# BELL ROAD PROJECT DRAINAGE STUDY

## Volume I

## Hydrologic Modeling

FOR

MARICOPA COUNTY FLOOD CONTROL DISTRICT

PREPARED BY

GREINER ENGINEERING SCIENCES, INC.

PHOENIX, ARIZONA

September, 1986

Revised

October, 1987

CONTRACT FCD 86-20

PROJECT No. E123061

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# BELL ROAD PROJECT DRAINAGE STUDY
# VOLUME I
# HYDROLOGIC MODELING

Prepared For:
MARICOPA COUNTY FLOOD CONTROL DISTRICT
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Phoenix, AZ 85009

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September 1986

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Contract FCD 86-20
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## IV. INTRODUCTION

The purpose of the Bell Road Project Drainage Study is to develop a storm-water management plan for the expansion of Bell Road to a six-lane, divided major urban arterial street.

The purpose of this report is to develop the hydrology for the areas without adequate hydrologic information using the HEC-1 Flood Hydrograph Package for existing and post-development (future) conditions.

The Bell Road Project Drainage Study encompasses the area between Grand Avenue and Scottsdale Road and has been divided into ten major drainage areas. These areas are briefly described as follows:

Area 1: Bound by Bell Road on the south, Grand Avenue on the west, McMicken Dam Outlet Channel on the north and the west boundary of Sun City West on the east.

Area 2: Bound by Bell Road on the south, Agua Fria River on the west, New River on the east and the ridge on the mountain in Section 4, Township 4 North, Range 1 East on the north.

Area 3: Bound by Bell Road on the south, New River on the west, Skunk Creek on the east and Union Hills Drive on the north.

Area 4: Bound by Bell Road on the south, Skunk Creek on the west, Beardsley Road on the north and Interstate-17 on the east.

Area 5: Bound by Bell Road on the south, Interstate-17 on the west, Cave Creek on the east and the ridge line of the Union Hills on the north.

Area 6: Bound by Bell Road on the south, Cave Creek on the west, East Fork of Cave Creek on the east and a ridge line just north of Beardsley Road on the north.

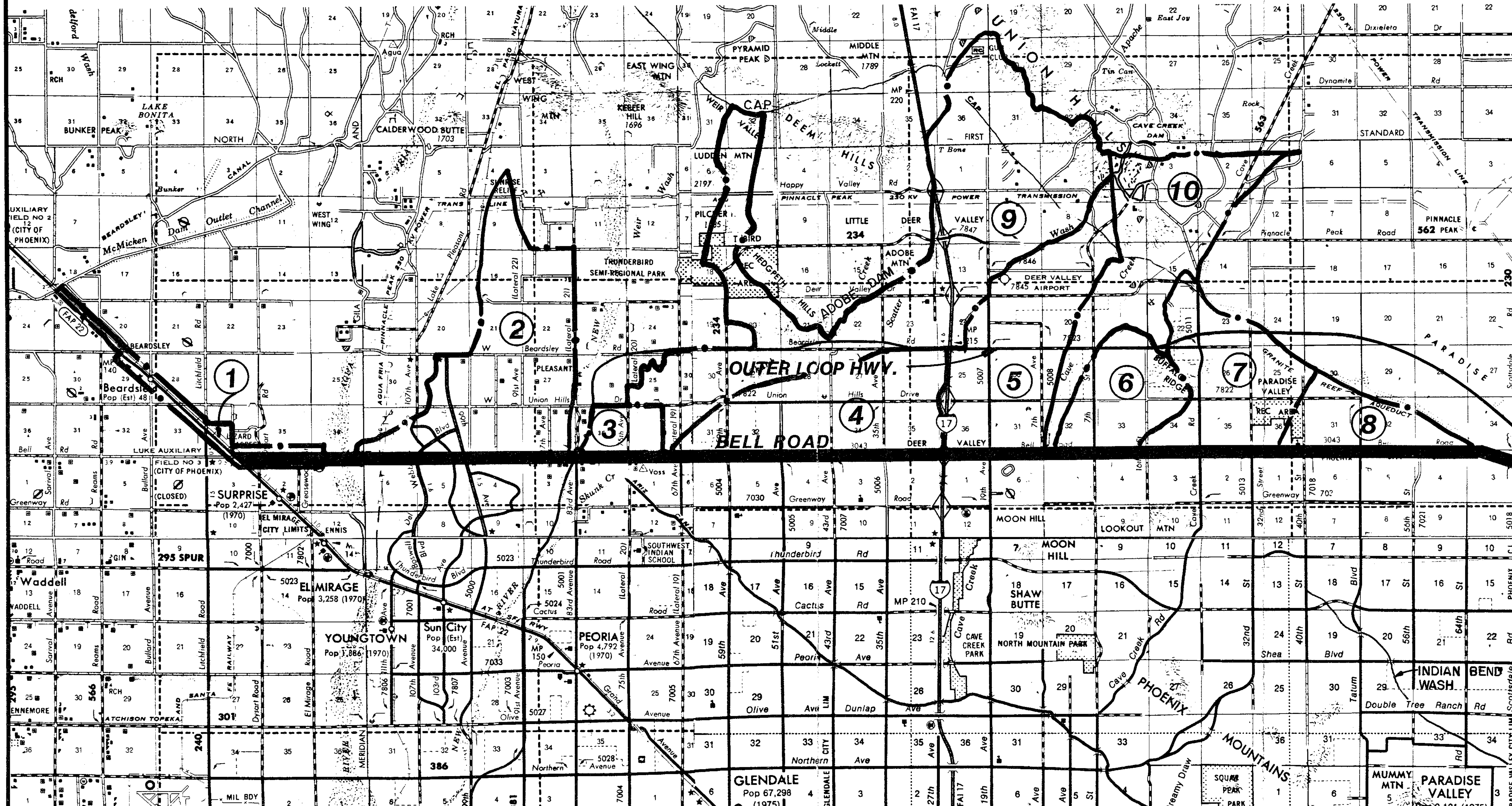
Area 7: East Fork of Cave Creek watershed.

Area 8: Bound by Bell Road on the south, East Fork of Cave Creek drainage divide on the west, and the Central Arizona Project on the north and east.

Area 9: Skunk Creek Watershed.

Area 10: Cave Creek Watershed.

The limits of all drainage areas are shown on Exhibit 1.




LEGEND

MAJOR DRAINAGE AREA BOUNDARIES

(1) MAJOR DRAINAGE AREA NUMBERS

SCALE : 1" = 2 MILES

Greiner Engineering

A Greiner Engineering Inc. Company

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Scale 1" = 2 Mi.

# BELL ROAD PROJECT

DRAINAGE STUDY

MAJOR DRAINAGE AREAS

Date JAN. 1987

Job No. E123061

Sheet 1 of 1

EXHIBIT 1

## A. Existing Drainage Area Descriptions

Drainage Area 1: Drainage Area 1 lies on the western most portion of the Bell Road Project Drainage Study area. It is bound on the north by McMicken Dam outlet channel, on the west by Grand Avenue, on the east by the west boundary of Sun City West and on the south by Bell Road. This drainage area is approximately 0.3 square miles and is 4.5 miles long and 300 feet wide except at the construction facility adjacent to Sun City West. This area consists primarily of the Atchison Topeka-Santa Fe (AT-SF) Railroad right-of-way and the Grand Avenue right-of-way.

The Sun City West area drainage system is sized for the 100-year, 24-hour storm event and outfalls to the Agua Fria River above Bell Road. This system also provides capacity for off-site flows between McMicken Dam and Sun City West. Since these flows are discharged to the Agua Fria River, the Sun City West area and the area between Sun City West and McMicken Dam were excluded from the hydrologic study.

No major drainage structures exist in Area 1. There are three small pipe culverts under Bell Road which convey flows to the south and are cataloged in Appendix A. This area does not contain any well-defined or major watercourses and primarily provides for right-of-way drainage for Grand Avenue and the Atchison Topeka-Santa Fe Railroad.

The general flow pattern in Drainage Area 1 is from northwest to southeast. Slopes range from 0.4% to 0.7% with an average slope of 0.55%. All soils are classified as hydrologic soil Group B, as described in "Soil Survey of Maricopa County, Arizona, Central Part" by the U.S. Department of Agriculture, Soil Conservation Service. The ground cover consists of desert brush and grass with poor ground cover.

Drainage Area 2: Drainage Area 2 is bound on the north by the hills just north of Happy Valley Road, on the east by 83rd Avenue, on the west

by 99th Avenue and by Bell Road on the south. This area is approximately 10.2 square miles. Sun City covers about 2.8 square miles and the undeveloped area north of Sun City covers approximately 7.4 square miles.

About 25% of Sun City lies west of Drainage Area 2 and the runoff from this area is diverted to the Agua Fria River.

Sun City was developed with large drainage structures to convey runoff through and away from the development. The drainage facilities are comprised of inverted crown streets and gunite channels. The area is fully developed with approximately 20% being golf courses, 70% residential and 10% commercial.

The area north and east of Sun City is relatively undeveloped with some low density housing in the northern portions. There are no major storm drainage facilities in this undeveloped area. A poor cover of desert brush exists over most of the area with some active orchards and abandoned agricultural areas. A large new residential development is under construction in Section 28, Township 4 North, Range 1 East.

Flow patterns in Drainage Area 2 are predominantly from north to south. Slopes range from 2% in the extreme northern portions to 0.4% in the south portion with an average slope of about 0.6%. Hydrologic soil groups within the area are 75% Group B and 25% Group D.

Drainage Area 3: Drainage Area 3 encompasses approximately 1.5 square miles of area. The boundaries of this area are the New River on the west, Union Hills Drive on the north, Skunk Creek on the east and Bell Road on the south. Drainage Area 3 is entirely within the City of Glendale.

Drainage Area 3 is a tributary area to the New River. Its confluence with Skunk Creek is approximately 1.5 miles south of Bell Road. The natural drainage pattern is from northeast to southwest. The pattern has been modified by both agricultural and residential developments to a more defined north to south direction. The only drainage facilities in this area are minor structures associated with the abandoned citrus orchard that occupies approximately 0.6 square mile in the western part of the drainage area. Soils in the area fall into the hydrologic soil Group B.

The slope of this drainage area ranges from flat to moderate. Slopes range from approximately 0.3% to 0.6%.

Ground cover consists of approximately 41% abandoned citrus groves, 10% are abandoned agricultural land with a poor vegetative cover and approximately 49% is urban lawns of a mix of native and imported landscaping.

Drainage Area 4: Drainage Area 4 is approximately eight square miles and is bound on the north by Beardsley Road and Scatter Wash, on the east by the Black Canyon Highway (I-17), on the south by Bell Road and by Skunk Creek on the west.

There are four culverts and two depressed roadway sections along a concrete-lined channel with side slopes of 5:1 and a 20 foot bottom width which conveys stormwater west of I-17 into an inverted crown street (Union Hills Drive). Another concrete-lined channel with side slopes of 5:1 and a six foot bottom width discharges flow from Drainage Area 5 through I-17 and conveys runoff south crossing Bell Road. One detention basin at Bellair Golf Course is located north of Bell Road between 43rd Avenue and 51st Avenue. No storm drain systems exist in this drainage area.

The drainage pattern, in general, is from northeast to southwest. Storm water runoff is carried through manmade channels and existing streets. The overall drainage area slopes at approximately 0.5%, but ranges within subareas from 0.2% to 0.8%. Runoff north of Union Hills Drive is directed west to Skunk Creek. All runoff south of Union Hills Drive flows south of Bell Road at 35th Avenue, 43rd Avenue, 51st Avenue, 59th Avenue and 67th Avenue. Runoff in the area immediately to the east of Skunk Creek flows west into Skunk Creek.

The drainage area east of 51st Avenue is urbanized and primarily residential with commercial areas located adjacent to the major streets. The area along I-17 is relatively undeveloped with a few industrial parks. The area west of 51st Avenue within the City of Glendale is developed primarily as residential. Approximately 20% of this area is undeveloped but zoned for industrial and commercial uses.

Hydrologic soil groups B and D were found in Drainage Area 4.

Drainage Area 5: Drainage Area 5 is bound on the north by the Union Hills ridge line, on the east by Cave Creek, on the south by Bell Road and by I-17 on the west. The north boundary has been modified by the Central Arizona Project Canal and its protective dike which permits runoff to cross southward through a limited number of overchutes.

The drainage area is approximately nine square miles. The drainage pattern, in general, is from northeast to southwest. Slopes are generally flat and range from 0.2% to 0.8%. Storm water runoff is carried through natural washes, manmade channels and existing streets. The I-17 embankment running north to south forms a barrier to the natural drainage pattern due to its embankment. Flows cross I-17 at four existing culverts and at the depressed roadway

sections with pumping stations located at Union Hills Drive and Bell Road. An existing 90 inch storm drain is located along 19th Avenue, extending from Cave Creek to Grovers Avenue.

The runoff from the area east of Seventh Avenue flows into Cave Creek. Flows west of 19th Avenue are conveyed through the existing culverts and the depressed roadway sections under I-17 to Drainage Area 4. Flow from the area between Seventh Avenue and 19th Avenue is conveyed south to Cave Creek along 19th Avenue.

In general, the drainage area is urbanized and principally residential with commercial areas located adjacent to the major streets. There are some industrial uses along I-17.

Soils in the drainage area fall into hydrologic soil Groups B and D.

Drainage Area 6: Drainage Area 6 is bound by Bell Road on the south, Cave Creek on the west, the west ridge of the East Fork of Cave Creek on the east and Buffalo Ridge on the north. This area encompasses approximately four square miles.

Stormwater runoff is carried overland, through natural and manmade channels and existing streets. There are no major watercourses within this drainage area. The slopes are generally flat throughout the drainage area and range from 0.2% to 2.0% with the exception of the rock outcrops east of 16th Street which have slopes ranging from 7% to 18%.

The flow pattern in Drainage Area 6 is generally from northeast to southwest with some street flows going south. Major concentration points along Bell Road are at Sixth Avenue, First Street and Seventh Street.

Land use in Drainage Area 6 is mostly residential with some commercial

along the major streets as follows: approximately 53% is residential, 44% is undeveloped with a poor ground cover of desert brush, 2% is commercial and 1% is industrial.

The predominant hydrologic soils group in Drainage Area 6 is Group B, with some Group A soils in the Cave Creek area and Group D soils in the rock outcrops east of 16th Street.

Drainage Area 7: Drainage Area 7 is the main tributary area for the East Fork of Cave Creek and is approximately 4.8 square miles. The drainage area is defined by: Buffalo Ridge and Union Hills on the west; the Central Arizona Project Canal on the north and northeast; a ridgeline extending diagonally from southwest to northeast from Bell Road and 32nd Street the Central Arizona Project Canal and 40th Street on the east; and Bell Road on the south.

The drainage pattern is generally from northeast to southwest except for the main branch of the East Fork which drains the Union Hills from the northwest southward.

The East Fork of Cave Creek is a poorly defined shallow channel except where manmade improvements or encroachments have confined the wash.

The Central Arizona Project Canal, which forms the northern and eastern boundaries of Drainage Area 7, was constructed with a dike system to protect both the aqueduct and to provide full flood protection to downstream properties. The average dike height is 30 feet. According to the unpublished design memorandum prepared by the Bureau of Reclamation for Reach 11 of the Granite Reef Aqueduct (CAP), the dike is designed to retain the maximum probable flood with the 100-year flood and with 100-year sedimentation.

Slopes in the area vary from steep (greater than 3%) in the Union Hills to moderate and flat (less than 0.5%) along Bell Road.

Soils in the area fall into hydrologic soil Group B. Soil Group D is associated with the Union Hills and other rock outcrops.

Drainage Area 8: Drainage Area 8 encompasses approximately three square miles. The boundaries of this area are defined on the west by a ridge line running diagonally from southwest to northeast from approximately Bell Road at 32nd Street to the Central Arizona Project Canal at 40th Street, on the north by the Central Arizona Project Canal from 40th Street to Scottsdale Road and on the south by Bell Road.

Drainage patterns are generally from northeast to southwest. The natural drainage pattern is typical of an alluvial fan. Very few well-defined channels drain the area. Sheet flow in desert or agricultural areas and street flow in developed areas dominate the drainage pattern.

A 30 foot high dike associated with the Central Arizona Project Canal, along the north boundary of Drainage Area 8, provides flood protection to downstream areas. The dike was constructed to retain the maximum probable flood with the 100-year flood and sedimentation.

Soils in the area fall into hydrologic soil Group B.

Slopes within this drainage area may generally be described as flat to moderate. Slopes range from 0.8% in the upper watershed, adjacent to the Central Arizona Project Canal, to approximately 0.4% at Bell Road.

There is a wide range of land uses in Area 8 including heavily urbanized multiple family subdivisions, suburban, agriculture and parks. Approximately one square mile of area is desert, 0.5 square mile is agricultural and 1.5 square mile is residential and commercial.

Ground cover in the area is generally poor and includes desert brush, irrigated pasture and turf.

Drainage Area 9: Drainage Area 9 consists of the Skunk Creek and Scatter Wash Watersheds. The boundary of these natural drainage courses is approximately the Arrowhead Ranch development on the west, Deem Hills, Adobe Dam and Union Hills on the north, 19th Avenue on the east (north of Beardsley Road) and Bell Road on the south (excluding Drainage Area 4 and 5).

Flood control projects and major features in this 7.3 square mile drainage area consist of the Adobe Dam, the Central Arizona Project Canal, the lake and channel systems associated with the Arrowhead Ranch development, the I-17 embankment and culverts and various improvements along Skunk Creek and Scatter Wash.

The general flow pattern in this study area is from northeast to southwest with slopes ranging from approximately 0.4% to 50% (in the various hills). The average slope, however, is approximately 0.6%. Hydrologic soil groups in the area are predominately B with some D soils in the rock outcrops in the more mountainous terrain. Ground cover in the area consists of desert brush with poor ground cover.

Some low density residential developments lie within the study area but most of the area is presently undeveloped.

Drainage Area 10: Drainage Area 10 is within the Cave Creek Watershed with an area of 6.9 square miles. The boundaries for this area are the Cave Buttes Dam and Dike on the north, Cave Creek Road (in the upper reaches) on the east, the eastern edge of the Phoenix - Deer Valley Municipal Airport on the west (above Beardsley Road) and Bell Road on the south.

Flood control projects and major features in this area include the Cave Buttes Dam and Dike, the Central Arizona Project Canal and some channel improvements to Cave Creek.

Flow patterns are generally from the northeast to the southwest with slopes ranging from 50% in the mountainous areas to 0.5% in the areas around Bell Road. The average slope is approximately 0.6%

Land use is primarily industrial and is associated with sand and gravel mining operations. Vegetative cover is primarily desert brush with poor ground cover. The hydrologic soil group in this area is predominantly Group B in the upper reaches, but between Beardsley Road and Bell Road Group A soils exist.

## B. Description of Existing Major Drainage Facilities at Bell Road

An inventory of existing drainage facilities at Bell Road between Grand Avenue and Scottsdale Road was performed. These structures have been inventoried to help identify points where stormwater currently discharges along Bell Road. This inventory will be used to develop alternative stormwater management plans and the subsequent modeling of the alternatives. These facilities are cataloged by drainage area and can be found in Appendix A.

## C. Summary of Existing and Ongoing Hydrologic Studies and Flood Control Facilities Within the Bell Road Project Drainage Study

Existing reports within the project study area were evaluated to determine what existing information could be used in developing the hydrology for the Bell Road Project Drainage Study. The following reports were evaluated:

1. Sun City West - Phase I Development Master Plan
2. Sun City West - Master Plan Update
3. City of Peoria Master Plan of Storm Drainage
4. Glendale - Peoria Area Drainage Master Plan
5. Glendale Storm Water Management Plan

6. Northwest Master Storm Drainage Study
7. North - Central Master Storm Drainage Study (West Half)
8. North - Central Master Storm Drainage Study (East Half)
9. Northeast Area Master Storm Drainage Study
10. East Fork of Cave Creek Area Drainage Master Study
11. Phoenix - Cordes Junction Highway - Peoria Avenue, Deer Valley Road Study
12. Hydrology and Concept Drainage Plan, Outer Loop Highway Section B
13. Paradise Valley, Scottsdale and Phoenix Drainage Study
14. Corps of Engineers - Gila River Basin Study

These hydrology studies were evaluated to determine if the criteria for establishing peak flows is consistent with the hydrologic criteria established by the Maricopa County Flood Control District for the Bell Road Project Drainage Study. This criteria is summarized as follows:

1. Rainfall/Runoff Model - HEC-1
2. Storm Frequencies - 2-, 5-, 10-, 50-, 100-Year
3. Storm Duration - 24-Hour
4. Precipitation Distribution - City of Phoenix S-Curve
5. Flow Paths to be Modeled - 2-, 5-, 10-, 50-, 100-Year
6. Development Status - Existing and Post-Development (Future) Conditions

The results of the evaluation are presented in Appendix B. Table 1 is a summary of the evaluations of the existing and ongoing studies.

On the basis of the criteria established by the Flood Control District, none of the studies provide the full range of peak flow values at Bell Road for both existing and future conditions. However, all of the studies do provide some useful data which was incorporated into the Bell

Road Project Drainage Study. Some of the subarea delineations were used, but development within the study area required that all subareas be checked and new subareas delineated where development has occurred. Curve numbers were used from the previous studies, however, new development within the study area necessitated field verification of all curve numbers and new curve numbers were calculated based on the current development. Flow paths for all of the above mentioned studies were only developed for a particular storm event. These flow paths were verified and flow paths were evaluated for the additional storm events. With the exception of the North Central Area Drainage Master Study (West Half), the flow routing paths were not made a part of the reports and, therefore, all routing paths were developed for the Bell Road Project Drainage Study.

TABLE 1

SUMMARY TABLE OF THE EVALUATION OF EXISTING AND ONGOING HYDROLOGIC STUDIES WITHIN THE BELL ROAD PROJECT DRAINAGE STUDY

| Study Name | Study Status | Model | Storm Frequencies Modelled 2 | 5 | 10 | 50 | 100 | Storm Duration | Precipitation Distribution | Subarea Delineation | CN's | Modelled Flow Patterns 2 | 5 | 10 | 50 | 100 | Peak Flows Calculated at Bell Rd. | Development Status Exist. | Development Status Future | Adequacy of Hydrology for Design |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sun City West - Phase I Development Master Plan | Final | TR-20 | - | - | -- | -- | X | X | SCS Type I | X | X | - | - | -- | -- | X | X | - | X | X |
| Sun City West Master Plan Update | Final | TR-20 | - | - | -- | -- | X | X | SCS Type I | X | X | | | | | X | X | - | X | X |
| City of Peoria Master Plan of Storm Drainage | Draft | SWMM HEC-1 | X | - | X | -- | X | - | C.O.P. s-curve | X | - | X | - | -- | -- | -- | X | X | X | - |
| Glendale - Peoria Area Drainage Master Plan | Final | SWMM | - | - | X | -- | -- | - | C.O.P. s-curve | X | - | - | - | X | -- | -- | X | X | X | - |
| Glendale Storm Water Management Plan | Final | SWMM | - | - | X | -- | X | - | C.O.P. s-curve | X | - | - | - | X | -- | X | X | X | X | - |
| Northwest Master Storm Drainage Study | Final | TR-20 | X | - | X | X | -- | X | C.O.P. s-curve | X | X | X | - | -- | -- | -- | X | - | X | - |
| North Central Master Storm Drainage Study (West Half) | Final | TR-20 | X | X | X | -- | -- | X | C.O.P. s-curve | X | X | X | - | -- | -- | -- | X | - | X | - |
| North Central Area Master Storm Drainage Study (East Half) | Final | TR-20 | X | X | X | X | X | X | C.O.P. s-curve | X | X | X | - | -- | -- | -- | X | - | X | - |
| Northeast Area Master Storm Drainage Study | Final | TR-20 | X | X | X | -- | -- | X | C.O.P. s-curve | X | X | X | - | -- | -- | -- | X | - | X | - |
| East Fork - Cave Creek Wash Area Drainage Master Study | Ongoing | TR-20 | - | - | X | X | X | X | C.O.P. s-curve | X | X | - | - | -- | -- | X | X | X | X | - |
| Phoenix - Cordes Junction Highway Peoria Avenue - Deer Valley Road | Ongoing | TR-20 | - | - | -- | X | X | X | NOAA Atlas II | X | X | - | - | -- | X | -- | X | X | X | - |
| Hydrology and Concept Drainage Plan, Outer-loop Highway, Section B | Ongoing | HEC-1 | - | - | X | X | X | X | NOAA Atlas II | X | X | - | - | -- | -- | X | X | X | - | - |
| PVSP Drainage Study | Final | SCS/COE | X | - | -- | -- | X | - | SCS-Type II | - | - | - | - | -- | -- | X | - | - | X | - |
| COE Gila River Basin Study | Final | HEC-1 | - | - | -- | -- | X | - | COE Summer Storm | - | - | - | - | -- | -- | -- | - | - | - | - |

* x = yes (Adequate)
- = no (Inadequate)

## V. OBJECTIVES

The objective of the study is to develop a stormwater management plan for the expansion of Bell Road from Grand Avenue to Scottsdale Road which includes a cost-effective method of handling drainage as well as to provide protection for the roadway. In addition, the plan will ensure that downstream drainage facilities can handle discharged flows or that new facilities can be provided to an adequate outfall. Upstream properties will not be adversely affected by the construction of the roadway or drainage facilities.

The objective of this report is to develop the hydrology for the areas within the study area where existing hydrologic information was inadequate. Hydrology was peformed using the HEC-1 Flood Hydrograph Package. Adequacy of hydrologic information was determined by the criteria established by the Maricopa County Flood Control District as outlined in Section IV.C of this report. All subareas were identified and the hydrologic characteristics tabulated for each. Peak flows for existing and post-development (future) conditions were calculated for the 24-hour duration storm for the 2-, 5-, 10-, 50- and 100-year storm events. Post-development conditions are based on adopted community land use master plans and current or pending drainage retention criteria for the appropriate jurisdiction. All hydrology studies are coordinated to give a consistent description of the hydrologic conditions along the project reach. This report is to be used as a basis for evaluating the effects of the proposed alternative storm water management plans being developed for Bell Road.

Runoff volumes for each subarea can be retrieved from the magnetic tape of all the HEC-1 input and output. This tape is available at the Flood Control District of Maricopa County.

## VI. SUMMARY OF RESULTS

The peak flows for the 100-year, 24-hour storm event concentrating along Bell Road have been calculated and are presented in the following tables. The concentration points are identified by cross street name or by major river or wash. The calculated peak flows were computed using the HEC-1 Flood Hydrograph Package. Tables 2 and 3 represent only the flows as they enter Bell Road and are not cumulative peak flows routed down Bell Road. Peak flows and the time of peak for the 2-, 5-, 10-, 50- and 100-year storm events concentrating along Bell Road and within the watershed can be found in the Runoff Summary and tables in Appendix C (Volume II).

## TABLE 2

## PEAK DISCHARGE FOR THE 100-YEAR, 24-HOUR STORM EVENT CONCENTRATING ALONG BELL ROAD (EXISTING CONDITIONS)

| Location | Peak Discharge (cfs) |
|---|---|
| Between Grand Avenue and AT-SF Railroad | 85 |
| Between AT-SF Railroad and Sun City West | 59 |
| Southwest Corner of Sun City West | 154 |
| Agua Fria River | 115,000 |
| At 115th Avenue | 1,868 |
| New River | 12,000 |
| At 99th Avenue | 1,795 |
| At 91st Avenue | 1,039 |
| At 600 Feet East of 91st Avenue | 355 |
| At 2000 Feet East of 91st Avenue | 53 |
| At Skunk Creek | 11,000 |
| At 77th Avenue Alignment | 261 |
| At 75th Avenue | 529 |
| At 67th Avenue | 111 |
| At 63rd Avenue | 422 |
| At 59th Avenue | 262 |
| At 57th Avenue | 351 |
| At 55th Avenue | 290 |
| At 51st Avenue | 980 |
| At 49th Avenue | 98 |
| At 45th Avenue | 134 |
| At 43rd Avenue | 824 |

Peak flows are tabulated for points of concentration at Bell Road and do not account for flows combining after reaching Bell Road.

