CITY OF PHOENIX, ARIZONA
PROJECT Nº ST-813840

ARCADIA AREA MASTER DRAINAGE STUDY

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DRAFT
STUDY WAS NEVER FINALIZED

NOVEMBER 1985

arthur beard engineers, Inc.
CONSULTING ENGINEERS

CITY OF PHOENIX

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BY

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I. INTRODUCTION AND SUMMARY OF FINDINGS

A. PURPOSE

The purpose of this report is to develop a conceptual plan to accommodate storm water runoff from the 2-year return period storm in the Arcadia Area of the City. The study area limits are generally described as the ridge line of Camelback Mountain, Cudia Wash, the Arizona Canal, and 64th Street (Invergordon). The study contains two major elements:

1. The hydrology for the study area is computed using the Soil Conservation Service's TR-20 method for a 2-year return period storm.

2. The available data is analyzed and evaluated and a conceptual plan developed for accommodating the computed flows from a 2-year return period storm, including the preliminary size, location, and a cost estimate for each proposed major storm drain.

B. SCOPE OF WORK

The Scope of Work for the project includes the City of Phoenix TR-20 Procedure and Administrative Procedure No. 40 dated July 1, 1979 regarding the preparation of aerial contour maps. Copies of each of the above documents are included in Appendix A of this report.

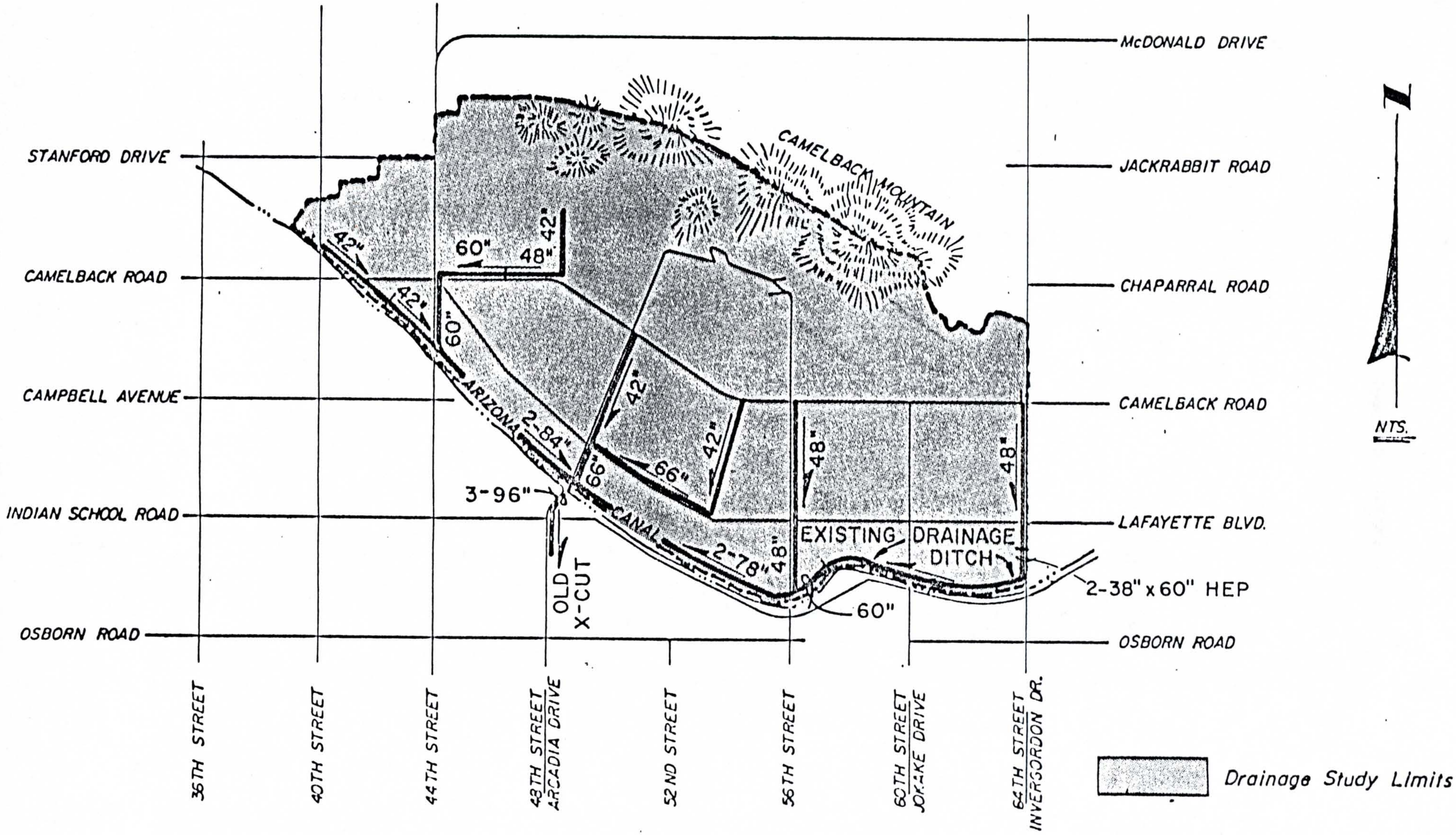
In addition to the preparation of this report, a total of 9 contour quarter-section maps were produced as outlined in the Scope of Work. The quarter section maps complete the contouring of the Arcadia Drainage Area.

C. HYDROLOGIC DESIGN METHOD

The hydrology of the Arcadia Drainage Area is based on the use of the Soil Conservation Service's TR-20 computer program which takes into account the physical characteristics of the drainage area (ie: soil type, ground slope, zoning, land use, drainage patterns, on-site retention) and computes the peak run-off from the drainage area. Expected changes in land-use patterns within the drainage area were incorporated in the calculation of the peak design runoffs.

D. EXISTING DRAINAGE SYSTEMS

The Arcadia Drainage Area is currently served by storm drains in Camelback Road from approximately 45th Street, west, to the Arizona Canal; by short storm drains serving small areas adjacent to the Arizona Canal; by drainage channels, especially in the mountainous areas north of Camelback Road; by direct discharge into the Arizona Canal, various washes, or roadways; by on-site stormwater retention



RECOMMENDED PLAN

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FIGURE I-1

NOV., 1985

in most commercial and residential areas downslope of the steep mountain areas to the Canal; and by overland flow whenever the runoff exceeds the capacity of the existing drainage systems.

Flooding has been reported to occur on lands just north of the Arizona Canal, especially after major rainstorms. Other localized problems have been reported in the steep slopes of Camelback Mountain where the construction of a street or other development has altered the natural drainage patterns and directs runoff on a particular homesite.

E. SELECTION OF ALTERNATIVES

The existing system consists of two storm sewers in Camelback Road which are not adequately sized to transport the runoff generated by the 2 year design storm. The existing system's maximum capacity is approximately 56 cfs and the expected runoff for this portion of the drainage area is 302 cfs.

New storm sewers have been sized on the basis of expected runoff from the 2 year design storm to collect and transport runoff. Two alternatives have been developed which differ only in their treatment of runoffs from that portion of the drainage area west of 44th Street. In Alternative 1, flows west of 44th Street are discharged to the proposed Arizona Canal Diversion Channel (ACDC), flows from the remaining portions of the drainage area are brought to 48th Street and the Arizona Canal and discharged to the Old Cross-Cut Canal. In Alternative 2, runoff from the entire Arcadia Drainage Area is discharged into the Old Cross-Cut Canal.

An evaluation of the two alternatives was performed using the following criteria:

1. Construction Costs
2. Flood Relief in Problem Areas
3. Implementation

The construction cost of the two alternatives are summarized in Table I-1 below. A contigency item of 15% has been added for undeveloped details and miscellaneous work items.

TABLE I-1

ESTIMATED COST SUMMARY

	COST ($)
Alternative 1	8,100,000
Alternative 2	8,246,000

The alternatives provide an equal amount of flood relief in problem areas along the Arizona Canal. The ease of implementing each alternative is an important criterion for evaluating both alternatives. Alternative 1 is the most difficult to implement because it requires coordinating with additional governmental agencies such as the Corps of Engineers and it is dependent upon the construction of the ACDC for the servicing of those areas west of 44th Street.

F. RECOMMENDED PLAN

It is recommended that Alternative 2 be implemented by the City for the following reasons:

1. Alternative 2 is the easiest to implement.

2. Alternative 1 is dependent upon the construction of the ACDC for drainage of those areas west of 44th Street. Present indications are that the ACDC would not be completed for several years. No construction schedule has been finalized.

3. The Arcadia Drainage Area is outside the ACDC drainage limits. The addition of Arcadia runoff may create surcharged conditions in the ACDC under certain storm flow conditions.

   Approval from the ACDC's responsible agencies for the acceptance of a portion of Arcadia flows to the ACDC is unknown at this time.

The recommended plan, Alternative 2, is shown in Figure I-1. Appendix D contains preliminary water surface profiles of the recommended plan to demonstrate the feasibility of the chosen conduit routing and to determine the extent of utility interferences.

II. STUDY AREA CHARACTERISITICS

A. STUDY AREA LOCATION

The project study area is in the east portion of the City of Phoenix known as Arcadia. The study area is bounded on the north by the ridge line of Camelback Mountain, on the west by 40th Street and the Cudia Wash, on the south by the Arizona Canal, and on the east by 64th Street (Invergordon). The limits of the study area are shown in Figure II-1; the detailed delineations of the study area are shown in Appendix B.

B. ZONING AND LAND USE

Zoning within the study area was obtained from the City of Phoenix Planning Department. The drainage area is predominantly residential in nature with large lots (14,000 sq.ft. to 35,000 sq.ft.). A commercial and multi-family strip is found along Camelback Road from approximately 45th Street, west, to the Arizona Canal. A majority of the single-family residences south of Camelback Road irrigate their yards by the flooding method, while most of the single family residences in the steep hillsides of Camelback Mountain have desert landscaping on relatively small areas of their lots.

Little undeveloped land remains within the study area. It was assumed that "in-fill" growth would take place at the same densities as adjacent parcels of like zoning.

C. TOPOGRAPHY

The study area has a diverse topography. Elevations vary from elev. 1250 at Camelback Road and the Arizona Canal to elev. 2704 at the summit of Camelback Mountain. The lands north of Camelback Road are moderately steep to excessively steep with average slopes in the 15% to 25% range; several cliffs and nearly vertical slopes are also found on the mountainside. Gentler grades are found south of Camelback Road. Slopes in these areas are in the 0.5% to 1.5% range with nearly level ground along the Arizona Canal.

The area's storm drainage is controlled by Camelback Mountain and the Arizona Canal. Storm flows are generally north-to-south from the steep mountain hillsides to the flat lands adjacent to the canal. Drainage off of Camelback Mountain is through washes or ditches, drainage south of Camelback Road is along the grid street pattern. The Arizona Canal acts as a barrier to prevent natural overland flow at the canal location.

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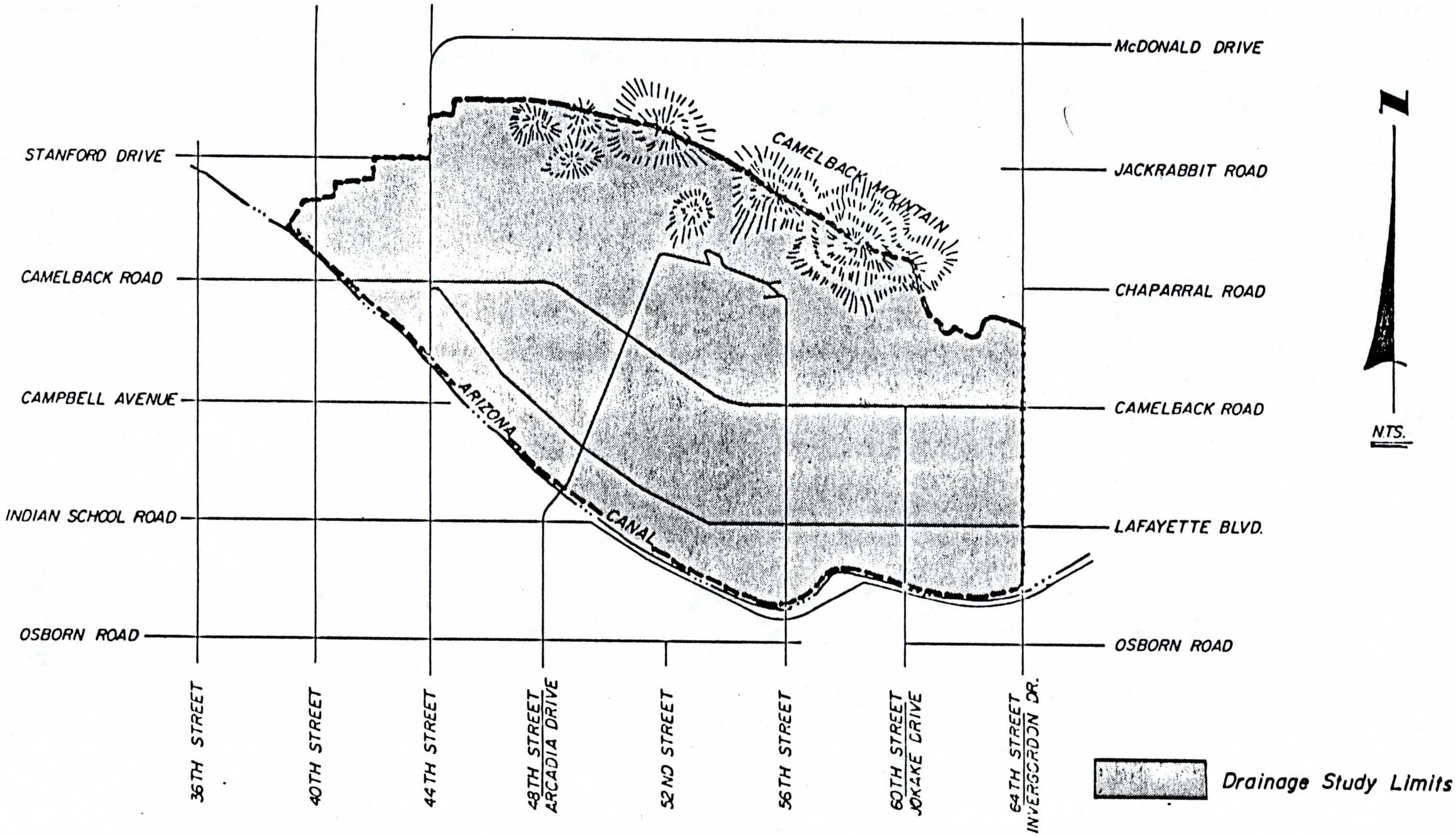

LOCATION MAP

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FIGURE II - 1

AUG., 1985

c. 56th Street to Royal Palm Road (approx.): flow is along Camelback Road to a low point at 54th Street, here, runoff is transported across Camelback Road in a 36-inch CMP.

d. Royal Palm Road to Arcadia Drive: flow is along Camelback Road to a 24-inch CMP culvert discharging across Camelback Road at Arcadia Drive.

e. Arcadia Drive to the Arizona Canal: all runoff is directed west in drainage channels to 45th Street; from this point, runoff is collected in a 36-inch and 24-inch diameter storm drain system to the Arizona Canal.

