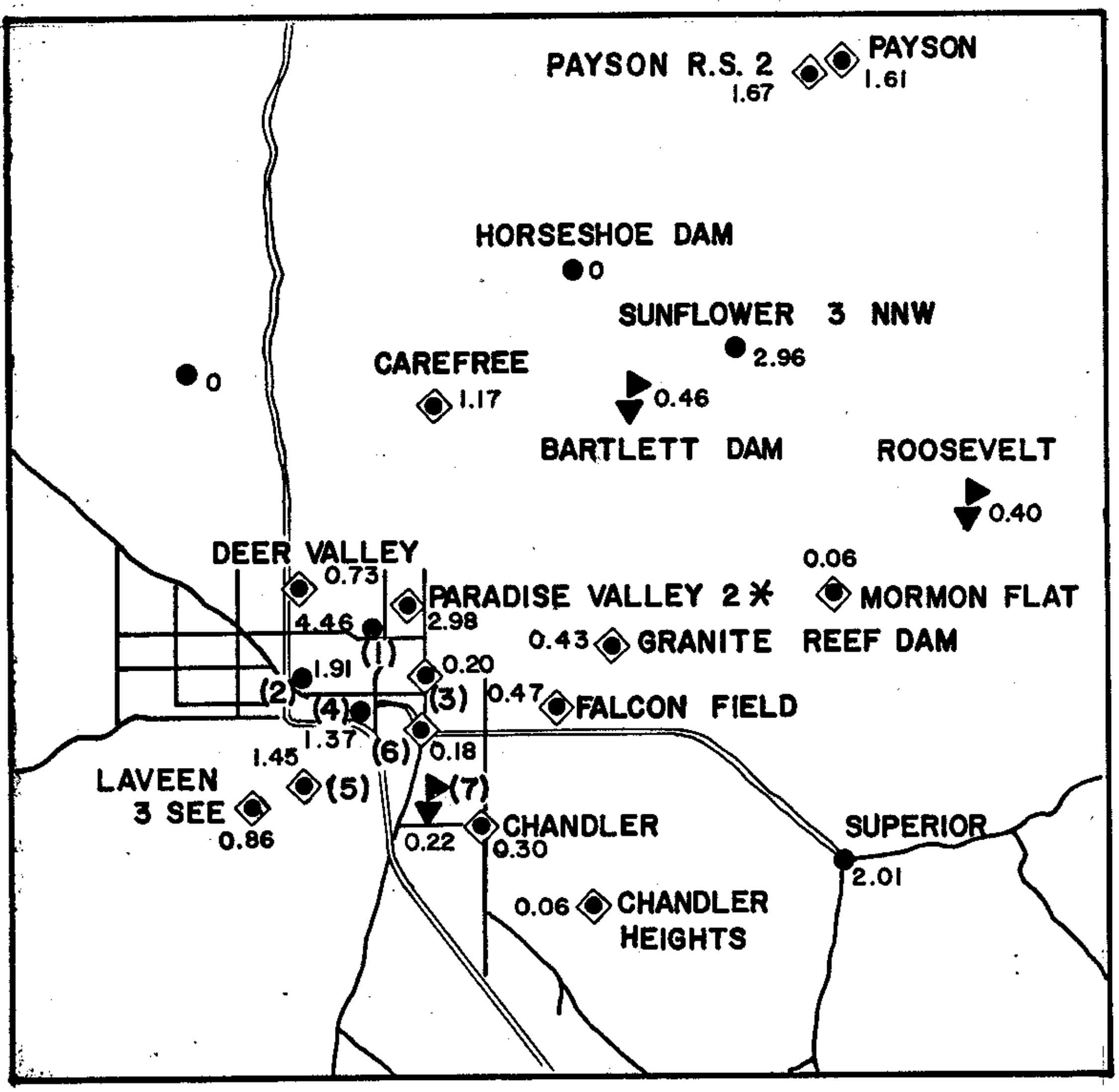
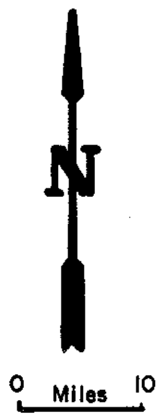


Figure 5: Distribution of June 22, 1972 Storm

Map Source: National Weather Service Stations Map as of March 1975, Prepared by Laboratory of Climatology, Arizona State University, Tempe, AZ.