**TABLE 2**
(Continued)

| Location | Peak Discharge (cfs) |
|---|---|
| At 42nd Avenue | 35 |
| At 41st Avenue | 523 |
| At 39th Avenue | 433 |
| At 37th Avenue | 185 |
| At 35th Avenue | 850 |
| At 33rd Avenue | 80 |
| At 32nd Avenue | 103 |
| At 31st Avenue | 291 |
| At 29th Avenue | 146 |
| At 21st Avenue | 432 |
| At 19th Avenue | 1,816 |
| At 17th Avenue | 156 |
| At 15th Avenue | 303 |
| At Cave Creek | 4,200 |
| At 325' East of Seventh Avenue | 117 |
| At Northeast Corner of Central Avenue | 168 |
| At 500' East of Central Avenue | 786 |
| At Northwest Corner of Seventh Street | 1,257 |
| At 900' West of Ninth Street | 102 |
| At Ninth Street | 1,275 |
| At 12th Street | 569 |
| At 500' East of 12th Street | 34 |
| At 275' West of 14th Street | 19 |
| At 275' East of 14th Street | 45 |
| At 600' West of 16th Street | 45 |

Peak flows are tabulated for points of concentration at Bell Road and do not account for flows combining after reaching Bell Road.

TABLE 2
(Continued)

| Location | Peak Discharge (cfs) |
|---|---|
| At 16th - 20th Streets (East Fork of Cave Creek) | 3,822 |
| At 21st Street | 58 |
| At 25th Street | 337 |
| At 26th Street | 885 |
| At 28th Street | 161 |
| At 30th Street | 205 |
| At 32nd Street | 438 |
| At Bell Road/33rd Place Alignment | 31 |
| At 250' West of 36th Street | 612 |
| At 38th Street | 95 |
| At 40th Street | 219 |
| At 250' East of 40th Street | 140 |
| At 850' East of 40th Street | 464 |
| Between 43rd and 44th Street | 317 |
| At 45th Street Alignment | 113 |
| At 1000' West of Tatum Boulevard | 33 |
| At 480' West of Tatum Boulevard | 44 |
| At Tatum Boulevard Roadway | 104 |
| At Tatum Boulevard Drainageway | 202 |
| At Drainageway 400' West of 52nd Street | 356 |
| At 53rd Street Alignment | 53 |
| At 54th Street Alignment | 94 |
| Between 56th and 57th Streets | 26 |
| At 300' East of 57th Street | 157 |
| At 58th Way | 157 |

Peak flows are tabulated for points of concentration at Bell Road and do not account for flows combining after reaching Bell Road.

**TABLE 2**
(Continued)

| Location | Peak Discharge (cfs) |
|---|---|
| At 300' East of 60th Street | 51 |
| At 300' East of 61st Street | 64 |
| At 48' West of 64th Street | 67 |

Peak flows are tabulated for points of concentration at Bell Road and do not account for flows combining after reaching Bell Road.

TABLE 3

**PEAK DISCHARGE FOR THE 100-YEAR, 24-HOUR STORM EVENT CONCENTRATING ALONG BELL ROAD (FUTURE CONDITIONS)**

| Location | Peak Discharge (cfs) |
|---|---|
| Between Grand Avenue and AT-SF Railroad | 99 |
| Between AT-SF Railroad and Sun City West | 59 |
| Southwest Corner of Sun City West | 154 |
| Agua Fria River | 115,000 *** |
| At 115th Avenue | 1,868 |
| At 99th Avenue | 1,795 |
| New River | 16,240 *** |
| At 91st Avenue | 2,661(792) ** |
| At 600 Feet East of 91st Avenue | 355(286) ** |
| At 2000 Feet East of 91st Avenue | 260 |
| Skunk Creek | 12,073 |
| At 77th Avenue Alignment | 662 |
| At 75th Avenue | 559 |
| At 67th Avenue | 67(40) ** |
| At 63rd Avenue | 31(210) ** |
| At 59th Avenue | 318(90) ** |
| At 57th Avenue | 316 |
| At 55th Avenue | 320 ** |
| At 51st Avenue | 398(32) |
| At 49th Avenue | 97 |
| At 45th Avenue | 132 |
| At 43rd Avenue | 630(89) ** |

Peak flows are tabulated for points of concentration at Bell Road and do not account for flows combining after reaching Bell Road.

**Flows within future storm drains.
***Corps of Engineers values.

**TABLE 3**
(Continued)

| Location | Peak Discharge (cfs) |
|---|---|
| At 42nd Avenue | 35 |
| At 41st Avenue | 371 |
| At 39th Avenue | 264(32) ** |
| At 37th Avenue | 154 |
| At 35th Avenue | 803(113) ** |
| At 33rd Avenue | 78 |
| At 32nd Avenue | 72(27) ** |
| At 31st Avenue | 262 |
| At 29th Avenue | 279 |
| At 21st Avenue | 376 |
| At 19th Avenue | 1,144(142) ** |
| At 17th Avenue | 124(27) ** |
| At 15th Avenue | 274(34) ** |
| At Cave Creek | 5,335 |
| At 325' East of 7th Avenue | 117 |
| At Northeast Corner of Central Avenue | 166 |
| At 500' East of Central Avenue | 533 |
| At Northwest Corner of 7th Street | 97 |
| At 900' West of 9th Street | 303 |
| At 9th Street | 544 |
| At 12th Street | 329 |
| At 500' East of 12th Street | 34 |
| At 275' West of 14th Street | 19 |
| At 275' East of 14th Street | 45 |

Peak flows are tabulated for points of concentration at Bell Road and do not account for flows combining after reaching Bell Road.

**Flows within future storm drains.

**TABLE 3**
(Continued)

| Location | Peak Discharge (cfs) |
|---|---|
| At 600' West of 16th Street | 45 |
| At 16th Street | 54 |
| At 18th Street | 134 |
| At 20th Street | 1,328 |
| At 21st Street | 60 |
| At 25th Street | 200 |
| At 26th Street | 160 |
| At 28th Street | 159 |
| At 30th Street | 107 |
| At 32nd Street | 86 |
| At Bell Road/33rd Place Alignment | 31 |
| At 250' West of 36th Street | 673 |
| At 38th Street | 95 |
| At 40th Street | 161 |
| At 250' East of 40th Street | 171 |
| At 850' East of 40th Street | 582 |
| Between 43rd and 44th Street | 379 |
| At 45th Street Alignment | 127 |
| At 1000' West of Tatum Boulevard | 33 |
| At 480' West of Tatum Boulevard | 44 |
| At Tatum Boulevard Roadway | 71 |
| At Tatum Boulevard Drainageway | 415 |
| At 400' West of 52nd Street | 347 |
| At 53rd Street Alignment | 53 |
| At 54th Street Alignment | 100 |
| Between 56th and 57th Streets | 26 |
| At 300' East of 57th Street | 157 |

**TABLE 3**
(Continued)

| Location | Peak Discharge (cfs) |
|---|---|
| At 58th Way | 157 |
| At 300' East of 60th Street | 51 |
| At 300' East of 61st Street | 64 |
| At 48' West of 64th Street | 67 |

Peak flows are tabulated for points of concentration at Bell Road and do not account for flows combining after reaching Bell Road.

## VII. PROCEDURES AND METHODOLOGY

### A. Developing Existing and Post-development (Future) Drainage Patterns, Drainage Areas and Subareas

#### 1. Existing Drainage Areas and Patterns

Watershed subareas were delineated and hydrologic/hydraulic parameters established. Street flow patterns in urban areas were identified as well as the effects of irrigation canals, highway embankments, railroad facilities and storm drain outfalls on drainage patterns. Sources of information to establish the drainage areas, drainage patterns and subareas include the following:

a. U.S.G.S. Quadrangle Maps 7.5 minute series. These were used to establish the limits of the major drainage areas and existing topographic features and to establish general flow patterns; i.e. sheet flow, well established channel, etc.

b. Landis Aerial Surveys, 1" = 1200'. These aerial maps were photographed in December 1985 and were used to identify street flow patterns and areas of significant development. These aerial maps were used to locate existing drainage facilities and to develop curve numbers for existing conditions.

c. City of Phoenix A.P. #40 Topographic Maps and Aerial Photos, 1" = 100". The maps for quarter sections 37-17 to 37-32 and 36-17 to 36-44 were used. These sections extend 1/2 mile north and 1/2 mile south of Bell Road. Portions of the north side of Bell Road in the study area are not within the City of Phoenix and maps are not available.

The A.P. #40 aerials and topographic maps were used to establish flow patterns and subarea delineations in the immediate vicinity

of Bell Road. The maps were also used to establish street geometry for capacity calculations.

d. Existing Hydrologic Studies. The existing reports identified in Section IV.C, were used to extract a variety of information about the study area. The reports were used to identify flow patterns, subarea delineations, curve numbers and peak flows. The evaluation of the reports formulated the future direction of the Bell Road Project Drainage Study by identifying deficiencies in hydrologic information within the watershed areas. In addition, the adopted alternative plans from these studies were used in the analysis of future conditions.

e. Communications with Government Agencies. The jurisdictions along the Bell Road alignment were contacted to discuss drainage problems that were unique to their area. Information was requested regarding their major concerns about drainage along Bell Road in an effort to identify existing drainage problems. Information regarding the area master drainage studies and the adopted alternative plan were obtained through conversations with the engineering departments of City of Phoenix, City of Glendale and City of Peoria. The Bureau of Reclamation was contacted about the impoundment north of the Central Arizona Project Canal. Questions regarding right-of-way along Bell Road were answered by the Maricopa County Highway Department and the Town of Surprise.

f. Field Reconnaissance. Intensive field investigations were undertaken to verify information from the existing hydrologic studies. Areas of new development or developments under construction were identified. These areas did not appear on the aerial photographs and were not referenced in the existing hydrologic studies. All drainage structures crossing Bell Road were identified by location, type and size. The flow paths of

all major mile and half mile streets were identified and other street drainage patterns affecting Bell Road were documented. Major drainage structures north of Bell Road were identified and cataloged. All drainage patterns in the upper watersheds were established including subdivision street flow, channel flow and flow into on-site retention facilities within existing developments.

g. As-Built Plans. As-built plans for drainage structures within the Atchison Topeka-Santa Fe Railroad right-of-way were used to identify flow routing to Bell Road. As-built plans of Bell Road were used to identify drainage structures along the alignment. As-builts of the I-17/Bell Road and Union Hills Drive interchanges were reviewed to verify the drainage patterns in these areas.

h. Digitizer. The digitizer was used to calculate drainage areas and subareas within the project. The total area was checked against the sum of the subareas and it was found that the sum of the subareas was within 1% of the total area. This was determined to be within acceptable tolerance levels.

2. Post-Development (Future) Drainage Patterns and Areas

Future development conditions were based on adopted community land use plans, proposed Outer Loop Highway Drainage plans, current drainage criteria for the appropriate jurisdictions and approved master drainage plans and studies.

Flow patterns were developed by applying street patterns from similar existing subdivisions with the same zoning classification and assuming that future subdivisions will be developed in a similar pattern as the existing subdivisions in the vicinity. Street widths were established by using the City of Phoenix typical sections for the appropriate type of development; i.e. residential, commercial, industrial, etc.

## B. Hydrologic Modeling Using U.S. Army Corps of Engineers HEC-1 Flood Hydrograph Package

General. The HEC-1, Flood Hydrograph Package computer program was originally developed in 1967 by Leo R. Beard and other members of the U.S. Army Corps of Engineers, Hydrologic Engineering Center staff. The first version of the HEC-1 package program was published in October 1968. It was expanded, revised and published again in 1969 and 1970. The first package version represented a combination of several smaller programs which had previously been operated independently.

In 1973, the 1970 version of the program underwent a major revision. The computational methods used by the program remained basically unchanged; however, the input and output formats were almost completely restructured. These changes were made in order to simplify input requirements and to make the program output more meaningful and readable.

Model Philosophy. The HEC-1 model is designed to simulate the surface runoff response of a watershed to precipitation by representing the watershed as an interconnected system of hydrologic and hydraulic components. Each component models an aspect of the precipitation runoff process within a portion of the watershed commonly referred to as a subarea. A component may represent a surface runoff entity, a stream channel or a reservoir. Representation of a component requires a set

of parameters which specify the particular characteristics of the component and mathematical relations which describe the physical processes. The result of the modeling process is the computation of streamflow hydrographs at desired locations in the watershed.

Theoretical Assumptions and Limitations. A watershed is represented as an interconnected group of subareas. The assumption is made that the hydrologic processes can be represented by model parameters which reflect average conditions within a subarea. If such averages are inappropriate for a subarea, it is necessary to consider smaller subareas within which the average parameters do apply. Model parameters represent temporal as well as spatial averages. Thus, the time interval to be used should be small enough such that averages over the computation interval are applicable.

There are several important limitations of the model. Simulations are limited to a single storm due to the fact that provision is not made for soil moisture recovery during periods of no precipitation. The model results are in terms of discharge and not stage, although stages can be printed out by the program based on a user specified rating curve. Streamflow routings are performed by hydrologic routing methods and do not reflect the full St. Venant equations which are required for very flat river slopes. Reservoir routings are based on the modified Puls techniques which are not appropriate where reservoir gates are operated to reduce flooding at downstream locations.

Model Components. The stream network model is the foundation capability of the HEC-1 program. All other program computation options build on this option's capability to calculate flood hydrographs at desired locations in a watershed.

Segmentation of the watershed into a number of subareas determines the number and types of stream network components to be used in the model.

Two factors impact the basin segmentation: the study purpose and the hydrometeorological variability throughout the basin. First, the study purpose defines the areas of interest in the watershed and, hence, the points where subarea boundaries should occur.

Second, the variability of the hydrometeorologial processes and watershed characteristics impact on the number and location of subareas. Each subarea is intended to represent an area of the watershed which, on the average, has the same hydraulic/hydrologic properties. Further, the assumption of uniform precipitation and infiltration over a subarea becomes less accurate as the subarea becomes larger. Consequently, if the subareas are chosen appropriately, the average parameters used in the components will more accurately model the subareas.

Each subarea is to be represented by a combination of model components. Subarea runoff, stream routing, reservoir and diversion are available to the user.

The subareas and their components are linked together to represent the connectivity of the watershed. HEC-1 has available a number of methods for combining or linking together outflow from different components. This step finalizes the watershed schematic.

Land Surface Runoff Component. The subarea land surface runoff component is used to represent the movement of water over the land surface and in stream channels. The input to this component is the precipitation hyetograph. Precipitation excess is computed by subtracting infiltration and detention losses based on a soil water infiltration rate function. Note that the rainfall and infiltration are assumed to be uniform over the subarea. The resulting rainfall excesses are then routed by the unit hydrograph or kinematic wave techniques to the outlet

of the subarea producing a runoff hydrograph. The unit hydrograph technique produces a runoff hydrograph at the most downstream point in the subarea.

The kinematic wave rainfall excess-to-runoff transformation allows for the uniform distribution of the land surface runoff along the length of the main channel. This uniform distribution of local inflow (subarea runoff) is particularly important in areas where many lateral channels contribute flow along the length of the main channel.

Base flow is computed relying on an empirical method and is combined with the surface runoff hydrograph to obtain flow at the subarea outlet.

Stream Routing Component. A stream routing component is used to represent flood wave movement in a stream channel. The input to the component is an upstream hydrograph resulting from individual or combined contributions of subarea runoff, stream routings or diversions. If the kinematic wave method is used, the local subbarea distributed runoff is also input to the main channel and combined with the upstream hydrograph as it is routed to the end of the reach. The hydrograph is routed to a downstream point based on the characteristics of the channel.

Combined Use of Stream Routing and Subarea Runoff Components. A suitable combination of the subarea runoff component and stream routing components can be used to represent the intricacies of any rainfall runoff and stream routing problem. The connectivity of the stream network components is implied by the order in which the data components are arranged. Simulation must always begin at the uppermost subarea in a branch of the stream network. The simulation (succeeding data components) proceeds downstream until a confluence is reached. Before simulating below the confluence, all flows above that confluence must be

computed and routed to that confluence. The flows are combined at the confluence and the combined flows are routed downstream.

Reservoir Component. Use of the reservoir component is similar to that of the stream routing component. The reservoir component can be used to represent the storage-outflow characteristics of a reservoir, lake, detention pond, highway culvert, etc. The reservoir component functions by receiving upstream inflows and routing these inflows through a reservoir using storage routing methods. Reservoir outflow is solely a function of storage (or water surface elevation) in the reservoir and not dependent on downstream controls.

Diversion Component. The diversion component is used to represent channel diversions, stream bifurcations, or any transfer or flow from one point of a watershed to another point in or out of the watershed. The diversion component receives an upstream inflow and divides the flow according to a user prescribed rating curve.

Rainfall-Runoff Simulation. The HEC-1 model components are used to simulate the rainfall-runoff process as it occurs in an actual watershed. The model components function based on simple mathematical relationships are intended to represent individual meteorologic, hydrologic and hydraulic processes which comprise the precipitation, interception/infiltration, transformation of precipitation excess to subbasin outflow, addition of baseflow and flood hydrograph routing.

SCS Curve Number. The Soil Conservation Service (SCS), U.S. Department of Agriculture, has instituted a soil classification system for use in soil survey maps across the country. Based on experimentation and experience, the agency has been able to relate the drainage characteristics of soil groups to a curve number, CN (SCS, 1972 and 1975). The

SCS provides information on relating soil group to the curve number as a function of soil cover, land use type and antecedent moisture conditions.

SCS Dimensionless Unit Hydrograph. Input data for the SCS, dimensionless Unit Hydrograph method (1972) consists of a single parameter, TLAG, which is equal to the lag (hrs) between the center of mass of rainfall excess and the peak of the Unit Hydrograph.

Kinematic Wave. In determining subbasin runoff by the kinematic wave method, three conceptual elements are used: flow planes, collector channels and a main channel. The kinematic wave technique transforms rainfall excess into subarea outflow.

In the kinematic wave interpretation of the equations of motion, it is assumed that the bed slope and water surface slope are equal and acceleration effects are negligible.

Kinematic wave routing can be utilized independently of the other elements of the subarea runoff. In this case, an upstream inflow is routed through a reach (independent of lateral inflows). The kinematic wave method in HEC-1 does not allow for explicit separation of main channel and overbank areas. Theoretically, a flood wave routed by the kinematic wave technique through these channel sections is translated, but does not attenuate. Consequently, the kinematic wave routing technique is most appropriate in channels where flood wave attenuation is not significant, as is typically the case in urban areas.

Diversion. Flow diversions may be simulated by linear interpolation from input tables of inflow versus diverted flow. The inflow corresponds to an amount of flow to be diverted to a designated point in or out of the watershed. The resulting diversion hydrograph can be routed

and combined with other flows anywhere in the system network downstream of the point of diversion or to a parallel drainage system.

While the HEC-1 model has many other features than what is described in this report, only the options that are applicable to the Bell Road Project Drainage Study have been mentioned.

C. Criteria used for HEC-1 Computer Modeling

The following criteria were used for HEC-1 computer modeling:

- A 24- hour storm duration
- The City of Phoenix rainfall table for the 24-hour storm (see Table 4)
- The City of Phoenix precipitation depth values per Technical Memorandum WBTM WR-44 (see Table 5)
- Precipitation depths were not varied through the watersheds.
- City of Phoenix curve numbers (CN) based on hydrologic soil groups and zoning (see Table 6). Where areas have not been identified on this table, Greiner used the standard SCS techniques to develop curve numbers. For desert areas with a hydrologic soil Group B, 79 was used for this CN. For subareas within the Cities of Glendale and Peoria and within Maricopa County, equivalent zoning classifications were translated to the City of Phoenix zoning classifications (see Table 7) and the City of Phoenix CN based on hydrologic soil groups and zoning, were applied.

TABLE 4

CURRENT CITY OF PHOENIX ENGINEERING DEPARTMENT
24-HOUR RAINFALL DISTRIBUTION

| Time (hours) | Total Rainfall % | Time (hours) | Total Rainfall % |
|---|---|---|---|
| 0 | 0.0 | 12.5 | 83.0 |
| .5 | 0.4 | 13.0 | 86.0 |
| 1.0 | 0.8 | 13.5 | 88.0 |
| 1.5 | 1.3 | 14.0 | 89.3 |
| 2.0 | 1.8 | 14.5 | 90.7 |
| 2.5 | 2.2 | 15.0 | 92.0 |
| 3.0 | 2.6 | 15.5 | 92.4 |
| 3.5 | 3.1 | 16.0 | 92.8 |
| 4.0 | 3.5 | 16.5 | 93.3 |
| 4.5 | 4.0 | 17.0 | 93.7 |
| 5.0 | 4.4 | 17.5 | 94.2 |
| 5.5 | 4.8 | 18.0 | 94.7 |
| 6.0 | 5.3 | 18.5 | 95.1 |
| 6.5 | 5.7 | 19.0 | 95.6 |
| 7.0 | 6.2 | 19.5 | 96.0 |
| 7.5 | 6.6 | 20.0 | 96.4 |
| 8.0 | 7.1 | 20.5 | 96.9 |
| 8.5 | 7.5 | 21.0 | 97.3 |
| 9.0 | 8.0 | 21.5 | 97.8 |
| 9.5 | 9.3 | 22.0 | 98.2 |
| 10.0 | 10.7 | 22.5 | 98.7 |
| 10.5 | 12.0 | 23.0 | 99.1 |
| 11.0 | 14.0 | 23.5 | 99.5 |
| 11.5 | 17.0 | 24.0 | 100.0 |
| 12.0 | 50.0 | | |

**TABLE 5**

**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

TABLE 6

CITY OF PHOENIX CURVE NUMBERS
BASED ON SOILS AND ZONING

| Zoning | Curve Numbers for Soil Type | | |
|---|---|---|---|
| | Type B | Type C | Type D |
| RE-43)<br>S-1 ) | 79 | 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 )<br>R -40)<br>R -5 ) | 86 | 89 | 91 |
| A -1 )<br>A -2 ) | 88 | 91 | 93 |
| C -1 )<br>C -2 )<br>C -3 ) | 92 | 94 | 95 |
| CO | 88 | 91 | 93 |
| PSC | 95 | 95 | 95 |
| HR | 95 | 95 | 95 |
| R4A | 87 | 90 | 92 |

# TABLE 7

## ZONING CLASSIFICATIONS FOR GOVERNMENTAL AGENCIES WITHIN THE WATERSHED AREAS

### PHOENIX

| Zoning | Use | Units/Acre |
|---|---|---|
| S 1 | Ranch or Farm Residence | |
| S 2 | Ranch or Farm Commercial | |
| RE-43 | Single Family Residence 43,560 Sq. Ft. Lots Minimum | 1.0 |
| RE-35 | Single Family Residence 1.10 Dwellings/Acre Base Density | 1.1 |
| RE-24 | Single Family Residence 24,000 Sq. Ft. Lots Minimum | 1.8 |
| R1-18 | Single Family Residence 1.95 Dwellings/Acre Base Density | 1.95 |
| R1-14 | Single Family Residence 14,000 Sq. Ft. Lots Minimum | 3.11 |
| R1-10 | Single Family Residence 3.50 Dwellings/Acre Base Density | 3.5 |
| R1-8 | Single Family Residence 4.30 Dwellings/Acre Base Density | 4.3 |
| R1-6 | Single Family Residence 5.30 Dwellings/Acre Base Density | 5.3 |
| R-2 | Multi-Family Residence 10.0 Dwellings/Acre Base Density | 10 |
| R-3 | Multi-Family Residence 14.5 Dwellings/Acre Base Density | 14.5 |
| R-3A | Multi-Family Residence 22.0 Dwellings/Acre Base Density | 22.0 |
| R-4 | Multi-Family Residence 29.0 Dwellings/Acre Base Density | 29.0 |
| R-4A | Multi-Family Residence 43.5 Dwellings/Acre Base Density | 43.5 |
| R-5 | Multi-Family Residence 43.5 Dwellings/Acre Base Density | 43.5 |
| P.A.D. 1-15 | Planned Area Development District | |
| RH | Resort District 20/Acre Minimum 50 Guest Rooms | |
| RO | Residential Office | |
| CO | Commerical Office District Restricted Commercial | |
| C-1 | Neighborhood Commercial | |
| C-2 | Intermediate Commercial | |
| C-3 | General Commercial | |
| M-R | Mid-Rise District Limited to 190' | |
| H-R | High Rise District Limited to 250' | |
| H-RI | High Rise District (Downtown) | |
| P.S.C. | Planned Shopping Center | |
| R.S.C. | Regional Shopping Center | |
| Ind. Pk. | Industrial Park | |
| A-1 | Light Industrial | |
| A-2 | Heavy Industrial | |
| P-1 | Parking (Open) | |
| P-2 | Parking (Structures) | |
| P-C | Planned Community | |
| S-P | Special Permit | |
| C/Z | Conditional Zoning | |

### MARICOPA COUNTY

| Zoning | Use | Units/Acre |
|---|---|---|
| RURAL 190 | Rural Zoning District 190,000 Sq. Ft. Per Dwelling Unit | 0.23 |
| RURAL 70 | Rural Zoning District 70,000 Sq. Ft. Per Dwelling Unit | 0.62 |
| RURAL 43 | Rural Zoning District One (1) Acre Per Dwelling Unit | 1.0 |
| R1-35 | Single Family Residential Zoning District 35,000 Sq. Ft. Per Dwelling Unit | 1.24 |
| R1-18 | Single Family Residential Zoning District 18,000 Sq. Ft. Per Dwelling Unit | 2.42 |
| R1-10 | Single Family Residential Zoning District 10,000 Sq. Ft. Per Dwelling Unit | 4.36 |
| R1-8 | Single Family Residential Zoning District 8,000 Sq. Ft. Per Dwelling Unit | 5.45 |
| R1-7 | Single Family Residential Zoning District 7,000 Sq. Ft. Per Dwelling Unit | 6.22 |
| R1-6 | Single Family Residential Zoning District 6,000 Sq. Ft. Per Dwelling Unit | 7.26 |
| R-5 | Multiple Family Residential Zoning District | 43.5 |
| R-4 | Multiple Family Residential Zoning District | 21.80 |
| R-3 | Multiple Family Residential Zoning District | 14.52 |
| R-2 | Two-Family Residential Zoning District | 10.89 |
| C-1 | Neighborhood Commercial Zoning District | |
| C-2 | Intermediate Commercial Zoning District | |
| C-3 | General Commercial Zoning District | |
| C-S | Planned Shopping Center Zoning District | |
| C-O | Commerical Office Zoning District | |
| IND-1 | Planned Industrial Zoning District | |
| IND-2 | Light Industrial Zoning District | |
| IND-3 | Heavy Industrial Zoning District | |
| SU | Special Uses | |
| NUP | Neighborhood Plan of Development | |
| RUP | Residential Plan of Development | |
| SC | Senior Citizen Overlay | |
| MHR | Manufactured House Residential Zoning District | |

### GLENDALE

| Zoning | Use | Units/Acre |
|---|---|---|
| A-1 | Agricultural Residence | 1.0 |
| SR-30 | Suburban Residence | 1.45 |
| SR-17 | Suburban Residence | 2.56 |
| SR-12 | Suburban Residence | 3.63 |
| R1-10 | Single Family Residence | 4.36 |
| R1-8 | Single Family Residence | 5.45 |
| R1-7 | Single Family Residence | 6.22 |
| R1-6 | Single Family Residence | 7.26 |
| R-2 | Two Family Residence | 14.52 |
| R-3 | Multi Family Residence | 43.50 |
| R-4 | Multi Family Residence | 43.50 |
| C-0 | Commercial Office | |
| C-1 | Neighborhood Retail | |
| C-2 | General Commercial | |
| C-3 | Unlimited Commercial | |
| M-P | Industrial Park | |
| M-1 | Light Industrial | |
| M-2 | Heavy Industrial | |
| P.A.D. | Planned Area Development | |
| P.R.D. | Planned Residential Development | |
| T.D. | Trailer District | |

### PEORIA

| Zoning | Use | P.A.D. DISTRICTS | MAXIMUM DWELLING UNITS PER GROSS ACRE |
|---|---|---|---|
| R1-35 | Single Family Residential 35,000 Sq. Ft. Lots Minimum | P.A.D.-1 | 0.75 |
| | | P.A.D.-2 | 1.00 |
| R1-18 | Single Family Residential 18,000 Sq. Ft. Lots Minimum | P.A.D.-3 | 1.35 |
| | | P.A.D.-4 | 1.75 |
| R1-8 | Single Family Residential 8,000 Sq. Ft. Lots Minimum | P.A.D.-5 | 2.20 |
| | | P.A.D.-6 | 2.75 |
| R1-7 | Single Family Residential 7,000 Sq. Ft. Lots Minimum | P.A.D.-7 | 3.50 |
| | | P.A.D.-8 | 4.75 |
| R1-6 | Single Family Residential 6,000 Sq. Ft. Lots Minimum | P.A.D.-9 | 6.00 |
| | | P.A.D.-10 | 8.00 |
| RM-1 | Multiple Residential | P.A.D.-11 | 10.00 |
| RMH-1 | Residential Mobile Home Park | P.A.D.-12 | 12.00 |
| RMH-2 | Mobile Home Park | P.A.D.-13 | 14.50 |
| O-1 | Offices | P.A.D.-14 | 29.00 |
| C-1 | Convenience Locations | P.A.D.-15 | 43.50 |
| C-2 | Intermediate Commercial | | |
| C-3 | Central Commercial | | |
| C-4 | Highway Commercial | | |
| PC-1 | Planned Community Commercial | | |
| I-1 | Light Industrial | | |
| I-2 | Heavy Industrial | | |
| AG | General Agriculture | | |
| PUD | Planned Unit Development | | |

- Two different lag time equations were used depending on the size and shape of the subarea.