Some neighborhoods south of Lafayette Boulevard drain directly to the Arizona Canal through small drainage channels. Drainage channels were noted extending to the canal from Calle Felix alley, 46th Place, 50th Place, and an alley perpendicular to Calle Redonda at 53rd Way.

A major drainage channel has been constructed from 64th Street, west, to 56th Street, immediately north and paralleling the Arizona Canal. This structure is trapezoidal in cross-section with a 10 ft. wide bottom and side slopes of approximately 2.5:1.0 (Horiz:Vert.). This channel intercepts all runoff from an area bounded by 56th Street and 64th Street. Discharge is to the Arizona Canal through dual 48-inch pipelines.

The drainage channel also receives runoff from a portion of the City of Scottsdale approximately bounded by Jackrabbit Road, 68th Street, the Arizona Canal, and 64th Street including the east basin of Camelback Mountain. Erie and Associates, Inc. have recently performed a drainage study for the above-described area and their results for runoff from a 2 year storm to the drainage channel at 64th Street are incorporated in this report.

2. Camelback Road Storm Drains

A 24-inch and 36-inch diameter storm drain system has been installed on the north side of Camelback Road from 45th Street west to the Arizona Canal. Catch basins located along Camelback Road and its north side streets collect runoff which is transported west to 44th Street and then south west, to the Arizona Canal in a 36-inch storm drain. The approximate area served extends from Arcadia Drive to 44th Street.

A 36-inch and 18-inch diameter storm drain has been installed on the south side of Camelback Road; it extends from 600 feet east of 44th Street, west, along Camelback Road, to the Arizona Canal. This storm drain services the areas north of Camelback west of 44th Street to approximately 40th Street through a 27-inch storm sewer extending 300 feet north of Camelback in 44th Street. The drain also collects runoff from a strip of land adjacent to the south side of Camelback Road from 44th Street to the canal. This storm sewer system discharges to the 40th Street system, a portion of the City's large diameter storm sewers installed in major North-South streets which eventually discharge to the SRP Canals or the Salt River.

3. Curbs and Gutters

Most of the streets south of Camelback Road have rolled curb and gutters which collect and transport storm water to drainage ditches and the Arizona Canal. The carrying capacity of these rolled curb and gutters may be approximated to that of vertical curb and gutters for the following reason:

- most of the land is irrigated by flooding. The water applied on the soil is contained within the parcel by a berm. This berm is generally installed just behind the curb and it acts as a channelization device which increases the carrying capacity of the rolled curb and gutter system.

Street drainage in areas north of Camelback Road is generally by sheet flow along or across the paved surfaces, as influenced by local topography. Some streets have side ditches or swales which carry the runoff.

4. Discharge to the Arizona Canal

As previously discussed, some of the areas located adjacent to the north bank of the Arizona Canal have drainage facilities which discharge directly into the canal. In three locations, there are no existing storm drains, and the canal's north bank is several feet higher than the adjacent property. Thus, the only method of draining these properties and streets is to drain into the canal.

There are two features of interest associated with the Arizona Canal. At 64th Street, provisions are made to feed the Grand Canal through the Cross-Cut Canal. The division of flows between the two canals is performed remotely by the Salt River Project from their operations center. There also exists, at 48th Street, a 3 1/2 mile canal known as the Old Cross-Cut Canal which fed the Grand Canal from the Arizona Canal before the construction of the Cross-Cut Canal in 1912. The Old Cross-Cut, also known as the Water Power Canal, is not currently in active use.

5. On-Site Retention

Throughout the Arcadia Drainage Area, off the steep slopes of Camelback Mountain, on-site retention of stormwater is provided both for legal requirements and as a by-product of the method of irrigation used. Three types of on-site retention systems are discussed below:

a. Retention Basins: On new commercial and multi-family zoned developments, existing City ordinances and development policies require that each property must provide on-site retention of at least the 10-year frequency storm which falls on the property. Compliance with the requirements is normally done by constructing a retention basin designed to hold a volume of water equal to the runoff calculated for the particular property. Therefore, this amount of stormwater never reaches the street drainage system.

   On-Site retention is required of all commercial, office, and multi-family residential zoning classifications, except for the following notable exceptions:

   - Developments of one-half acre or less are normally not required to provide on-site retention if the developer proves that it would be uneconomical or would grossly impair the use of the property.

   - When an existing developed property is redeveloped, the on-site retention of stormwater is required only if the existing development provides it.

b. Non-Irrigated Residential Developments: In new developments of single-family residential classifications which do not plan for the use of flood irrigation, existing City ordinances require that each lot be finished with depressed front and back yards, such that stormwater from the lot does not runoff to the street. The depth of the depression is usually 4-6 inches below the sidewalk or top of curb.

c. Irrigated Developments: In developments designed to be flood-irrigated, the lots are bermed up to retain the irrigation water. Total depth inside the berms is normally at least 8 inches. As a result of this berming, these lots also will retain any stormwater which falls on it.

F. FUTURE LAND USE

1. Future Development

The project area's existing land use is primarily residential in nature, and is not expected to change appreciably in the foreseeable future. The area is almost completely developed, and is noted as being among the most desirable residential areas in the City of Phoenix.

Some redevelopment on the Camelback Mountain hillside is noted from large lot residential estates to resort and planned community developments with required retention facilities. These changes in land use patterns are not expected to greatly modify the runoff characteristics of the drainage area.

2. Future Irrigation Practices

It is expected that the existing practice of flood irrigation of many residential lots, parks, churches and schools will continue with its added benefit of stormwater retention.

3. Future Stormwater Management Policies

The existing ordinances and development policies for stormwater retention are expected to be continued into the future for all types of development. These policies are particularly important in the urban development areas south of Camelback Road, where existing policies of stormwater retention should be rigidly enforced to prevent future problems with drainage.

G. EXISTING PROBLEM AREAS

Reports of localized flooding during rainstorms can be subdivided into three types: a) Flooding along the north bank of the Arizona Canal, b) Street flooding along North-South Streets carrying storm flows from Camelback Road, and, c) Flooding along hillside washes and drainage channels.

1. The Arizona Canal acts as a barrier to the north-south movement of runoff. The north bank is generally several feet in elevation above the adjacent land and, during rainstorms, runoff ponds against the north bank of the canal. Drainage is sluggish, in a NW direction along the canal to a drainage ditch or other facility which intercepts the surface flow and discharges the

accumulated runoff directly to the canal. Complaints of this nature have been received from homeowners in the vicinity of Calle Redondo and 52nd Street, Camelback and 40th Street, and 57th Street and Calle del Paisano/Calle Camelia.

2. Runoff from the area south of Camelback Road generally drains in curb and gutters. The north-south streets act as major drainage ways, bringing stormwater to the Arizona Canal. Arcadia Drive, 54th Street, 56th Street, and 64th Street carry additional runoffs from areas north of Camelback Road. The hillside flows are generally discharged to these streets through corrugated metal culverts which have been installed under Camelback Road. These culvert discharges to streets south of Camelback Road have occasionally caused local flooding when the runoff exceeds the curb and gutter capacities. Several complaints have been received from homeowners near Exeter Boulevard and 54th Street, and 64th Street and just south of Camelback Road of lot flooding or excessively deep water in the street caused by upstream culvert discharges across Camelback Road.

3. In developing the south slopes of Camelback Mountain, the existing drainage swales were modified by the construction of steets and homesites. In many locations, several small swales were routed into a single, large drainage channel by the construction of berms or by regrading. During rainstorms, runoff has been reported to leave the drainage ways and spill onto adjacent lots and streets. Erosion of the rerouted swales and downstream deposition on streets and lots has been noted in many locations. Complaints of flooding are noted in two areas: a) Rockridge Road from Arcadia Drive to Camelhead Road, and, b) Wonderview Road from 56th Street to 53rd Street. The Rockridge Road complaints are from a relocated drainage swale which occasionally "jumps" its channel or erodes a portion of an adjacent lot. The Wonderview Road complaints stem from the relocation of a system of small drainage swales into erodible channels.

4. The area between Dromedary Road and Camelhead Road between Rockridge and Palomino Roads deserves special mention. Prior to the development of this portion of the hillside, runoff was concentrated in three major drainage swales which ran through the area in a generally northeast to southwest direction. The construction of Rockridge and Palomino Roads greatly modified this drainage pattern: the three swales have been combined into one "collector" swale which parallels Rockridge Road from Dromedary to Camelhead Roads. Runoff is now concentrated and is more likely to spill from its designated channel onto adjacent lots especially during intense storms. This situation was

further aggravated by the 1971 paving improvements of Rockridge and Palomino Roads which raised the roadway and filled the road swales or 'dips' which had previously allowed some relief to the concentrating runoff in the roadway drainage channels; the roadways now perform as "levees" which funnel all runoff to a discharge point at Camelhead Road. Numerous complaints have been received by the City from property owners in this area in which the concentrated runoff deposits stones and sand onto their properties.

III. HYDROLOGIC DESIGN PARAMETERS

A. METHOD OF ANALYSIS

The method of analysis used for the determination of peak discharges in the drainage area is the Soil Conservation Service TR-20 program. This method of analysis conforms to existing City of Phoenix standards for hydrologic design of storm drainage systems, and requires the following input data:

1. Rainfall intensity and duration.
2. Drainage area size.
3. Time of concentration
4. Drainage area runoff characteristics, expressed as a Composite Curve Number.
5. Distance and Velocity of routing between drainage areas.

For reference, the City of Phoenix TR-20 Procedure is included in Appendix A of this report.

B. RAINFALL INTENSITY AND DURATION

The rainfall intensity and duration used in the hydrologic design is based on the 2-year, 24-hour return period storm, with a rainfall distribution and intensity in accordance with the above-mentioned City of Phoenix TR-20 Procedure (Tables II and III). For purposes of evaluation and comparison, the 1-year, 24-hour return period storm is also used in this project.

C. DRAINAGE SUB-AREA DELINEATION

The overall Arcadia Drainage Area was divided into 20 drainage sub-areas for purposes of determining the drainage characteristics. In making the sub-area delineations, the following general criteria was used:

1. Maximum size of each sub-area of approximately 0.25 square mile.
2. Minimum concentration time within each sub-area of 10 minutes.
3. Location of existing surface drainage features.
4. General direction of ground slopes.
5. Location of existing and/or planned storm drains.

Delineation of these sub-areas is shown on the drainage maps included in Appendix B of this report.

D. CURVE NUMBER DETERMINATION

The Curve Number (CN) or hydrologic soil cover complex, used in the TR-20 procedure combines the effects of soil type, land use and ground cover to determine runoff from a drainage area. For this project, CN's for various zoning classifications and soil types are contained in the City of Phoenix TR-20 Procedure and are therefore used as a basis for producing CN's for the project.

There are several zoning classifications in the Arcadia Drainage Area which are not included in the established CN list. Field investigations, contour quarter-section maps, aerial quarter-section photographs, and investigation of the zoning ordinances which created these new classifications were all used in the development of CN values for these unlisted zoning classifications. A summary of all CN values used in the project appears in Table III-1.

1. Planned Area Development (PAD)

For this zoning classification, a field observation of such areas in the Arcadia Drainage Area showed that the PAD's varied widely in their makeup, but overall they appeared to have drainage characteristics similar to that of a small single-family residential lot development (i.e., RI-6 zoning). For this reason, all PAD zoning classifications have been given a CN of 84 for this project.

Using a method similar to the above example, CN's were established for the P-1 zoning classification which does not appear in the TR-20 Procedure memorandum.

2. R-2 SP(PC) and PC

These zoning classifications are found in sub-area 20. From the review of all available information and conversations with representatives of the City Planning Department, it was assumed that all lands zoned PC would be developed as R-2 SP(PC) lands, a lower density multi-family zoning classification (e.g. Townhomes). The regular CN value was given the same value as for R-3.

Soil group 'D' CN values were also taken from R-3 values for 'D' soils.

TABLE III -1

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ARCADIA STORM DRAINAGE STUDY
CURVE NUMBER SELECTION

Zoning Class	Reg. CN	Slopes 10% or more	If Irrig. % Contrib.	Lot's CN	If Design 10-Yr Retention, % of Lot Contrib.
RESORT	77,86**	95	8.7	95	-
RE-35 RE-35PAD RE-35(PC)	79*,87**	95	9.8	95	-
RE-35SP SP RE-35 (PC) SP RESORT (PC) SP (PC)	77	95	-	-	5
RE-24	79*	95	11.4	95	-
RI-18	80*	95	17.7	95	-
RI-14	80*	95	21.7	95	-
RI-10	81*	95	26.0	95	-
R-2 SP(PC) PC	85,90**	95	50.0	95	-
R-3	85*	95	-	-	33
R-4,5	86*	95	-	-	33
C-1,2	92*	95	-	-	15
C-O	88*	95	-	-	15
PAD(all)	84	95	-	-	15
P-1	95	95	-	-	15

* Source: City of Phoenix, Curve Number Selection for 'B' Soil Group

** Ibid: CN for 'D' Soil Group

3. Golf Courses

The following zoning classifications were identified as golf courses, driving ranges, and like useages from field verifications and aerial photographs: RE-35SP, SP RE-35(PC), SP RESORT(PC), and SP(PC). The CN value was assumed to reflect the lowest density zoning classification found in the curve number selection table: RE-43/S-1.

4. RE-35

Zoning classifications RE-35 (PAD) and RE-35 (PC) were found to have similar land use characteristics to RE-35 and were all given the same CN values. Soil group 'D' CN values for RE-35 were assigned to RE-35 (PAD) and RE-35 (PC).

5. Resort

The City Planning Department identified the lands so zoned in sub-areas 8 and 20 to the planned First Phoenician and Jokake resorts.

CN values from RE-43/S-1 were chosen as being the most representative of the drainage characteristics of this zoning category for soil groups 'B' and 'D'.

It is recognized that ground slopes have a major impact in determining the rapidity with which rain water runs off the ground's surface. The TR-20 Procedures stipulate that all subareas having a ground slope exceeding 10% will be assigned a curve number of 95 regardless of zoning. Subareas 2, 3, 4, 6, 7, 8, and 20 have slopes ranging from 10.6% to 25.1%, are classified as mountainous, and all zoning designations are given a CN = 95.