Data Source: Laboratory of Climatology, Arizona State University, Tempe, Az.



1) 34th Street & Coolidge
2) Phoenix Indian School
3) Scottsdale
4) Phoenix WSO AP
5) South Phoenix
6) Tempe
7) Tempe U. of A. Citrus Experiment Farm

● PRECIPITATION

◈ PRECIPITATION AND TEMPERATURE

▼ PRECIPITATION, TEMPERATURE AND EVAPORATION

▶ WIND

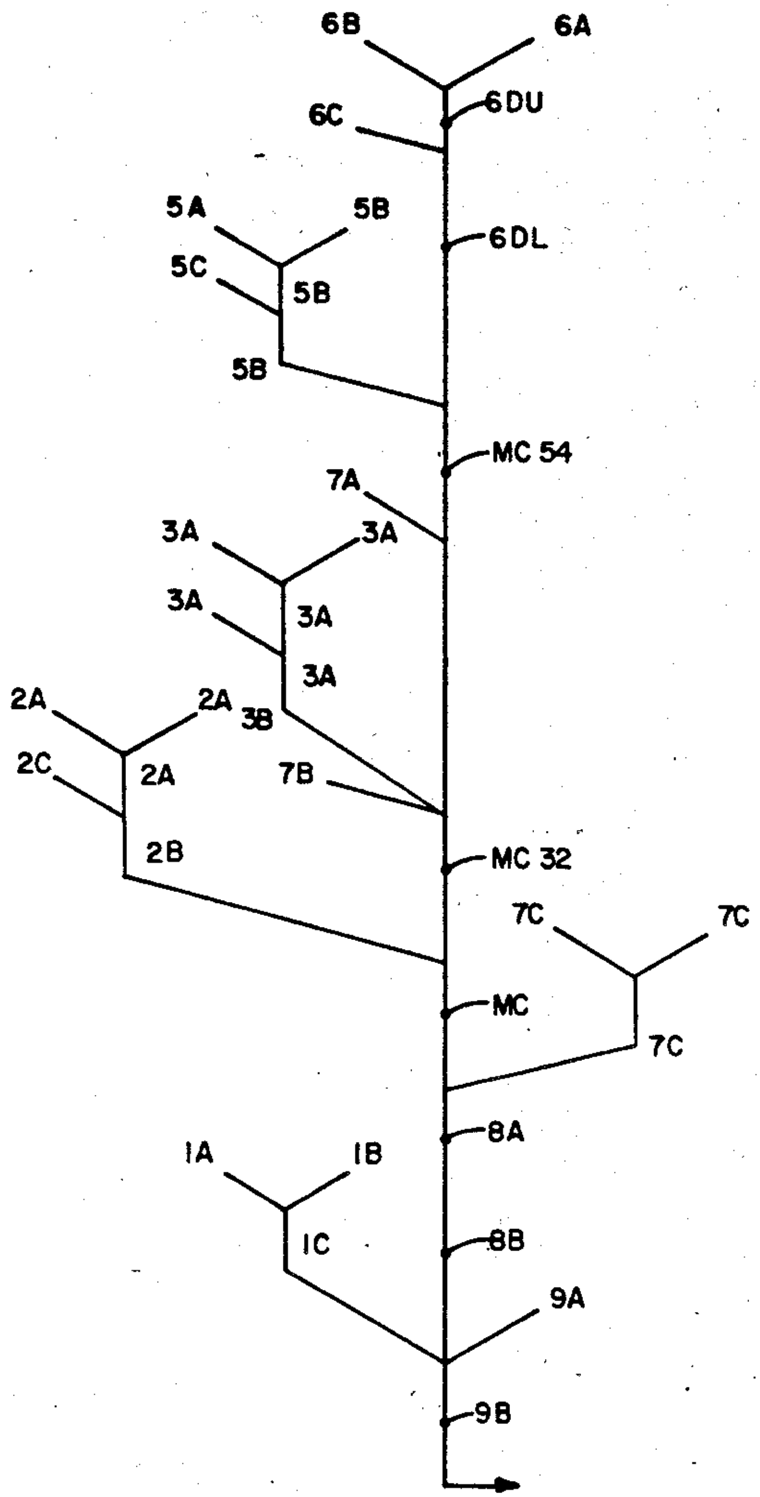
✳ F.K.A. MUMMY MOUNTAIN STATION

up to two typical overland flow planes representing pervious and impervious portions of the watershed. The descriptive data used as input to the model for each of these areas are representations of average conditions over the subwatershed and not a specific flow path. The Cudia City Wash drainage area was divided into 9 major subbasins. These subbasins were further subdivided into 23 smaller watersheds with one major tributary (where possible) in each, Figure 6 (in Map Pocket). A final subdivision of these 23 into 57 relatively uniform channel sections was made to ensure uniform slopes in each segment modeled. A schematic of the watershed routing is contained in Figure 7.

Model Calibration and Results

Two steps are needed when modeling a hydrologic flow system. The first involves the calibration of the model data input using a recorded precipitation value and the resultant measured runoff. The second step then uses this calibrated model to predict the future runoff. The more data available for the watershed (that is the runoff hydrograph shape and time distribution with respect to the timing and distribution of the responsible rainfall) the better the model calibration. In addition, the more of these rainfall - runoff events which are available for calibration, the better the calibration will be.

In this situation, there is only the one (June 22, 1972) event, and neither the peak runoff nor the precipitation over the watershed were actually measured for that event. With those constraints, the calibration of the model began with an assumed precipitation of 3.68 inches, the arithmetic average of 2.9 inches (Mummy Mountain) and 4.46 inches (34th Street and Coolidge). The assumption made at this time was that the