  For large and/or elongated watersheds, the equation below was used. This is based on the modified Snyders equation:

$$Lag = 24n(LL_{ca}/s^{0.5})^{0.38}$$

where L = the length of the longest watercourse (in miles)

$L_{ca}$ = the upstream length along the longest watercourse to a point opposite the subbasin centroid (in miles)

s = the overall slope of the longest watercourse, from headwater to concentration point (in feet/mile)

n = the overland flow roughness factor for the subbasin

Lag = lag time (in hours)

Values of "n" for the above equation are as follows:

"n" values for undeveloped areas:

0.05 where slopes > 0.04'/ft
0.035 slopes from 0.01 to 0.04'/ft
0.030 slopes flatter than 0.01'/ft

"n" values for developed areas:

0.022 3-5 houses/acre
0.030 1-2 houses/acre
0.020 multiple residential and light commercial

For small watersheds of regular shape, the following equation was used. This is based on the SCS modified curve number method:

$$\text{Lag} = \frac{L^{0.8}(1000/CN - 9)^{0.7}}{(1900)s^{.5}}$$

where L = length of the longest watercourse (in feet)

s = the overall slope of the longest watercourse, from headwater to concentration point (in percent)

Lag = lag time (in hours)

Adjustments to lag time for this equation based on percent of the hydraulic length that has been modified and the percent of impervious area were made per SCS Technical Release 55, pages 3-8 and 3-9 (see Figures 1 and 2 and Table 8).

- Different flow patterns and routing paths for different storm frequencies were evaluated and utilized based on calculating peak flows and capacities of the facilities.

- For modeling post-development (future) conditions, the master drainage plans were used. Where storm sewers or basins were proposed, flows were diverted into these facilities using the design capacities as specified in the respective studies. Proposed basins were modeled using routing techniques. All governmental agencies were contacted to verify that these storm drainage master plans will be followed. See Section VIII.B for further details.

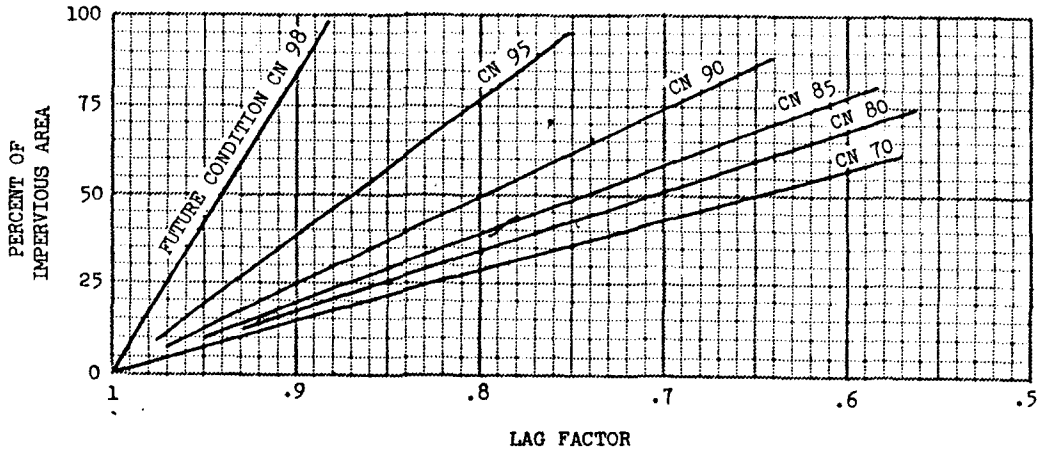



Figure 1 -- Factors for adjusting lag when the main channel has been hydraulically improved.

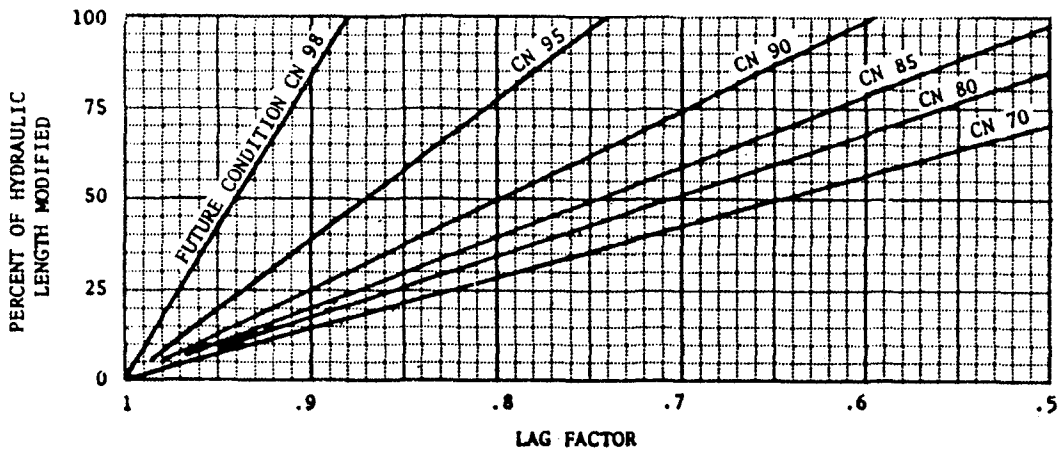



Figure 2 -- Factors for adjusting lag when impervious areas occur in the watershed.

## TABLE 8

## ESTIMATING THE PERCENT OF IMPERVIOUS COVER FOR DEVELOPED AREAS

| *Type of Development Anticipated in Watershed | Percent of Impervious Cover Minimum | Average | Maximum |
|---|---|---|---|
| Suburban: | | | |
| (a) Less than 1 house/acre | 5% | 10% | 20% |
| (b) 1 house/acre | 15% | 20% | 25% |
| (c) 2 houses/acre | 25% | 30% | 35% |
| Light to Moderate Urbanization: | | | |
| (a) 3 houses/acre | 30% | 35% | 40% |
| (b) 4 houses/acre (detached) | 35% | 40% | 45% |
| (c) 5 houses/acre (detached) | 45% | 50% | 55% |
| Highly Urbanized: | | | |
| (a) Multiple Dwellings (4 units/acre, or more) | 50% | 65% | 90% |
| (b) Light Industrial & Commercial | 50% | 65%-75% | 80% |
| (c) Heavy Industrial & Commercial | 80% | 85%-95% | 100% |

*It is assumed, in all cases, that paved streets are adjacent to at least one side of a developed lot.

- For modeling post-development (future) conditions for commercial areas 1/4 of a square mile in area or over, the retention policy developed in the Drainage Policies and Standards for Maricopa County, Arizona was utilized. Runoff will be retained from a rainfall event up to and including the 100-year, 2-hour duration storm falling within its boundaries.

- The coefficients "K" and "X" for Muskingum routing were developed from the techniques as described in Introduction to Hydrology.

All other criteria used for HEC-1 modeling is specified in the remaining sections.

D. Development of HEC-1 Input

The HEC-1 Flood Hydrograph Package has many input component options. This section documents the input components used for hydrologic modeling for this study. Modeling techniques and methods are described in Section VII.E.

Job Initialization. The "IT" card was used to define the time interval of ten minutes and the number of hydrograph ordinates to be computed (300 were used). The "IN" card was used to define the time interval of 0.5 hours for reading the "PC" card (cumulative precipitation time series). When the time series data is read from the "PC" card, values are computed internally using linear interpolation to match the tabulation interval on the "IT" card.

Precipitation Data. A precipitation hyetograph is used as the input for all runoff calculations. The synthetic storm used for input was the Current City of Phoenix Engineering Department 24-Hour Rainfall Distribution (see Table 4). The "PC" card was used to input this precipitation mass curve. The "PB" card was used to define the total

storm, basin-average precipitation values in inches. The values used for this study were derived from the Phoenix WBO Records (24-hour duration storm) (see Table 5). The "PC" values for precipitation were used as a distribution pattern for the storm amount. The "PH" card was used to compute a hypothetical storm for determining the 100-year, 2-hour volume requirements for commercial retention basins. The total storm is automatically distributed according to the specified depth duration data and a triangular precipitation distribution was constructed such that the depth occurs during the central part of the storm.

Loss Rate Data. Precipitation loss is calculated based on the curve number (CN) and is input using the "LS" card.

Unit Graph Data. Input data for the SCS dimensionless Unit Hydrograph method was used in areas where street flow patterns have not been developed. The "UD" card is used where this method is applied. The "UK" and "RK" cards are used to define the characteristics for kinematic wave routing of precipitation excess to the subbasin outlet. The "UK" card defines overland flow and the "RK" card defines the collector and or main channel used for routing.

Basin Data. The "BA" card was used for subbarea runoff computation and for direct input of hydrographs. The main component for this card is the drainage area in square miles. The "BF" cards were used to define the base flow parameter for the outlet structures for Adobe and Cave Creek dams. No flow recession was assumed for our models.

Hydrograph Transformation. The "HC" card was used to calculate hydrograph combination.

Routing Data. The "RM" card was used to perform the Muskingum routing method. This method was used for routing on Cave Creek, Skunk Creek and Scatter Wash. Input components are "AMSKK" ("K" value) which is the

total travel time through the reach in hours, and "X" which is the Muskingum weighting factor ($0 \leq x \leq .5$). Routing procedures were repeated for several subreaches defining the integer steps equal to the number of subreaches. The "RS" card was used to perform storage discharge routing for detention basins, retention basins, the depressed roadway sections under I-17 and for outlet structures along the Central Arizona Project Canal embankment. A storage-discharge relationship was input using the reservoir volume versus discharge relationships as explained in the Storage Routing Data. The "RK" card was used for kinematic wave routing as explained earlier in Unitgraph Data.

Storage Routing Data. All storage routing was performed using the modified Puls routing method. This method determines the outflow rate based on either a pipe or weir discharge coefficient, times the length of the spillway crest (feet) or the cross sectional area of the discharge pipe (square feet) times the head above the free outlet elevation or the spillway crest (feet) to the power of the theoretical exponent. The components used for storage routing are the "SE", "SQ" and "SV" cards to describe elevation (feet), discharge (cfs) and volume (ac - ft). The "SL" card was used to describe the flow through a low level outlet along with an "SS" card to compute the flow for weir or ogee spillways. The "SL" card describes the elevation of the low level outlet, the cross-sectional area, the discharge coefficient and the exponent of head. The "SS" card describes the spillway crest elevation, the spillway length, the discharge coefficient and the exponent of head.

Diverson Data. The "DT", "DI" and DQ" cards were used for flow diversions. The "DT" card is a diversion identifier card and names the diverted flow for future retrieval. The "DI" card specifies the inflow in cfs to the diversion location and the flow to be diverted. The "DG" card specifies the rate of flow in cfs to be diverted. The "DR" card was used to retrieve previously diverted flows.

Hydrograph Data. The "QI" card was used to input a hydrograph directly (without rainfall - runoff computation) at any point in the river network.

## E. Modeling Techniques and Methods

This section describes the HEC-1 modeling techniques and hydrologic/hydraulic computation methods used for this study.

General Modeling. For modeling simplicity the total watershed area contributing to Bell Road from Grand Avenue to Scottsdale Road was divided into ten major drainage areas (see Exhibit 1). These areas were further divided into major subbasins. Each major subbasin was modeled generating the first runoff hydrograph in the uppermost reach of this subbasin for a specific subarea. The runoff from this subarea was then routed downstream to the concentration point of another subarea. The runoff hydrograph at this point was then calculated for the next subarea by methods employing either the unit hydrograph or kinematic wave techniques. Both hydrographs are then combined and either routed downstream or diverted and then routed. At each concentration point the peak flow was analyzed for diversion potential. Where diversion took place between the boundaries of two subbasins or if flows were routed from one major drainage area to another, the outflow hydrograph was directly input into the other subbasin or major drainage area model.

Storm Water Routing Procedure. Various routing procedures were required in modeling runoff hydrographs through the drainage areas. Specific procedures were required for routing through the Central Arizona Project Canal embankment, the depressed roadway sections under I-17, through retention basins and street flow routing with diversions. These procedures are described in detail below.

Central Arizona Project Canal Embankment Routing. A number of concrete and steel pipe overchutes convey upstream runoff across the Central Arizona Project Canal between Scatter Wash and Cave Creek Wash. The Bureau of Reclamation provided Greiner with locations and pipe geometry data as well as elevation-storage data for the ponding area behind the overchute inlets. Elevation and storage data are input on "SE" and "SV" cards, respectively. Overchute data was input on the "SL" card.

Concrete flume crossings are located at Scatter Wash and Cave Creek. These structures were designed to convey the 100-year discharge. No special provisions were required for routing.

Depressed Roadway Sections Under I-17 Routing. The depressed roadway sections of Union Hills Drive and Bell Road under I-17 are flooded during storm events greater than the 2-year storm. Flooding occurs when either street conveyance capacities east of I-17 are exceeded or the capacities of the culverts under I-17 north of the depressed roadway sections are exceeded.

It was determined from topographic analysis and field observations that the flooded sections will discharge excess flows southwestward.

The storage capacities of the depressed roadway sections were calculated from I-17 as-built drawings and 1" = 100' scale topographic maps. The modified Puls routing ("RS", "SV", "SE" cards) technique was used to route flows through the depressed roadway sections.

Retention Basin Routing. Hydrographs were routed through existing retention facilities using the modified Puls method as previously described. A procedure was also developed for routing hydrographs through retention basins that will be constructed by future development of currently vacant commercial or industrial areas greater than 0.25 square miles.

A proposed retention ordinance that is expected to be adopted throughout the study area requires on-site retention of the 100-year, 2-hour storm runoff volume. This volume was calculated by using a total storm depth of 2.75 inches. This value was distributed according to the procedure described in the "National Oceanic and Atmospheric Administration, Atlas 2, Volume VIII - Arizona, Precipitation Frequency Atlas of the Western United States, Washington, D.C."

Future retention facilities were assumed to be rectangular in shape and to have a uniform ponding depth of three feet. An additional foot was added for freeboard. The required basin area was calculated by the following formula:

$$\text{Area (Sq Ft.)} = \frac{\text{Volume(ac-ft)} \times 43{,}560}{\text{4(ft)deep}}$$

The modified Puls routing routine was used to model the effects of the retention basins on the 24-hour storm events.

Street Flow Routing and Diversions. The conveyance of storm runoff within the street is an important element in the hydrograph routing

routine. Street conveyance capacities were calculated using the Manning's equation for normal depths of flow. A Manning's roughness coefficient of .016 was used for asphalt paved streets. Capacities were calculated for typical City of Phoenix street cross sections as shown in the Phoenix Supplemental Standard Details for Public Works Construction, 1981. Capacities were calculated for typical streets with varying depths of flow and longitudinal slopes.

Beginning with the 100-year storm event, calculated peak flow values were compared with the street capacity at each location. If the discharge exceeded the street capacity a determination was made as to whether excess flows would remain within the same general flow path or whether a diversion would occur. Several factors were taken into consideration in this evaluation including the street cross section, the longitudinal slopes and the amount of runoff in excess of the street capacity. Local features such as the adjacent flow pattern or obstructions to flow in either the main flow path or within the diverted flow path were considered. The HEC-1 divert ("DT", "DI" and "DQ") commands were used. This procedure was repeated at all major half-mile and mile street intersections or where a major wash crossed a street.

For post-development (future) conditions, the divert commands were used to reflect the interception of flows into the proposed storm drains and channels. Flows up to the conveyance capacity values specified in the various master drainage studies were routed into the storm drain systems. Flows in excess of the storm drain capacity remained within the street.

## VIII. HYDROLOGIC MODELING

The hydrologic modeling for the study area is separated into existing conditions and post-development (future) conditions. Each condition was analyzed for the 2-, 5-, 10-, 50- and 100-year, 24-hour storm events.

The Agua Fria River and New River watersheds were not modeled in the Bell Road Project Drainage Study. Federal Emergency Management Agency and U.S. Army Corps of Engineers studies were used to establish the peak discharges at Bell Road along these rivers. These discharges will be used in the evaluation of alternative stormwater plans for the areas contributing to the Agua Fria and New River.

Sun City West and portions of Sun City discharge directly into the Agua Fria River and were not included in the hydrologic analysis for the Bell Road Project Drainage Study.

Cave Creek and Skunk Creek were modeled for future conditions only because all alternative concepts for this study will be based on future development conditions. The models will only be used as a comparison to analyze potential impacts of the proposed facilities.

Existing Conditions. The study consists of ten major drainage areas. Subareas were delineated and hydrologic/hydraulic parameters were established. Land use, channel geometry, drainage paths and points of diversion were analyzed to subdivide the drainage areas. Flows were first routed through a common flow path and then evaluated for split flows.

Exhibit 2 is the sheet index for the hydrology exhibit maps. Exhibit 3A shows the delineated subareas for existing conditions. The runoff for each subarea is summarized in Tables 9 through 13 in Appendix B.

Future Conditions. The ten major drainage areas were divided into subareas based on land use, channel geometry, drainage paths and points of diversion. The future development conditions were based on adopted community land use plans, proposed Outer Loop Highway drainage plans, current drainage criteria for the appropriate jurisdiction and approved master drainage plans and studies.

Zoning maps were used in conjunction with the City of Phoenix method of developing curve numbers based on zoning and soil group to establish curve numbers for future conditions. Flow patterns were developed by applying street patterns from existing subdivisions with the same zoning classification and assuming that future subdivisions will be developed in a similar pattern as the existing subdivisions in the vicinity. Street widths were established using the City of Phoenix typical sections for the appropriate type of development. Points of diversion were established by using the adopted storm sewer alternate from the appropriate drainage master study and diverting flows into these proposed storm sewers.

Exhibit 3B shows the delineated subareas for post-development (future) conditions. The runoff for each subarea is summarized in Tables 14 through 18, in Appendix B.

## A. Existing Conditions

Drainage Area 1: Drainage Area 1 is primarily the right-of-way for the Atchison Topeka-Sante Fe Railroad and Grand Avenue. Flows originate from the northwest and flow to the southeast between Grand Avenue and the railroad embankment and between the railroad embankment and the masonry fence on the west edge of Sun City West. The area east of the railroad embankment is divided into two parts because the northern

portion on the east side of the railroad embankment is diverted to the west side through a culvert and then continues to flow south between Grand Avenue and the railroad.

The flow that drains the area between Grand Avenue and the railroad crosses under Bell Road through a 24 inch reinforced concrete pipe (RCP). The flow between the railroad and the west edge of Sun City West drains through a 36 inch RCP under Bell Road. The construction facility adjacent to Sun City West drains through a 24 inch RCP under Bell Road.

Flow patterns for all storm events are the same for existing conditions due to the constraints imposed by Grand Avenue, the railroad embankment and the masonry fence on the west side of Sun City West.

The Corps of Engineers method to calculate lag time was used because of the elongated shape of the subareas.

Drainage Area 2: Flow patterns within Sun City were determined from the Sun City Drainage Master Plan. Flows concentrate in a gunite channel which drains the west part of Sun City and flows under Bell Road at 115th Avenue. The rest of Sun City drains to a gunite channel which flows to Bell Road at 99th Avenue. The flow pattern at Bell Road is the same for each storm event because the area drains to the gunite channel.

The golf course areas were modeled using the SCS Unit Graph method and the Corps of Engineers method for calculating lag time. The remaining area runoff calculations were performed using the kinematic wave method.

The northern portion of Drainage Area 2 drains from north to south and is mainly sheet flow.

The Westbrook Village development in Section 28, Township 4 North, Range 1 East, has provided a retention area with a volume of 427 acre-feet within the golf course. All of the area north of Section 28, Township 4 North, Range 1 East within Drainage Area 2 drains to this retention facility. The remaining portion of Area 2 drains southward along 91st Avenue.

Split flows were not used for areas outside of the Sun City area. Concentration points are along 91st Avenue.

Drainage Area 3: 75th Avenue and a depression parallel to and approximately 1300 feet west of 75th Avenue were identified as the major collectors of runoff conveying flows to Bell Road. Drainage patterns were not changed for the various frequencies evaluated. According to the Master Drainage Report for Arrowhead Ranch prepared in 1982, the development's lake system and grading scheme will divert flows westward to the New River north of Union Hills Drive. A drainage channel along the 71st Avenue alignment intercepts flows from the east and conveys them southward to Skunk Creek above Bell Road.

Drainage Area 4: The runoff pattern north of Union Hills Drive is directed west in the inverted crown street (Union Hills Drive) to Skunk Creek. A concrete-lined channel was designed to convey flows from Drainage Area 5 into Union Hills Drive. A pumping station is located at the depressed roadway section under I-17 at Union Hills Drive. The maximum pumping rate, pumping flows to the west, is approximately 50 cfs. Immediately east of Skunk Creek, runoff flows to the west into Skunk Creek.

All stormwater runoff south of Union Hills Drive flows south to Bell Road at 35th Avenue, 43rd Avenue, 51st Avenue, 59th Avenue and 67th Avenue.

A concrete-lined channel was designed to convey flows from Drainage Area 5 to Drainage Area 4. Runoff flows south crossing Bell Road away from Drainage Area 4.

For the 2-, 5- and 10-year storm events, drainage for the area north of Union Hills Drive was conveyed west by Union Hills Drive to Skunk Creek. Some flows for the area south of Union Hills Drive were diverted westward from the general drainage pattern through the major half-mile streets.

For the 50 and 100-year storms, flows exceed the street capacity of Union Hills Drive and some flows were diverted southward along 31st Avenue, 35th Avenue and 39th Avenue.

Reservoir routing was applied to the existing Bellair Golf Course which is located north of Bell Road between 43rd Avenue and 51st Avenue.

Drainage Area 5: Drainage for the area east of Seventh Avenue flows into Cave Creek. Flows west of 19th Avenue are directed through existing culverts under I-17. These culverts are located at Behrend Drive, Utopia Road, Union Hills Drive and Bell Road. The flow for the area between Seventh Avenue and 19th Avenue is conveyed south to Cave Creek along 19th Avenue. The 90 inch storm drain along 19th Avenue was incorporated into the routing.

The flow pattern for the drainage areas above Beardsley Road to north of the Central Arizona Project Canal is dominated by desert sheet flow patterns and flow in minor washes. Major streets including 23rd Avenue, 19th Avenue, 15th Avenue and Seventh Avenue intercept these flows and convey them southward across Beardsley Road. Runoff from above the Central Arizona Project Canal was routed through the Canal embankment as described in Section VII.E. The flow patterns were not varied for the various frequency storm events.

The capacities of the four existing culverts along I-17 were calculated based on Hydraulic Charts for the Selection of Highway Culverts, Hydraulic Engineering Circular No. 5 by the U.S. Department of Transportation, 1965. Culverts were assumed flowing with inlet control. Flows were routed through these culverts based on the capacity calculations. Flows exceeding the culverts' capacity were routed south along I-17 embankment.

For the 2-year storm, some flows were diverted from the general westward drainage pattern through the major half-mile streets. The four culverts at I-17 were determined to have adequate capacities to convey the 2-year storm.

For the 5 and 10-year storm events, flows exceeded the total capacities of the culverts. Floodwaters were routed southward through frontage roads and streets, flooding the depressed interchange sections at Union Hills Drive and Bell Road. The storage-discharge method for reservoir routing was used to analyze the outflows. The depressed roadway sections were modeled as major collectors of stormwater, conveying runoff west into Drainage Area 4.

For the 50- and 100-year storm events, minor flows were routed south on 15th Avenue and 20th Avenue at Bell Road.

Drainage Area 6: The kinematic wave method was used to calculate runoff for 2.3 square miles of subareas that were fully developed. The SCS Unit Graph method was used to calculate runoff for 1.7 square miles of undeveloped area. Most of the major channelization through the developed areas is in the form of collector streets.

Flow patterns for Drainage Area 6 were determined from field investigations, topographic maps, aerial maps and Off-Site Hydrology, Existing Conditions, Outer Loop Highway, Bell Road to Central Arizona Project Canal Crossing.

Natural gullies convey runoff from the mountain areas between 12th Street and 16th Street north of Union Hills Drive. Street flow in the urban areas was modeled taking into consideration the street geometry and slope. Natural and manmade channels are found throughout the drainage area. Major mile and half-mile streets that collect storm water are Central Avenue, Seventh Street, Ninth Street, 12th Street and 16th Street.

Flow splits for the larger storm events were evaluated at Seventh Street and Union Hills Drive, Seventh Street and Grovers Avenue, Second Street and Grovers Avenue, 12th Street and Marco Polo Road, Ninth Street and Grovers Avenue, 20th Street and Michigan Avenue and 16th Street and Campobello Drive.

Runoff concentrates along Bell Road at several locations. At 16th Street, minor flows are contained in a channel on the west side. Major flows will spill out of the channel into the intersection of 16th Street and Bell Road. At 500 feet east of 12th Street, minor flows are contained in a small channel and the larger flows spill out of the channel into Bell Road. At 12th Street the same condition exists; minor flows are confined to a channel and large flows are carried to the west by Bell Road. Flows at Ninth Street are conveyed to Seventh Street where they flow into the storm drain system at Seventh Street. Flow concentrating at Seventh Street and Bell Road are carried in the street and in the storm sewer. About 500 feet east of Central Avenue, flows concentrate at a 10' x 5' box culvert. At Central Avenue, flows coming down Central Avenue are directed to a two- 10' x 5' culvert under Bell Road. Just east of Seventh Avenue, flows are concentrated at a two- 6' x 4' box culvert.

Drainage Area 7: Drainage Area 7 is the tributary area to the East Fork of Cave Creek. The main channel of the wash is generally poorly defined except where channelization work has been undertaken in conjunction with development. Large flows discharge across Bell Road as sheet

flow between 14th and 20th Streets. Diversions from Drainage Area 7 in Drainage Area 6 were modeled for larger flow events.

Drainage Area 7 was sub-divided into two major subareas. One major subarea is a tributary to the East Fork of Cave Creek above Bell Road and the other is a tributary to the East Fork of Cave Creek south of Bell Road. The first major subarea discharges across Bell Road between 16th Street and 20th Streets. The second major subarea has multiple discharge points located between 21st Street and 23rd Street, at 25th Street, 28th Street and 32nd Street. For the 2-year and 5-year storm events, the flow pattern is dominated by the north-south streets. Flows in the East Fork of Cave Creek were modeled as being contained within the floodway. For the larger frequency events flow diversion to the west begins to occur. Major diversions were modeled at Union Hills, Michigan Avenue, Grovers Avenue and Campobello Drive. Most diverted flows will flow west and then turn southward through low lying developments or open areas, eventually entering the East Fork of Cave Creek floodway. The majority of these flows will turn southward east of 16th Street. Flows were modeled to cross 16th Street at Grovers Avenue and Campobello Drive.