The steep grades in subareas 2, 3, 4, 6, 7, 8, and 20 require a correction to the area calculations. The area for each subarea is measured from a two-dimensional map. Subareas having slopes between 10% and 17% require a 1% addition to their areas; subareas with 18% to 22% require a 2% addition, and subareas with 23% to 26% require a 3% addition to correct for their steep slopes. The following table identifies the area corrections for each hillside subareas:

Subarea	Initial Slopes	Slope in Degrees	Correction Factor (1 - COSINE of angle)
2	0.1204	6.87	0.007, say 1%
3	0.1829	10.36	0.016, say 2%
4	0.2501	14.04	0.029, say 3%
6	0.2614	14.65	0.033, say 3%
7	0.2310	13.01	0.026, say 3%
8	0.2657	14.88	0.034, say 3%
20	0.1426	8.12	0.010, or 1%

The additional area is apportioned between the largest zoning classification areas in each subarea.

E. EFFECTIVE SLOPES

The calculation of a subarea's slope is generally performed by first calculating the net change in elevation between the highest point in the subarea and its point of concentration, or outlet. This elevation difference is divided by the length of flow of the runoff, Lc, determined from topographical and development patterns to obtain the subarea's slope.

In mountainous areas which have been developed, the above procedure is modified to reflect the grading which occurs in homebuilding and road construction. Homesites are generally level, or near so, and runoff which flows down the steep hillside onto a graded property is retarded, its velocity greatly reduced. The time of concentration within the subarea is somewhat increased and adjustments to the time of concentration calculations are required to reflect the hillside slope modifications.

1. Subareas 2, 3, 4, 6, 7, and 8 have hillside developments which require an adjustment to the slope calculations. There is no hillside development in subarea 20; the remaining subareas have slopes less than 10% and are not considered to be significantly affected by homesite and street grading.

2. In each of the above-referenced subareas, a count is taken of all homes graded within the hillside. All homes within a retention area are excluded from the count because ground slope in these areas is much less than 10%.

   From aerial photographs, field verifications, and contour quarter-section maps, it has been determined that each hillside dwelling has approximately 10,000 sq.ft. of its lot levelled for the house, driveway, pool, garage, and similar structures. The total area of "levelled" lands within a subarea is obtained by multiplying the hillside house count by 10,000 sq.ft.

3. The subdrainage area which is unaffected by hillside development is obtained by subtracting the "levelled" area computed in 2. above from the total area of the subarea. This figure is then calculated as a percent of the total area.

4. The "effective" slope, that is the subarea's slope corrected for influences from hillside developments, is calculated by multiplying the initial slope by the percent value computed in 3 above. The results of this analysis are shown below:

Subarea	Initial Slope	Correction for Hillside Dev.	Effective Slope
2	0.1204 '/'	0.88	0.1062 '/'
3	0.1829	0.84	0.1534
4	0.2501	0.92	0.2310
6	0.2614	0.96	0.2501
7	0.2310	0.90	0.2078
8	0.2657	0.94	0.2510

The effective slopes are used to generate velocities and times of concentration (Tc) for the affected subareas.

F. STORMWATER RETENTION FACILITIES

Within the Arcadia Drainage Area, three types of stormwater retention exist:

1. Single-family residential lots which are irrigated by the flooding technique. These lots are bermed to trap the water on-site, with berms averaging 6 to 8 inches in height. During storm events, these berms also trap the rainwater which falls on the lot, except for fringe areas of the lot and areas on each lot which are elevated above the irrigated area (primarily driveways and sidewalks). To account for this type of retention, the estimated percentage of impervious, unretained surface area associated with an "average" lot within each zoning classification was made. An example of this calculation is as follows, for R1-18 zoning:

Lot Area	=	18,000 S.F.
50% of adjacent 50' R.O.W.	=	3,000 S.F.
Gross Area Per Lot	=	21,000 S.F.
Unretained Area:		
Street R.O.W.	=	3,000 S.F.
Driveway & Sidewalk	=	400 S.F.
Roof Area Over Driveway	=	320 S.F.
Total Unretained Area	=	3,720 S.F.
% Unretained = 3,720/21,000	=	17.7%

This 17.7% of the gross area which is unretained consists primarily of paved or concrete surfaces, and contributes to storm drainage within the drainage area. This percentage of gross area is then assigned a CN of 95, and the runoff computed on that basis.

Other single family zoning classifications are treated in a similar manner.

2. Single-Family residential lots which are not irrigated by flooding. This type of development is landscaped by desert landscaping, or is irrigated by sprinklers connected to the Phoenix water system.

   By zoning ordinance, these lots are required to have depressed yards, so that on-site stormwater is retained. New subdivisions are developed according to this ordinance, but subsequent improvements to the individual lots, such as swimming pools, building additions, or landscpaing revisions frequently result in the filling of these retention areas. Since this type of activity is difficult to detect, the rigorous enforcement of the ordinance regarding stormwater retention on single-family lots has not been accomplished in the past. It is therefore concluded that this source of stormwater retention should be neglected during the hydrologic portion of this report.

3. Other zoning classifications, such as Multi-Family, Commercial, and Office, which are required by ordinance to be designed to retain stormwater on-site for storms of up to and including the 10-year frequency storm. This type of retention usually involves a retention basin designed for a specific volume of water; subject to approval by the City of Phoenix prior to the start of construction.

For the purposes of this report, designed retention basins in the above zonings are included in the drainage area hydrology when a field check verifies its existence in developed areas, and for undeveloped parcels which are zoned for other than single-family residential uses. As was done above for irrigated single-family lots, a certain percentage of gross area is assumed to be unretained, to account for adjacent streets and for fringe lot areas which do not drain into the retained areas. The unretained percentage of gross area differs with each zoning classification in accordance with both field observations of existing systems and discussions with City of Phoenix staff regarding existing and planned retention practices which are acceptable to the City.

Two notable exceptions to the above practices are apparent, after discussing the matter with the City:

- Developments on undeveloped parcels of one-half acre or less are normally not required to provide on-site retention. (This generally involves the commercial strip zonings along major street corridors, where much of the lot is paved parking area).

- In areas undergoing redevelopment, the proposed construction is required to provide on-site retention only when existing occupations already have on-site retention.

  To verify the above discussions concerning on-site stormwater retention, the entire drainage area was driven and observed. The results of this field observation was then incorporated into the above data, and a set of CN's and on-site retention data was developed. A summary of the resulting information which is used for the Arcadia Drainage Area appears in the Table III-1.

G. DRAINAGE SUB-AREA CHARACTERISTICS

Input data required for each sub-area to perform the TR-20 procedure generally consists of the following:

- Net contributing area (Square Miles)
- Composite Curve Number
- Location of concentration point for each Sub-Area
- Time of Concentration (Hours)

The following discussions generally note the methods used in the formulation of the required data.

1. Net Contributing Area of each drainage sub-area is calculated from the overall dimensions of each sub-area, less the total area which is flood irrigated or has designed retention and does not contribute to runoff.

2. Composite Curve Number is the weighted average of CN's of each zoning classification which is found in the sub-area. To arrive at this composite CN, the contributing area of each zoning classification within the sub-area is multiplied by its respective CN. The sum of the resulting products is then divided by the sum of the contributing areas to compute the Composite CN.

3. Point of Concentration is the location at which flows originating within each sub-area would tend to concentrate.

4. Time of Concentration (TC) is the time required for flows to reach the point of concentration from the most remote part of the sub-area. To compute this TC, the length of travel from the remote part of the sub-area, and the average velocity along the length of travel are required.

   The length of travel is determined by measuring the distance along existing curbs, gutters and drainage ways from the point of concentration to the most remote part of the drainage sub-area.

   The velocity is determined by finding the average ground slope along the length of travel as corrected for hillside development, if necessary, and entering the Gutter Flow Chart shown in Figure III-1 for the full gutter flow condition in paved roadways, and the utilization of the Overland Flow Nomograph (Figure III-2) for flow through drainage ways assuming 'Bare Soil' conditions to obtain the concentration time.

   The average velocity for the subarea is obtained by adding the travel lengths for roadway and overland (drainage swales) flow and dividing by the sum of roadway overland flow travel times.

A summary of the data and computations for all sub-area characteristics appears in Appendix B of this report, on either the data sheets or on the drainage maps.

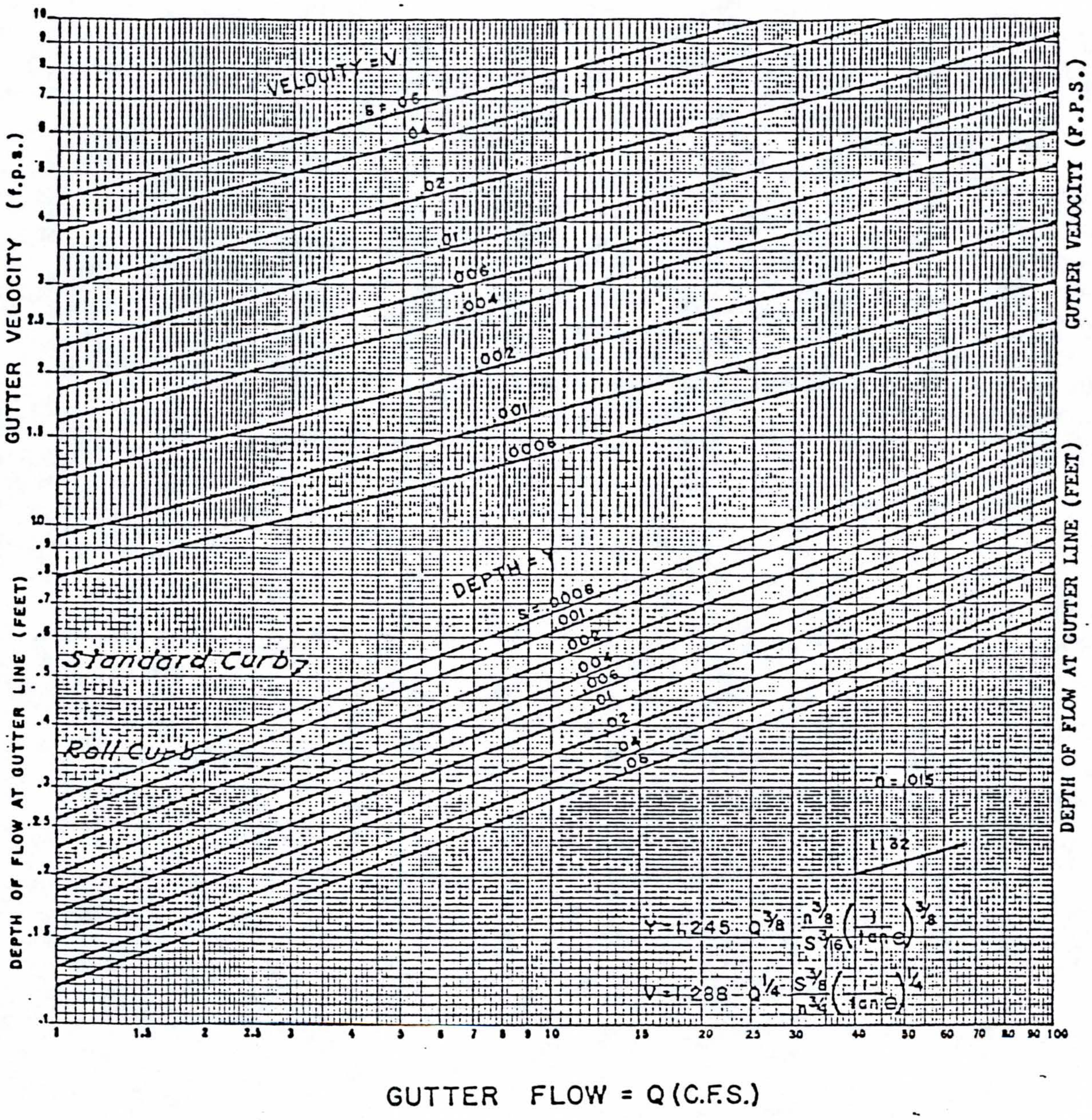


FIGURE III-1

GUTTER FLOW CHART

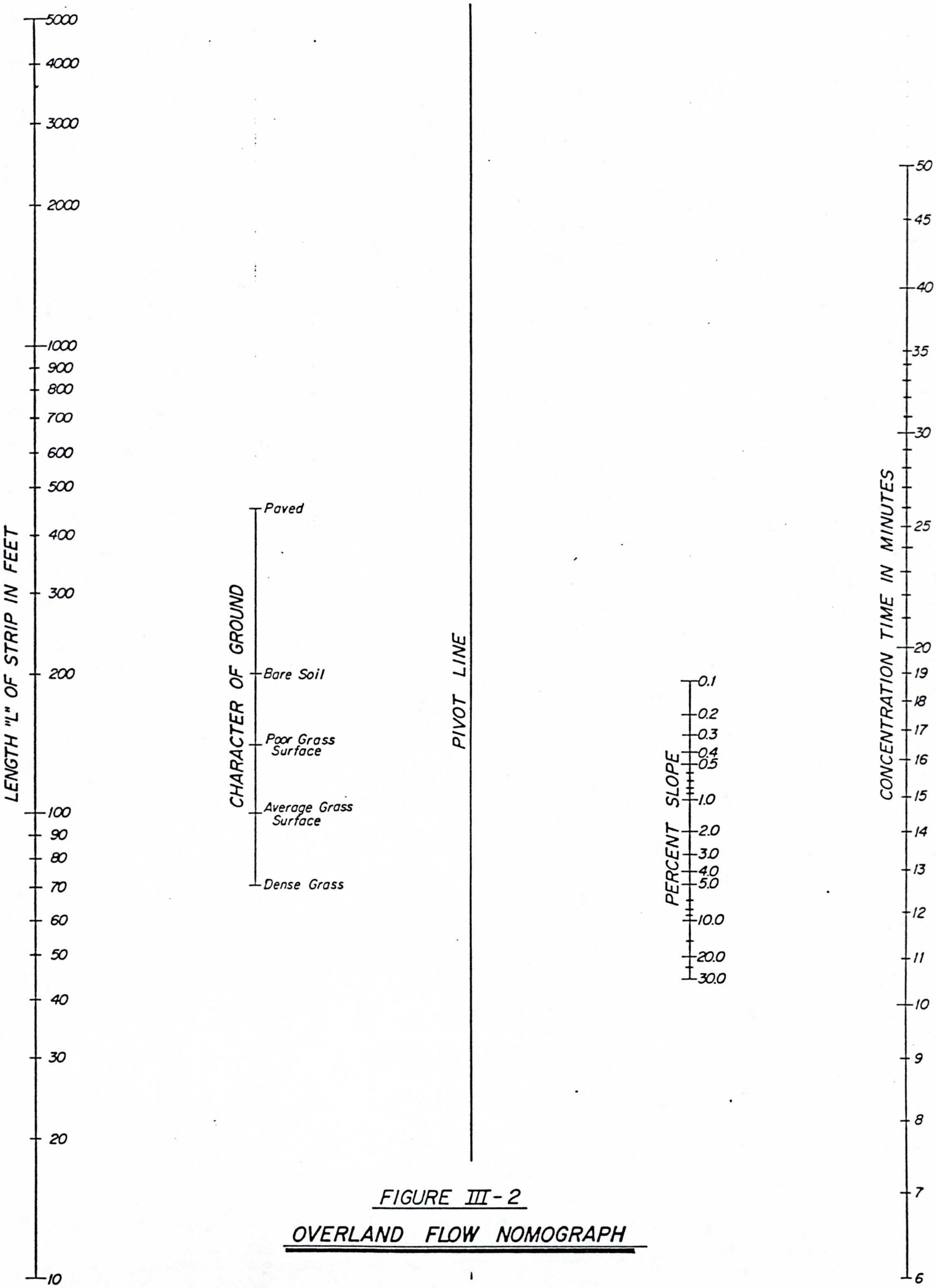


FIGURE III-2

OVERLAND FLOW NOMOGRAPH

IV. HYDRAULIC DESIGN PARAMETERS

A. BASIC DESIGN CRITERIA

The hydraulic sizing of the storm drainage system in the Arcadia Drainage Area is based on the following major criteria:

1. Stormwater flows from the study area will be collected by storm sewers in major north-south streets and routed south to the Arizona Canal where large conduits transport the runoff to the Old Cross-Cut Canal in 48th Street.