data taken from the topographic map and aerial photographs (areas, slopes, channel lengths and percent impervious) and the data obtained from the site visits, (roughness and channel width) adequately described the watershed. With this assumption, the data that needed to be calibrated are the loss rates for the subwatersheds. A different loss rate can be applied to each subwatershed. Original loss rates for the model were the permeability rates given by the Soil Conversation Service as shown in Table 2, and were assumed to remain uniform in time. The calibration procedure therefore involved the adjustment of the loss rates until the modeled flow at 2.16 square miles approximately equaled the 3,000 cfs calculated by the USGS for 1972 flow event. Once the model was calibrated, several runs were made using the Mummy Mountain precipitation and the 34th Street and Coolidge precipitation and the 100 year 6-hour precipitation. The results from these four runs are shown in Table 3, runs A1 through A4. Peak flows ranged from 3,641 cfs to 9887 cfs. The loss rates in the calibrated model were, on the average, twice the SCS permeability values.



MC	MAIN CHANNEL
I A,7A	SUBWATERSHEDS
3A,5B	SUBDIVIDED SUBWATERSHEDS
6 DU	UPPER SUBWATERSHED 6D

N.T.S.

FIGURE 7:

SCHEMATIC DIAGRAM OF WATERSHED ROUTING IN CUDIA CITY WASH DRAINAGE AREA

TABLE 3
MODEL RESULTS

RUN	PRECIPITATION (INCHES)	SOURCE OF PRECIP VALUE	SOURCE OF LOSS RATE VALUE	PEAK FLOW FROM 4.9 SQ MI (cfs)	PEAK FLOW 2.2 SQ MI (cfs)
A1	3.68	Arithmetic Average of 6/22/72 data	Calibration	6636	3082
A2	2.90	Mummy Mtn 6/22/72	A1	3641	1648
A3	4.40	34th & Coolidge 6/22/72	A1	9887	4626
A4	3.15	100-year, 6-hour storm	A1	4492	2069
B1	2.90	Mummy Mtn 6/22/72	Calibration	6517	3156
B2	4.40	34th & Coolidge 6/22/72	B1	14505	7027
B3	3.15	100-year, 6-hour storm	B1	7820	3726
C1	3.35	Weighted Average of 6/22/72 data	Calibration	6578	3146
D1	3.68	Arithmetic Average of 6/22/72 data	A1 % Impervious Revised to Match 1972 Conditions	6554	3090
E1	3.10	Revised Weighted Average of 6/22/72 data to Match Model Loss Rate and SCS Loss Rate	Calibration	6553	3153
E2	3.15	100-year, 6-hour storm	E1	6774	3261