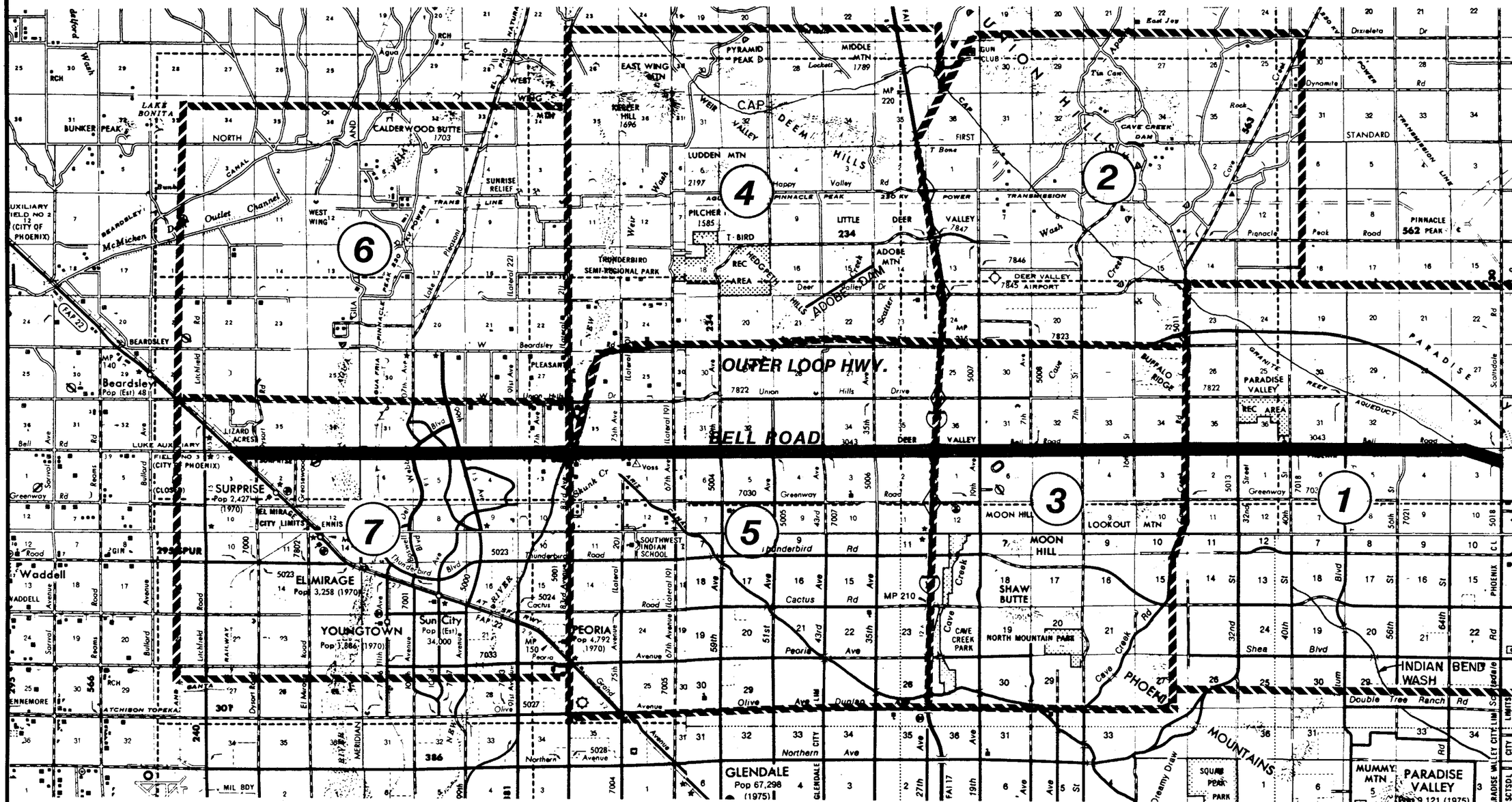
According to the 100-year floodway boundary map for the East Fork of Cave Creek, the floodplain limits within Drainage Area 7 extend along Bell Road from approximately 16th Street to 21st Street. No attempt was made in this phase of the study to perform a hydraulic analysis to determine discharges at intermediate locations between 16th and 21st Streets.

Drainage Area 8: Fortieth Street and Tatum Boulevard are the major north-south collectors of runoff in Drainage Area 8. Eighteen other concentration points at Bell Road were identified for the purpose of runoff modeling, including a major drainageway located approximately 2400 feet east of 32nd Street.

Modifications for routing flows were not necessary. Runoff for the various frequency storm events are well defined from north to south and stay within the major streets.

Drainage Area 9: Drainage Area 9 was modeled for future conditions only, as previously explained.

Drainage Area 10: Drainage Area 10 was modeled for future conditions only, as previously explained.




Revisions

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**BELL ROAD PROJECT**

DRAINAGE STUDY

HYDROLOGY SHEET INDEX MAP

Date JAN. 1987

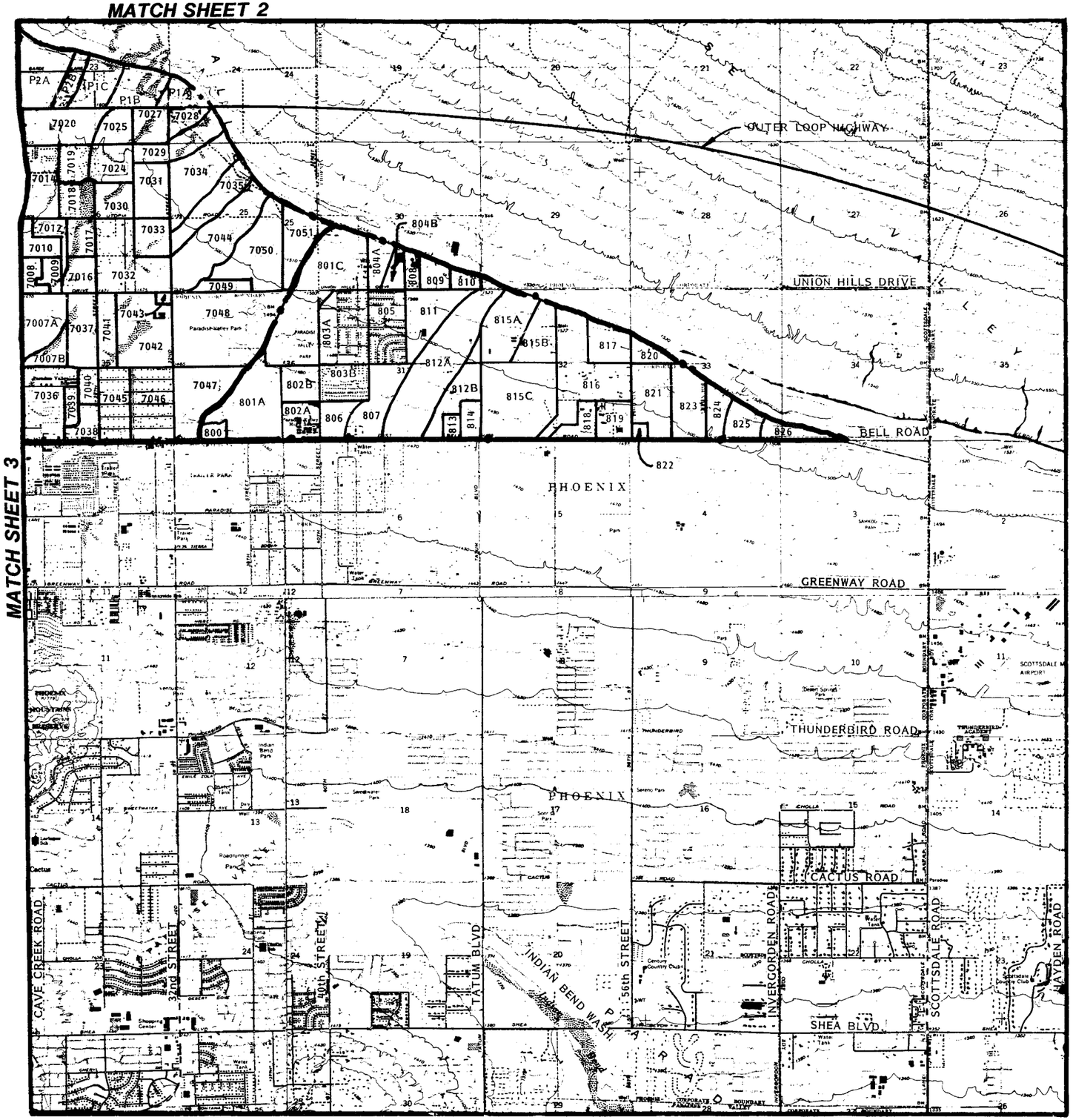
Job No. E123061

Sheet — of —

EXHIBIT 2

MATCH SHEET 2

MATCH SHEET 3




LEGEND

201 - SUB AREA NUMBER

- MAJOR DRAINAGE AREA

- SUB AREA BOUNDARY

0' 4000'

Scale 1" = 4000'

Revisions

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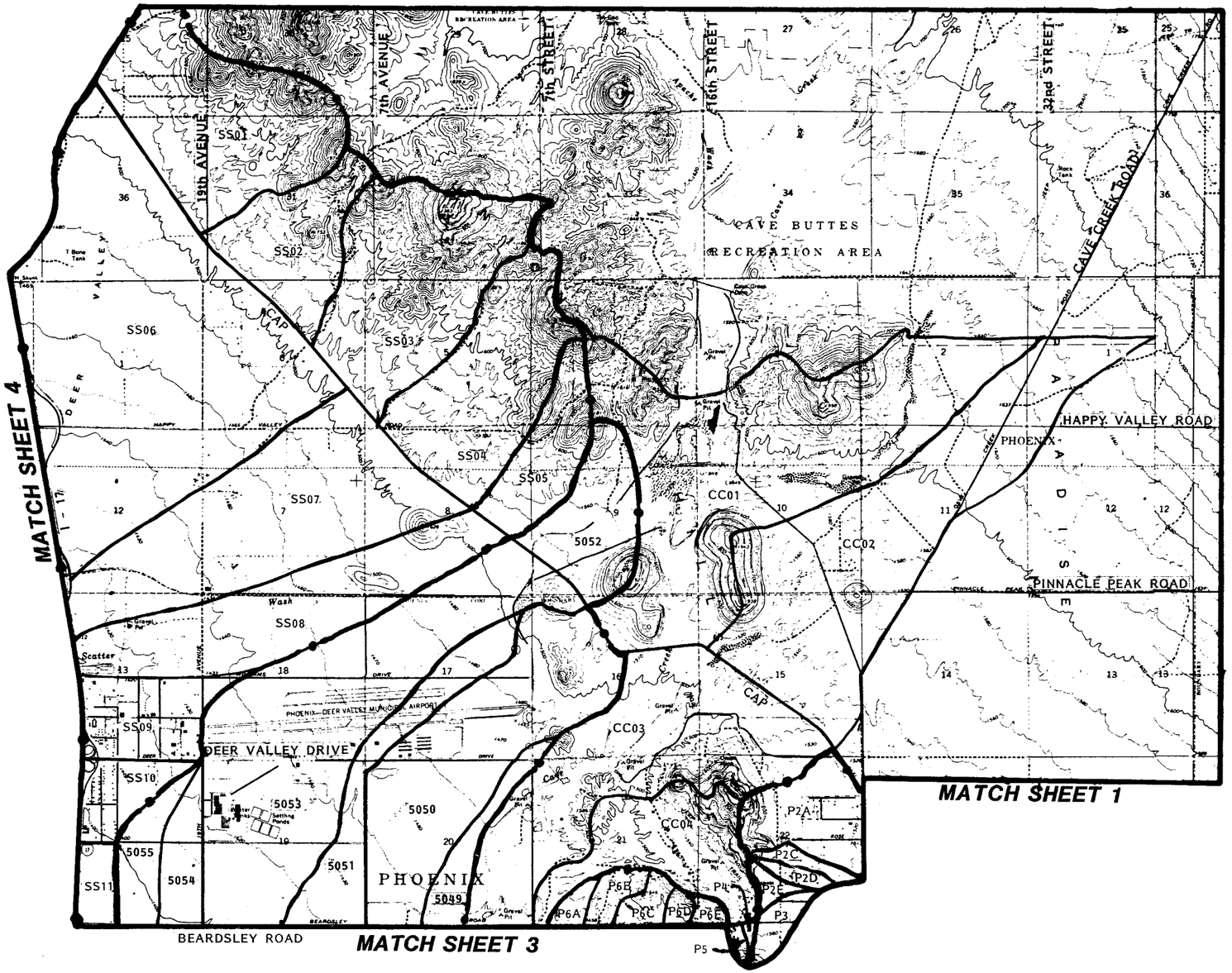
**BELL ROAD PROJECT**

**DRAINAGE STUDY**

HYDROLOGY EXHIBIT FOR EXISTING CONDITIONS

| | |
|---|---|
| Date | JAN. 1987 |
| Job No. | E123061 |
| Sheet | 1 of 7 |

EXHIBIT 3A




LEGEND

201 - SUB AREA NUMBER
- MAJOR DRAINAGE AREA
- SUB AREA BOUNDARY

0' 4000'
Scale 1" = 4000'

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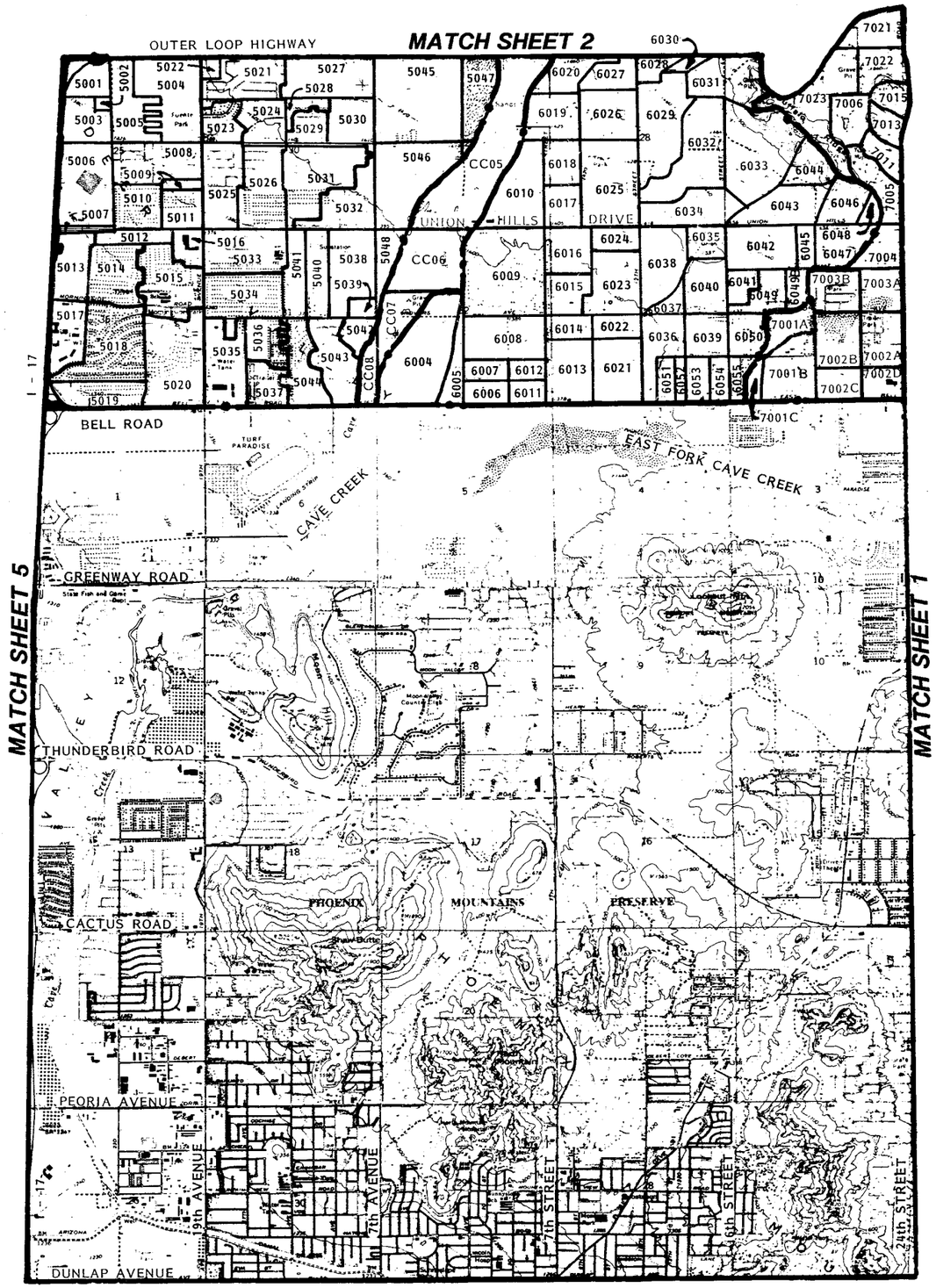
Check J.S.S.
Scale 1" = 4000'

**BELL ROAD PROJECT**
**DRAINAGE STUDY**
HYDROLOGY EXHIBIT FOR EXISTING CONDITIONS

Date JAN. 1987
Job No. E123061
Sheet 2 of 7

**EXHIBIT 3A**




LEGEND

201 - SUB AREA NUMBER
- MAJOR DRAINAGE AREA
- SUB AREA BOUNDARY

0' 4000'
Scale 1" = 4000'

Revisions

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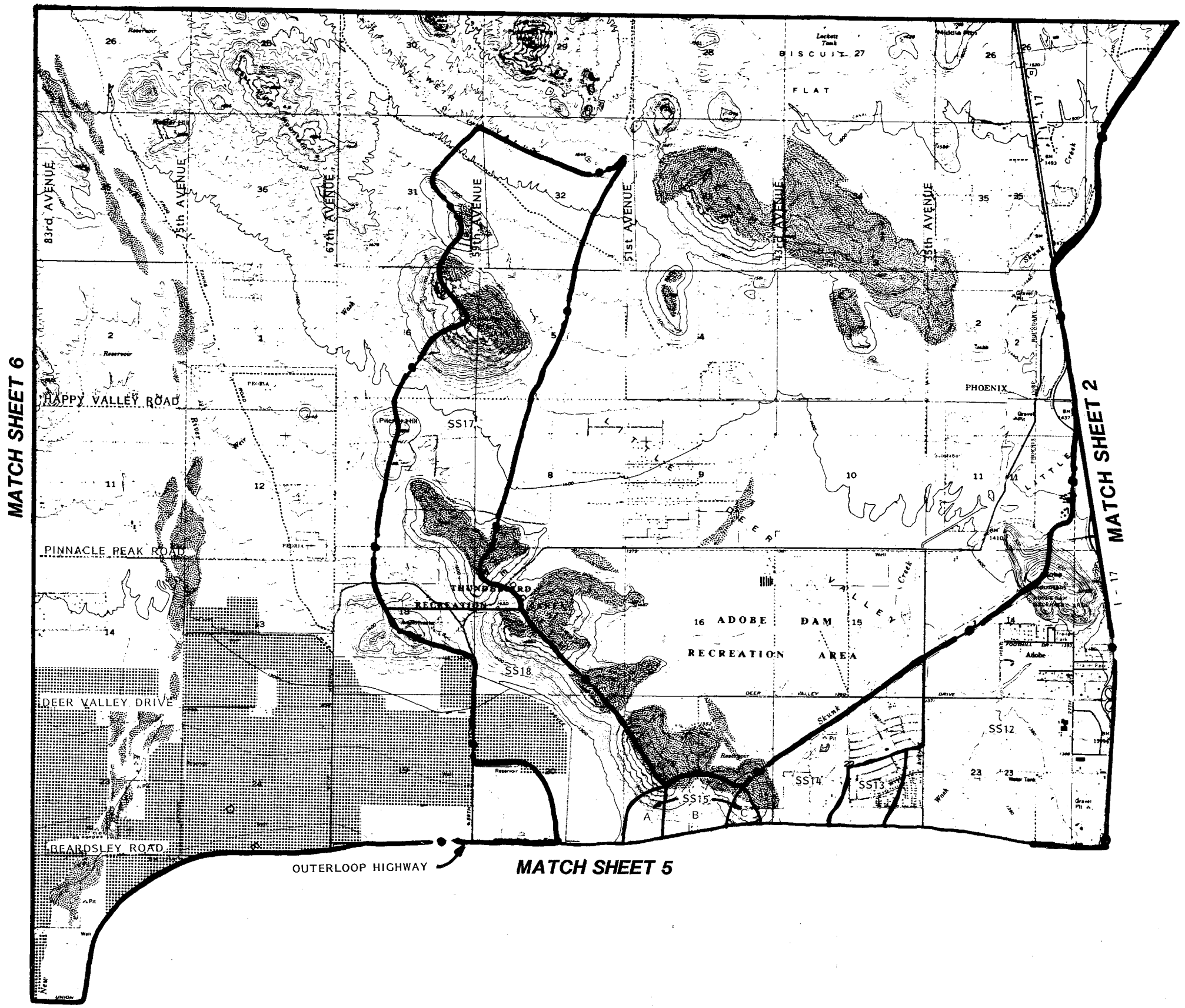
Drawn F.C.
Check
Scale 1" = 4000'

**BELL ROAD PROJECT**
*DRAINAGE STUDY*
HYDROLOGY EXHIBIT FOR EXISTING CONDITIONS

Date JAN. 1987
Job No. E123061
Sheet 3 of 7

**EXHIBIT 3A**




LEGEND

201 - SUB AREA NUMBER
- MAJOR DRAINAGE AREA
- SUB AREA BOUNDARY

0' 4000'
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BELL ROAD PROJECT
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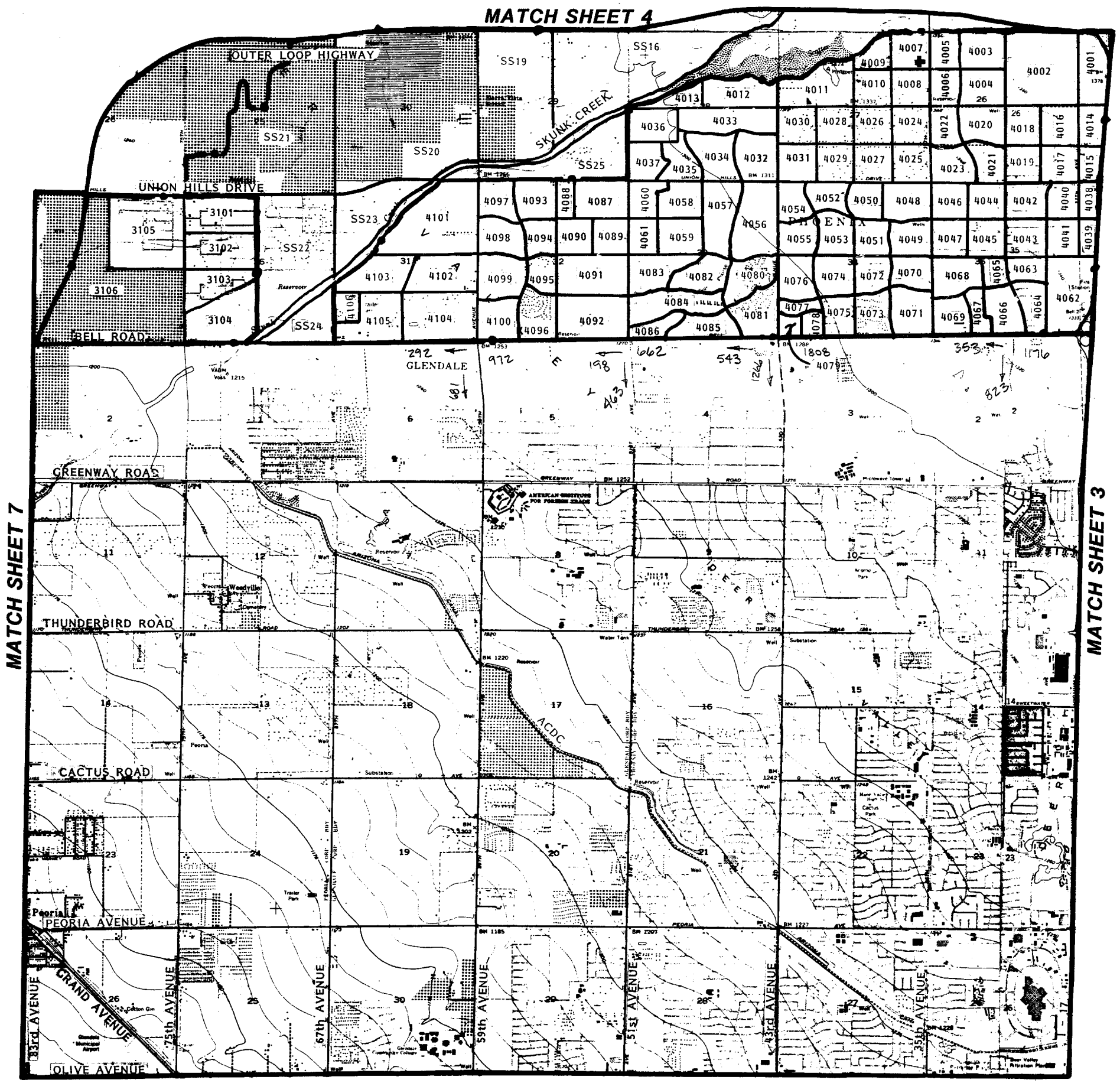


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Sheet 5 of 7

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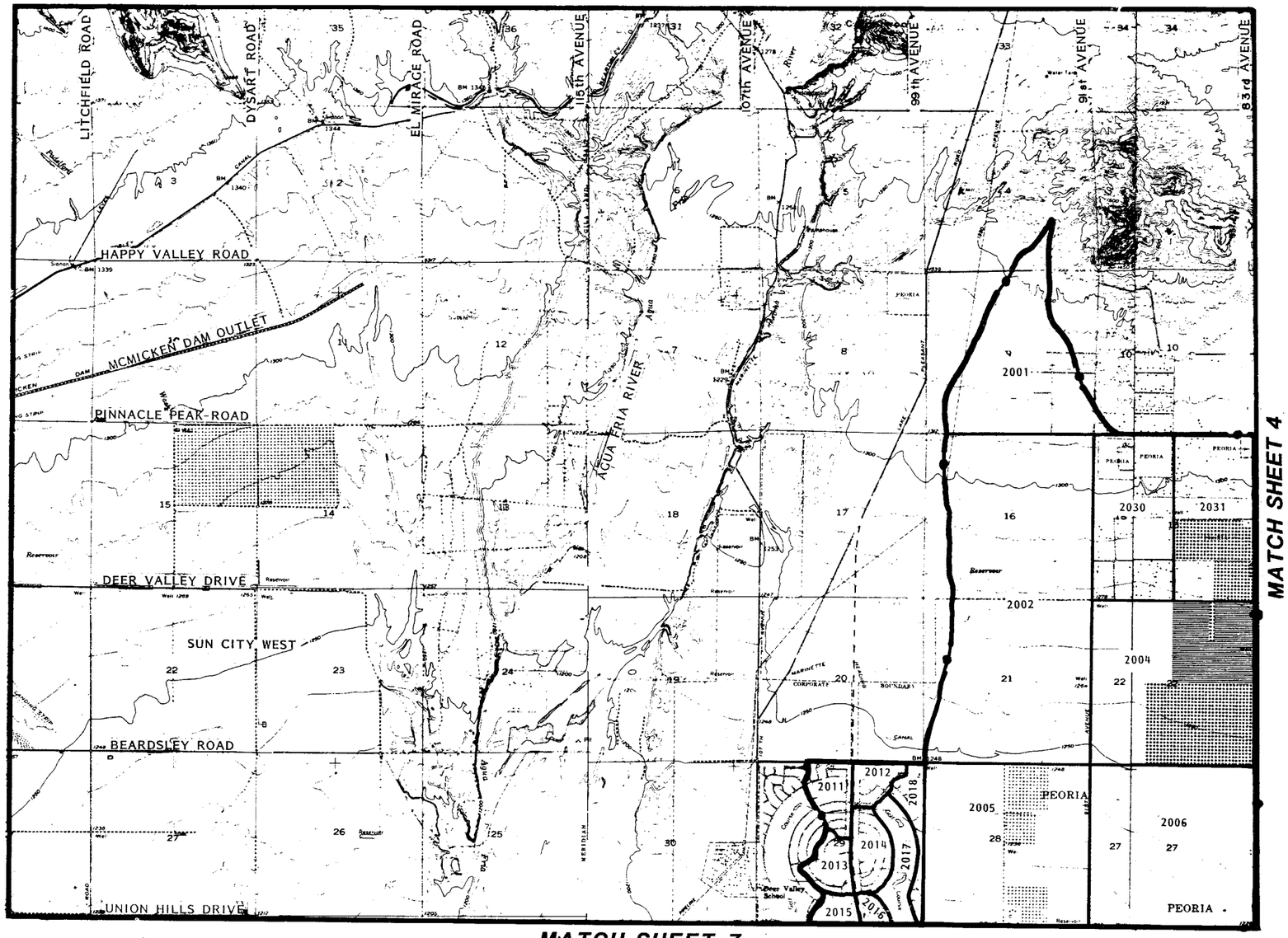


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Sheet 6 of 7

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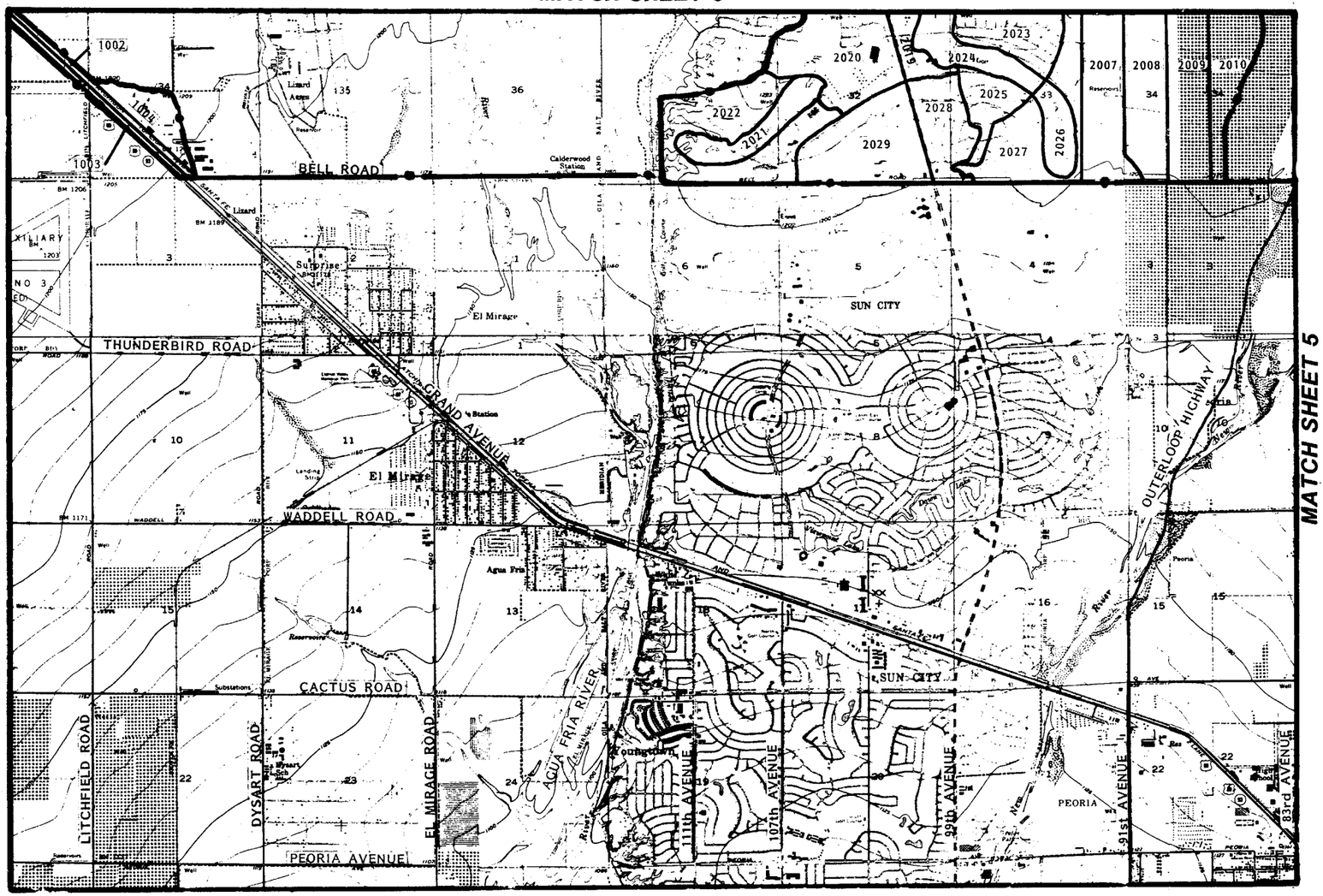
MATCH SHEET 6




MATCH SHEET 5

LEGEND

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- SUB AREA BOUNDARY

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Sheet 7 of 7

EXHIBIT 3A

B. Post-Development (Future) Conditions

Drainge Area 1: The flow paths and subareas for the future conditions remain the same as for existing conditions. The area was modified to reflect the expansion of Grand Avenue to a six-lane roadway. The curve numbers and lag time were adjusted to reflect the change to Grand Avenue.