2. Sizing of conduits in the study area will be based on the following hydraulic conditions:

   a) Manning's "n" = 0.012 for pipe, "n" = 0.015 for concrete box culverts (CBC).

   b) Minimum Pipe Velocity = 5 feet per second.

   c) Surcharging of conduits is allowable, but the hydraulic grade line must remain at least 3 feet below ground level at all times during the design conditions. This provides the head required for catch basins to function properly.

   d) Ground elevations and slopes are taken from available contour maps and from maps which were produced as a part of this project.

   e) The steep grades within the study area required the control of velocities within the proposed conduits. The maximum pipe velocity was set at 14 feet per second to minimize scour and obectionable hydraulic conditions within the storm drain system.

   Control of velocity in the conduits was obtained by oversizing the lines and assuming a "stair step" piping design in which each manhole has a drop connection to the upstream line and an increased depth to reduce downstream pipe slopes.

3. Owing to the large flows and relatively small slopes for the proposed conduits along the Arizona Canal, double and triple barrel conduits were chosen to reduce inverts and minimize installation difficulties along the Canal. Concrete Box Culverts may be used in lieu of reinforced concrete pipe when necessitated by utility conflicts or other requirements uncovered during the final design.

No major conflicts uncovered by this study [illegible]

4. The existing drainage system in the vicinity of Camelback Road and 44th Street has been allocated storm water flows equal to its carrying capacity, 56 cu.ft. per sec. These flows are diverted from the computer-generated routing path along 44th Street to the Camelback and 40th Street system.

   Flows carried by the existing 36-inch storm sewer which discharge directly to the Arizona Canal at 42nd Place are included in the computer analysis of the drainage area because the 36-inch storm sewer will be intercepted by a proposed conduit to be installed along the Arizona Canal.

5. Storm flows from this project will be discharged into the existing Old Cross-Cut Canal which begins at 48th Street and the Arizona Canal.

B. PEAK DISCHARGES FROM DRAINAGE AREA

Using the hydrologic data which was developed in Section III of this report, the peak discharges for the 2-year storms were computed using the TR-20 Procedure contained in Appendix A. Peak flows for the 2-year storm are shown on the drainage maps in Appendix B, and on the TR-20 Summary Table included in Appendix C of this report. Table IV-1 shows a summary of peak 2-year storm flows at various locations within the drainage area.

TABLE IV-1

DRAINAGE AREA PEAK FLOW SUMMARY

ARCADIA AREA MASTER DRAINAGE STUDY

LOCATION	PEAK FLOWS (CFS) ALT. 1	ALT 2.
Camelhead and Camelback	141	141
Camelback and 44th Street	180	180
44th Street and Arizona Canal	262	289
Arizona Canal and Arcadia Drive (West)	271	297
Camelback and Arcadia Drive	77	77
Camelback and 54th Street	123	123
54th Street and Lafayette Blvd.	130	130
Arcadia Drive and Lafayette Blvd.	213	213
Arizona Canal and Arcadia Drive (North)	211	211
Camelback and 64th Street	118	118
64th Street and Arizona Canal	161	161
60th Street and Arizona Canal	167	167
Camelback and 56th Street	132	132
56th Street and Lafayette	150	150
56th Street and Arizona Canal	310	310
Arizona Canal and Arcadia Drive (East)	305	305
Flows to Old Cross-Cut Canal	755	780

1

1) Plus 56 cfs diverted to existing storm sewer system.
2) Includes 30 cfs from Scottsdale.

V. EVALUATION OF ALTERNATIVES

A. FORMULATION OF ALTERNATIVES

In preliminary discussions with members of the City staff concerning this project, the following alternatives were considered:

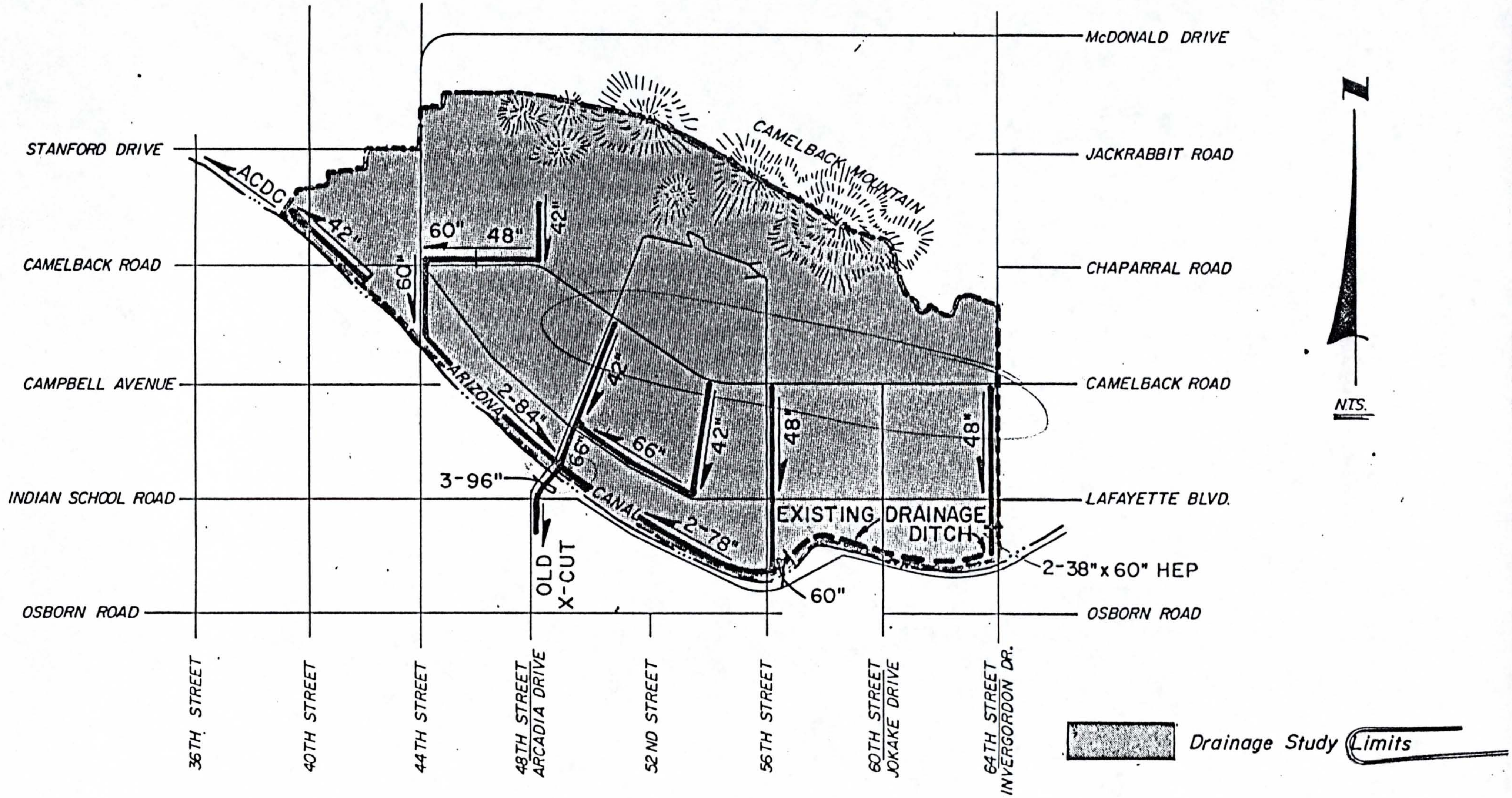
1. Alternative 1

a. The existing 36-inch storm drain in Camelback Road which discharges to the 40th Street storm drain system is used to carry as much runoff as possible from subarea 2. The excess flows are routed south on 44th Street to the Arizona Canal. (See Figure V-1).

b. Flows from the subareas west of 44th Street are discharged to the Arizona Canal Diversion Channel (ACDC) at 40th Street and Camelback. Runoff from subareas east of 44th Street are not routed to the ACDC because this proposed structure will be designed to carry runoff from areas north of the Arizona Canal to 40th Street. Little excess capacity remains and the addition of large quantities of runoff would result in design changes to the ACDC.

c. Runoff from subareas north of Camelback Road and east of 44th Street are collected at the major north-south streets and brought across Camelback in adequately sized culverts to a proposed storm sewer network servicing the area between Camelback and the Arizona Canal. It is proposed to install storm sewers in 44th Street, Arcadia Drive, 56th Street, 60th Street, and 64th Street. Flows from these storm sewers would be collected by the existing Arcadia Drainage Channel (64th and 60th Streets) or by a large diameter storm sewer installed just north of the Canal. Ultimate discharge is to the Old Cross-Cut Canal at 48th Street. The depth of the Old Cross-Cut Canal and the relative flatness of the grades between 44th and 48th Streets permits the installation of a storm sewer "against grade" on the north side of the Arizona Canal between those two streets.

d. The runoff originating from Scottsdale is discharged into the Arcadia Drainage Area at 64th Street through the existing Arcadia Drainage Channel. It has been determined from review of the results of a drainage study performed by Erie and Associates, Inc., that the 2-year storm event will generate approximately 30 cu.ft. per sec. of



ALTERNATIVE I

Project No. ST-813840

FIGURE V-I

NOV., 1985

runoff from Scottsdale at 64th Street. These flows will be incorporated in the storm sewerage of the Arcadia Drainage Area but are not expected to have a great impact on the recommended drainage solutions.

2. Alternative 2

This alternative resembles Alternative 1 but no runoff is discharged to the ACDC (See Fig. V-2). It is recognized that approval may not be given for the addition of runoff to the ACDC from lands east of 40th Street. Flows from subareas 1, 2, and 9 in excess of the capacity of the existing storm sewers in Camelback Road would be collected at the north side of the Arizona Canal and brought southeastward to the Old Cross Cut Canal in a large diameter storm sewer as discussed in Alternative 1. The flatness of the grades between 40th and 48th Streets and the depth of the Old Cross Cut Canal make this a viable solution.

The other elements of Alternative 1 are unchanged in this alternative.

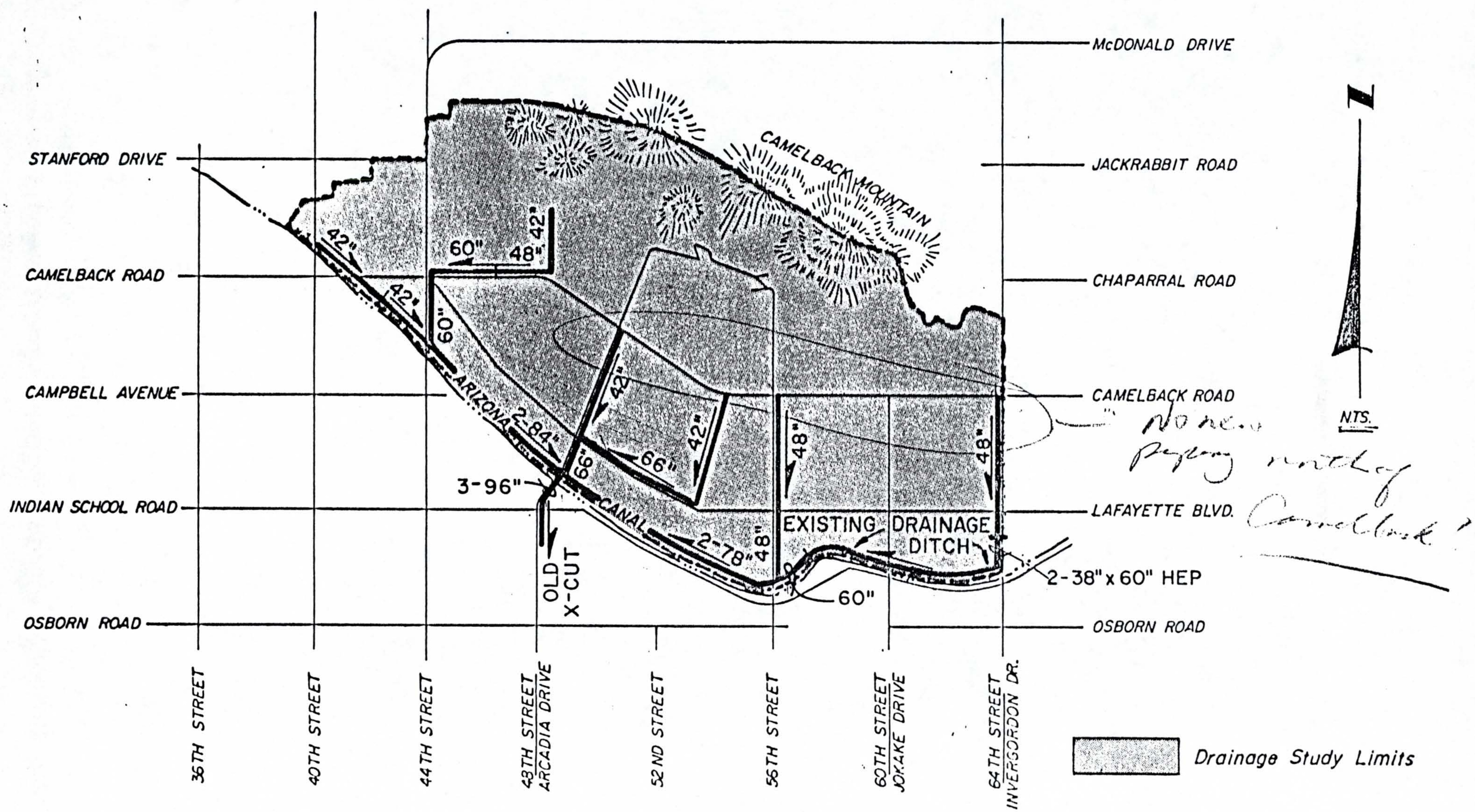
3. Other Considerations

a. New Storm Drain Outfalls

The possibility of directing runoff from the Arcadia Drainage Area to major streets such as 44th or 56th Streets south of the Arizona Canal to the Salt River bed was studied but dropped from consideration after preliminary discussions with City Staff and further investigations. A major storm drain along the section or half-section line streets would be in conflict with the Papago Buttes, the Papago Park Military Reservation, or the Hohokam Expressway depending on the drain's location. Forty-eighth street offers the only unimpeded alignment for drainage facilities because of the Old Cross-Cut Canal. The use of the Canal for the transport of runoff has been incorporated in Alternatives 1 and 2.

b. Retention Facilities

The possibility of utilizing stormwater retention basins with controlled discharge outlets has also been considered as a method of reducing the peak flows which are generated within the study area. However, no City-owned land exists at strategic locations where retention would benefit the project, and land acquisition required from existing businesses and residents would be quite expensive, due to the nature of the area. In addition,



ALTERNATIVE 2

Project No. ST-813840

FIGURE V-2

NOV., 1985

retention basins might also be considered unacceptable for the heavily developed areas bordering the Arizona Canal. For these reasons, the use of retention basins has been eliminated from further consideration.