The next step in the model calibration was to make sure that the first, simplest, estimate of precipitation was actually the most representative for the watershed. In reviewing the location of the two gages with respect to the watershed area, coupled with a working knowledge of thunderstorm patterns, it was decided to calibrate against the Mummy Mountain precipitation of 2.9 inches. The loss rates were again adjusted until the model flows matched the estimated 1972 flow. Two further runs were made using 4.4 inches of precipitation and 3.15 inches. The peak flows for these runs, listed in Table 3, are 14,505 cfs and 7,820 cfs. Loss rates for this model were less than the permeability rates given by the SCS.

The last two calibration runs using 3.35 inches and 3.10 inches of precipitation, were made to find a range of loss rates used in the model that were similar to the higher permeability range given by the SCS. Peak flows for the 100-year, 6-hour rainfall using the loss rates developed in these two calibration runs were 5,667 cfs and 6,800 cfs respectively.

Comparison of model loss rates with the SCS permeability rates showed that the loss rates in the calibration model run using 3.1 inches of precipitation more closely approximated the SCS permeability rates. The calibration run which most closely describes the watershed characteristics therefore was chosen as the run which used the 3.1 inches of precipitation. Final loss rate values were taken from this run. The peak flow the 100-year, 6-hour precipitation of 3.15 inches is 6,800 cfs. Data input and the output for this model are contained in Appendix C. Based upon data available for this study, the range of peak flow from a 100-year, 24-hour may be from 5,700 cfs to 7,800 cfs with the most likely flow being 6,800 cfs.

Three items should be clarified regarding these calulations. All model runs were made using present development conditions. Test runs comparing peak flows using the percent impervious for 1972 conditions, present conditions, and future (year 2015) conditions, showed less than a two percent change in peak flows between the runs. It was decided therefore to make all runs for present conditions. The second item that should be explained is that all model runs were made using the 100-year, 6-hour precipitation. The accepted practice of distributing rainfall intensities throughout a hypothetical storm nests the one-hour storm within the six-hour storm which is contained within the 24-hour storm. The loss rate, which ranged from 1 inch/hour to 5.7 inches/hour, must be satisfied before runoff from the rainfall can occur. Only the nested one-hour storm within the 24-hour storm will actually cause runoff, because the remainder of the storm is of lesser intensity than the loss rates. Since this is true, the six-hour storm will adequately describe the peak flow for the 24-hour storm. This is beneficial for our use because one of the problems in using HEC-1 is that the number of hydrograph ordinates is restricted to 300, and that the smaller the time interval between the ordinates, the more accurately the peak flow is calculated. Using a one-minute interval and the six-hour storm ensures that numerical dispersion is minimized and the peak is most correct. Testing a larger hydrograph increment of 5 minutes showed the peak was lowered by 15 percent, resulting from numerical dispersion and from the peak occurring during the 5-minute interval. Third, since the 24-hour peak was obtained from the 6-hour storm, the total runoff volume from the 24-hour storm cannot be reported, only flow rates for a portion of the storm. However, this volume was not requested at the inception of this study.

Conclusion

Based upon the data available for this study as outlined in this report, the 100-year, 24-hour peak flow from Cudia City Wash may range from 5,700 cfs to 7,800 cfs, with the most probable value being 6,800 cfs.

LIST OF REFERENCES

Arizona Department of Transportation Highways Division 1975, Hydrologic Design for Highway Drainage in Arizona.