Drainage Area 2: Existing flow patterns are from north to south and the future development flow patterns were assumed to be the same. Since 91st Avenue is the lowest elevation in the area, it was assumed that it would be used for drainage for future development runoff. Split flows were not used since 91st Avenue is the only concentration point along Bell Road.

The kinematic wave and the SCS Unit Graph method were used for future conditions. In areas with low density housing, the predominant form of runoff is sheet flow. The SCS method was used in these areas. For higher density areas, the kinematic wave method was used.

Sun City was considered to be fully developed for existing conditions, therefore, future conditions were not modeled. The Master Plan for Storm Drainage for the City of Peoria was used for modeling future conditions. This report proposes both storm drains and open channels. The storm drain system extends to Beardsley Road. North of Beardsley Road, the channel system was used. Runoff was diverted into the storm drain system at various concentration points. This system runs along 91st Avenue and crosses Bell Road and was designed for the 2-year storm event.

Drainage Area 3: Under future conditions, subarea 3106 will convert from abandoned orchards to commercial and residential uses. The

kinematic wave model was, therefore, utilized to calculate runoff for this subarea. The City of Glendale will be adopting a retention ordinance requiring storage volume for the 100-year, 2-hour storm. This peak discharge and associated volume was abstracted from the 100-year, 24-hour storm. This procedure was described in detail in Section VII.E.

The proposed alignment for the Outer Loop Highway will generally follow the existing west drainage boundary for Drainage Area 3. It is assumed that the Arizona Department of Transportation will follow standard highway drainage design procedures, and all on-site runoff will be kept within the highway right-of-way. It is, therefore, anticipated that there will be no changes to Drainage Area 3 drainage patterns due to construction of the Outer Loop Highway.

No other significant changes in runoff modeling were required to reflect future conditions in Drainage Area 3.

Drainage Area 4: Curve numbers were re-evaluated based on the future zoning. The kinematic wave method was used to calculate runoff for all subareas. Future storm drains for the City of Phoenix, as proposed in the Northwest Storm Drainage Study, City of Phoenix, 1977, were incorporated into the drainage routing scheme. This system was designed for the 2-year storm event. For the City of Glendale, future storm drains proposed in the Glendale Storm Water Management Plan, 1986 were modeled according to information provided by the City of Glendale Engineering Department. The storm drain system was designed for the 10-year storm. A proposed detention basin at the northwest corner of 55th Avenue and Bell Road was modeled using the reservoir routing technique. The proposed Union Hills Drive storm drain, designed for the 10-year storm, was also incorporated into the model.

Flows entering future commercial and industrial areas were routed by assuming volume of on-site retention for the 100-year, 2-hour storm.

There are no changes in the drainage patterns between existing and future conditions.

Drainage Area 5: The area north of Beardsley Road is eliminated due to the future construction of the Outer Loop Highway. Curve numbers were re-evaluated based on the future zoning. The kinematic wave model was applied for calculating runoff for all subareas.

Flow patterns, in general, are the same as existing conditions. Alternate 2 in the North Central Master Storm Drainage Study (West Half) will be adopted by the City of Phoenix for their storm drain system. The system was designed for the 2-year storm event. Storm water was diverted into the adopted storm drain for all runoff frequencies utilizing the techniques and methodology as discussed in Section VII.E.

For the 2-year storm event, Greiner's calculated peak flows exceeded the design capacities of the future storm drains.

For the 5-year storm, flows were diverted westward through the major half-mile streets.

The drainage improvements proposed for I-17 were incorporated into the model. It was determined that with the proposed improvements there will be no breakout of flows from the depressed roadway sections at I-17 and Union Hills Drive and Bell Road.

Drainage Area 6: Drainage facilities recommended by the Upper East Fork Cave Creek Area Drainage Master Study (UEFCC ADMS) were incorporated into the existing hydrology model. The drainage and flood control facilities are comprised of four independent systems draining to the proposed Greenway Parkway flood control channel located south of Bell Road between Cave Creek Road and Cave Creek. Storm drain systems will be located north of Bell Road on Central Avenue, Seventh Street and 16th

Street. A combination storm drain detention basin system is proposed for Ninth Street. The detention basins would be located on the northeast corner of Ninth Street and Campobello Street and on the southwest corner of Union Hills Drive and Ninth Street.

Drainage Area 7: Drainage facilities recommended by the UEFCC ADMS were incorporated into the existing hydrology model. The drainage and flood control facilities are comprised of two separate drainage systems conveying runoff to the proposed Greenway Parkway channel located south of Bell Road between Cave Creek Road and Cave Creek.

One system intercepts flows in the primary flood plain of the East Fork of Cave Creek Wash. The system consists of a detention basin located along the northern right-of-way of Beardsley Road at 26th Street and a basin located at the northwest corner of Grovers Avenue and Cave Creek Road. The latter basin discharges into an open channel which conveys flows along 20th Street to the Greenway Parkway channel. A storm drain extending from 28th Street along Bell Road discharges flows into a channel at 20th Street.

The second system is comprised of storm drains along Union Hills Drive, Grovers Avenue, Bell Road and Paradise Lane that conveys runoff to a storm drain along 32nd Street. A detention basin will be located at the northeast corner of Grovers Avenue and 32nd Street. A second basin will be located south of Paradise Lane between Cave Creek Road and 26th Street. Outflows from this basin will discharge into the Greenway Parkway channel.

Drainage Area 8: The modeling of Drainage Area 8 for post-development (future) conditions required two significant changes from existing conditions. All undeveloped land was assumed to be fully developed as indicated by existing zoning maps and/or the "General Plan for Phoenix - 1985/2000". Curve numbers were adjusted to reflect this

increased urbanization. Future storm drains as proposed in the Northeast Area Master Storm Drainage Study in 1979 have been incorporated into the routing scheme.

According to information provided by the City of Phoenix Engineering Department, a storm drain will be installed at 40th Street from Bell Road to Grovers Avenue and 42nd Avenue. Storm drains will extend northward from Bell Road on 44th Street to Union Hills Drive with a stub on Grovers Avenue. Storm drains will be installed On Tatum Boulevard from Bell Road to 0.25 miles north of Grovers Avenue with a 0.25 mile long stub on Grovers Avenue. A storm drain on 52nd Street from Bell Road to Grovers Avenue with a stub on Grovers Avenue will be installed. Pipe sizes range from 24 inches to 36 inches in diameter. Storm drains have been sized for the 2-year, 24-hour storm event. Diversions of street flows into the proposed storm drain were performed for all runoff frequencies. The methods and techniques for storm drain diverson are described in Section VII.E.

Drainage Area 9: Flow patterns for Drainage Area 9 were determined from field investigations, topographic mapping, aerial photography, Arrowhead Ranch Master Drainage Studies, the Hydrology Report, Off-Site Hydrology, Existing Conditions, Outer Loop Highway, Bell Road to Central Arizona Project Canal Crossing and from communications with PRC Toups which is preparing a drainage study for the Arizona Department of Transportation, titled, Phoenix - Cordes Junction Highway, Peoria Avenue - Deer Valley Road Study.

Discharges from Adobe Dam through an uncontrolled outlet were determined from information provided by the U.S. Army Corp of Engineers for each storm frequency modeled. These discharges were treated as base flow.

Runoff from areas above the Central Arizona Project Canal embankment were routed through the existing culverts along this embankment using stage - storage data obtained from the Bureau of Reclamation.

Runoff from areas upstream of the I-17 embankment were routed through this embankment at the location of existing drainage structures. Conversations with PRC Toups provided the information that these structures will be improved to convey the 100-year storm frequency.

Flows from Adobe Dam and Scatter Wash have their confluence and form Skunk Creek just south of Beardsley Road within subarea SS16.

Runoff from Hedgpeth Hills between Skunk Creek and 51st Avenue will be diverted westward by the proposed Outer Loop Highway and discharge into the improved drainageway at 55th Avenue.

Flows from subareas SS17 and SS18 were routed through the lake system within the Arrowhead Ranch Development. Detailed plans of this lake system were not available, therefore, routing was made through the lake system without making any adjustments for the possible effects of storage.

Flows from the lake system within the Arrowhead Ranch area discharge between 59th Avenue and 51st Avenue adjacent to the northern right-of-way of Beardsley Road. Flows head south through an earthen channel along the 55th Avenue alignment and enter Skunk Creek approximately 4,800 feet downstream of Beardsley Road.

Skunk Creek has been improved from 55th Avenue just north of Union Hills Drive to approximately 1,400 feet southwest of Union Hills Drive. From this point to Bell Road, Skunk Creek is in a natural condition (no improvements).

Areas bounding Skunk Creek between Skunk Creek and Bell Road flow to the southwest concentrating at the mile and half-mile streets.

In Section 25, Township 4 North, Range 2 East, another on-site lake system is incorporated into the drainage system as part of the Arrowhead Ranch development. This system could provide some storage potential, but was not considered in our modeling due to a lack of detailed information. The outfall from this area discharges to Skunk Creek via an improved channel along 71st Avenue.

Runoff from Drainage Area 4 enters Skunk Creek at three locations between Union Hills Drive and Bell Road. Hydrographs were directly input into the model as derived from the modeling performed from Drainage Area 4.

The Muskingum routing method was used to model the tributary areas of Scatter Wash and Skunk Creek. The kinematic routing method was used for all areas south of Beardsley Road to route flows to Skunk Creek. In each case, routing has been modified and adjusted to take into account any channel improvements made within the system.

The kinematic wave method was used in two other areas: the urbanized area north of Bell Road and south of Arrowhead Ranch and the area north of Beardsley Road at the southern base of Hedgpeth Hills.

A large commercial area within Section 30, Township 4 North, Range 2 East, was modeled incorporating an on-site retention basin sized for the 100-year, 2-hour storm.

Subareas within the Arrowhead Ranch development were determined from the Arrowhead Ranch Master Drainage Study. Curve numbers within these subareas were determined from this study.

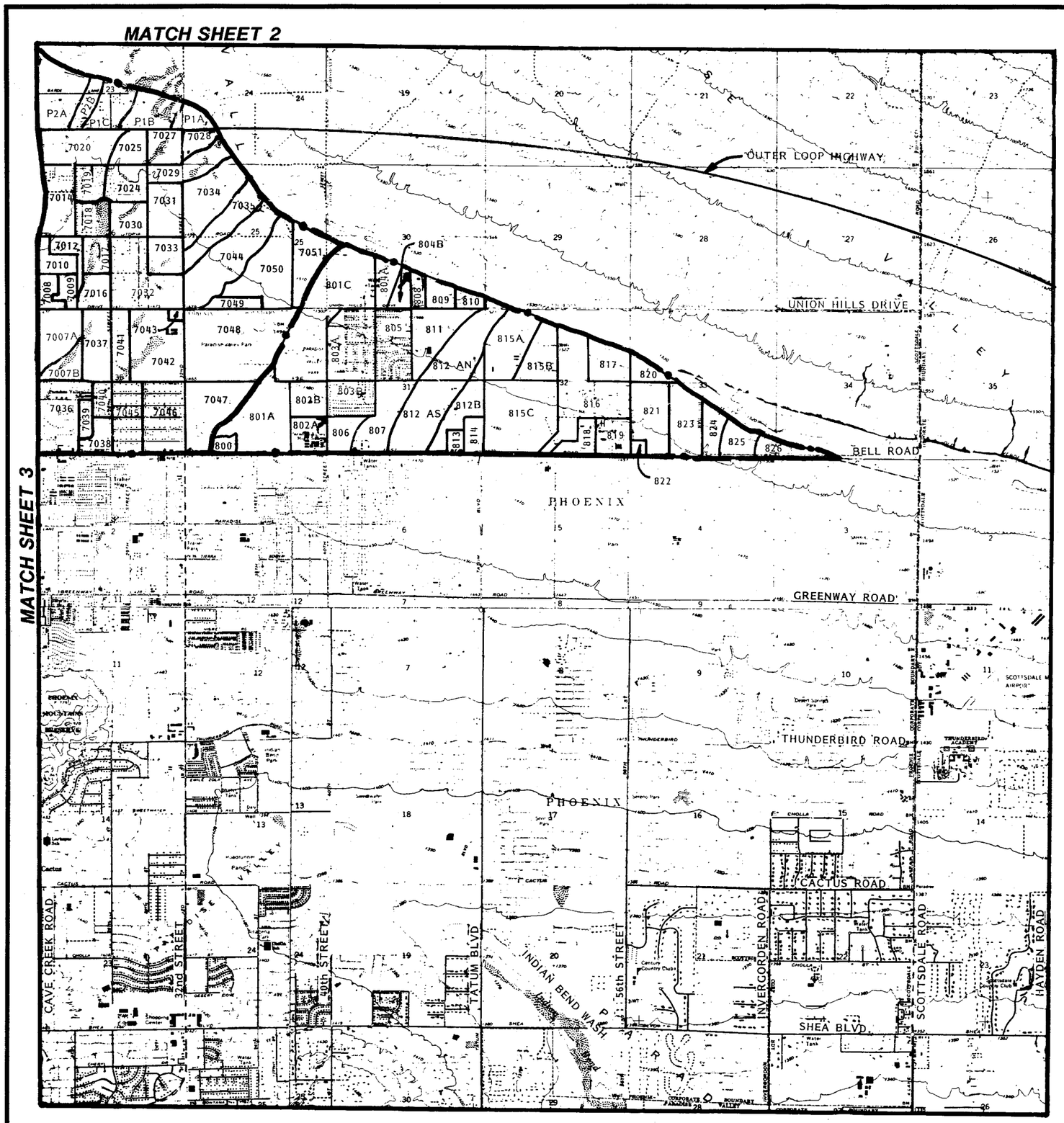
Drainagea Area 10: Flow patterns for Drainage Area 10 were determined from field investigations, topographic mapping, aerial photography, and the Hydrology Report, Off-Site Hydrology, Existing Conditions, Outer Loop Highway, Bell Road to Central Arizona Project Canal Crossing.

Curve numbers were developed using future zoning information based on the City of Phoenix current zoning maps, the Maricopa County Composite Land Use Plan and the General Plan for Phoenix - 1985/2000 map.

Future zoning and land use within Drainage Area 10 range from industrial to single family. Areas north of Beardsley Road are primarily zoned RE-43 (90%) with the remaining zoned industrial (10%). Areas south of Beardsley Road are primarily medium-density single family (90%) with the remaining areas being multi-family dwellings (10%).

Discharge from the uncontrolled outlet from Cave Buttes Dam entering Cave Creek was modeled as base flow. Discharge values for the different storm frequencies modeled from this outlet were determined from the stage-frequency and stage-discharge curves obtained from the U.S. Army Corps of Engineers.

The Muskingum routing method was used for Cave Creek stream routing. Adjustments were made to the Muskingum "X" coefficient between the Central Arizona Project Canal and Beardsley Road to incorporate channel modifications made by the sand and gravel operations within this reach. This reach has some storage potential because of these modifications.




LEGEND

201 - SUB AREA NUMBER

- MAJOR DRAINAGE AREA

- SUB AREA BOUNDARY

0' 4000'

Scale 1" = 4000'

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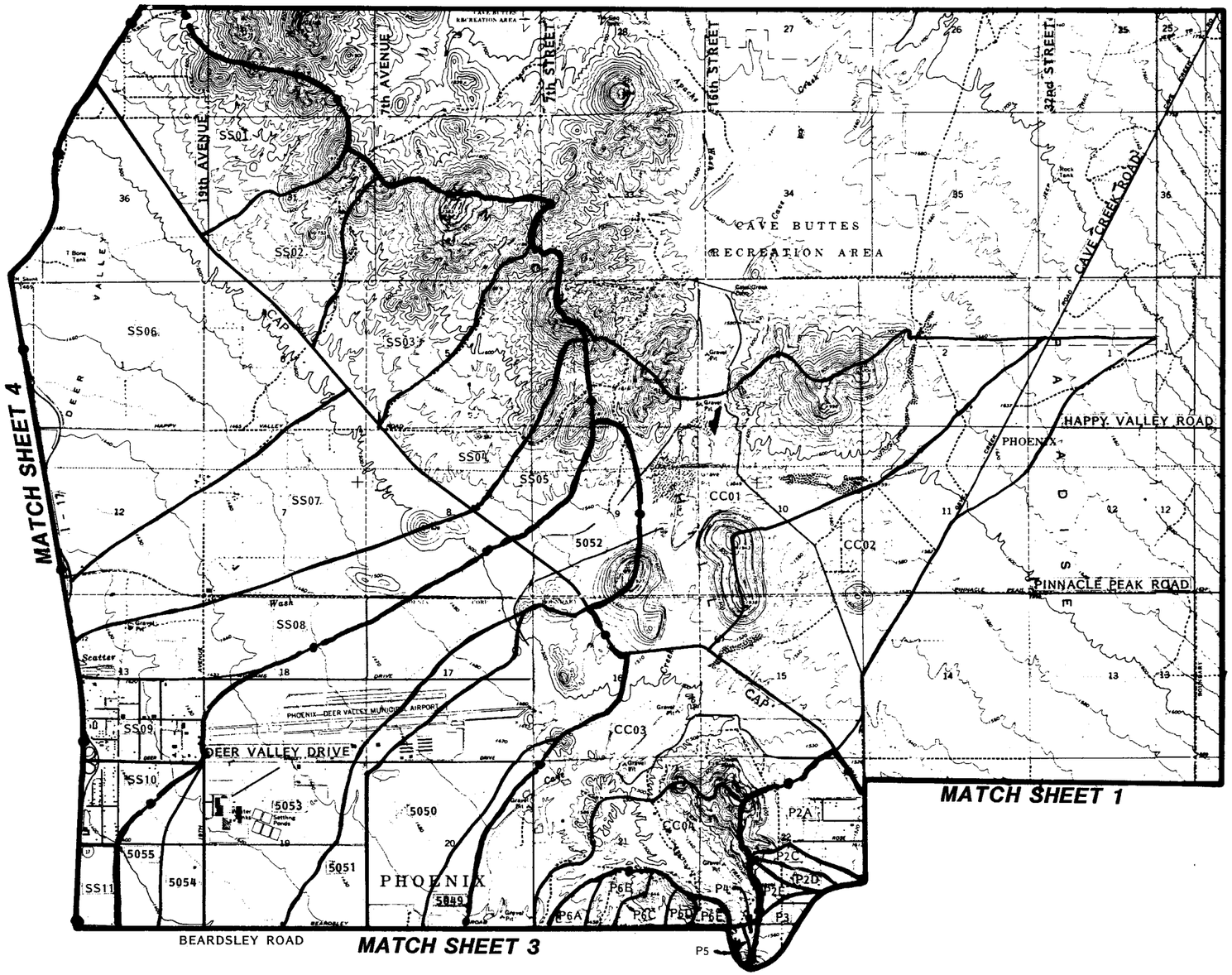
**BELL ROAD PROJECT**

**DRAINAGE STUDY**

HYDROLOGY EXHIBIT FOR FUTURE CONDITIONS

Date JAN. 1987
Job No. E123061
Sheet 1 of 7

**EXHIBIT 3B**

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Date JAN. 1987
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Sheet 2 of 7

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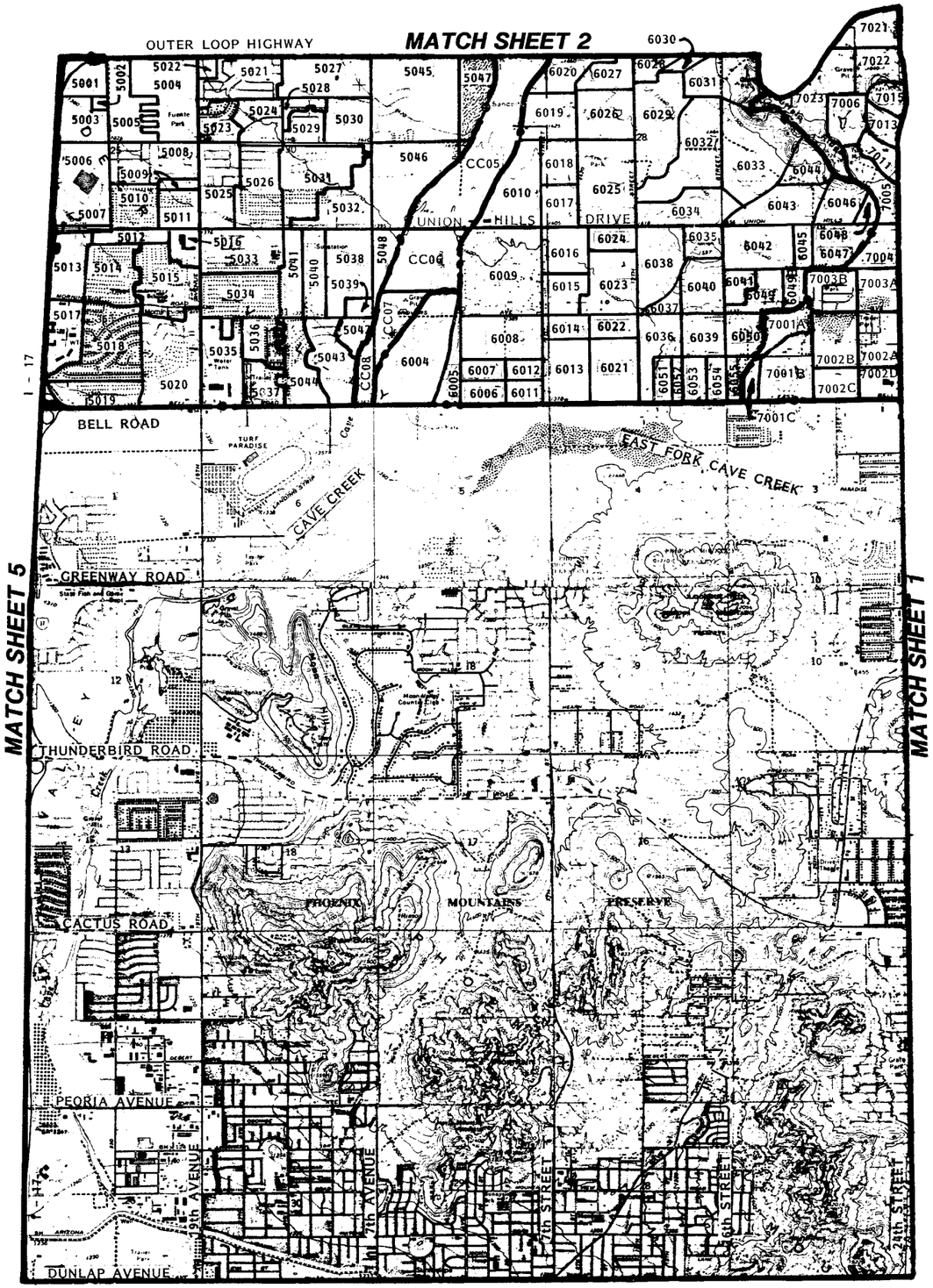


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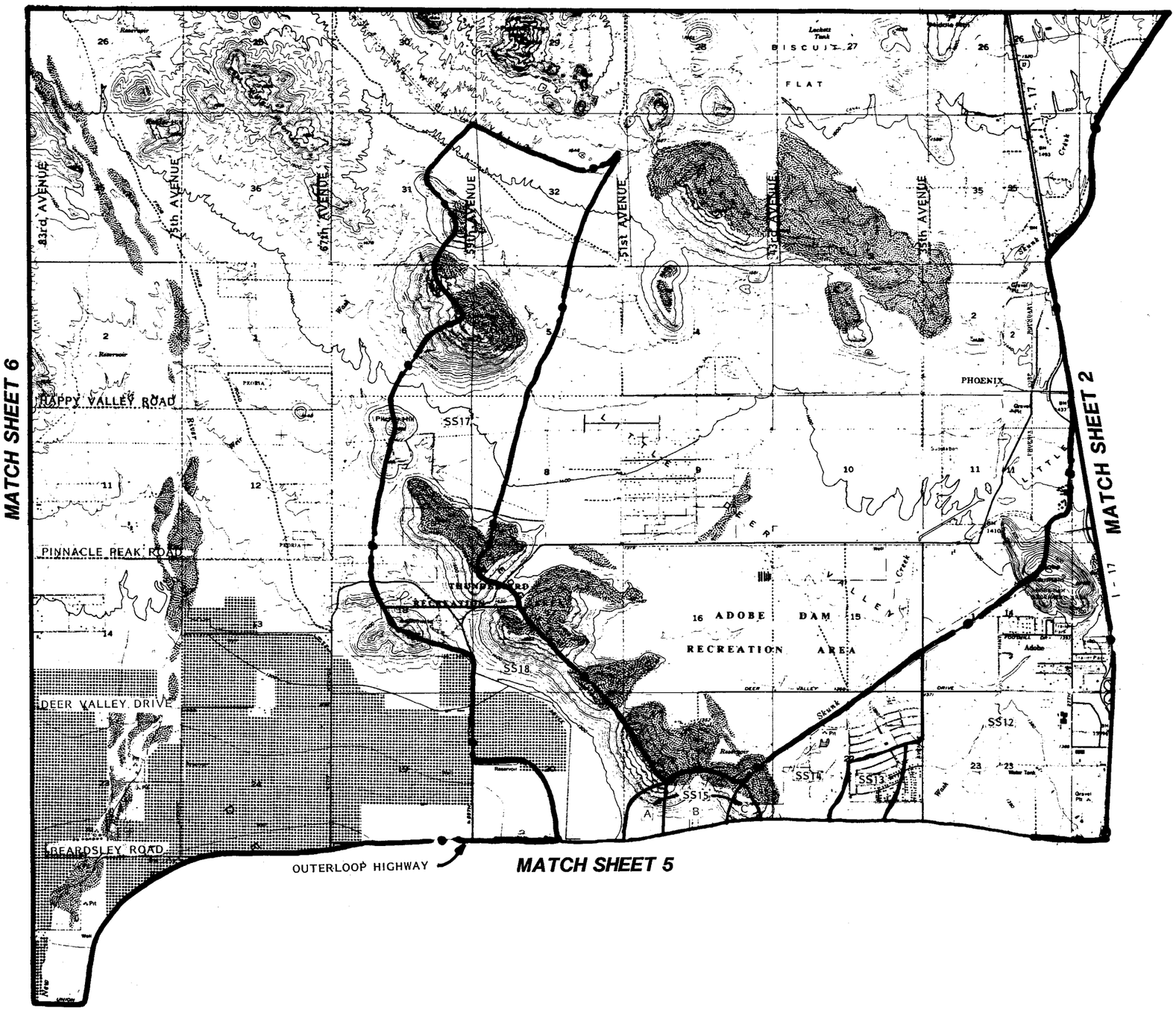