4. Preliminary profiles along the route are included in Appendix D for the recommended alternative. This information is prepared to demonstrate the feasibility of the project and to assist in determining the extent of utility conflicts along the proposed storm sewer alignments.

B. ESTIMATED PROJECT COSTS

In order to obtain estimated costs for each of the alternatives described above, bid tabulations of recently bid storm drain projects in the City of Phoenix were obtained from City staff, with correction factors applied to account for inflation and project variations. A 15% contingency factor has been applied to each alternative to account for undeveloped design details and other unlisted project costs for the purpose of comparison and preliminary budget estimates.

Tabulation of cost estimates for both alternatives are presented in Tables V-1 and V-2.

C. DISCUSSION AND EVALUATION

Factors considered to be of primary importance to the project include costs of construction, ease of implementation, and degree of resolution of problem areas were frequent flooding occurs.

1. Costs of Construction

Comparison of costs between Alternative 1 and Alternative 2 reveals that Alternative 2 costs are somewhat higher because of additional piping length required to bring runoff from Camelback and 40th Street to 44th Street and the Arizona Canal. The impact on the proposed conduit system east of 44th Street by the addition of runoff from those areas west of 44th Street is minimal. Inspection of Figures V-1 and V-2 reveals that the conduit sizes and lengths for those areas east of 44th Street are identical for both alternatives.

2. Ease of Implementation

The primary factors involved in project implementation are the degree of coordination with other affected utilities and the ability of the project to be segmented for construction purposes.

TABLE V-1

ESTIMATED COSTS - ALTERNATIVE 1

ARCADIA AREA MASTER DRAINAGE STUDY

ITEM	QUANTITY & UNIT	UNIT COST	TOTAL
96" Storm Drain*	400 L.F.	$220	88,000
84" Storm Drain**	11,400 L.F.	$205	2,337,000
78" Storm Drain**	8,600 L.F.	$190	1,634,000
66" Storm Drain	4,300 L.F.	$110	473,000
60" Storm Drain	4,200 L.F.	$ 95	399,000
48" Storm Drain	9,150 L.F.	$ 75	686,250
42" Storm Drain	7,400 L.F.	$ 60	444,000
Storm Drain MH	60	$2,600 ea.	156,000
38" x 60" HEP Drain**	1,500 L.F.	$100	150,000
Pavement Replacement	16,310 S.Y.	$ 20	326,200
Modifications to Old X-Cut Canal	LS	$350,000	350,000
		SUBTOTAL	$ 7,043,250
Undeveloped Details and Misc. Work (15%)			1,056,750
		TOTAL	$ 8,100,000

* triple pipe run

** double pipe run

TABLE V-2

ESTIMATED COSTS - ALTERNATIVE 2

ARCADIA AREA MASTER DRAINAGE STUDY

ITEM	QUANTITY & UNIT	UNIT COST	TOTAL
96" Storm Drain*	400 L.F.	$220	88,000
84" Storm Drain**	11,400 L.F.	$200	2,337,000
78" Storm Drain**	4,300 L.F.	$190	1,634,000
66" Storm Drain	4,300 L.F.	$110	473,000
60" Storm Drain	4,200 L.F.	$ 95	399,000
48" Storm Drain	9,150 L.F.	$ 75	686,250
42" Storm Drain	9,300 L.F.	$ 60	558,000
Storm Drain MH	65	$2,600 ea.	169,000
38" x 60" HEP Drain**	1,500 L.F.	$100	150,000
Pavement Replacement	16,310 S.Y.	$ 20	326,200
Modifications to Old X-Cut Canal	LS	$350,000	350,000
		SUBTOTAL	$ 7,170,450
Undeveloped Details and Misc. Work (15%)			1,075,550
		TOTAL	$ 8,246,000

* triple pipe run

** double pipe run

Alternative 1 is dependent upon the completion of the ACDC for the servicing of those areas west of 44th Street. Additional coordination is also required between the City of Phoenix and the Corps of Engineers, the Maricopa County Flood Control District, and other public and private entities. The scheduling of the ACDC construction to 40th Street will have a direct impact on the time of completion of this portion of Alternative 1. At this time, no firm schedules for the construction of the ACDC to 40th Street are known.

The implementation of both alternatives is also dependent on the successful negotiation by the City of Phoenix with the Salt River Project for the use of the Old Cross-Cut Canal as a conduit for accumulated runoff in the Arcadia Drainage Area. The use of the Old Cross-Cut Canal and approval for the installation of large diameter storm sewers on the north bank of the Arizona Canal is expected from the Salt River Project.

Both alternatives have substantially equal segmentation or construction phasing capabilities. The connection

APPENDIX A

SCOPE OF SERVICES

ARCADIA AREA MASTER STORM DRAINAGE STUDY

PROJECT NO. ST-813840

DECEMBER 2, 1983

I. GENERAL

The purpose of the project is to analyze the existing storm drainage system in the Study Area and to investigate alternatives to upgrade the existing system to properly manage the 2-year frequency storm within the drainage area. The work will conform to the requirements of the Project Design Memorandum dated November 21, 1983, and the attached TR-20 Procedure.

As a part of the project, contour quarter section maps will be produced for a portion of the Study Area, with a total of 9 quarter-sections being prepared.

II. STUDY AREA

The proposed Study Area for the project is bounded by the Arizona Canal on the south, 64th Street (Invergordon) on the east, the ridge line of Camelback Mountain on the north, and Cudia City Wash and Echo Canyon Wash on the west and northwest. Total surface area of the proposed Study Area is approximately 4.6 square miles.

III. CONTOUR QUARTER-SECTION MAPPING

As a part of the project requirements, a total of 9 contour quarter-section maps will be prepared for portions of the study area. The following maps numbers will be required:

16-42, 17-39, 17-40, 17-41, 17-42, 19-36, 19-37, 20-37, 21-37

All work involved in the preparation of the contour maps will be done in strict accordance with Administrative Procedure No. 40, dated July 1, 1979.

IV. STORM DRAINAGE STUDY

The study of the storm drainage within the drainage area is proposed to be produced in six steps, with two interim review periods, as described below:

A. Data Collection

During this step, the Consultant will gather from the City and other agencies all information and data on facilitites within the drainage area which may affect the results of the study. Typical information which may be requested includes the following:

1. City of Phoenix quarter-sections for water, sewer, right-of-way, and existing contour mapping.

2. As-built plans of existing storm sewers in the drainage area.

3. Zoning maps of the drainage area.

4. Major or critical facilities of other utilities.

5. Other existing storm water management facilities, such as existing washes and culverts, retention areas, dry wells, canal inlets and/or overflows, and other items which may have an effect on area drainage.

Pertinent data regarding proposed drainage systems by others (Flood Control District, Corps of Engineers, Salt River Project, Etc.) which may affect the results of this study, will be requested from the appropriate agency.

In addition to the above, the Consultant will schedule meetings with appropriate City of Phoenix staff as required to discuss areas known to have drainage problems, and to gather data on proposed or future projects within the drainage area which could affect storm water management.

B. Drainage Area Maps and Sub-Area Breakdowns

When sufficient data is available from the mapping portion of this project, the drainage area base maps will be prepared. These maps, done at a scale of approximately 1"=400', will show the following information:

1. Limits of study area
2. Zoning
3. Drainage patterns
4. Sub-area delineations
5. General elevation data
6. Other features which directly affect storm drainage

In delineating the drainage sub-areas, factors such as area, concentration time, zoning, soil type and point of concentration will be considered, so that the sub-area evaluation will produce the best information for study purposes.

For each delineated sub-area, the following list of data will be tabulated:

1. Area
2. Zoning
3. Soil Type
4. Composite Curve Number (CN).
5 Travel distance, slope and concentration time
6. Surface velocities between concentration points

Existing drainage facilities, such as storm sewers, culverts, washes, and drainage channels, will be located, and approximate capacities will be established for each major segment.

The above data will be submitted to the City for review and comment, prior to the start of hydrologic computations.

C. Analysis of Existing System

Using the data prepared in A and B above, an initial routing of the 1 and 2-year frequency storm will be performed on the existing system, utilizing the TR-20 computer program. Results of this computed hydrology will then be studied to locate points of deficiency in the existing stormwater system, and to determine the required capacity of additional storm sewers in the area.

D. Proposed Alternatives

Using the existing system analysis, a total of not more than four alternative storm sewer routings will be investigated to alleviate deficiencies in the existing system for the 2-year frequency storm. Each alternative will seek to maximize the use of the existing system, and will be arranged to allow for discharge into other drainage systems as identified in Part A above, or for direct discharge to the Salt River. Based on the preliminary investigation, the recommended alternative will be developed.

Preliminary sizing for the recommended storm drainage system will be estimated on the basis of a design velocity of approximately 5 feet per second, at a slope equal to the general ground slope of the area, and an outlet elevation compatible with the method of discharge proposed.

E. Preliminary Report

After part D above, but before final computer analysis of the recommended alternative routing, a preliminary report which discusses the findings and conclusions of the study will be prepared and submitted to the City for review and comment. Three copies of the Preliminary Report will be submitted.

Up to four feasible alternatives may be developed, including preliminary location, sizing and costs. Comparison of the alternatives will include the advantages and disadvantages of each system.

F. Final Analysis and Report

After receipt of comments and/or revisions based upon the preliminary review by the City, the computed hydrology of the recommended alternative will be run, using the TR-20 computer program. Based on the results of this final run, a final report will be prepared.

The final report will contain a summary of recommendations, a general location plan, estimated construction costs, and a list of special considerations which are deemed appropriate for use by the City in making a decision on the route selection. Up to ten (10) copies of the Final Report and up to 35 copies of an Executive Summary of the Report, will be submitted.

TR-20 PROCEDURE

1. Prepare a map of the drainage area (approximately 1" = 400').

2. Divide the study area into sub areas. Select sub areas such that the maximum area does not exceed 0.5 square miles and also such that the time of concentration is greater than 10 minutes. Of course, the topography of the study area will be important in sub area selection.

3. On the map, indicate the flow pattern within each individual sub area to the concentration point.

4. Show how the flow is routed from one point of concentration to another.

5. For each sub area provide the following:

   a) The zoning. Use the City of Phoenix zoning maps. If more than one zoning class is found within a sub area, list all and establish a weighted average based on the area of each class. If the slope of the ground exceeds 10%, designate the sub area as mountainous and, regardless of the zoning, assign a curve number of 95.

   b) The hydrologic soil type or types. The different hydrologic soil types found in the City of Phoenix are contained in a publication entitled "Soil Survey of Maricopa County, Arizona, Central Part" by the U.S. Department of Agriculture, Soil Conservation Service. If any sub area contains more than one soil type, each soil type must be used separately to assign a curve number. The various curve numbers can then be used to obtain a weighted average curve number based on areas.

   c) The contributing area in square miles.

      1) If any part of a sub area is bermed or has any features that prevent contribution, exclude such part.

      2) If a sub area is zoned commercial or industrial and is already developed without retention, use 100% of the area as contributing. If there is retention, exclude the area for which the retention is effective.

      3) If a sub area is zoned commercial or industrial and is not yet developed, use 15% of the area as contributing with an equivalent curve number of 98.

   d) The equivalent curve number, CN, see Table I.

e) The time of concentration, t_c. Analyze the terrain and the development called for by the zoning when computing the velocities of flow for each reach of the system.

1) For surface flows use ground slopes amd either gutter flow charts or the "upland method" to compute time of concentration.

2) For the first computer run, assume velocity in pipes to be 5 fps; then later perform the first iteration using calculated pipe velocities.

6. Use the rainfall table shown in Table II in the input to the TR-20 program.

7. Depending on the service to be provided, use the 24-hour precipitation values given in Table III in the executive command part of input to the TR-20 program.

8. Request that the printout include Summary Tables 1, 2, and 3.

9. Show the following calculations:

a) In tabular form, the time of concentration for each sub area (show hydraulic distance and the velocity used).

b) In tabular form, the determination of the equivalent curve number for each sub area (show hydrologic soil type, zoning, and weighted averaging).

10. Add to the drainage area map the computer node numbers so easy identification can be made between locations and the expected flows as computed and printed out.

TABLE I

BASED CN
SOIL AND ZONING

ZONING	CN for soil type TYPE B	TYPE C	TYPE D
RE-43) S-1)	77	83	86
RE-35	79	84	87
RE-25	79	84	87
R1-18	80	84	87
R1-14	80	85	88
R1-10	81	86	89
R1-8	82	87	90
R1-6	84	88	90
R -3	85	88	90
R -4) R -40) R -5)	86	89	91
A-1) A-2)	88	91	93
C-1.) C-2) C-3)	92	94	95
CO	88	91	93
PSC	95	95	95
HR	95	95	95
R4A	87	90	92

TABLE II

Rainfall Table

(Percent total rainfall/100 by 0.5 hour increments for 24 hour storm)

.000	.004	.008	.013	.018
.022	.026	.031	.035	.040
.041	.048	.053	.057	.062
.066	.071	.075	.080	.093
.107	.120	.14	.17	.60
.86	.86	.88	.893	.907
.92	.924	.928	.933	.937
.942	.947	.951	.956	.96
.964	.969	.973	.978	.982
.987	.991	.995	1.00	1.00

TABLE III

PHOENIX WBO RECORDS*

(24-hour duration storm)

Return Periods, Years	Precipitation, Inches
1	1.02
2	1.44
5	2.10
10	2.53
25	3.12
50	3.57
100	4.04

*Technical Memorandum WBTM WR-44

CITY OF PHOENIX, ARIZONA
ENGINEERING DEPARTMENT

ADMINISTRATIVE
PROCEDURE NO. 40
July 1, 1979

SUBJECT: AERIAL CONTOUR MAP PREPARATION AND STANDARDS

All contracts for aerial contour mapping shall contain the following format:

I. SCOPE OF WORK

A. The contractor shall provide all services, materials, supplies, labor and all work necessary to execute and deliver to the City of Phoenix, Arizona in strict accordance with these specifications certain finished contour maps as designated by the City Engineer.