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Appendix A

Agencies Contacted During This Study

CUDIA WASH/PARADISE VALLEY
DOCUMENTATION OF PEOPLE CONTACTED AND RESULTS

BY ROBIN D. JENKINS

DATE	FIRM/ AGENCY	PERSON CONTACTED	RESULTS OF DISCUSSION
5/27/87	Landis Aerial Photography	Paula	Topographic maps not available for any area. Photos available: 8½ x 11 to 40 x 60. Photos in stock are 20 x 20, labeled, 1":1200', $20.00 each, flown Dec. 1986.
5/27/87	Kenney Aerial Mapping	Eric Hodgins	Paradise Valley flown last month. Topographic maps available of only local, small areas; none available for Cudia Wash Area. KENNEY will enlarge our USGA quad maps to 1":1000', then match that scale on the air photos. Cost = $135.00, no later than Friday morning for finished product. The enlarged quad map will be mylar that we can make bluelines of.
5/27/87	Paradise Valley City Engineer	Dick Edwards	Requested ¼-section maps of Paradise Valley area (T2N R4E). His maps are mylar, 5 years old, 1":200' scale and <u>not</u> contour maps. EDWARDS said the county would have copies of ¼-section maps. He also said the cheapest and easiest way would be to enlarge our USGS quads.
5/27/87	USDA Soil Conservation Service, Field Office 3150 N 35th Av	Nelson	I asked for Eastern Maricopa County detailed soils maps and book. No problem, copies were free of charge. He provided me with a copy of Soil Survey of Eastern Maricopa and Northern Pinal Counties
5/27/87	Maricopa County Assoc of Govern (MAG)	Art Auerbach	I requested information on any reports written concerning projections of growth, population, urban development. He explained what is available & directed me to the MAG office downtown. There I bought a report entitled "Update of the Population & Socioeconomic Database for Maricopa County, Arizona", and various tables showing projections to the year 2015.
5/28/87	MAG	Art Auerbach	I asked him to explain some of the TAZ tables. For example "Undeveloped Employment Areas" and other. He fully explained.

CUDIA WASH
FLOW & PRECIPITATION DATA ACQUISITION
DOCUMENTATION OF CONTACTS

BY ROBIN D. JENKINS

DATE	AGENCY	NAME OF CONTACT	DISCUSSION
6/1/87	USGS	Bob Wallace	Informed me that USGS flow monitoring gages no longer exist, but there is data available for Indian Bend Wash. Referred me to DWR.
6/1/87	ADWR	Ron Stulik	ADWR not monitoring
6/1/87	ASU Climatology Lab	Receptionist in Lab	Informed me of precipitation charts for various years, for 100-year events @ 1 minute to 24 hours time periods. Gave me 1969 for Carefree Station, 4.04 inches.
6/1/87	USGS	Fran Jelinek	Historic flow records have been archived. Information is available in USGS Water Resources Data of Arizona books.
6/1/87	Nat'l Oceanic and Atmospheric Admin.	Meteorologist	I was informed that Tom Zickus (hydrologist) could help me with acquiring precipitation data. He is out of town.
6/3/87	Soil Cons. Service	Carl Glocker	Referred to me SCS Soil Survey reports for data.
6/3/87	Salt River Project	Charlie Ester	SRP doesn't gage small watersheds or urban areas. SRP meteorologists and NOAA supply precipitation data.
6/3/87	Water Cons. Lab	Dan Janes	They are strictly research on project-by-project basis.They do have data for South Phoenix.
6/3/87	Maricopa County Fld. Control	Keba Buckley	Referred me to Tim Sutko for watershed information. He is out of town.
6/3/87	USGS	Bob Wallace	I went to the USGS office and copied the monthly precipitation report that they receive from NOAA

CUDIA WASH DOCUMENTATION

DATE	AGENCY	NAME OF CONTACT	DISCUSSION
6/4/87	Maricopa County Fld. Control	Tim Sutko	They have 12 runoff gages throughout the Count and 60-70 precipitation gages. They also use NOAA Atlas II, Volume 8, AZ.
6/5/87	Maricopa County Fld Control	Tim Sutko	No flow data because their gages are experimental. Precipitation data is recorded in hourly and daily increments. They have precipitation gages @ South Mountain and Phoenix Mtns, and flow gage in the Phoenix Mtns. They use SCS "Urban Hydrology for small watersheds" TR55 and Army Corps of Engineers methods for estimating runoff.
6/5/87	Soil Cons. Service	Janice	Did not have copy of "Urban Hydrology...." I have to order it.
6/5/87	USGS	Burt Thompson	I was asked to inquire about a Flood Frequency Report. He informed me of special reports on particular floods, with magnitude of frequency of ungaged watersheds, Agua Fria, Santa Cruz, Gila River, and 1965, 1978, 1980 Salt River floods. Also a statistical summary (pub 1979) of high, low & mean flows, and the percent possibility of recurrence. There is an annual summary of flood events dating back approximately 50 years.
6/8/87	USGS	Burt Thompson	I inquired about obtaining copies of Cudia Cit Wash drainage data. The information was in their miscellaneous watershed filed. I was met with opposition due to the interpretive nature of their field data and their possible position of liability. Mr. Thompson called his Superior, Mr. Aldridge, for authorization to release such information. Mr. Aldridge said the Freedon of Information Act allows the release of such USGS file material.
6/8/87	ASU Climatology Lab	Pat	I requested hourly precipitation for all the gage stations near the Cudia City Wash area. Pat said that only first order stations record hourly values, and the nearest station is Sky Harbor Airport. Other stations record daily and monthly values. Pat and I made copies of hourly values for 6/22/72, daily and monthly from other stations, and a 1969 report entitle "Estimated Return for Short Duration Precipitation in Arizona