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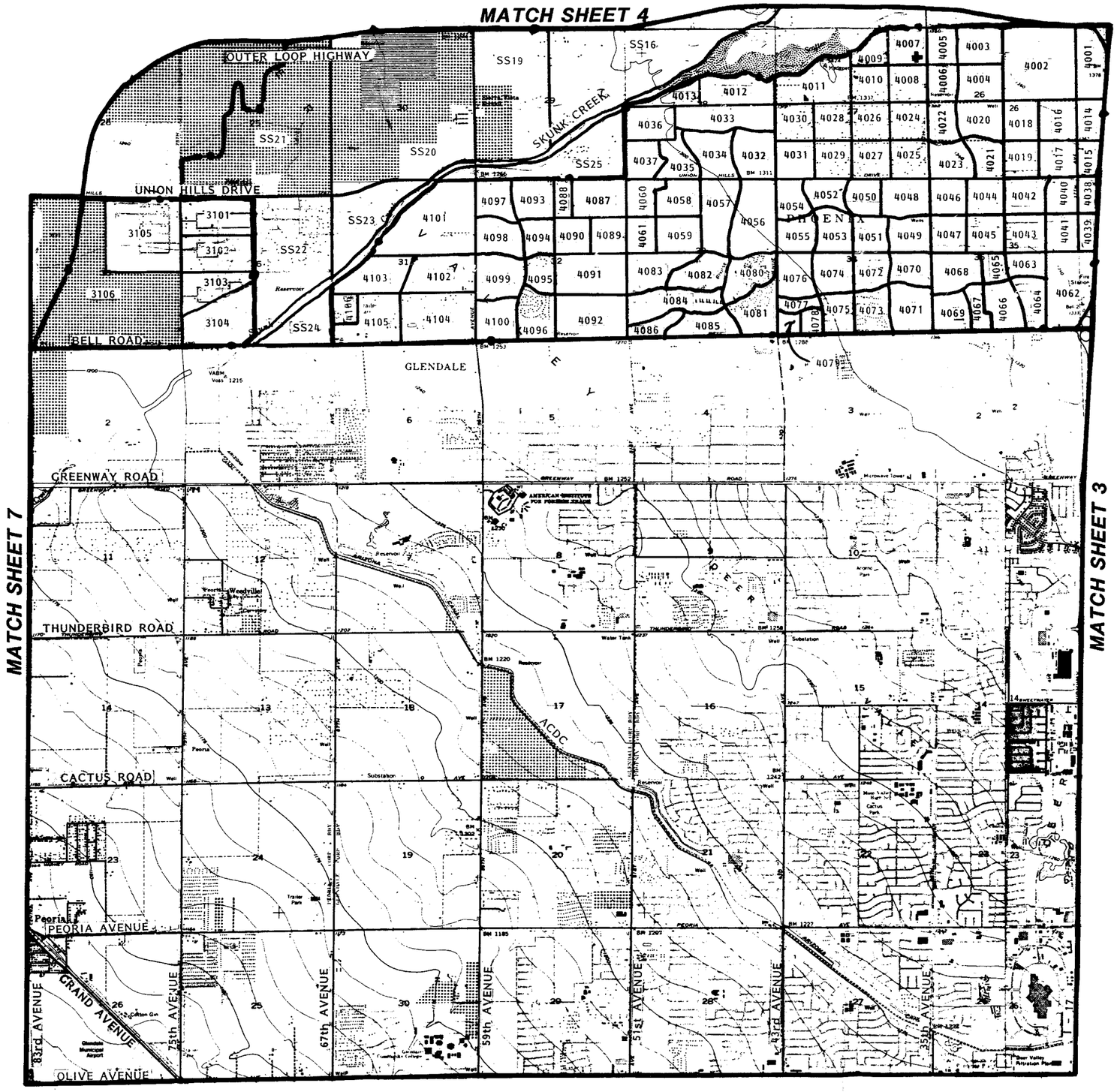


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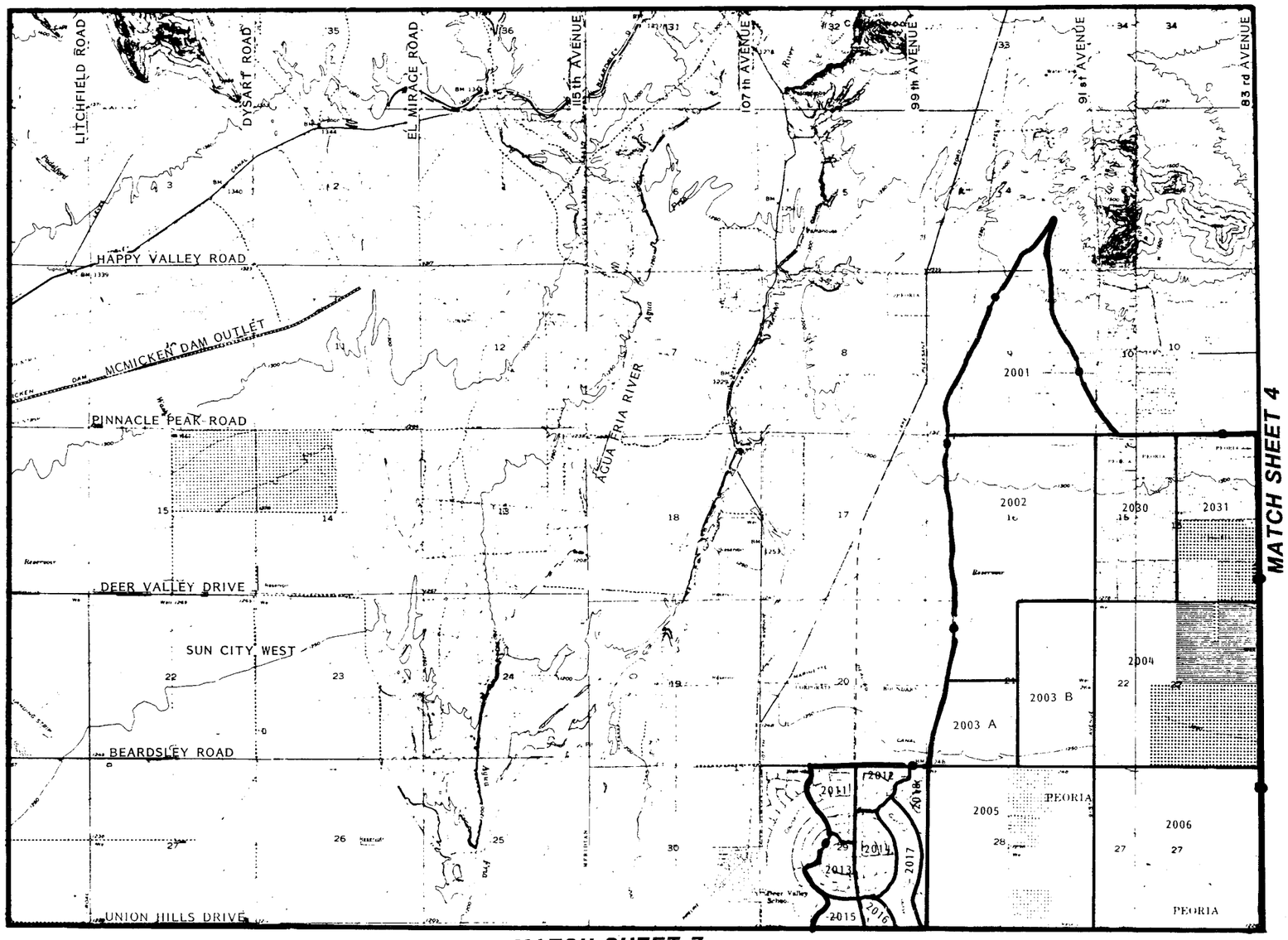


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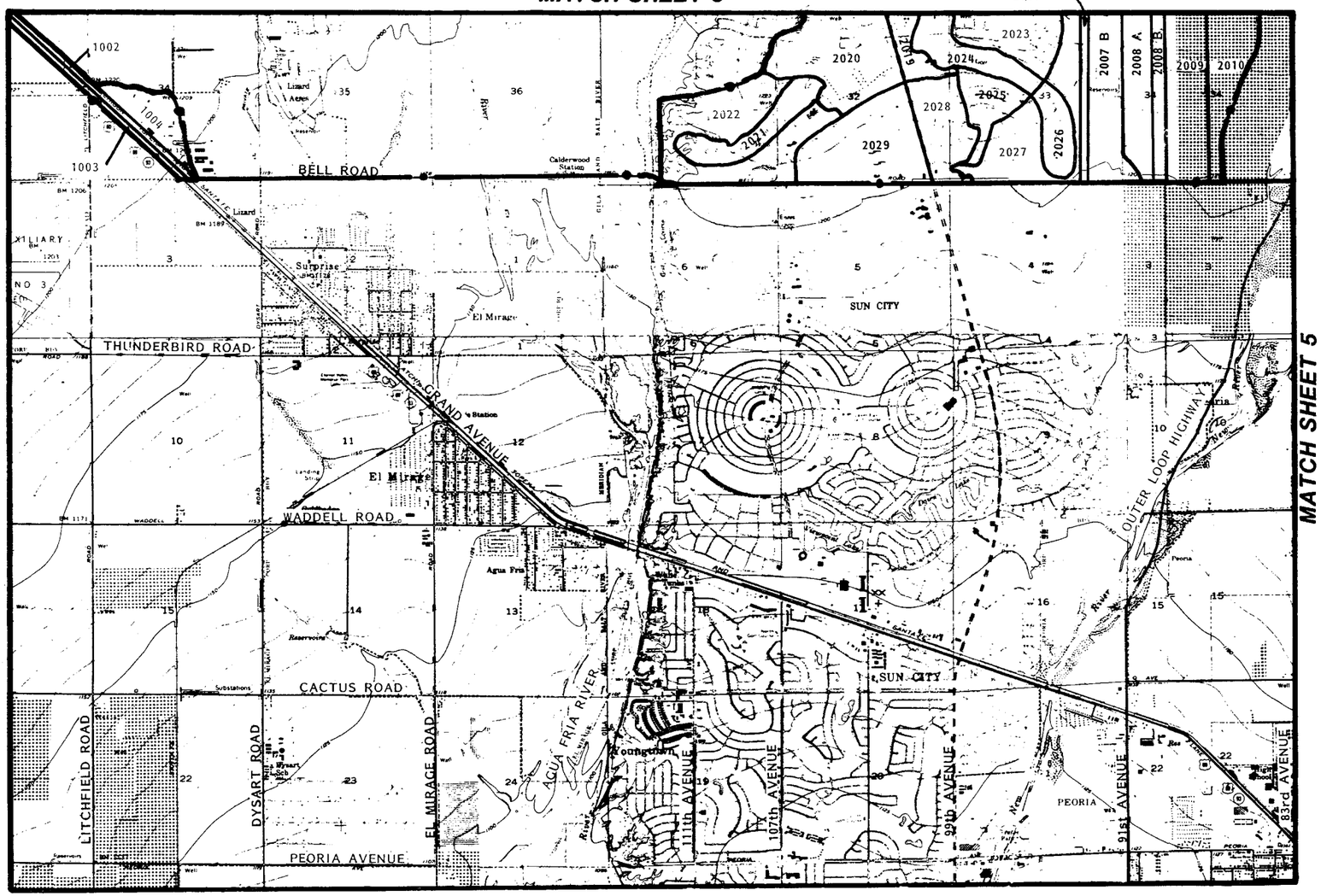


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Sheet 7 of 7

EXHIBIT 3B

## C. Subarea Characteristics

The following table lists the subarea characteristics for each subarea within the drainage areas analyzed. The subarea characteristics listed include: subarea number, area, hydrologic soil group, average weighted equivalent curve number, lag time, hydraulic length and slope along hydraulic length.

This table provides a brief overview of some of the input components used for the HEC-1 modeling. The Technical Reference List of this report contains further information regarding the HEC-1 modeling (see items A, B, C, D and E).

An asterisk appears in the table in the subarea number column and denotes that the area has been modified for post-development (future) conditions. All other subareas are fully developed and there is no change in the subarea characteristics from existing conditions for future conditions.