II. FIELD SURVEY PREPARATION

A. The horizontal and vertical control shall be sufficient to control the aerial mapping. The horizontal control will be established on the Arizona State Plane Coordinate System and the vertical control will be established on the U.S. Coast and Goedetic benchmarks designated by the City. All horizontal and vertical control will be of third order accuracy. The horizontal control points located in paved areas will be paneled with paint and other horizontal control points will be paneled with white flagging which will be removed after the area is flown. Maps are available in the Engineering Department showing which section corners, 1/4 corners, and center of section markers have been found along with the type of marker. All established section corners, 1/4 corners, and center of sections will be premarked or a station in the approximate location of said corners will be identified. This will give the City X and Y coordinates of all premarked stations to an accuracy of .5 of a foot. The basic vertical control will be established at third order accuracy on all 1/4 and section corners found or set in approximate location.

III. EQUIPMENT AND MATERIALS

A. The equipment and materials used and methods of procedure shall be suitable for the production of photographs and maps of the quality and accuracy required to meet these specifications.

B. Cameras foı Mapping. Cameras used for mapping with stereo-plotting instruments shall be calibrated, precision cartographic type, suitable for use with precision stereoscopic mapping instruments. Said cameras shall have a calibration certificate, not over three (3) years old, as of the date of the contract. The certificate shall be issued by the U. S. Geological Survey or any other competent testing organization. The report shall precede or accompany the contract. The cameras shall be equipped with an Avigon, Pleogon, or equal type distortion free lens, and shall have the following charateristics:

(1) The size of the negative image shall be 9 by 9 inches.

(2) Usable angular field of at least 65 degrees.

SUBJECT: AERIAL CONTOUR MAP PREPARATION AND STANDARDS

(3) Minimum resolving power of 15 lines per mm as measured with a high contrast target on the spectroscopic emulsion.

(4) Maximum tangential distortion of 0.015 mm., and radial lens distortion shall not exceed ± .015 mm. from the lens axis to an edge of field that is at least 42 degrees from the lens axis.

(5) The angle between the lines joining opposite pairs of fiducial marks shall be within 1 minute of 90 degrees, and the intersection of the lines shall indicate the position of the principal point within ± 0.03 mm.

(6) Cameras shall be equipped with a means of flattening the film at the instant of exposure. The platen against which the film is pressed at the instant of exposure shall not depart from true plane by more than ± 0.005 inch.

(7) An appropriate minus-blue filter with an antivignetting metallic coating shall be used. The filter shall have its two surfaces parallel to within 10 seconds of arc, and its optical quality shall not cause an undesirable reduction in image resolution.

(8) The cameras shall be equipped with a between-the-lens shutter of variable-speed type. Provision shall be made for holding the shutter leaves open for laboratory tests, when required.

(9) The focal length of the camera shall be 153 mm. ± 3.0 mm.

(10) Cameras used for photographic work only shall be precise single-lens aerial mapping cameras with between-the-lens shutter, producing negatives 9 by 9 inches in size.

(11) Said cameras shall be so equipped that the location of the true principal point is directly shown or may be determined from fiducial marks on each negative.

C. Aerial Photography. The aerial negatives taken shall be suitable for printing appropriate photographic reproductions of the proper scale and size with sufficient stereoscopic overlap, freedom from insufficient film flattening, and free of other failures that would prevent use of the photography in precise, photogrammetric instruments to compile topographic maps to the scale, contour interval and map accuracy required and/or when necessary to compile planimetric maps and measure profiles and cross sections by photogrammetric methods to the scales and accuracies required.

SUBJECT: AERIAL CONTOUR MAP PREPARATION AND STANDARDS

(1) Aerial Flight Lines. Unless otherwise stated, flight lines shall be laid out by the contractor to best serve the requirements, based on maps and/or photographs and instructions.

(2) Overlap. Photographic overlap in the line of flight shall average approximately 60 percent, and any overlap of less than 55 percent or more than 65 percent will be grounds for rejecting all photographs of the series. Side-lap shall not be in excess of 40 percent nor less than 20 percent and will average 30 percent between adjacent flight lines and shall be no less than 15 percent beyond the area boundaries.

(3) Crabbing. Crabbing, as measured from the line of flight and as indicated by the principal points of the consecutive photographs shall in no case exceed 10 degrees, between any two consecutive photographs, and shall not average more than 5 degrees on any one flight line nor more than 2 degrees for the entire area.

(4) Tilt. Aerial photographic negatives made with the optical axis of the camera in a vertical position are required and tilt (departure from the vertical) of any negative exceeding 5 degrees or any average tilt of more than 1 degree for the entire area, or relative tilt between any two successive negatives exceeding 6 degrees may be cause for rejection.

(5) Time of Photography. Unless otherwise directed by the City Engineer, photography shall be undertaken at the time of day consistent with the terrain, physical conditions, and use of photography. Long or dark shadows may be cause for rejection.

(6) Image Quality. The photographic imagery shall be sharp and free of any discernable image motion.

(7) Stereoscopic Coverage

(a) The entire area to be photographed shall be stereoscopically covered within the usable portion of the field of the lens. This stipulation is a prime requisite of these specifications.

(b) Nonattainment of acceptable stereoscopic coverage caused by the contractor's failure to adhere to the required photographic mission design shall be corrected by a retake of the unusable areas or a complete retake of the mission, all at his expense.

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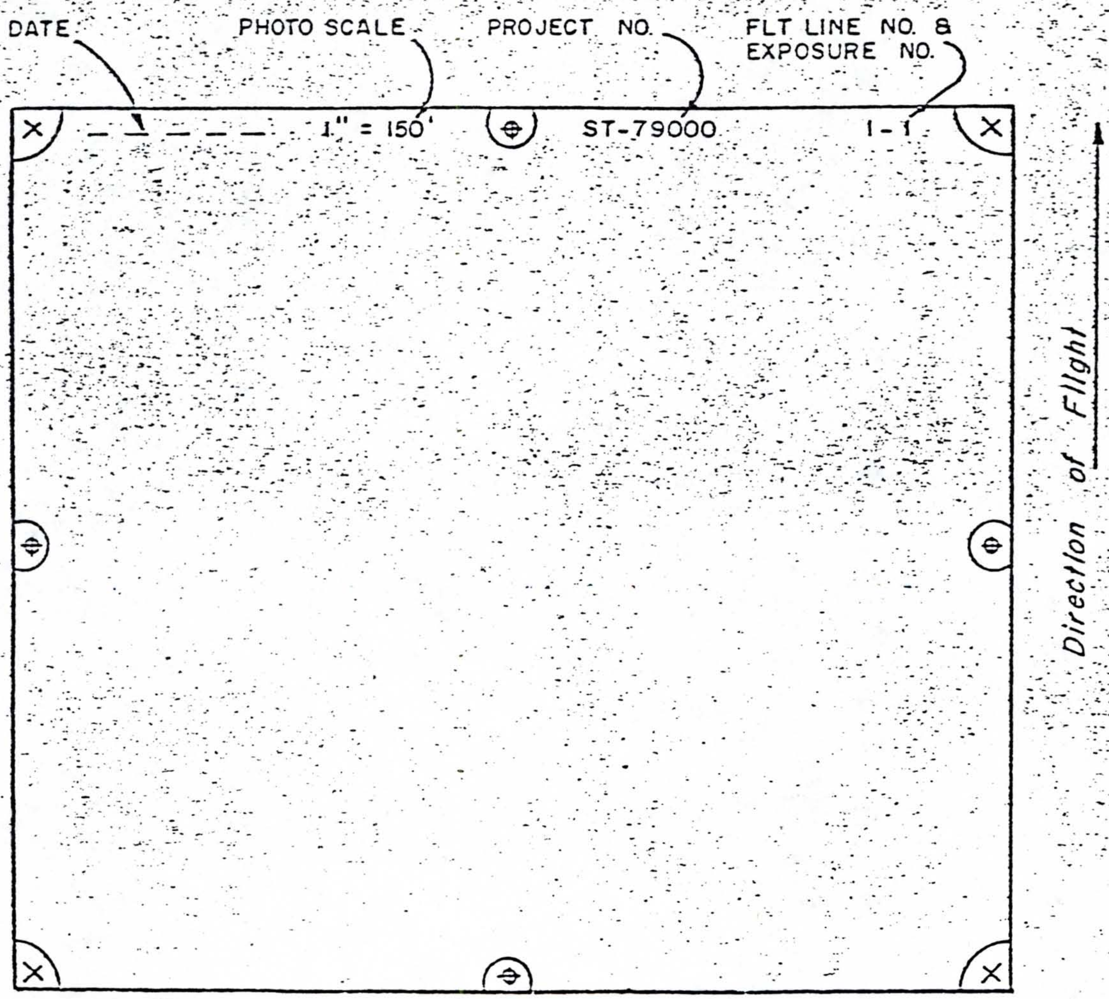
(c) Nonattainment of acceptable stereoscopic coverage caused by factors which cannot be overcome by the exercise of reasonable diligence and care on the part of the contractor shall be corrected at City Engineer expense, when authorized by the City Engineer.

(d) Aerial Negatives. The aerial negatives shall be lettered and numbered in a legible manner (as per example). The project number will be supplied by the City Engineer.



EXAMPLE

SUBJECT: AERIAL CONTOUR MAP PREPARATION AND STANDARDS

(e) Control Prints. The contractor shall furnish a complete set of contact prints that show the photoidentified position of the vertical and horizontal control points used to control all of the compiled stereo models required to satisfy the mapping contract.

If photogrammetric control methods have been used, the contractor shall distinguish between which control points were obtained by field methods and which control points were obtained by photogrammetric methods.

The identified position of the vertical control is to be circled in ink with the elevation inked adjacent to the circle. The horizontal control is to be identifed by an inked triangle surrounding its photo position. The horizontal control point is to be further identified with a name or number inked adjacent to the triangle which will reference it to its listed coordinates values. If a point is both a vertical and horizontal control point it is to be identified with both an inked circle and a triangle.

In order to avoid the expense of a duplicate set of contact prints and the cost of any reidentification of the control, the contractor shall comply with this provision by furnishing the original control prints that were used for and during stereocompilation of the mapping.

(f) "C" Factor. "C" Factor is defined as the average flight height above ground elevation divided by the contour interval. Example: $\frac{\text{3000' flight height}}{\text{2' contour interval}}$ = 1500 "C" Factor

The following "C" Factors for various mapping instrument types listed shall not be exceeded:

(1) Double projection instruments:
Kelsh or equivalent: 1000 ("C" Factor)

(2) Optical mechanical instruments:
Kern PG-2, stereosimplex G6,
Wild B-8, -------- or equivalent: 1500 ("C" Factor)

(3) "C" Factors for mapping instruments not listed are subject to review and approval.

SUBJECT: AERIAL CONTOUR MAP PREPARATION AND STANDARDS

IV. FINISHED MAPS

A. Accuracy of Maps

(1) The plotted position of each plan coordinate grid line shall not vary by more than one-hundredth (0.01) of an inch from their calculated position.

(2) Ninety percent (90%) of all contours shall be within one-half contour of true elevation, and the remaining ten percent (10%) of such elevations shall not be in error by more than one contour interval.

(3) At least seventy percent (70%) of all spot elevations placed on the maps shall be accurate to within at least one-fourth the contour interval.

(4) Ninety percent (90%) of all map worthy planimetric features which are well defined on the photographs shall be accurate to within one-fortieth (1/40) of an inch of their true coordinate position as determined by test surveys and none of the features tested shall be misplaced on the finished map by more than one-twentieth (1/20) of an inch from their true coordinate position.

B. Material - Mylar (Preferred thickness .005, minimum allowed .003) Suggested Brand - K & E Herculene.

C. Sheet Size - Use Standard Detail 10 for Quarter Section Maps.

D. Top of Sheet will be NORTH.

E. Scale - 1 inch equals 100 feet unless otherwise noted.

F. Lettering

(1) Title - The Title shall include the following:

Line 1. The words "City of Phoenix" (LeRoy 240-Pen 3)

Line 2. Quarter section number using City's system (LeRoy 240-3)

Line 3. The words "Contour Interval ___"; Scale 1" = 100' (LeRoy 100-00)

Line 4. The words "Date Flown" ___" with date (LeRoy 100-00)

SUBJECT: AERIAL CONTOUR MAP PREPARATION AND STANDARDS

Line 5. The Company's Name that prepared the map (LeRoy 80-00)

This information shall be located in the lower right portion of the map.

(2) Index Contour Elevation figures 100 LeRoy on slant 00 pen

(3) Elevation figures of known points 60 LeRoy 00 pen

(4) Quarter Section Corner Identification 100 LeRoy 00 pen

(5) Street Names 140 LeRoy on slant 0 pen

(6) Other reference notes may be 100 or 80 LeRoy 00 pen

G. Contours:

(1) Index contours are those contours having even elevations which are multiples of 10 feet.

(2) Contours shall be on two (2) foot intervals unless otherwise specified.

(3) Line Weights:

(a) Index contours - 1 Rapidograph

(b) Contours other than Index - 00 Rapidograph

(4) All Index Contours shall be numbered according to their actual elevation.

(5) No less than four (4) contours per map shall have the full elevation figure, regardless of contour elevation figure.

(6) Low spots or holes shall be denoted with hachures on the down-slope side.

(7) Known elevations, high and low points will be noted by a "+" with the elevation figure.

(8) Spot elevations shall be shown as outlined in (G7), plus every 1/8 of a mile along the center line of the boundary streets of the Quarter section.

SUBJECT: AERIAL CONTOUR MAP PREPARATION AND STANDARDS

(9) Contour Elevations shall be shown a maximum of every:

(a) 18 inches as measured along the contour when the contours are more than 1 1/2 inches apart.

(b) 8 inches as measured along the contour when the contours are more than 1/2 inch apart. In tight meandering contours follow G9c.

(c) 5 inches as measured along the contour when the contours are less than 1/2 inch apart or in tight meandering contours. In these situations every contour shall have an elevation figure. Where necessary an abbreviated figure may be used.

(10) Wherever index contours are closer together than one-quarter of an inch (1/4"), the intermediate contours may be omitted wherever the ground slope is uniform, but wherever it is not uniform, omission will not be permissable unless contours are shown at changes in ground slope.

H. Scribe Film

(1) When scribed film is used in the process of preparing a contour map the finished product will be a cronoflex positive or an approved equal (preferred thickness .005, minimum allowed .003). See IV B.

(2) Scribe points shall be of equal size when used in place of LeRoy or Rapidograph pens.

I. Professionalism

(1) Professional standards of draftsmanship shall be maintained throughout the preparation of all maps.

J. Topography:

(1) The symbols to be used for the planimetric and topographic features shall be in accordance with the U.S. Geological Survey Standards.

(2) Streets with curbs and gutters shall show the curb line solid. 0 Rapidograph.

(3) All other roads and streets shall be shown as a broken line depicting the outer boundaries. 00 Rapidograph.