Appendix B

U.S.G.S. Data for Cudia City Wash
near Phoenix, Arizona. 1972
Miscellaneous Site, Flood of June 22, 1972

Cudia City Wash near Phoenix, Ariz.
Gila River Basin
Part 9 - 1972- Miscellaneous Site

Flood of June 22, 1972

Type of measurement: 3-section slope-area.

Location of site: Lat 33°31'32", Long 111°58'43", in $SE\frac{1}{4}SE\frac{1}{4}$ sec.7, T.3N., R.4 E., G.&SRB&M. Slope-area reach is about 1,000 ft upstream of McDonald Drive and about $1\frac{1}{2}$ miles upstream of point where Cudia City Wash dumps into the Arizona Canal. Section 1 and 2 are on north side of knoll located between McDonald Drive and the wash.

Survey of site: Slope-area site was selected by F. Arteaga on June 24, 1972. The high-water marks and cross sections were surveyed June 29, 1972 by T. W. Anderson and E. E. Denis. Survey was run to an arbitrary datum and one reference mark was established (no previous surveys at this site). Instrument was last 2-peg tested on June 26, 1972, prior to running survey and has subsequently been 2-peg tested on July 7, 1972 and instrument was found in adjustment on both dates.

Discharge and gage height: 3,000 cfs; no gage height, miscellaneous site.

Drainage area: 2.16 sq mi.

Unit discharge: 1,389 csm. 1390 csm

Nature of flood: The flood was a result of an intense thunderstorm over the area on the morning of June 22, 1972. 1.64 inches of rainfall was recorded at the U.S. Weather Bureau station at Sky Harbor Airport (7 miles to the southwest). 2.90 inches of rain fell at Mummy Mountain Observatory, 2.3 miles north-northeast of the slope-area site and 4.46 inches of rain fell at U.S.G.S. non-recording rain gage site at 34th St. & Coolidge, $2\frac{1}{2}$ miles southwest. The thunderstorm resulted from movement into the area of moist, tropical air from the Gulf of California which encountered a high-level, unstable, low pressure area over the North Phoenix-Paradise Valley area.

Field condtions: The slope-area reach is straight and contracting throughout. Bed material in the main channel generally gets smaller in the downstream direction; being largely angular cobbles with some gravel at cross-section 1, half cobbles and half gravel at cross-section 2, and mostly gravel with some cobbles at cross-section 3. The banks of the main channel are composed of silt and cobbles. A red conglomerate is exposed on parts of bed and left bank between cross sections 1 and 2 and upstream of the reach. The overflow areas have sand and silt bottoms with much scattered brush and boulders. The cross sections were subdivided on basis of "n" only. The "n" values chosen were:

Cudia City Wash near Phoenix, Ariz.

Section	Left bank	Main channel	Right bank
1	-	0.035	0.080
2	0.080	.030	.080
3	.080	.030	.080

There was no evidence of fill in the reach, there may have been some minor amount of scour. Large waves of sand below section 3 indicate considerable fill in that area.

The high-water marks ranged from poor to good debris and mud lines, being generally good on the left bank and fair on the right bank. Some marks on right bank were apparently affected by local rainfall or tributary inflow in the reach. The quality of inflow possible in each of the small tributaries entering from the right within the reach should not be enough to cause differences in discharge in the downstream direction (probably less than 40 cfs in each). The cross sections were located in the field sketch of the left bank high-water marks.