## TABLE 9

## SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| | | | (Area 1) | | | |
| 1001 | 0.07 | B | 79 | 0.58 | 13,200 | 0.0056 |
| 1002 | 0.10 | B | 81 | 0.65 | 15,300 | 0.0056 |
| *1002 | 0.10 | B | 84 | 0.57 | 15,300 | 0.0056 |
| 1003 | 0.07 | B | 80 | 0.61 | 13,200 | 0.0045 |
| 1004 | 0.09 | B | 98 | 0.13 | 3,300 | 0.0070 |
| | | | (Area 2) | | | |
| 2001 | 0.68 | B, D | 83 | 1.64 | 8,200 | 0.0079 |
| *2001 | 0.68 | B, D | 83 | 1.55 | 8,200 | 0.0079 |
| 2002 | 1.75 | B, D | 84 | 2.38 | 10,600 | 0.0060 |
| *2002 | 1.06 | B, D | 87 | 1.66 | 7,700 | 0.0060 |
| *2003A | 0.26 | B, D | 83 | N/A | 2,400 | 0.0049 |
| *2003B | 0.43 | B, D | 83 | N/A | 6,000 | 0.0049 |
| 2004 | 1.00 | B, D | 73 | 2.77 | 7,150 | 0.0046 |
| *2004 | 0.95 | B, D | 82 | N/A | 9,500 | 0.0035 |
| 2005 | 1.00 | B | 79 | N/A | 1,680 | 0.0049 |
| 2006 | 1.00 | B, D | 80 | 2.09 | 6,650 | 0.0048 |
| *2006 | 0.94 | B, D | 81 | N/A | 9,500 | 0.0034 |
| 2007 | 0.27 | B, D | 80 | 0.35 | 6,250 | 0.0038 |
| *2007A | 0.06 | B, D | 84 | N/A | 5,280 | 0.0045 |
| *2007B | 0.21 | B, D | 92 | N/A | 5,280 | 0.0045 |
| 2008 | 0.24 | B | 81 | 0.38 | 6,700 | 0.0037 |
| *2008A | 0.18 | B | 92 | N/A | 5,280 | 0.0047 |
| *2008B | 0.06 | B | 84 | N/A | 5,280 | 0.0047 |
| 2009 | 0.25 | B | 85 | N/A | 6,100 | 0.0044 |
| 2010 | 0.18 | B | 55 | 0.32 | 5,450 | 0.0042 |
| *2010 | 0.18 | B | 86 | N/A | 6,000 | 0.0038 |
| 2011 | 0.12 | D | 89 | N/A | 3,960 | 0.0025 |
| 2012 | 0.06 | D | 89 | N/A | 2,070 | 0.0034 |
| 2013 | 0.10 | D | 90 | N/A | 3,740 | 0.0027 |
| 2014 | 0.12 | D | 90 | N/A | 3,110 | 0.0045 |
| 2015 | 0.05 | D | 91 | N/A | 3,010 | 0.0025 |
| 2016 | 0.04 | D | 92 | N/A | 3,240 | 0.0025 |
| 2017 | 0.11 | D | 80 | 0.31 | 5,200 | 0.0037 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| 2018 | 0.09 | D | 89 | N/A | 6,800 | 0.0035 |
| 2019 | 0.08 | D | 92 | N/A | 2,580 | 0.0043 |
| 2020 | 0.34 | D | 84 | 1.36 | 5,040 | 0.0025 |
| 2021 | 0.13 | D | 80 | 0.30 | 4,600 | 0.0028 |
| 2022 | 0.39 | D | 89 | N/A | 7,060 | 0.0025 |
| 2023 | 0.16 | D | 89 | N/A | 4,090 | 0.0025 |
| 2024 | 0.11 | D | 80 | 0.31 | 4,200 | 0.0025 |
| 2025 | 0.11 | D | 90 | N/A | 4,060 | 0.0037 |
| 2026 | 0.06 | D | 80 | 0.21 | 3,200 | 0.0058 |
| 2027 | 0.30 | D | 89 | N/A | 8,190 | 0.0025 |
| 2028 | 0.17 | D | 90 | N/A | 4,760 | 0.0027 |
| 2029 | 0.30 | D | 91 | N/A | 4,660 | 0.0026 |
| 2030 | 0.50 | B | 80 | 1.31 | 5,300 | 0.0066 |
| *2030 | 0.50 | B | 80 | 0.80 | 5,300 | 0.0066 |
| 2031 | 0.50 | B, D | 75 | 1.63 | 5,300 | 0.0064 |
| *2031 | 0.50 | B, D | 81 | 0.80 | 5,300 | 0.0064 |
| | | | (Area 3) | | | |
| 3101 | 0.13 | B | 80 | N/A | 2,800 | 0.0025 |
| 3102 | 0.13 | B | 80 | N/A | 2,800 | 0.0036 |
| 3103 | 0.13 | B | 80 | N/A | 3,100 | 0.0058 |
| 3104 | 0.13 | B | 79 | 1.05 | 3,200 | 0.0063 |
| *3104 | 0.13 | B | 81 | 0.83 | 3,200 | 0.0063 |
| 3105 | 0.25 | B | 81 | N/A | 3,300 | 0.0039 |
| 3106 | 0.57 | B | 55 | 4.07 | 5,500 | 0.0036 |
| *3106 | 0.57 | B | 91 | N/A | 5,500 | 0.0036 |
| | | | (Area 4) | | | |
| 4001 | 0.081 | B, D | 79 | 0.902 | 2,300 | 0.0052 |
| *4001 | 0.069 | B, D | 83 | N/A | 2,300 | 0.0052 |
| 4002 | 0.251 | D, B | 79 | 1.501 | 4,400 | 0.0052 |
| *4002 | 0.251 | D, B | 86 | N/A | 4,400 | 0.0052 |
| 4003 | 0.067 | D, B | 79 | 0.740 | 1,680 | 0.0045 |
| *4003 | 0.067 | D, B | 83 | N/A | 1,680 | 0.0045 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| 4004 | 0.073 | B, D | 79 | 0.896 | 2,280 | 0.0050 |
| *4004 | 0.073 | B, D | 86 | N/A | 2,280 | 0.0050 |
| 4005 | 0.055 | D, B | 82 | N/A | 2,500 | 0.0048 |
| *4005 | 0.044 | D, B | 82 | N/A | 2,500 | 0.0048 |
| 4006 | 0.056 | B, D | 86 | N/A | 2,380 | 0.0050 |
| *4006 | 0.056 | B, D | 86 | N/A | 2,380 | 0.0050 |
| 4007 | 0.064 | B | 81 | 0.780 | 2,200 | 0.0055 |
| *4007 | 0.051 | B | 82 | N/A | 2,200 | 0.0055 |
| 4008 | 0.066 | D, B | 79 | 0.864 | 2,700 | 0.0055 |
| *4008 | 0.066 | D, B | 83 | N/A | 2,700 | 0.0055 |
| 4009 | 0.051 | B | 79 | 0.577 | 2,200 | 0.0060 |
| *4009 | 0.051 | B | 81 | N/A | 2,200 | 0.0060 |
| 4010 | 0.064 | B, D | 79 | 0.689 | 2,200 | 0.0055 |
| *4010 | 0.064 | B, D | 80 | N/A | 2,200 | 0.0055 |
| 4011 | 0.142 | B | 79 | 1.174 | 3,240 | 0.0045 |
| *4011 | 0.142 | B | 79 | N/A | 3,240 | 0.0045 |
| 4012 | 0.090 | B | 79 | 0.935 | 2,250 | 0.0045 |
| *4012 | 0.090 | B | 82 | N/A | 2,250 | 0.0045 |
| 4013 | 0.040 | B | 79 | 1.008 | 2,640 | 0.0050 |
| *4013 | 0.040 | B | 79 | N/A | 2,640 | 0.0050 |
| 4014 | 0.043 | B | 79 | 0.759 | 1,560 | 0.0038 |
| *4014 | 0.043 | B | 82 | N/A | 1,560 | 0.0038 |
| 4015 | 0.033 | D, B | 90 | N/A | 1,680 | 0.0042 |
| 4016 | 0.066 | D, B | 84 | N/A | 2,450 | 0.0045 |
| 4017 | 0.063 | D, B | 87 | N/A | 2,530 | 0.0040 |
| 4018 | 0.064 | D, B | 86 | N/A | 1,380 | 0.0065 |
| 4019 | 0.061 | D, B | 84 | N/A | 1,380 | 0.0065 |
| 4020 | 0.064 | D, B | 84 | N/A | 3,200 | 0.0028 |
| 4021 | 0.065 | D, B | 85 | N/A | 2,580 | 0.0043 |
| 4022 | 0.054 | D, B | 84 | N/A | 2,260 | 0.0044 |
| 4023 | 0.071 | D, B | 88 | N/A | 2,520 | 0.0040 |
| 4024 | 0.063 | D, B | 81 | N/A | 2,580 | 0.0043 |
| 4025 | 0.066 | B, D | 81 | N/A | 2,580 | 0.0043 |
| 4026 | 0.062 | D, B | 80 | N/A | 2,580 | 0.0050 |
| 4027 | 0.063 | D, B | 79 | N/A | 2,580 | 0.0047 |
| 4028 | 0.063 | B | 79 | N/A | 2,580 | 0.0043 |
| 4029 | 0.064 | B | 79 | N/A | 2,580 | 0.0039 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| 4030 | 0.063 | B | 79 | N/A | 2,580 | 0.0035 |
| 4031 | 0.065 | B | 79 | N/A | 2,500 | 0.0028 |
| 4032 | 0.095 | B | 83 | N/A | 3,520 | 0.0023 |
| *4032 | 0.081 | B | 84 | N/A | 3,520 | 0.0023 |
| 4033 | 0.121 | B | 82 | N/A | 3,840 | 0.0034 |
| 4034 | 0.072 | B | 82 | N/A | 2,200 | 0.0059 |
| 4035 | 0.063 | B | 82 | N/A | 2,120 | 0.0052 |
| 4036 | 0.090 | B | 79 | 1.149 | 2,400 | 0.0033 |
| *4036 | 0.090 | B | 79 | N/A | 2,400 | 0.0033 |
| 4037 | 0.057 | B | 82 | N/A | 2,200 | 0.0050 |
| 4038 | 0.031 | B, D | 84 | 0.571 | 1,440 | 0.0035 |
| *4038 | 0.016 | B, D | 90 | N/A | 1,440 | 0.0035 |
| 4039 | 0.031 | D, B | 84 | N/A | 1,900 | 0.0041 |
| *4039 | 0.031 | D, B | 88 | N/A | 1,900 | 0.0041 |
| 4040 | 0.057 | B, D | 87 | N/A | 2,560 | 0.0035 |
| 4041 | 0.057 | D, B | 88 | N/A | 2,080 | 0.0043 |
| 4042 | 0.072 | D, B | 88 | N/A | 2,440 | 0.0053 |
| 4043 | 0.069 | D, B | 87 | N/A | 2,420 | 0.0037 |
| 4044 | 0.064 | D, B | 87 | N/A | 2,500 | 0.0037 |
| 4045 | 0.064 | D, B | 88 | N/A | 2,500 | 0.0048 |
| 4046 | 0.065 | B, D | 82 | N/A | 2,560 | 0.0023 |
| *4046 | 0.042 | B, D | 84 | N/A | 2,560 | 0.0023 |
| 4047 | 0.065 | D, B | 86 | N/A | 2,200 | 0.0040 |
| 4048 | 0.084 | D, B | 87 | N/A | 2,600 | 0.0046 |
| 4049 | 0.066 | D, B | 83 | N/A | 3,900 | 0.0026 |
| 4050 | 0.049 | D, B | 86 | N/A | 2,200 | 0.0032 |
| 4051 | 0.060 | D, B | 86 | N/A | 2,520 | 0.0044 |
| 4052 | 0.069 | D, B | 82 | N/A | 2,910 | 0.0031 |
| 4053 | 0.070 | D, B | 85 | N/A | 2,580 | 0.0043 |
| 4054 | 0.055 | B | 81 | N/A | 2,340 | 0.0038 |
| *4054 | 0.055 | B | 82 | N/A | 2,340 | 0.0038 |
| 4055 | 0.058 | D, B | 83 | N/A | 2,140 | 0.0056 |
| 4056 | 0.141 | D, B | 82 | N/A | 4,000 | 0.0045 |
| 4057 | 0.113 | D, B | 81 | N/A | 3,740 | 0.0042 |
| 4058 | 0.069 | B | 82 | N/A | 2,900 | 0.0031 |
| 4059 | 0.078 | B | 82 | N/A | 2,840 | 0.0039 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| 4060 | 0.050 | B | 79 | 0.821 | 1,860 | 0.0043 |
| *4060 | 0.050 | B | 82 | N/A | 1,860 | 0.0043 |
| 4061 | 0.046 | B | 82 | N/A | 2,200 | 0.0045 |
| 4062 | 0.161 | B | 79 | 0.966 | 3,240 | 0.0059 |
| *4062 | 0.145 | B | 89 | N/A | 3,240 | 0.0059 |
| 4063 | 0.042 | D, B | 88 | N/A | 1,780 | 0.0051 |
| 4064 | 0.061 | B | 82 | N/A | 2,500 | 0.0048 |
| 4065 | 0.026 | D, B | 83 | N/A | 1,660 | 0.0030 |
| *4065 | 0.026 | D, B | 88 | N/A | 1,660 | 0.0030 |
| 4066 | 0.065 | D, B | 84 | N/A | 2,500 | 0.0036 |
| 4067 | 0.047 | D, B | 89 | N/A | 1,960 | 0.0046 |
| 4068 | 0.095 | D, B | 86 | N/A | 4,060 | 0.0034 |
| 4069 | 0.065 | D, B | 90 | N/A | 2,200 | 0.0041 |
| 4070 | 0.063 | B | 82 | N/A | 2,200 | 0.0050 |
| 4071 | 0.081 | B | 85 | N/A | 2,840 | 0.0028 |
| 4072 | 0.060 | D, B | 84 | N/A | 2,200 | 0.0059 |
| 4073 | 0.069 | B | 82 | N/A | 2,600 | 0.0035 |
| 4074 | 0.063 | D, B | 82 | N/A | 2,200 | 0.0059 |
| 4075 | 0.063 | B | 82 | N/A | 2,200 | 0.0041 |
| 4076 | 0.070 | D, B | 83 | N/A | 2,760 | 0.0036 |
| 4077 | 0.028 | B | 82 | N/A | 1,660 | 0.0036 |
| 4078 | 0.026 | B | 82 | N/A | 1,180 | 0.0034 |
| 4079 | 0.028 | B | 79 | 0.454 | 1,200 | 0.0058 |
| *4079 | 0.017 | B | 82 | N/A | 1,200 | 0.0058 |
| 4080 | 0.089 | B | 76 | N/A | 2,750 | 0.0033 |
| 4081 | 0.087 | B | 88 | N/A | 2,690 | 0.0030 |
| 4082 | 0.102 | B | 79 | N/A | 3,140 | 0.004 |
| 4083 | 0.074 | B | 84 | N/A | 3,140 | 0.0045 |
| 4084 | 0.075 | B | 78 | N/A | 3,630 | 0.004 |
| 4085 | 0.070 | B | 84 | N/A | 3,000 | 0.0037 |
| 4086 | 0.056 | B | 82 | N/A | 2,300 | 0.0039 |
| *4086 | 0.034 | B | 88 | N/A | 2,300 | 0.0039 |
| 4087 | 0.09 | B | 84 | N/A | 2,150 | 0.0047 |
| 4088 | 0.03 | B | 79 | 0.697 | 1,560 | 0.0045 |
| *4088 | 0.03 | B | 84 | N/A | 1,560 | 0.0045 |
| 4089 | 0.06 | B, D | 82 | 0.476 | 2,040 | 0.0049 |
| *4089 | 0.06 | B, D | 84 | N/A | 2,040 | 0.0049 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| 4090 | 0.06 | B, D | 79 | 0.851 | 2,000 | 0.0045 |
| *4090 | 0.06 | B, D | 85 | N/A | 2,000 | 0.0045 |
| 4091 | 0.12 | B | 79 | 1.208 | 3,100 | 0.0045 |
| *4091 | 0.12 | B | 88 | N/A | 3,100 | 0.0045 |
| 4092 | 0.16 | B, D | 79 | 1.384 | 3,360 | 0.0039 |
| *4092 | 0.16 | B, D | 88 | N/A | 3,360 | 0.0039 |
| 4093 | 0.08 | B | 84 | N/A | 2,620 | 0.0042 |
| 4094 | 0.06 | D, B | 86 | N/A | 1,780 | 0.0045 |
| 4095 | 0.04 | D, B | 86 | N/A | 1,600 | 0.0050 |
| 4096 | 0.08 | D, B | 83 | N/A | 2,500 | 0.0040 |
| *4096 | 0.048 | D, B | 86 | N/A | 2,500 | 0.0040 |
| 4097 | 0.06 | B | 82 | N/A | 2,220 | 0.0041 |
| *4097 | 0.036 | B | 84 | N/A | 2,220 | 0.0041 |
| 4098 | 0.06 | B | 84 | N/A | 1,960 | 0.0031 |
| 4099 | 0.08 | B | 84 | N/A | 2,640 | 0.0034 |
| 4100 | 0.07 | D, B | 79 | 0.742 | 1,800 | 0.0050 |
| *4100 | 0.07 | D, B | 93 | N/A | 1,800 | 0.0050 |
| 4101 | 0.26 | B | 81 | 0.840 | 4,200 | 0.0064 |
| *4101 | 0.26 | B | 84 | N/A | 4,200 | 0.0064 |
| 4102 | 0.12 | B | 84 | N/A | 3,720 | 0.0046 |
| 4103 | 0.09 | B | 81 | 0.532 | 2,160 | 0.0079 |
| *4103 | 0.09 | B | 84 | N/A | 2,160 | 0.0079 |
| 4104 | 0.17 | B | 79 | 0.715 | 3,240 | 0.0046 |
| *4104 | 0.145 | B | 82 | N/A | 3,240 | 0.0046 |
| 4105 | 0.111 | B | 79 | 0.446 | 2,400 | 0.0054 |
| *4105 | 0.083 | B | 81 | N/A | 2,400 | 0.0054 |
| 4106 | 0.049 | B | 84 | N/A | 1,960 | 0.0026 |
| *4106 | 0.049 | B | 84 | N/A | 1,960 | 0.0026 |
| | | | (Area 5) | | | |
| 5001 | 0.54 | D | 79 | 0.595 | 1,700 | 0.0071 |
| *5001 | 0.54 | D | 93 | N/A | 1,700 | 0.0071 |
| 5002 | 0.009 | D, B | 91 | N/A | 1,000 | 0.003 |
| 5003 | 0.046 | B, D | 91 | N/A | 1,660 | 0.0060 |
| 5004 | 0.136 | D, B | 83 | 0.475 | 2,500 | 0.0060 |
| *5004 | 0.136 | D, B | 87 | N/A | 2,500 | 0.0060 |
| 5005 | 0.098 | B, D | 88 | N/A | 3,100 | 0.0055 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| 5006 | 0.075 | B, D | 91 | N/A | 1,200 | 0.0058 |
| 5007 | 0.003 | D, B | 81 | N/A | 1,600 | 0.0050 |
| *5007 | 0.001 | D, B | 85 | N/A | 1,600 | 0.0050 |
| 5008 | 0.114 | D, B | 82 | N/A | 3,660 | 0.0052 |
| 5009 | 0.024 | B | 82 | N/A | 1,420 | 0.0042 |
| 5010 | 0.065 | B | 82 | N/A | 2,800 | 0.0046 |
| 5011 | 0.051 | B | 81 | N/A | 2,080 | 0.0048 |
| *5011 | 0.036 | B | 83 | N/A | 2,080 | 0.0048 |
| 5012 | 0.031 | B | 85 | N/A | 3,160 | 0.0038 |
| 5013 | 0.079 | D, B | 88 | N/A | 2,960 | 0.0041 |
| 5014 | 0.107 | B | 82 | N/A | 3,100 | 0.0042 |
| 5015 | 0.134 | B | 82 | N/A | 2,980 | 0.0050 |
| 5016 | 0.040 | B | 91 | N/A | 1.300 | 0.0046 |
| 5017 | 0.086 | B | 88 | N/A | 2,820 | 0.0039 |
| 5018 | 0.168 | D, B | 85 | N/A | 3,700 | 0.0041 |
| 5019 | 0.08 | B, D | 90 | N/A | 2,620 | 0.0038 |
| 5020 | 0.174 | D, B | 86 | N/A | 3,820 | 0.0058 |
| *5020 | 0.139 | D, B | 86 | N/A | 3,820 | 0.0058 |
| 5021 | 0.108 | B | 84 | N/A | 2,980 | 0.0057 |
| 5022 | 0.016 | B | 79 | 0.384 | 800 | 0.0057 |
| *5022 | 0.016 | B | 84 | N/A | 800 | 0.0050 |
| 5023 | 0.062 | B | 84 | N/A | 3,100 | 0.0055 |
| 5024 | 0.066 | B | 83 | N/A | 2,140 | 0.0047 |
| 5025 | 0.107 | B | 83 | N/A | 3,880 | 0.0052 |
| *5025 | 0.080 | B | 83 | N/A | 3,880 | 0.0052 |
| 5026 | 0.155 | B | 82 | N/A | 3.460 | 0.0052 |
| 5027 | 0.132 | B | 82 | N/A | 3,100 | 0.0061 |
| *5027 | 0.132 | B | 85 | N/A | 3,100 | 0.0061 |
| 5028 | 0.024 | B | 82 | N/A | 1,780 | 0.0045 |
| 5029 | 0.40 | B | 82 | N/A | 1,900 | 0.0042 |
| 5030 | 0.072 | B | 82 | N/A | 2,280 | 0.0057 |
| *5030 | 0.072 | B | 84 | N/A | 2,280 | 0.0057 |
| 5031 | 0.151 | B | 82 | N/A | 4,950 | 0.0044 |
| 5032 | 0.100 | B | 82 | N/A | 4,900 | 0.0045 |
| 5033 | 0.138 | B | 82 | N/A | 3,700 | 0.0049 |
| 5034 | 0.113 | B | 82 | N/A | 3,340 | 0.0048 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| 5035 | 0.108 | B, D | 89 | N/A | 3,580 | 0.0050 |
| *5035 | 0.100 | B, D | 88 | N/A | 3,580 | 0.0050 |
| 5036 | 0.051 | B | 84 | N/A | 2,430 | 0.0045 |
| 5037 | 0.058 | B | 86 | N/A | 2,250 | 0.0049 |
| 5038 | 0.117 | B | 83 | N/A | 3,700 | 0.0043 |
| 5039 | 0.014 | B | 82 | N/A | 840 | 0.0048 |
| 5040 | 0.062 | B | 83 | N/A | 2,700 | 0.0048 |
| *5040 | 0.059 | B | 82 | N/A | 2,700 | 0.0048 |
| 5041 | 0.07 | B | 79 | 0.892 | 3,120 | 0.0048 |
| *5041 | 0.07 | B | 83 | N/A | 3,120 | 0.0048 |
| 5042 | 0.03 | B | 84 | N/A | 1,400 | 0.0050 |
| 5043 | 0.099 | B | 84 | N/A | 2,900 | 0.0038 |
| 5044 | 0.96 | B | 85 | N/A | 3,390 | 0.0045 |
| *5044 | 0.91 | B | 84 | N/A | 3,390 | 0.0045 |
| 5045 | 0.249 | B | 83 | N/A | 3,960 | 0.006 |
| *5045 | 0.249 | B | 84 | N/A | 3,960 | 0.006 |
| 5046 | 0.195 | B | 81 | N/A | 4,780 | 0.0042 |
| *5046 | 0.195 | B | 82 | N/A | 4,780 | 0.0042 |
| 5047 | 0.079 | B | 79 | 1.038 | 3,360 | 0.0048 |
| *5047 | 0.079 | B | 82 | N/A | 3,360 | 0.0048 |
| 5048 | 0.046 | B | 79 | 0.680 | 2,200 | 0.0082 |
| *5048 | 0.046 | B | 82 | N/A | 2,200 | 0.0082 |
| 5049 | 0.230 | B | 80 | 0.34 | 7,500 | 0.0187 |
| 5050 | 1.30 | B, D | 83 | 0.58 | 13,500 | 0.0067 |
| 5051 | 0.46 | B | 85 | 0.40 | 12,200 | 0.0139 |
| 5052 | 0.39 | B, D | 83 | 0.59 | 4,900 | 0.0531 |
| 5053 | 2.26 | B, D | 82 | 0.63 | 16,000 | 0.0072 |
| 5054 | 0.18 | B | 84 | 1.07 | 5,300 | 0.0055 |
| 5055 | 0.20 | B | 87 | 0.83 | 5,600 | 0.0059 |
| | | | (Area 6) | | | |
| P6A | 0.05 | B | 80 | 0.48 | 2,300 | 0.0165 |
| *P6A | 0.05 | B | 85 | N/A | 2,300 | 0.0165 |
| P6B | 0.09 | B, D | 81 | 0.28 | 2,900 | 0.0678 |
| *P6B | 0.09 | B, D | 83 | N/A | 2,900 | 0.0678 |
| P6C | 0.08 | B, D | 84 | 0.17 | 2,800 | 0.0314 |
| *P6C | 0.08 | B, D | 84 | N/A | 2,800 | 0.0314 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| P6D | 0.02 | B, D | 83 | 0.09 | 1,000 | 0.11 |
| *P6D | 0.02 | B, D | 83 | N/A | 1,000 | 0.11 |
| P6E | 0.04 | B, D | 83 | 0.09 | 1,100 | 0.0245 |
| *P6E | 0.04 | B, D | 83 | N/A | 1,100 | 0.0245 |
| P5 | 0.04 | B, D | 83 | 0.11 | 1,800 | 0.1778 |
| *P5 | 0.04 | B, D | 83 | N/A | 1,800 | 0.1778 |
| 6004 | 0.17 | A | 68 | 0.26 | 3,900 | 0.0031 |
| 6005 | 0.12 | B | 84 | 0.14 | 4,900 | 0.0061 |
| *6005 | 0.12 | B | 84 | N/A | 4,900 | 0.0061 |
| 6006 | 0.028 | B | 84 | 0.27 | 1,000 | 0.0105 |
| *6006 | 0.028 | B | 87 | N/A | 1,000 | 0.0105 |
| 6007 | 0.029 | B | 85 | 0.54 | 1,200 | 0.0033 |
| *6007 | 0.029 | B | 85 | N/A | 1,200 | 0.0033 |
| 6008 | 0.12 | B | 82 | 1.03 | 2,500 | 0.0036 |
| *6008 | 0.12 | B | 82 | N/A | 2,500 | 0.0036 |
| 6009 | 0.23 | B | 82 | 1.20 | 3,500 | 0.0046 |
| *6009 | 0.23 | B | 82 | N/A | 3,500 | 0.0046 |
| 6010 | 0.142 | B | 83 | 1.04 | 3,500 | 0.0057 |
| *6010 | 0.142 | B | 83 | N/A | 3,500 | 0.0057 |
| 6011 | 0.032 | B | 92 | 0.33 | 1,100 | 0.0045 |
| 6012 | 0.035 | B | 85 | 0.71 | 1,600 | 0.0031 |
| 6052 | 0.013 | B | 87 | 0.057 | 1,300 | 0.0038 |
| 6053 | 0.030 | B | 87 | 0.64 | 1,700 | 0.0036 |
| 6054 | 0.029 | B | 89 | 0.40 | 1,400 | 0.0057 |
| 6013 | 0.084 | B | 88 | N/A | 2,500 | 0.0040 |
| 6014 | 0.0385 | B | 87 | N/A | 1,400 | 0.0043 |
| 6015 | 0.064 | B | 85 | N/A | 2,340 | 0.0034 |
| 6016 | 0.070 | B | 79 | 0.71 | 1,800 | 0.0055 |
| *6016 | 0.053 | B | 84 | N/A | 1,800 | 0.0055 |
| 6017 | 0.040 | B | 80 | N/A | 1,760 | 0.0080 |
| *6017 | 0.018 | B | 82 | N/A | 1,760 | 0.0080 |
| 6018 | 0.049 | B | 85 | N/A | 2,000 | 0.0055 |
| 6019 | 0.075 | B | 83 | N/A | 1,900 | 0.0058 |
| 6020 | 0.055 | B | 79 | 0.70 | 2,400 | 0.0088 |
| *6020 | 0.022 | B | 85 | N/A | 2,400 | 0.0088 |
| 6021 | 0.081 | B | 81 | N/A | 2,400 | 0.0038 |
| *6021 | 0.02 | B | 88 | 1.00 | 2,400 | 0.0038 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| 6022 | 0.0385 | B | 87 | N/A | 1,800 | 0.0039 |
| 6023 | 0.110 | B | 84 | N/A | 2,900 | 0.0055 |
| *6023 | 0.110 | B | 85 | N/A | 2,900 | 0.0055 |
| 6024 | 0.02 | B | 79 | 0.094 | 1,500 | 0.0080 |
| *6024 | 0.02 | B | 82 | N/A | 1,500 | 0.0080 |
| 6025 | 0.159 | B | 82 | N/A | 3,200 | 0.0069 |
| 6026 | 0.085 | B | 82 | N/A | 2,300 | 0.0091 |
| 6027 | 0.074 | B | 85 | N/A | 1,500 | 0.0147 |
| 6028 | 0.049 | D, B | 81 | 0.38 | 2,000 | 0.0200 |
| *6028 | 0.049 | D, B | 84 | 0.38 | 2,000 | 0.0200 |
| 6029 | 0.133 | B | 82 | N/A | 4,100 | 0.0112 |
| 6030 | 0.011 | B, D | 84 | 0.074 | 1,200 | 0.0200 |
| *6030 | 0.011 | B, D | 86 | N/A | 1,200 | 0.0200 |
| 6031 | 0.108 | B, D | 89 | 0.26 | 2,400 | 0.0310 |
| *6031 | 0.108 | B, D | 89 | N/A | 2,400 | 0.0310 |
| 6032 | 0.175 | B | 84 | N/A | 5,100 | 0.0122 |
| 6033 | 0.161 | B, D | 89 | 0.27 | 2,800 | 0.0393 |
| *6033 | 0.161 | B, D | 89 | N/A | 2,800 | 0.0393 |
| 6034 | 0.101 | D | 93 | 0.50 | 3,600 | 0.0119 |
| *6034 | 0.101 | D | 93 | N/A | 3,600 | 0.0119 |
| 6035 | 0.041 | D | 92 | 0.25 | 1,500 | 0.0133 |
| *6035 | 0.041 | D | 90 | N/A | 1,500 | 0.0133 |
| 6036 | 0.065 | B | 79 | 0.97 | 2,400 | 0.0046 |
| *6036 | 0.065 | B | 87 | N/A | 2,400 | 0.0046 |
| 6037 | 0.022 | D | 92 | 0.17 | 1,600 | 0.0319 |
| *6037 | 0.022 | D | 92 | N/A | 1,600 | 0.0319 |
| 6038 | 0.103 | D | 93 | 0.25 | 2,700 | 0.0300 |
| *6038 | 0.103 | D | 93 | N/A | 2,700 | 0.0300 |
| 6039 | 0.065 | B | 87 | N/A | 2,600 | 0.0054 |
| *6039 | 0.065 | B | 87 | N/A | 2,600 | 0.0054 |
| 6040 | 0.095 | B, D | 88 | 0.26 | 2,400 | 0.0338 |
| *6040 | 0.095 | B, D | 88 | N/A | 2,400 | 0.0338 |
| 6041 | 0.032 | D | 90 | N/A | 1,200 | 0.0158 |
| 6042 | 0.095 | B | 85 | N/A | 1,500 | 0.0047 |
| 6043 | 0.089 | D | 90 | N/A | 2,500 | 0.0104 |
| 6044 | 0.041 | D | 95 | 0.11 | 1,100 | 0.0311 |
| *6044 | 0.041 | D | 95 | 0.11 | 1,100 | 0.0311 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| 6045 | 0.035 | B | 79 | 0.11 | 1,900 | 0.0079 |
| *6045 | 0.035 | B | 82 | N/A | 1,900 | 0.0079 |
| 6049A | 0.046 | B | 80 | 0.74 | 2,300 | 0.0070 |
| *6049A | 0.046 | B | 82 | N/A | 2,300 | 0.0070 |
| 6049B | 0.056 | B | 84 | N/A | 2,100 | 0.0081 |
| 6050 | 0.063 | B | 79 | 0.64 | 1,600 | 0.0056 |
| *6050 | 0.063 | B | 84 | N/A | 1,600 | 0.0056 |
| 6051 | 0.023 | B | 87 | N/A | 1,500 | 0.0047 |
| 6046 | 0.081 | D | 94 | 0.12 | 1,400 | 0.0450 |
| *6046 | 0.081 | D | 94 | N/A | 1,400 | 0.0450 |
| 6048 | 0.023 | B | 79 | 0.20 | 800 | 0.0190 |
| 6047 | 0.109 | B | 85 | N/A | 3,100 | 0.0081 |
| | | | (Area 7) | | | |
| P2E | 0.09 | B, D | 80 | 0.17 | 3,200 | 0.1072 |
| *P2E | 0.09 | B, D | 82 | N/A | 3,200 | 0.1072 |
| P2D | 0.04 | B, D | 82 | 0.23 | 3,500 | 0.1206 |
| *P2D | 0.04 | B, D | 83 | N/A | 3,500 | 0.1206 |
| P2C | 0.080 | B, D | 82 | 0.30 | 4,300 | 0.0853 |
| *P2C | 0.080 | B, D | 83 | N/A | 4,300 | 0.0853 |
| P2A | 0.45 | B, D | 84 | 0.28 | 5,100 | 0.0039 |
| *P2A | 0.45 | B, D | 85 | N/A | 5,100 | 0.0039 |
| P1C | 0.08 | B | 83 | 0.64 | 3,000 | 0.0053 |
| *P1C | 0.08 | B | 83 | N/A | 3,000 | 0.0053 |
| P2B | 0.05 | B | 81 | 0.59 | 2,300 | 0.007 |
| *P2B | 0.05 | B | 81 | N/A | 2,300 | 0.007 |
| P1B | 0.07 | B | 82 | 0.58 | 2,000 | 0.007 |
| *P1B | 0.07 | B | 83 | N/A | 2,000 | 0.007 |
| P1A | 0.04 | B | 81 | 0.35 | 1,100 | 0.0091 |
| *P1A | 0.04 | B | 81 | N/A | 1,100 | 0.0091 |
| P3 | 0.05 | B, D | 83 | 0.31 | 5,200 | 0.062 |
| 7003B | 0.053 | B | 85 | N/A | 2,300 | 0.0065 |
| *7003B | 0.053 | B | 86 | N/A | 2,300 | 0.0065 |
| 7002B | 0.082 | B | 83 | N/A | 2,300 | 0.0039 |
| *7002B | 0.082 | B | 84 | N/A | 2,300 | 0.0039 |
| 7002A | 0.082 | B | 86 | N/A | 2,400 | 0.0050 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| 7002C | 0.043 | B | 79 | 0.675 | 1,600 | 0.0048 |
| *7002C | 0.043 | B | 84 | N/A | 1,600 | 0.0048 |
| 7001B | 0.095 | B | 84 | 1.28 | 3,000 | 0.0017 |
| *7001B | 0.095 | B | 85 | N/A | 3,000 | 0.0017 |
| 7001A | 0.028 | B | 89 | N/A | 1,700 | 0.0035 |
| 7001C | 0.037 | B | 84 | 0.33 | 1,800 | 0.0067 |
| *7001C | 0.037 | B | 86 | N/A | 1,800 | 0.0067 |
| 7023 | 0.220 | D, B | 84 | 0.393 | 3,600 | 0.390 |
| *7023 | 0.220 | D, B | 87 | N/A | 3,600 | 0.390 |
| 7022 | 0.054 | B, D | 84 | 0.371 | 1,900 | 0.0158 |
| *7022 | 0.054 | B, D | 88 | N/A | 1,900 | 0.0158 |
| 7021 | 0.080 | B | 79 | 0.466 | 2,100 | 0.0162 |
| *7021 | 0.080 | B | 87 | N/A | 2,100 | 0.0162 |
| 7009 | 0.033 | B | 86 | N/A | 1,560 | 0.0064 |
| 7007A | 0.091 | B | 88 | N/A | 2,600 | 0.005 |
| 7007B | 0.049 | B | 84 | N/A | 2,200 | 0.005 |
| 7003A | 0.067 | B | 85 | N/A | 1,700 | 0.0052 |
| *7003A | 0.067 | B | 86 | N/A | 1,700 | 0.0052 |
| 7006 | 0.077 | D, B | 87 | 0.14 | 2,100 | 0.0190 |
| *7006 | 0.077 | D, B | 86 | N/A | 2,100 | 0.0190 |
| 7005 | 0.110 | B, D | 82 | 0.450 | 2,900 | 0.0241 |
| *7005 | 0.110 | B, D | 85 | N/A | 2,900 | 0.0241 |
| 7004 | 0.05 | B | 87 | N/A | 1,600 | 0.0125 |
| 7017 | 0.051 | B | 82 | N/A | 1,300 | 0.0046 |
| 7032 | 0.127 | B | 82 | N/A | 2,800 | 0.0053 |
| 7016 | 0.064 | B | 81 | N/A | 1,300 | 0.0054 |
| *7016 | 0.064 | B | 82 | N/A | 1,300 | 0.0054 |
| 7015 | 0.004 | D | 92 | 0.150 | 1,200 | 0.0250 |
| *7015 | 0.004 | D | 90 | N/A | 1,200 | 0.0250 |
| 7014 | 0.127 | B, D | 86 | N/A | 4,000 | 0.0068 |
| 7013 | 0.004 | D | 92 | 0.1 | 1,300 | 0.0892 |
| *7013 | 0.004 | D | 90 | N/A | 1,300 | 0.0892 |
| 7012 | 0.049 | B | 82 | N/A | 3,800 | 0.0087 |
| 7011 | 0.023 | D, B | 87 | 0.155 | 900 | 0.0222 |
| *7011 | 0.023 | D, B | 89 | N/A | 900 | 0.0222 |
| 7010 | 0.033 | B | 79 | 0.359 | 1,400 | 0.0143 |
| *7010 | 0.033 | B | 83 | N/A | 1,400 | 0.0143 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| 7008 | 0.040 | B | 81 | 0.67 | 2,200 | 0.0068 |
| *7008 | 0.040 | B | 83 | N/A | 2,200 | 0.0068 |
| 7020 | 0.122 | B | 79 | 0.466 | 2,000 | 0.0150 |
| *7020 | 0.122 | B | 84 | N/A | 2,000 | 0.0150 |
| 7025 | 0.05 | B | 79 | 0.554 | 1,500 | 0.0067 |
| *7025 | 0.05 | B | 84 | N/A | 1,500 | 0.0067 |
| 7024 | 0.062 | B | 82 | N/A | 2,000 | 0.0055 |
| 7019 | 0.050 | B | 82 | N/A | 1,400 | 0.0057 |
| 7028 | 0.016 | B | 79 | 0.297 | 850 | 0.0094 |
| *7028 | 0.016 | B | 85 | N/A | 850 | 0.0094 |
| 7027 | 0.070 | B | 79 | 0.461 | 1,700 | 0.0118 |
| *7027 | 0.070 | B | 86 | N/A | 1,700 | 0.0118 |
| 7029 | 0.08 | B | 79 | 0.840 | 2,800 | 0.0079 |
| *7029 | 0.08 | B | 86 | N/A | 2,800 | 0.0079 |
| 7018 | 0.062 | B | 81 | 0.32 | 1,400 | 0.0028 |
| *7018 | 0.062 | B | 82 | N/A | 1,400 | 0.0028 |
| 7031 | 0.10 | B | 82 | N/A | 5,400 | 0.0025 |
| 7030 | 0.050 | B | 84 | N/A | 2,400 | 0.0050 |
| 7034 | 0.13 | B | 79 | 0.17 | 2,700 | 0.0096 |
| *7034 | 0.13 | B | 79 | N/A | 2,700 | 0.0096 |
| 7033 | 0.07 | B | 79 | 0.70 | 2,100 | 0.0071 |
| *7033 | 0.07 | B | 84 | N/A | 2,100 | 0.0071 |
| 7035 | 0.07 | B | 79 | 0.21 | 3,600 | 0.0086 |
| *7035 | 0.07 | B | 86 | N/A | 3,600 | 0.0086 |
| 7032A | 0.063 | B | 81 | N/A | 1,700 | 0.0076 |
| *7032A | 0.063 | B | 82 | N/A | 1,700 | 0.0076 |
| 7044 | 0.167 | B | 79 | 0.26 | 4,700 | 0.0094 |
| *7044 | 0.167 | B | 85 | N/A | 4,700 | 0.0094 |
| 7043 | 0.17 | B | 79 | N/A | 700 | 0.0086 |
| *7043 | 0.008 | B | 85 | N/A | 700 | 0.0086 |
| 7042 | 0.168 | B | 84 | N/A | 2,600 | 0.0046 |
| 7041 | 0.060 | B | 80 | 0.91 | 2,600 | 0.0048 |
| *7041 | 0.060 | B | 82 | N/A | 2,600 | 0.0048 |
| 7040 | 0.30 | B | 82 | N/A | 1,900 | 0.0052 |
| 7039 | 0.053 | B | 80 | N/A | 1,950 | 0.0051 |
| *7039 | 0.053 | B | 82 | N/A | 1,950 | 0.0051 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| 7038 | 0.035 | B | 86 | N/A | 2,200 | 0.0050 |
| *7038 | 0.035 | B | 87 | N/A | 2,200 | 0.0050 |
| 7050 | 0.140 | B | 82 | N/A | 4,500 | 0.0051 |
| *7050 | 0.140 | B | 84 | N/A | 4,500 | 0.0051 |
| 7049 | 0.060 | B | 79 | 0.59 | 1,200 | 0.0042 |
| *7049 | 0.060 | B | 85 | N/A | 1,200 | 0.0042 |
| 7051 | 0.136 | B | 79 | 0.75 | 2,600 | 0.0088 |
| *7051 | 0.136 | B | 80 | N/A | 2,600 | 0.0088 |
| 7048 | 0.34 | B | 74 | N/A | 5,200 | 0.0071 |
| 7047 | 0.12 | B | 85 | N/A | 4,600 | 0.0048 |
| 7046 | 0.14 | B | 86 | N/A | 3,500 | 0.0046 |
| 7045 | 0.11 | B | 86 | N/A | 3,500 | 0.0043 |
| 7037 | 0.12 | B | 84 | N/A | 3,400 | 0.0044 |
| 7036 | 0.140 | B | 82 | N/A | 3,500 | 0.0046 |
| 7002D | 0.043 | B | 82 | N/A | 1,600 | 0.0054 |
| *7002D | 0.043 | B | 84 | N/A | 1,600 | 0.0054 |
| | | | (Area 8) | | | |
| 800 | 0.02 | B | 92 | 0.25 | 960 | 0.0063 |
| 801C | 0.3 | B | 79 | 0.27 | 5,400 | 0.0083 |
| *801C | 0.3 | B | 81 | N/A | 5,400 | 0.0083 |
| 801A | 0.22 | B | 84 | N/A | 4,500 | 0.0042 |
| 802B | 0.07 | B | 80 | 0.77 | 1,800 | 0.0044 |
| 802A | 0.07 | B | 90 | 0.40 | 2,000 | 0.0059 |
| 803A | 0.16 | B | 83 | N/A | 3,600 | 0.0070 |
| 803B | 0.08 | B | 82 | N/A | 2,160 | 0.0060 |
| 806 | 0.05 | B | 79 | 0.59 | 1,680 | 0.0071 |
| *806 | 0.05 | B | 84 | N/A | 1,680 | 0.0071 |
| 804A | 0.05 | B | 79 | 0.61 | 1,920 | 0.0083 |
| 804B | 0.04 | B | 79 | 0.42 | 1,440 | 0.0111 |
| 805 | 0.14 | B | 82 | N/A | 3,000 | 0.0077 |
| 807 | 0.09 | B | 81 | 0.93 | 3,120 | 0.0067 |
| *807 | 0.09 | B | 84 | N/A | 3,120 | 0.0067 |
| 808 | 0.03 | B | 82 | 0.26 | 1,200 | 0.0117 |
| 809 | 0.04 | B | 85 | 0.21 | 1,200 | 0.0092 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| 810 | 0.01 | B | 79 | 0.33 | 960 | 0.0094 |
| *810 | 0.01 | B | 84 | N/A | 960 | 0.0094 |
| 811 | 0.12 | B | 80 | 0.75 | 3,120 | 0.0106 |
| *811 | 0.12 | B | 81 | N/A | 3,120 | 0.0106 |
| 812A | 0.31 | B | 79 | 0.31 | 6,600 | 0.074 |
| *812AN | 0.15 | B | 81 | N/A | 3,800 | 0.0063 |
| *812AS | 0.16 | B | 81 | N/A | 2,900 | 0.0086 |
| 812B | 0.1 | B | 79 | 0.22 | 3,600 | 0.0083 |
| *812B | 0.1 | B | 80 | N/A | 3,600 | 0.0083 |
| 813 | 0.02 | B | 92 | N/A | 960 | 0.0033 |
| 814 | 0.03 | B | 86 | N/A | 1,440 | 0.0076 |
| 815A | 0.14 | B | 80 | 0.75 | 3,000 | 0.0080 |
| 815B | 0.07 | B | 68 | 1.10 | 2,400 | 0.0067 |
| *815B | 0.07 | B | 80 | N/A | 2,400 | 0.0067 |
| 815C | 0.25 | B | 79 | 0.69 | 3,840 | 0.0193 |
| *815C | 0.25 | B | 80 | N/A | 3,840 | 0.0193 |
| 817 | 0.09 | B | 81 | N/A | 2,400 | 0.0079 |
| 820 | 0.03 | B | 79 | 0.33 | 960 | 0.0094 |
| *820 | 0.03 | B | 80 | N/A | 960 | 0.0094 |
| 816 | 0.21 | B | 80 | 0.27 | 4,560 | 0.0061 |
| 818 | 0.05 | B | 82 | 0.42 | 1,560 | 0.0083 |
| 819 | 0.07 | B | 82 | N/A | 1,560 | 0.0071 |
| *819 | 0.07 | B | 85 | N/A | 1,560 | 0.0071 |
| 822 | 0.02 | B | 80 | N/A | 840 | 0.0048 |
| 821 | 0.12 | B | 80 | N/A | 3,300 | 0.0071 |
| 823 | 0.12 | B | 80 | N/A | 2,760 | 0.0041 |
| 824 | 0.04 | B | 80 | N/A | 2,040 | 0.0049 |
| 825 | 0.05 | B | 80 | N/A | 1,440 | 0.0063 |
| 826 | 0.06 | B | 80 | 0.26 | 960 | 0.0073 |
| | | | (Area 9) | | | |
| SS01 | 1.33 | B, D | 86 | 0.54 | 10,200 | 0.0490 |
| SS02 | 0.53 | B, D | 85 | 0.31 | 6,800 | 0.0684 |
| SS03 | 1.18 | B, D | 87 | 0.44 | 9,700 | 0.0897 |
| SS04 | 0.93 | B, D | 85 | 0.53 | 10,100 | 0.0351 |
| SS05 | 0.38 | B, D | 85 | 0.37 | 6,900 | 0.0478 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