SUBJECT: AERIAL CONTOUR MAP PREPARATION AND STANDARDS

(4) All culverts, head walls, canals, railroads, and dams shall be shown by solid line. 0 Rapidograph.

(5) 1/4 Corners or reference corners shall identify the corner along with the type of marker, i.e., 1/2" rebar, 3/4" pipe, brass cap, or brass cap in HH, with the marker elevation and ground line elevation (GL).

K. State Plane Coordinates

(1) State Plane Coordinates will be shown on even 1,000 foot intervals around the outer perimeter of the map (100 LeRoy on slant 00 pen).

(2) Grid North to True North will be shown. (Computation sheets shall be submitted wth first transmittals.)

(3) Grid to ground factor will be shown. (Computation sheets shall be submitted with first transmittals.)

IV. OWNERSHIP

Unless otherwise specified in the agreement or contract schedule, all negatives shall become the property of the City of Phoenix and shall be delivered in accordance with instructions from the City Engineer. During the period the negatives are in possession of the contractor, he may make only such reproductions as are authorized by the City Engineer and (if for stereo plotting equipment) under no condition will he be allowed to make any enlargements or reductions.

V. SPECIAL SYMBOLOGY

A. △ Horizontal control points (See IIA).

B. ——···——···—— Center line of drainage ways.

VI. PERMITTED DEVIATION

A. Deviation from the above Administration Procedure may be permitted, but only as approved by the City Engineer.

J. E. Attebery
City Engineer

RCM

APPENDIX B

DRAINAGE AREA NO.	TOTAL AREA (SQ. MI.)	LAND USE (ZONING)	GROSS AREA	% CONTRIBUTING	NET CONTRIB. AREA (SQ. MI.)	LAND USE CN	TOTAL CONTRIB. AREA (SQ.MI.)	WEIGHTED CN	Lc (FEET)	AVG. SLOPE (1/FT.)	VELOCITY (FPS)	Tc (HOURS)	AREA W/10 YR. RETENTION (SQ. MI.)	REMARKS
1	0.2625													
		C-0	0.0025	100.0	0.0025	88								
		* C-0	0.0219	15.0	0.0033	88								
		C-2	0.0212	100.0	0.0212	92								
		* C-2	0.0158	15.0	0.0024	92								
		* P-1	0.0039	15.0	0.0006	95								
		R-5	0.0008	100.0	0.0008	86								
		* R1-14	0.0363	21.7	0.0079	95								
		R1-18	0.0229	100.0	0.0229	80								
		RE-24	0.1264	100.0	0.1264	79								
		* RE-24	0.0086	11.4	0.0010	95								
		Maj. Streets	0.0022	100.0	0.0022	95								
							0.1912	82.01	4,500	0.0072	1.8	0.68		END
2	0.2740					(slopes > 10%)								
		* C-0	0.0020	15.0	0.0003	95								
		* C-1	0.0058	15.0	0.0009	95								
		* C-2	0.0010	15.0	0.0002	95								
		* P-1	0.0089	15.0	0.0013	95								
		PAD 4	0.0247	100.0	0.0247	95								
		* PAD 4	0.0407	15.0	0.0061	95								
		* PAD 9	0.0176	15.0	0.0026	95								
		* PAD 9 SP	0.0135	15.0	0.0020	95								
		RE-24	0.1124	100.0	0.1124	95								
		RE-35	0.0325	100.0	0.0325	95								
		RE-35 PAD	0.0057	100.0	0.0057	95								
		Maj. Streets	0.0093	100.0	0.0093	95								
							0.1980	95.00	5,200	0.1062	3.5	0.41		36" CAMELBACK Rd STORM DRAIN
						(slopes > 10%)								
3	0.1334	RE-24	0.0430	100.0	0.0430	95								
		RE-35	0.0660	100.0	0.0660	95								
		RE-35 PAD	0.0215	100.0	0.0215	95								
		Maj. Streets	0.0029	100.0	0.0029	95								
							0.1334	95.00	4,100	0.1534	3.4	0.33		24" CAMELBACK Rd STORM DRAIN
4	0.2221					(slopes > 10%)								
		RE-35	0.2221	100.0	0.2221	95								
							0.2221	95.00	4,700	0.2310	3.6	0.37		REACH TO 3

arthur beard engineers, inc. | Comp. by ______ Date ______ | Chk. by ______ Date ______ | Project ______ | Subject: SUB-AREA CHARACTERISTICS | Proj. No. ______ Client ______ | Sheet 2 of

DRAINAGE AREA NO.	TOTAL AREA (SQ. MI.)	LAND USE (ZONING)	GROSS AREA	% CONTRIBUTING	NET CONTRIB. AREA (SQ. MI.)	LAND USE CN	TOTAL CONTRIB. AREA (SQ. MI.)	WEIGHTED CN	Lc (FEET)	AVG. SLOPE (1/FT.)	VELOCITY (FPS)	Tc (HOURS)	AREA W/10 YR. RETENTION (SQ. MI.)	REMARKS
5A	0.0957													
Class 'B' soil		RE-35	0.0802	100.0	0.0802	79								
		*RE-35	0.0117	9.8	0.0011	95	0.0851							
		Maj. Street	0.0038	100.0	0.0038	95		80.73	4,000	0.0703	2.1	0.53		24" CAMELBACK STORM DRAIN
5B	0.0109													
Class 'D' soil		RE-35	0.0109	100.0	0.0109	87	0.0109							
						(slopes > 10%)								
6	0.1735	RE-35	0.1432	100.0	0.1432	95								
		*RE-35 SP	0.0286	5.0	0.0014	95								
		Maj. Street	0.0017	100.0	0.0017	95								
							0.1463	95.00	5,300	0.2501	4.8	0.31		REACH TO 13
7	0.2644					(slopes > 10%)								
		RE-35	0.2300	100.0	0.2300	95								
		*RE-35	0.0287	9.8	0.0028	95								
		Maj. Street	0.0057	100.0	0.0057	95								
							0.2385	95.00	6,000	0.2078	4.6	0.36		REACH TO 13
						(slopes > 10%)								
8	0.2572	RESORT	0.0530	100.0	0.0530	95								
		RE-35	0.2008	100.0	0.2008	95								
		Maj. Street	0.0034	100.0	0.0034	95								
							0.2572	95.00	5,200	0.2510	4.0	0.36		REACH TO 17
9	0.0753													
		C-O	0.0043	100.0	0.0043	88								
		C-2	0.0025	100.0	0.0025	92								
		P-1	0.0013	100.0	0.0013	95								
		R-3	0.0211	100.0	0.0211	85								
		*R-3	0.0025	33.0	0.0008	95								
		R1-10	0.0292	100.0	0.0292	81								
		*R1-10	0.0072	26.0	0.0019	95								
		Maj. Street	0.0072	100.0	0.0072	95								
							0.0683	85.37	2,400	0.0057	1.2	0.58		END

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DRAINAGE AREA NO.	TOTAL AREA (SQ. MI.)	LAND USE (ZONING)	GROSS AREA	% CONTRIBUTING	NET CONTRIB. AREA (SQ. MI.)	LAND USE CN	TOTAL CONTRIB. AREA (SQ. MI.)	WEIGHTED CN	Lc (FEET)	AVG. SLOPE (1/FT.)	VELOCITY (FPS)	Tc (HOURS)	AREA W/10 YR. RETENTION (SQ. MI.)	REMARKS
10	0.1406													
		C-O	0.0114	100.0	0.0114	88								
		C-1	0.0008	100.0	0.0008	92								
		P-1	0.0022	100.0	0.0022	95								
		R-4	0.0007	100.0	0.0007	86								
		R1-10	0.0161	100.0	0.0161	81								
		*R1-10	0.0359	26.0	0.0093	95								
		R1-18	0.0013	100.0	0.0013	80								
		*R1-18	0.0204	17.7	0.0036	95								
		RE-24	0.0109	100.0	0.0109	79								
		*RE-24	0.0341	11.4	0.0039	95								
		Maj. Streets	0.0068	100.0	0.0068	95								
							0.0670	87.42	4,500	0.0104	2.0	0.63		END
11	0.2619													
		*R1-10	0.0165	26.0	0.0043	95								
		*R1-18	0.0222	17.7	0.0038	95								
		RE-24	0.0239	100.0	0.0239	79								
		*RE-24	0.1945	11.4	0.0222	95								
		Maj. Streets	0.0048	100.0	0.0048	95								
							0.0590	88.52	6,000	0.0107	2.8	0.61		END
12	0.0717	R-5	0.0045	100.0	0.0045	86								
		R1-10	0.0018	100.0	0.0018	81								
		*R1-10	0.0412	26.0	0.0107	95								
		R1-14	0.0183	100.0	0.0183	80								
		RE-24	0.0059	100.0	0.0059	79								
							0.0412	84.45	2,800	0.0049	1.3	0.60		END
13	0.2779													
		PAD-9	0.0038	100.0	0.0038	84								
		RE-24	0.0076	100.0	0.0076	79								
		*RE-24	0.0348	11.4	0.0040	95								
		RE-35	0.0029	100.0	0.0029	79								
		*RE-35	0.2163	9.8	0.0212	95								
		Maj. Streets	0.0125	100.0	0.0125	95								
							0.0520	90.97	5,900	0.0081	4.2	0.39		REACH TO 14

DRAINAGE AREA NO.	TOTAL AREA (SQ. MI.)	LAND USE (ZONING)	GROSS AREA	% CONTRIBUTING	NET CONTRIB. AREA (SQ. MI.)	LAND USE CN	TOTAL CONTRIB. AREA (SQ.MI.)	WEIGHTED CN	Lc (FEET)	AVG. SLOPE (1/FT.)	VELOCITY (FPS)	Tc (HOURS)	AREA W/10 YR. RETENTION (SQ. MI.)	REMARKS
14	0.2400													
		R1-10	0.0011	100.0	0.0011	81								
		R1-14	0.0059	100.0	0.0059	80								
		*R1-14	0.1889	21.7	0.0410	95								
		RE-24	0.0008	100.0	0.0008	79								
		*RE-24	0.0404	11.4	0.0046	95								
		Maj. Streets	0.0029	100.0	0.0029	95								
							0.0563	92.93	6,100	0.0034	1.8	0.94		END
15	0.1378													
		RE-24	0.0072	100.0	0.0072	79								
		*RE-24	0.0125	11.4	0.0014	95								
		RE-35	0.0227	100.0	0.0227	79								
		*RE-35	0.0931	9.8	0.0091	95								
		Maj. Streets	0.0023	100.0	0.0023	95								
							0.0427	83.80	3,600	0.0152	2.0	0.50		REACH TO 13
16	0.1218	*R1-10	0.0075	26.0	0.0020	95								
		R1-14	0.0073	100.0	0.0073	80								
		*R1-14	0.0785	21.7	0.0170	95								
		R1-18	0.0019	100.0	0.0019	80								
		RE-24	0.0045	100.0	0.0045	79								
		*RE-24	0.0169	11.4	0.0019	95								
		Maj. Streets	0.0052	100.0	0.0052	95								
							0.0398	89.72	3,900	0.0082	1.3	0.83		END
17	0.2441													
		RE-24	0.0032	100.0	0.0032	79								
		*RE-24	0.1251	11.4	0.0143	95								
		RE-35	0.0549	100.0	0.0549	79								
		*RE-35	0.0488	9.8	0.0048	95								
		Major Streets	0.0121	100.0	0.0121	95								
							0.0893	84.59	4,900	0.0100	2.8	0.49		REACH TO 16

arthur beard engineers, inc.	Comp. by / Date	Chk. by / Date	Project	Subject: SUB-AREA CHARACTERISTICS	Proj. No. / Client	Sheet 5 of 5

DRAINAGE AREA NO.	TOTAL AREA (SQ. MI.)	LAND USE (ZONING)	GROSS AREA	% CONTRIBUTING	NET CONTRIB. AREA (SQ. MI.)	LAND USE CN	TOTAL CONTRIB. AREA (SQ. MI.)	WEIGHTED CN	Lc (FEET)	AVG. SLOPE (1/FT.)	VELOCITY (FPS)	Tc (HOURS)	AREA W/10 YR. RETENTION (SQ. MI.)	REMARKS
18	0.2165													
		*R1-14	0.1105	21.7	0.0240	95								
		*RE-24	0.0775	11.4	0.0088	95								
		RE-35	0.0072	100.0	0.0072	79								
		*RE-35	0.0092	9.8	0.0009	95								
		Maj. Streets	0.0121	100.0	0.0121	95								
							0.0530	92.83	4,100	0.0146	5.7	0.20		ARIZONA CANAL DRAINAGE CHANNEL
19	0.2219	R1-14	0.0065	100.0	0.0065	80								
		*R1-14	0.0207	21.7	0.0045	95								
		*R1-18	0.0112	17.7	0.0020	95								
		RE-24	0.0093	100.0	0.0093	79								
		*RE-24	0.0415	11.4	0.0047	95								
		RE-35	0.0277	100.0	0.0277	79								
		*RE-35	0.0942	9.8	0.0092	95								
		Maj. Streets	0.0108	100.0	0.0108	95								
							0.0747	85.77	6,300	0.0088	2.8	0.63		ARIZONA CANAL DRAINAGE CHANNEL
						(slopes > 10%)								
20	0.3746	RESORT	0.1291	100.0	0.1291	95								
		*RESORT	0.0179	8.7	0.0016	95								
		P.C	0.0176	100.0	0.0176	95								
		* P.C.	0.0390	50.0	0.0195	95								
		*SP RE-35(PC)	0.0195	5.0	0.0010	95								
		*SP, RESORT(PC)	0.0089	5.0	0.0004	95								
		* RE-35(PC)	0.0271	9.8	0.0027	95								
		* S.P. (P.C.)	0.0003	5.0	neg.	95								
		* R-2 S.P. (P.C)	0.0173	50.0	0.0087	95								
		RE-35	0.0404	100.0	0.0404	95								
		* RE-35	0.0482	9.8	0.0047	95								
		Maj. Streets	0.0093	100.0	0.0093	95								
							0.2350	95.00	7,000	0.1426	4.6	0.42		REACH TO 19