Seven stereo pictures of the reach were taken.

Computations: Discharge computed on the Wang desk calculator.

Reach	Discharge	Fall	Length	Type of reach
1-2	2,691	1.39	332	Contracting
2-3	3,287	2.01	201	Contracting
1-2-3	2,998	3.40		

$IF_1 = 0.58$ $IF_2 = 0.52$ $IF_3 = 0.67$

T. W. Anderson
July 12, 1972

Review: The plan should be plotted so that flow goes up the page and the main channel should have been located.

Sections are located satisfactorily.

The "n" values appear low for the main channel and high for the overflow area at section 1. I recomputed the measurement using values of 0.040 to 0.045 for the main channel. and 0.060 to 0.080 for the overflow sections. These values were concurred with by other engineers. If the field party disagrees I would like them to contact me.

The recomputed result to the nearest ten cfs is 3,000 cfs. Use 3,000 cfs and rate the measurement fair.

B. N. Aldridge
Nov. 17, 1972

I inspected this reach on Jan. 17, 1973 and was able to locate only one stake. I had concluded that this was probably the right end of section 1 but after returning to the office and studying pictures, I found that it was apparently the right end of section 2 or 3. If a complete field sketch including the hill and access road had been drawn by the field crew, the confusion would have been avoided.

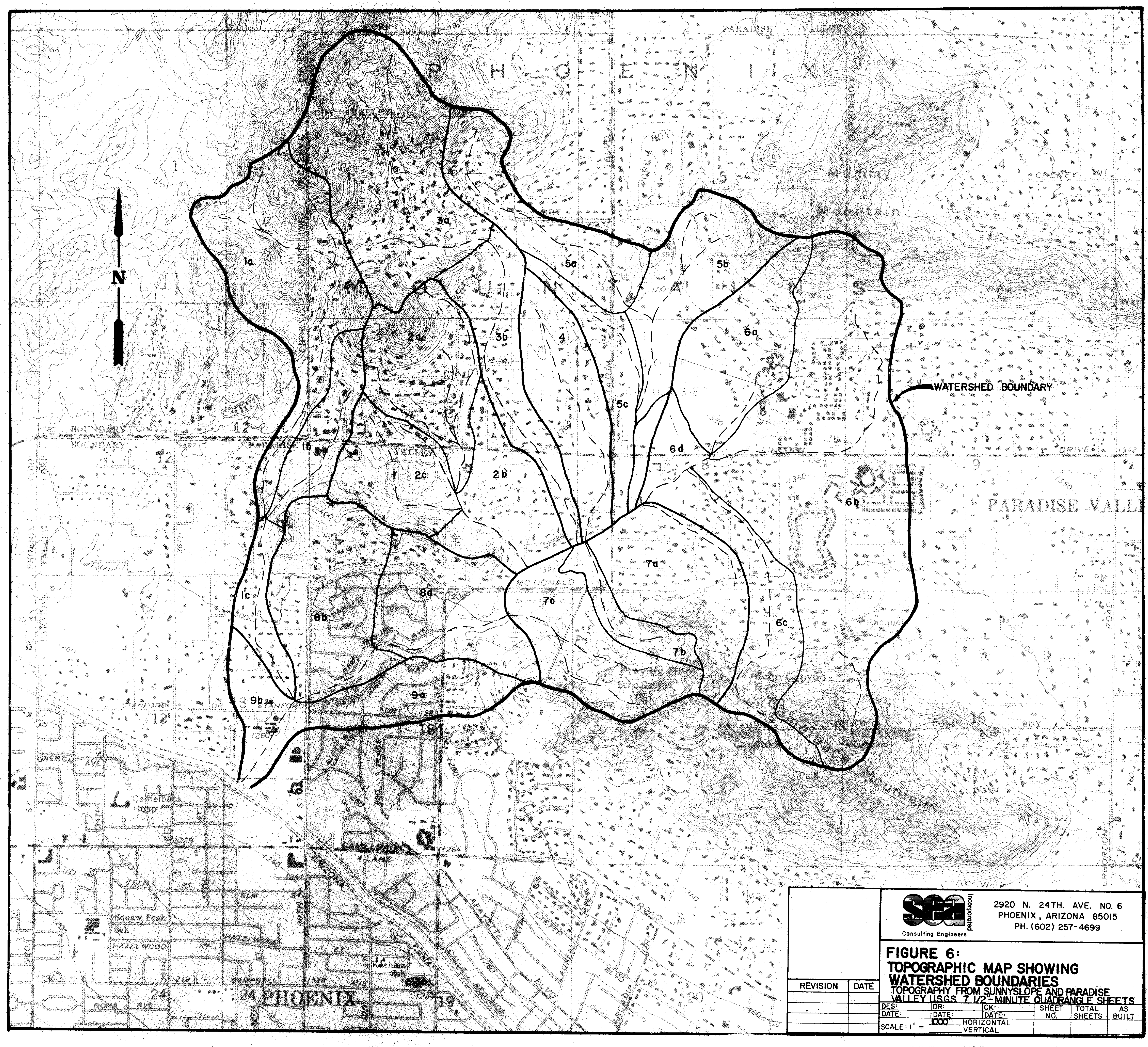
All possible land marks should be shown on field sketch and on the plan-view so that someone not familiar with the reach can relocate the sections. We may want to use the reach again 15 or 20 years from now.

The main channel should always be located on the plan. If there is overflow the channel should be located with a transit survey. If no survey of the main channel was made the location of the channel can be obtained from the cross section and plotted back on the plan.

From my field inspection I believe that I may have raised n for section 3 too much. A value of 0.035 would be better but the decrease in n would be offset by increase in alpha and the net affect would probably be negligible.

Use 3,000 cfs and rate the measurement fair.

B. N. Aldridge
Flood Specialist
Tucson District, WRD
Jan. 26, 1973



sea incorporated
Consulting Engineers
2920 N. 24TH. AVE. NO. 6
PHOENIX, ARIZONA 85015
PH. (602) 257-4699

FIGURE 6:
TOPOGRAPHIC MAP SHOWING WATERSHED BOUNDARIES
TOPOGRAPHY FROM SUNNYSLOPE AND PARADISE VALLEY U.S.G.S. 7 1/2" MINUTE QUADRANGLE SHEETS

REVISION	DATE

DES:	DR:	CK:	SHEET NO.	TOTAL SHEETS	AS BUILT
DATE:	DATE:	DATE:			
SCALE: 1" =	1000' HORIZONTAL	VERTICAL			

EXECUTIVE SUMMARY

for

Cudia City Wash
Drainage Study
June 12, 1987

Prepared by:

Skibitzke Engineers & Associates
A Subsidiary of SEA, Inc.

On May 27, 1987, SEA, Inc. was commissioned by the City of Phoenix and the Citizens Against Reach Four to prepare an independent analysis to determine the peak flow from a 100 year 24 hour precipitation event occurring on the Cudia City Wash. The probable peak flow for the 100 year 24 hour precipitation of 3.80 inches over the Cudia City Wash drainage area is 6800 cfs. The peak flow from the 100 year 24 hour storm could range from 5700 cfs to 7800 cfs depending upon soil infiltration rates on the watershed.

These results were obtained using the following information:

- The kinematic wave routing technique of the U.S. Army Corps. of Engineers HEC-1 computer program was the basis of the watershed model.
- Topographic data, watershed areas, land slopes and channel lengths were obtained from the Paradise Valley and Sunnyslope 7.5 minute U.S.G.S. Quadrangle sheets.
- The watershed area, 4.92 square miles, was divided into 9 subwatersheds. These were further subdivided into 57 areas having similar land slopes and soil types.
- The 100 year 6 hour rainfall is 3.15 inches. The 100 year 24 hour rainfall is 3.80 inches.
- Soils data were obtained from the U.S. Soil Conservation Service.

- Channel roughness and widths were obtained during three visits to the watershed.

- Calibration for the watershed model was provided by U.S.G.S. data for a June 22, 1972 rainfall runoff event at Cudia City Wash. The runoff, approximately 3000 cfs from the eastern part of the watershed (2.16 square miles), was caused by a precipition of approximately 3.1 inches.