APPENDIX C

SUMMARY TABLE 1 ALT. 1

ALT	STORM	ID	DA SQ-MI.	RAIN TBLE	AMC	DELTA-T HRS.	TZERO HRS.	PRECIP IN.	PRECIP DURATION	PEAK-Q CFS	PEAK-TIME	PEAK-ELEV	RUNOFF IN.	CSM
1	1	4	0.22	1	2	0.10	0.0	1.44	24.00	114.26	12.49	0.0	0.96	514.43
1	1	105	0.22	1	2	0.10	0.0	1.44	24.00	113.70	12.50	0.0	0.96	511.93
1	1	5	0.19	1	2	0.10	0.0	1.44	24.00	29.60	12.65	0.0	0.28	152.49
1	1	105	0.42	1	2	0.10	0.0	1.44	24.00	140.59	12.54	0.0	0.64	337.80
1	1	103	0.42	1	2	0.10	0.0	1.44	24.00	139.02	12.56	0.0	0.64	334.02
1	1	3	0.13	1	2	0.10	0.0	1.44	24.00	69.64	12.48	0.0	0.96	522.03
1	1	103	0.55	1	2	0.10	0.0	1.44	24.00	207.26	12.53	0.0	0.72	377.11
1	1	102	0.55	1	2	0.10	0.0	1.44	24.00	205.25	12.55	0.0	0.72	373.45
1	1	2	0.20	1	2	0.10	0.0	1.44	24.00	100.19	12.50	0.0	0.96	506.00
1	1	102	0.75	1	2	0.10	0.0	1.44	24.00	304.96	12.54	0.0	0.78	407.92
1	1	102	0.37	1	2	0.10	0.0	1.44	24.00	57.06	13.05	0.0	0.75	152.64
1	1	102	0.19	1	2	0.10	0.0	1.44	24.00	69.78	12.85	0.0	0.65	373.37
1	1	9	0.07	1	2	0.10	0.0	1.44	24.00	15.52	12.64	0.0	0.43	227.17
1	1	1	0.19	1	2	0.10	0.0	1.44	24.00	29.47	12.71	0.0	0.31	154.13
1	1	101	0.07	1	2	0.10	0.0	1.44	24.00	15.16	12.69	0.0	0.43	221.89
1	1	101	0.26	1	2	0.10	0.0	1.44	24.00	44.59	12.70	0.0	0.34	171.82
1	1	110	0.19	1	2	0.10	0.0	1.44	24.00	66.47	12.85	0.0	0.65	355.64
1	1	110	0.19	1	2	0.10	0.0	1.44	24.00	180.14	12.57	0.0	0.97	963.83
1	1	10	0.07	1	2	0.10	0.0	1.44	24.00	17.25	12.65	0.0	0.51	257.43
1	1	110	0.37	1	2	0.10	0.0	1.44	24.00	245.14	12.57	0.0	0.81	655.80
1	1	110	0.44	1	2	0.10	0.0	1.44	24.00	262.01	12.57	0.0	0.77	594.40
1	1	111	0.44	1	2	0.10	0.0	1.44	24.00	257.92	12.59	0.0	0.77	585.11
1	1	11	0.06	1	2	0.10	0.0	1.44	24.00	16.91	12.63	0.0	0.56	286.64
1	1	111	0.50	1	2	0.10	0.0	1.44	24.00	274.73	12.60	0.0	0.74	549.68
1	1	112	0.50	1	2	0.10	0.0	1.44	24.00	269.95	12.64	0.0	0.74	540.11
1	1	12	0.04	1	2	0.10	0.0	1.44	24.00	8.38	12.66	0.0	0.39	203.50
1	1	112	0.54	1	2	0.10	0.0	1.44	24.00	278.39	12.64	0.0	0.72	514.59
1	1	114	0.54	1	2	0.10	0.0	1.44	24.00	270.98	12.74	0.0	0.72	500.89
1	1	6	0.15	1	2	0.10	0.0	1.44	24.00	76.65	12.47	0.0	0.96	523.94
1	1	113	0.15	1	2	0.10	0.0	1.44	24.00	75.16	12.52	0.0	0.96	513.76
1	1	7	0.24	1	2	0.10	0.0	1.44	24.00	122.56	12.48	0.0	0.96	513.87
1	1	115	0.24	1	2	0.10	0.0	1.44	24.00	120.81	12.53	0.0	0.96	506.53
1	1	15	0.04	1	2	0.10	0.0	1.44	24.00	9.14	12.61	0.0	0.37	214.14
1	1	115	0.28	1	2	0.10	0.0	1.44	24.00	129.58	12.55	0.0	0.87	460.80
1	1	113	0.28	1	2	0.10	0.0	1.44	24.00	123.51	12.73	0.0	0.87	439.24
1	1	13	0.05	1	2	0.10	0.0	1.44	24.00	20.71	12.53	0.0	0.69	398.25
1	1	113	0.33	1	2	0.10	0.0	1.44	24.00	139.92	12.67	0.0	0.84	419.92
1	1	113	0.48	1	2	0.10	0.0	1.44	24.00	212.55	12.59	0.0	0.87	443.27
1	1	114	0.48	1	2	0.10	0.0	1.44	24.00	211.00	12.61	0.0	0.87	440.04
1	1	14	0.06	1	2	0.10	0.0	1.44	24.00	18.49	12.75	0.0	0.81	328.44
1	1	114	0.54	1	2	0.10	0.0	1.44	24.00	228.80	12.62	0.0	0.87	427.02
1	1	114	1.08	1	2	0.10	0.0	1.44	24.00	491.71	12.68	0.0	0.79	456.64
1	1	20	0.23	1	2	0.10	0.0	1.44	24.00	118.11	12.51	0.0	0.96	502.61
1	1	119	0.23	1	2	0.10	0.0	1.44	24.00	116.29	12.62	0.0	0.96	494.86
1	1	19	0.07	1	2	0.10	0.0	1.44	24.00	16.74	12.67	0.0	0.44	224.08
1	1	119	0.31	1	2	0.10	0.0	1.44	24.00	133.07	12.63	0.0	0.83	429.68
1	1	119	0.59	1	2	0.10	0.0	1.44	24.00	160.52	12.61	0.0	0.60	272.20
1	1	118	0.59	1	2	0.10	0.0	1.44	24.00	156.28	12.77	0.0	0.60	265.01
1	1	18	0.05	1	2	0.10	0.0	1.44	24.00	25.88	12.46	0.0	0.80	488.29
1	1	118	0.64	1	2	0.10	0.0	1.44	24.00	166.96	12.61	0.0	0.62	259.77
1	1	116	0.64	1	2	0.10	0.0	1.44	24.00	161.99	12.83	0.0	0.62	252.04
1	1	8	0.26	1	2	0.10	0.0	1.44	24.00	132.17	12.48	0.0	0.96	513.87
1	1	117	0.26	1	2	0.10	0.0	1.44	24.00	130.20	12.54	0.0	0.96	506.22
1	1	17	0.09	1	2	0.10	0.0	1.44	24.00	20.63	12.61	0.0	0.40	231.02
1	1	117	0.35	1	2	0.10	0.0	1.44	24.00	150.17	12.55	0.0	0.81	433.40
1	1	116	0.35	1	2	0.10	0.0	1.44	24.00	148.29	12.58	0.0	0.81	427.96
1	1	16	0.04	1	2	0.10	0.0	1.44	24.00	10.95	12.75	0.0	0.62	275.17

1	1	116	0.39	1	2	0.10	0.0	1.44	24.00	158.49	12.59	0.0	0.79	410.28
1	1	116	1.03	1	2	0.10	0.0	1.44	24.00	309.91	12.66	0.0	0.68	301.18
1	1	114	1.03	1	2	0.10	0.0	1.44	24.00	305.28	12.93	0.0	0.68	296.68
1	1	199	2.11	1	2	0.10	0.0	1.44	24.00	754.77	12.76	0.0	0.74	358.42

SUMMARY TABLE 1 ALT 2

ALT	STORM	ID	DA SQ-MI.	RAIN TBLE	AMC	DELTA-T HRS.	TZERO HRS.	PRECIP IN.	PRECIP DURATION	PEAK-Q CFS	PEAK-TIME	PEAK-ELEV	RUNOFF IN.	CSM
1	1	4	0.22	1	2	0.10	0.0	1.44	24.00	114.26	12.49	0.0	0.96	514.43
1	1	105	0.22	1	2	0.10	0.0	1.44	24.00	113.70	12.50	0.0	0.96	511.93
1	1	5	0.19	1	2	0.10	0.0	1.44	24.00	29.60	12.65	0.0	0.28	152.49
1	1	105	0.42	1	2	0.10	0.0	1.44	24.00	140.59	12.54	0.0	0.64	337.80
1	1	103	0.42	1	2	0.10	0.0	1.44	24.00	139.02	12.56	0.0	0.64	334.02
1	1	3	0.13	1	2	0.10	0.0	1.44	24.00	69.64	12.48	0.0	0.96	522.03
1	1	103	0.55	1	2	0.10	0.0	1.44	24.00	207.26	12.53	0.0	0.72	377.11
1	1	102	0.55	1	2	0.10	0.0	1.44	24.00	205.25	12.55	0.0	0.72	373.45
1	1	2	0.20	1	2	0.10	0.0	1.44	24.00	100.19	12.50	0.0	0.96	506.00
1	1	102	0.75	1	2	0.10	0.0	1.44	24.00	304.96	12.54	0.0	0.78	407.92
1	1	102	0.37	1	2	0.10	0.0	1.44	24.00	57.06	13.05	0.0	0.75	152.64
1	1	102	0.19	1	2	0.10	0.0	1.44	24.00	69.78	12.85	0.0	0.65	373.37
1	1	9	0.07	1	2	0.10	0.0	1.44	24.00	15.52	12.64	0.0	0.43	227.17
1	1	1	0.19	1	2	0.10	0.0	1.44	24.00	29.47	12.71	0.0	0.31	154.13
1	1	109	0.19	1	2	0.10	0.0	1.44	24.00	28.87	12.76	0.0	0.31	151.00
1	1	109	0.26	1	2	0.10	0.0	1.44	24.00	43.63	12.72	0.0	0.34	168.14
1	1	110	0.26	1	2	0.10	0.0	1.44	24.00	42.52	12.90	0.0	0.34	163.84
1	1	110	0.19	1	2	0.10	0.0	1.44	24.00	66.47	12.85	0.0	0.65	355.64
1	1	110	0.19	1	2	0.10	0.0	1.44	24.00	180.14	12.57	0.0	0.97	963.83
1	1	10	0.07	1	2	0.10	0.0	1.44	24.00	17.25	12.65	0.0	0.51	257.43
1	1	110	0.37	1	2	0.10	0.0	1.44	24.00	245.14	12.57	0.0	0.81	655.80
1	1	110	0.44	1	2	0.10	0.0	1.44	24.00	262.01	12.57	0.0	0.77	594.40
1	1	110	0.70	1	2	0.10	0.0	1.44	24.00	288.88	12.59	0.0	0.61	412.51
1	1	111	0.70	1	2	0.10	0.0	1.44	24.00	284.00	12.62	0.0	0.61	405.54
1	1	11	0.06	1	2	0.10	0.0	1.44	24.00	16.91	12.63	0.0	0.56	286.64
1	1	111	0.76	1	2	0.10	0.0	1.44	24.00	300.90	12.62	0.0	0.61	396.29
1	1	112	0.76	1	2	0.10	0.0	1.44	24.00	294.44	12.67	0.0	0.61	387.78
1	1	12	0.04	1	2	0.10	0.0	1.44	24.00	8.38	12.66	0.0	0.39	203.50
1	1	112	0.80	1	2	0.10	0.0	1.44	24.00	302.82	12.67	0.0	0.60	378.29
1	1	114	0.80	1	2	0.10	0.0	1.44	24.00	297.11	12.77	0.0	0.60	371.16
1	1	6	0.15	1	2	0.10	0.0	1.44	24.00	76.65	12.47	0.0	0.96	523.94
1	1	113	0.15	1	2	0.10	0.0	1.44	24.00	75.16	12.52	0.0	0.96	513.76
1	1	7	0.24	1	2	0.10	0.0	1.44	24.00	122.56	12.48	0.0	0.96	513.87
1	1	115	0.24	1	2	0.10	0.0	1.44	24.00	120.81	12.53	0.0	0.96	506.53
1	1	15	0.04	1	2	0.10	0.0	1.44	24.00	9.14	12.61	0.0	0.37	214.14
1	1	115	0.28	1	2	0.10	0.0	1.44	24.00	129.58	12.55	0.0	0.87	460.80
1	1	113	0.28	1	2	0.10	0.0	1.44	24.00	123.51	12.73	0.0	0.87	439.24
1	1	13	0.05	1	2	0.10	0.0	1.44	24.00	20.71	12.53	0.0	0.69	398.25
1	1	113	0.33	1	2	0.10	0.0	1.44	24.00	139.92	12.67	0.0	0.84	419.92
1	1	113	0.48	1	2	0.10	0.0	1.44	24.00	212.55	12.59	0.0	0.87	443.27
1	1	114	0.48	1	2	0.10	0.0	1.44	24.00	211.00	12.61	0.0	0.87	440.04
1	1	14	0.06	1	2	0.10	0.0	1.44	24.00	18.49	12.75	0.0	0.81	328.44
1	1	114	0.54	1	2	0.10	0.0	1.44	24.00	228.80	12.62	0.0	0.87	427.02
1	1	114	1.34	1	2	0.10	0.0	1.44	24.00	512.61	12.70	0.0	0.70	383.61
1	1	20	0.23	1	2	0.10	0.0	1.44	24.00	118.11	12.51	0.0	0.96	502.61
1	1	119	0.23	1	2	0.10	0.0	1.44	24.00	116.29	12.62	0.0	0.96	494.86
1	1	19	0.07	1	2	0.10	0.0	1.44	24.00	16.74	12.67	0.0	0.44	224.08
1	1	119	0.31	1	2	0.10	0.0	1.44	24.00	133.07	12.63	0.0	0.83	429.68
1	1	119	0.59	1	2	0.10	0.0	1.44	24.00	160.52	12.61	0.0	0.60	272.20
1	1	118	0.59	1	2	0.10	0.0	1.44	24.00	156.28	12.77	0.0	0.60	265.01
1	1	18	0.05	1	2	0.10	0.0	1.44	24.00	25.88	12.46	0.0	0.80	488.29
1	1	118	0.64	1	2	0.10	0.0	1.44	24.00	166.96	12.61	0.0	0.62	259.77
1	1	116	0.64	1	2	0.10	0.0	1.44	24.00	161.99	12.83	0.0	0.62	252.04
1	1	8	0.26	1	2	0.10	0.0	1.44	24.00	132.17	12.48	0.0	0.96	513.87
1	1	117	0.26	1	2	0.10	0.0	1.44	24.00	130.20	12.54	0.0	0.96	506.22
1	1	17	0.09	1	2	0.10	0.0	1.44	24.00	20.63	12.61	0.0	0.40	231.02
1	1	117	0.35	1	2	0.10	0.0	1.44	24.00	150.17	12.55	0.0	0.81	433.40

1	1	116	0.35	1	2	0.10	0.0	1.44	24.00	148.29	12.58	0.0	0.81	427.96
1	1	16	0.04	1	2	0.10	0.0	1.44	24.00	10.95	12.75	0.0	0.62	275.17
1	1	116	0.39	1	2	0.10	0.0	1.44	24.00	158.49	12.59	0.0	0.79	410.28
1	1	116	1.03	1	2	0.10	0.0	1.44	24.00	309.91	12.66	0.0	0.68	301.18
1	1	114	1.03	1	2	0.10	0.0	1.44	24.00	305.28	12.93	0.0	0.68	296.68
1	1	199	2.37	1	2	0.10	0.0	1.44	24.00	780.33	12.77	0.0	0.70	329.91

APPENDIX D