TABLE 9

SUBAREA CHARACTERISTICS

| Subarea Number | Area (Sq. Mi.) | Hydrologic Soil Group | Average Weighted Equivalent Curve Number | Lag Time (Hrs.)** | Hydraulic Length (Ft.) | Slope Along Hydraulic Length (Ft/Ft) |
|---|---|---|---|---|---|---|
| SS06 | 3.05 | B | 80 | 0.77 | 16,800 | 0.0060 |
| SS07 | 1.57 | B | 80 | 0.68 | 11,800 | 0.0089 |
| SS08 | 1.02 | B | 86 | 0.68 | 13,200 | 0.0087 |
| SS09 | 0.45 | B | 90 | 0.31 | 6,000 | 0.0057 |
| SS10 | 0.26 | B | 89 | 0.26 | 4,500 | 0.0056 |
| SS11 | 0.06 | B | 88 | 0.10 | 1,480 | 0.0049 |
| SS12 | 2.33 | B, D | 83 | 0.66 | 17,000 | 0.0056 |
| SS13 | 0.17 | B | 82 | 0.17 | 3,440 | 0.0058 |
| SS14 | 0.56 | B, D | 83 | 0.40 | 8,800 | 0.0091 |
| SS15A | 0.12 | B, D | 85 | N/A | | |
| SS15B | 0.14 | B, D | 93 | N/A | | |
| SS15C | 0.06 | B, D | 93 | N/A | | |
| SS16 | 0.83 | B | 80 | 0.30 | 12,500 | 0.0050 |
| SS17 | 2.73 | B, D | 86 | 0.84 | 19,400 | 0.0093 |
| SS18 | 1.22 | B, D | 94 | 0.35 | 10,800 | 0.0046 |
| SS19 | 0.47 | B | 83 | 1.27 | 5,300 | 0.0045 |
| SS20 | 0.93 | B | 92 | 0.97 | 6,000 | 0.0036 |
| SS21 | 0.68 | B | 82 | 1.40 | 6,200 | 0.0032 |
| SS22 | 0.40 | B | 81 | N/A | 4,300 | 0.0070 |
| SS23 | 0.23 | B | 82 | 0.21 | 3,200 | 0.0113 |
| SS24 | 0.11 | B | 82 | 0.16 | 2,700 | 0.0044 |
| SS25 | 0.20 | B | 82 | 0.27 | 6,800 | 0.0054 |
| | | | (Area 10) | | | |
| CC01 | 2.26 | D, B | 86 | 0.84 | 16,000 | 0.0334 |
| CC02 | 1,86 | D, B | 82 | 0.66 | 17,700 | 0.0099 |
| CC03 | 1.45 | B, D | 84 | 0.79 | 14,500 | 0.0059 |
| CC04 | 0.64 | B, D | 84 | 0.45 | 8,200 | 0.0139 |
| CC05 | 0.30 | A | 73 | 0.32 | 6,100 | 0.0062 |
| CC06 | 0.12 | A | 74 | 0.43 | 2,000 | 0.0060 |
| CC07 | 0.25 | A | 73 | 0.77 | 3,900 | 0.0059 |
| CC08 | 0.02 | A | 72 | 0.17 | 2,500 | 0.0052 |

*Changes Due to Future Conditions/Development
**N/A Indicates Kinematic Routing Method was Used

## IX. TECHNICAL REFERENCE LIST

A. Work maps at a scale of 1"=1200' and USGS quadrangle maps containing contour mapping, zoning and site survey information used to provide input for the HEC-1 computer program within the drainage area, were provided to the Flood Control District of Maricopa County.

B. Evaluations of maximum street capacities (cfs) for a range of longitudinal slopes and various street cross sections to assist in determining percent of diversion for different storm events for the hydrologic modeling, provided upon request.

C. Drainage area summary sheets, provided upon request.

D. Kinematic wave model data sheets, provided upon request.

E. Input, schematic diagrams of stream networks and runoff summaries in printout form from the HEC-1 flood hydrograph package, provided to the Flood Control District of Maricopa County for the two and 100 year storm events. Other storm events provided upon request.

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24. National Oceanic and Atmoshperic Administration, Atlas 2, Volume VIII - Arizona, Precipitation Frequency Atlas of the Western United States, Washington, D.C., 1973.

## AERIAL MAPPING

1. Landis Aerial Surveys, 1" = 1200', Photodate: December 17, 1986, Photos J-12 through J-18 and K-12 through K-18.

2. City of Phoenix AP #40 Aerial Maps, 36-17 to 36-44 and 37-17 to 37-32, 1" = 100' scale.

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## MAPS

1. U.S. Geological Survey 7.5 Minute Quadrandle Maps, 1" = 2000'

   McMicken Dam
   Calderwood Butte
   Hedgpeth Hills
   El Mirage
   Glendale
   Paradise Valley
   Hieroglyphic Mountains, S.W.
   Baldy Mountain
   Currys Corner
   Union Hills
   Sunnyslope

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3. East Fork of Cave Creek Wash Work Map, Flood Boundary and Floodway Map, U.S Department of Housing and Urban Development, Federal Emergency Management Administration 4-1-80

4. City of Phoenix Zoning Maps

5. City of Glendale Zoning Maps, December 1985

6. Floodplain Maps and Computer Output Summary for the New River, Skunk Creek and the Agua Fria River

7. Floodplain Delineation Maps for Cave Creek Wash and East Fork Cave Creek Wash

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16. I-17 As-Builts from South of Bell Road to Union Hills.

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# XI. APPENDICES

# APPENDIX A

## SUMMARY OF EXISTING DRAINAGE FACILITIES AT BELL ROAD

Drainage Area 1: 24" RCP crossing under Bell Road between Grand Avenue and ATSF railroad.

36" RCP crossing under Bell Road between AT-SF Railroad and the west edge of Sun City West.

24" RCP crossing under Bell Road at the southwest corner of Sun City West.

Gunite channel 32' wide x 16' deep with 1/2:1 side slopes. Runs parallel to Bell Road on the north side and carries flows from Sun City West to the Agua Fria River.

7 - 9' x 5' concrete box crossing under El Mirage Road just north of Bell Road. This is the crossing for the gunite channel under El Mirage Road.

2 - 9' x 5' concrete box at Bell Road and 115th Avenue.

2 - 13' x 4' concrete box at Bell and 99th Avenue.

Agua Fria Watershed: Agua Fria Bridge crossing at Bell Road between Sun City and Sun City West.

Drainage Area 2: Gunite channel 21' wide x 5' deep with 2:1 side slopes. Runs parallel to Bell Road on the north side and carries flows from Sun City to the Agua Fria River.

2 - 9' x 5' concrete box under Bell Road. This structure carries flows from the gunite channel on the north side of Bell Road. South of this concrete box is a gunite channel 21' wide x 5' deep with 2:1 side slopes and it flows south at 115th Avenue.

Bridge on Bell Road at 99th Avenue with a gunite channel 20' wide x 4' deep with 1:1 side slopes flowing under Bell Road to the South.

New River Watershed: New River Bridge crossing under Bell Road near 83rd Avenue.

Drainage Area 3: No existing cross road drainage facilities in this area.

Skunk Creek Watershed: Skunk Creek Bridge crossing under Bell Road near 71st Avenue (290 foot span).

Drainage Area 4: Existing swale on north side of Bell Road from 63rd Avenue to 43rd Avenue.

2 - 6' x 3' box culvert near 28th Avenue.

Interchange drainage at I-17 and Bell Road.

Drainage Area 5: No existing cross road drainage facilities in this area.

Cave Creek Wash Watershed: 9.5' bridge opening under Bell Road at Cave Creek Wash with an 80' span.

Drainage Area 6: 2 - 6' x 4' concrete box crossing under Bell Road near Sixth Avenue.

2 - 5' x 10' concrete box crossing under Bell Road near First Street.

1 - 5' x 10' concrete box crossing under Bell Road near Second Street.

2 - 10' x 3' concrete box crossing under Bell Road near Seventh Street.

2 - 10' x 3' concrete box crossing under Bell Road at Seventh Street.

Drainage Area 7: No existing crossroad drainage facilities in this area.

Drainage Area 8: 2 - 29" x 18" Corrugated Metal Arched Pipe (CMPA) crossing under Bell Road near 32nd Street.

2 - 43" x 27" CMPA crossing under Bell Road near 40th Street.

2 - 36" x 22" CMPA crossing under Bell Road near 44th Place.

2 - 36" x 22" CMPA crossing under Bell Road near 45th Place.

36" x 22" CMPA crossing under Bell Road near 47th Street.

2 - 43" x 27" CMPA crossing under Bell Road near 48th Street.

2 - 36" x 22" CMPA crossing under Bell Road near 49th Place.

2 - 36" x 22" CMPA crossing under Bell Road near 51st Place.

29" x 18" CMPA crossing under Bell Road near 52nd Street.

29" x 18" CMPA crossing under Bell Road near 56th Street.

36" x 22" CMPA crossing under Bell Road near 57th Street.

29" x 18" CMPA crossing under Bell Road near 60th Place.

36" x 22" CMPA crossing under Bell Road near 61st Place.

22" x 36" CMPA crossing under Bell Road near 63rd Street.

29" x 18" CMPA crossing under Bell Road near 69th Street.

# APPENDIX B

# EVALUATION OF EXISTING AND ONGOING HYDROLOGIC STUDIES AND FLOOD CONTROL FACILITIES AFFECTING THE BELL ROAD PROJECT DRAINAGE STUDY

## I. INTRODUCTION

This appendix documents Greiner's evaluation of existing and ongoing hydrologic studies and the hydrology of major flood control, water transport and highway facilities affecting the Bell Road Project Drainage Study. The purpose of this evaluation is to determine what existing information may be utilized in developing the hydrology for the Bell Road Project Drainage Study. This report also represents the accomplishment of Phase I of the Bell Road Drainage Study as described in the Scope of Work.

For the purpose of this investigation, the study area was divided into eight subareas. These areas are described below.

Area 1: Bound by Bell Road, Grand Avenue, McMicken Dam Outlet Channel and the Agua Fria

Area 2: Bound by Bell Road, Agua Fria and New River

Area 3: Bound by Bell Road, New River, the Outer Loop Highway and Skunk Creek

Area 4: Bound by Bell Road, Skunk Creek, the Outer Loop Highway and I-17

Area 5: Bound by Bell Road, I-17, the Outer Loop Highway and Cave Creek

Area 6: Bound by Bell Road, Cave Creek, East Fork of Cave Creek Drainage Divide

Area 7: East Fork of Cave Creek Wash Watershed

Area 8: Bell Road, East Fork of Cave Creek Drainage Divide and the CAP Canal.

In addition to these eight areas, a separate review was made of the drainage area north of the Outer Loop Highway and of the major river crossings at Bell Road at the Agua Fria River, the New River, Skunk Creek and Cave Creek. The limits of these areas are shown on Exhibit 1.

In the second section of this appendix, the evaluation of the existing hydrology and facilities is presented. Conclusion and recommendations are presented in Section III.

## II. EVALUATION

Hydrology from a number of different sources was reviewed. These sources include Master Storm Drainage Studies prepared for the City of Phoenix; recently completed and ongoing Area Drainage Master Studies (ADMS); U.S. Army Corps of Engineers (USCOE) Design Memoranda; Highway Drainage Studies (Outer Loop and I-17); drainage reports for major subdivisions (Arrowhead Ranch, Sun City and Sun City West); and the Central Arizona Project, Granite Reef Aqueduct hydrology files.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: Grand Avenue Corridor Study; Interim Report Volume I, Analysis of Alternatives

Date: April 11, 1986 - Draft

Author: Parsons, Brinckerhoff, Quade & Douglas, Inc. with U.S.D.O.T., Federal Highway Administration and A.D.O.T.

Study Area Description: Twenty-six mile long corridor from Van Buren Street and Seventh Avenue to Deer Valley Road by Sun City West. Study area is limited to area along corridor.

Purpose of Study: "Document the alternative roadway concepts considered as part of the Grand Avenue Corridor Study and provide a comparative evaluation of those alternatives."

Design Storm: Ten year

Other Frequencies Modeled: 25 and 50-year storms

Precipitation Distribution: N/A

Rainfall-Runoff Model Used: N/A

Storm Frequency Runoff Pattern Modeled: N/A

Watershed Development Status Modeled: N/A

Comments: This report was not intended as a drainage report, it only discusses hydrology briefly (above New River) to identify any existing or future problems associated with future expansion. Not adequate for design. Only on-site hydrology evaluated.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: Sun City West - Phase I Development Master Plan

Date: July 1977

Author: Hennington, Durham & Richardson (HDR)

Study Area Description: Land bound on the north by the McMicken Dam Outlet Channel, on the south by Bell Road, on the west by A.T. & S.F. Railroad and Grand Avenue and on the east by the Agua Fria River

Purpose of Study: Master Drainage planning for new major development

Design Storm: 100-year, 24-hour

Other Frequencies Modeled: None

Precipitation Distribution: SCS Type I

Rainfall-Runoff Model Used: TR-20

Storm Frequency Overland and Street Flow Pattern Modeled: 100-year

Watershed Development Status Modeled: Fully developed per Master Plan

Comments: The on-site and off-site drainage was calculated using the 100-year, 24-hour storm plus flows from McMicken Dam. The entire on-site flows for 100-year, 24-hour storm exit the property at El Mirage and Bell Road and then to the Agua Fria River. Since this report was prepared, the western half changed design to incorporate more golf course and detention facilities. Therefore, the 1977 report is conservative in the total discharge from on-site. There appears to be no impact from on-site drainage to Bell Road.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: Sun City West Master Plan Update

Date: 1984

Author: Hennington, Durham & Richardson (HDR)

Study Area Description: 4.1 square miles of an 8.9 square mile area of Phase I. Area is bound on west by AT & SF Railroad and Grand Avenue, on the east by El Mirage Road, on the north by Deer Valley Road and the south by Bell Road.

Purpose of Study: Revise hydrology for development of subdivision

Design Storm: 100-year with the storm duration yielding the highest peak flow (either the 1-hour, 2-hour, 6-hour or 24-hour)

Other Frequencies Modeled: None

Precipitation Distribution: SCS Type II

Rainfall-Runoff Model Used: TR-20

Storm Frequency Overland and Street Flow Patterns Modeled: 100-year

Watershed Development Status Modeled: Fully developed per Master Plan

Comments: This development was designed to handle the 100-year frequency storm with whatever duration gave the highest Q (usually 1 or 2-hour). The project contains 22 detention ponds which reduce peak flows calculated in the original study. All flows are kept on-site until the outfall at El Mirage and Bell Road and to the Agua Fria River.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: City of Peoria, Master Plan of Storm Drainage

Date: May 1986 - Draft

Author: James M. Montgomery, Consulting Engineers, Inc.

Study Area Description: Approximately 62 square miles, 32 square miles with land plan, 30 square miles without land plan. This area is bound by Carefree highway on north, City of Glendale on the south and east, on the west by Sun City, and north of Beardsley approximately the east side of the Agua Fria River

Purpose of Study: Plans for the City of Peoria to develop a storm drain system which will diminish flood hazards from local runoff within the City, particularly from runoff from relatively minor but frequent storm events

Design Storm: 2-year, 2-hour (for ultimate conditions only)

Other Frequencies Modeled: 10-, 25- and 100-year, 2-hour for both existing and ultimate conditions

Precipitation Distribution: City of Phoenix s-curve

Rainfall-Runoff Model Used: Storm Water Management Model for urban areas (southern areas)/ HEC-1 for natural areas (northern areas)

Storm Frequency Runoff Pattern Modeled: Routing was the same for each storm

Watershed Development Status Modeled: Both existing and ultimate

Comments: Existing storm drain (1984) was designed with rational method drainage patterns shown.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: Glendale Storm Water Management Plan

Date: January 1986

Author: Camp Dresser and McKee Inc.

Study Area Description: North - Pinnacle Peak Road
South - Camelback Road
East - 51st Avenue and 43rd Avenue
West - New River, Northern Avenue, 67th Avenue and Arizona Canal

Purpose of Study: The reduction of existing storm drainage problems in the City

Design Storm: 10-year, 6-hour

Other Frequencies Modeled: None

Precipitation Distribution: City of Phoenix s-curve

Rainfall-Runoff Model Used: Stormwater Management Model (SWMM)

Storm Frequency Overland/Street Flow Routing Pattern Modeled: 10-year, 6-hour

Watershed Development Status Modeled: Future conditions

Comments: Study provides discharge values for a 10-year storm at Bell Road. Overland flow patterns will still need to be developed for the 2, 5, 50 and 100-year frequency storms. The proposed storm drain system at Bell Road is not adequate for a 100-year storm.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: Glendale - Peoria Area Drainage Master Plan

Date: April 1986 - Final Draft

Author: Camp Dresser and McKee, Inc. and James M. Montgomery, Consulting Engineers, Inc.

Study Area Description: North - Roughly the CAP Canal
South - Camelback Road
East - 43rd Avenue and 51st Avenue
West - Agua Fria River

Purpose of Study: Determine potential benefits of combining storm drain systems for Cities of Glendale and Peoria

Design Storm: 10-year, 6-hour

Other Frequencies Modeled: 100-year, 6-hour

Precipitation Distribution: City of Phoenix s-curve

Rainfall-Runoff Model Used: Storm Water Management Model (SWMM)

Storm Frequency Overland and Street Flow Patterns Modeled: 10-year storm drains, 100-year storm drains, streets and channels

Watershed Development Status Modeled: Future conditions with ultimate development of current land use plans

Comments: Provides rough drainage patterns only, no areas or timing information. Discharge given for storm drains only. Adequate for flow patterns for 10-year, 6-hour flows.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: Northwest Storm Drainage Study

Date: 1977

Author: Arthur Beard Engineers, Inc.

Study Area Description: North - Skunk Creek
South - The Arizona Canal
East - Black Canyon Freeway
West - 51st Avenue
Approximately 23 square miles

Purpose of Study: Developing a stormwater drainage master plan

Design Storm: 2-year

Other Frequencies Modeled: 1-, 10-, and 50-year

Precipitation Distribution: SCS Type II, 24-hour storm distribution

Rainfall-Runoff Model Used: SCS TR-20 Program

Storm Frequency Runoff Pattern Modeled: 2-year storm with the Illinois Storm Sewer System Simulation Model (ISS)

Watershed Development Status Modeled: Existing and ultimate land use

Comments: Study provides the flow patterns of existing condition for the 1, 2-, 10- and 50-year storms. Drainage subareas and flow patterns may be utilized. The proposed storm drain system at Bell Road is not adequate for a 100-year storm.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: North Central Master Storm Drainage Study (West Half)

Date: July 1980

Author: SCI Consulting Engineers, Inc.

Study Area Description: North - Scatter Wash
South - Thunderbird Road
East - Cave Creek
West - The Black Canyon Freeway
Approximately 12 square miles

Purpose of Study: Developing a stormwater drainage master plan

Design Storm: 2-year

Other Frequencies Modeled: 1-, 5-, and 10-year

Precipitation Distribution: City of Phoenix s-curve

Rainfall-Runoff Model Used: SCS TR-20 Program

Storm Frequency Runoff Pattern Modeled: 2-year

Watershed Development Status Modeled: The ultimate development based on existing zoning

Comments: Watershed subareas and flow patterns may be utilized. The proposed storm drain system at Bell Road is not adequate for a 100-year storm.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: North Central Area Master Storm Drainage Study (East Half)

Date: April 1981

Author: Cella Barr Associates

Study Area Description: North - The Central Arizona Project Granite Reef Aqueduct
South - The ridge line in the mountains
East - 32nd Street
West - Cave Creek Wash

Purpose of Study: Present solutions for storm drainage in the study area

Design Storm: 2-year

Other Frequencies Modeled: 1-, 5-, 10-, 50- and 100-year

Precipitation Distribution: City of Phoenix s-curve

Rainfall-Runoff Model Used: SCS TR-20 Program

Storm Frequency Runoff Pattern Modeled: 2-year

Watershed Development Status Modeled: Fully developed conditions

Comments: Drainage subareas and flow patterns may be utilized. The proposed storm drain system at Bell Road is not adequate for a 100-year storm.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: Northeast Area Master Storm Drainage Study

Date: December 1979

Author: . Southwest Computing, Inc.

Study Area Description: North - The Central Arizona Project Canal
South - The Indian Bend Wash
East - 56th Street
West - 32nd Street
Approximately 14 square miles

Purpose of Study: Provide an optimized solution of storm drainage for the study area

Design Storm: 2-year

Other Frequencies Modeled: 1-, 5-, and 10-year

Precipitation Distribution: City of Phoenix s-curve

Rainfall-Runoff Model Used: SCS TR-20 Program

Storm Frequency Runoff Pattern Modeled: 2-year

Watershed Development Status Modeled: Full development based on existing zoning

Comments: Drainage subareas and flow patterns may be utilized. The proposed storm drain system at Bell Road is not adequate for a 100-year storm.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: Greenway Road Location Study

Date: August 1982

Author: Dibble and Associates

Study Area Description: A five mile reach between Greenway Road extended and Bell Road from 19th Avenue to 32nd Street around the north slope of Lookout Mountain

Purpose of Study: Establish the required right-of-way corridor for the roadway and drainageway

Design Storm: N/A

Other Frequencies Modeled: N/A

Precipitation Distribution: N/A

Rainfall-Runoff Model Used: N/A

Storm Frequency Runoff Pattern Modeled: N/A

Watershed Development Status Modeled: N/A

Comments: Study used flows established in the Cella Barr & Associates 1981 Master Storm Drainage Study.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: Drainage Study of East Fork Cave Creek Wash for Haspro Development

Date: March 1985

Author: Cella Barr Associates

Study Area Description: A 44 acre shopping and commercial center at the northeast corner of Bell Road and 16th Street

Purpose of Study: Analyze the off-site flows that are presently directed toward the property from the East Fork of Cave Creek Wash

Design Storm: 100-year

Other Frequencies Modeled: None

Precipitation Distribution: N/A

Rainfall-Runoff Model Used: N/A

Storm Frequency Runoff Pattern Modeled:

Watershed Development Status Modeled: Existing conditions

Comments: Although this study provides discharge values for a 100-year storm at Bell Road, a hydrologic model should be redeveloped for the whole watershed.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: East Fork of Cave Creek Wash Area Drainage Master Study

Date: Ongoing

Author: NBS Lowry

Study Area Description: Watershed of East Fork of Cave Creek Wash

Purpose of Study: Develop alternative drainage mitigation schemes for East Fork

Design Storm: 100-year, 24-hour

Other Frequencies Modeled: 10-, 50-, 500-year

Precipitation Distribution: City of Phoenix s-curve

Rainfall-Runoff Model Used: SCS TR-20 and Diffusion Model

Storm Frequency Runoff Pattern Modeled: 100-year

Watershed Development Status Modeled: Existing, future conditions

Comments: Study will provide discharge values at Bell Road. Overland flow patterns will have to be redeveloped for 2-year storm.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: ADOT Project #IR-17-1(151) Phoenix-Cordes Junction Highway, Peoria Avenue-Deer Valley Road

Date: Ongoing

Author: PRC

Study Area Description: All watersheds tributary to I-17 between Peoria Avenue and Deer Valley Road, westward to 35th Avenue

Purpose of Study: Analyze existing drainage problems at I-17 and develop alternative solutions

Design Storm: 25-, 50-year, 24-hour

Other Frequencies Modeled: 100-year

Precipitation Distribution: NOAA Atlas II

Rainfall-Runoff Model Used: SCS TR-20

Storm Frequency Runoff Pattern Modeled:

Watershed Development Status Modeled: Existing and future fully developed

Comments: Study will develop discharge values at Bell Road west of I-17 and east of 35th Avenue. Watershed subarea limits and characteristics may be utilized.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: Hydrology and Concept Drainage Plan Development, Outer Loop Highway Project, Section B

Date: Ongoing

Author: Greiner Engineering Sciences, Inc.

Study Area Description: All watersheds tributary to the Outer Loop Highway between Bell Road and the CAP Canal Crossing

Purpose of Study: Develop preliminary drainage plans for off-site drainage to the Outer Loop Highway

Design Storm: 100-year, 24-hour

Other Frequencies Modeled: 10-, 50-year

Precipitation Distribution: NOAA Atlas II

Rainfall-Runoff Model Used: HEC-1

Storm Frequency Runoff Pattern Modeled: 100-year

Watershed Development Status Modeled: Ultimate development of existing zoning +20% to account for future development

Comments: Basic model may be adopted with modifications to reflect MCFCD and COP criteria.

## DRAINAGE STUDY SUMMARY SHEET

Report Title: Untitled hydrologic studies for Reaches 10 and 11 of the Granite Reef Aqueduct (CAP)

Date:

Author: Bureau of Reclamation

Study Area Description: Reach 10 extends across the north of the study area from the west study limit at Grand Avenue to Cave Creek Road. Reach 11 extends from Cave Creek Road to the east study limit at Bell and Scottsdale Roads intersection.

Purpose of Study: Develop flow-through discharges for Reach 10 and detention design for the Reach 11 Paradise Valley Detention Dikes

Design Storm: Reach 10 - $Q_{100}$; Reach 11 - Combined maximum probable and 100-year floods

Other Frequencies Modeled: 50-year

Precipitation Distribution: Unknown

Rainfall-Runoff Model Used: Unknown

Storm Frequency Runoff Pattern Modeled: Unknown

Watershed Development Status Modeled: Unknown

Comments: Stage storage data is available for routing flows through Reach 10 overchutes (used in Outer Loop Study). No flow through from Reach 11; no further study is required.

## III. CONCLUSION AND RECOMMENDATIONS

The hydrology studies were evaluated on the basis of whether the peak discharges developed by these studies meet the hydrologic criteria established by the Maricopa County Flood Control District (MCFCD) for the Bell Road Project Drainage Study. This criteria is briefly summarized below.

a. Rainfall/Runoff Model - HEC-1
b. Storm Frequencies - 2-, 5-, 10-, 50-, 100-year
c. Storm Duration - 24-hour
d. Precipitation Distribution - City of Phoenix s-curve
e. Flow Paths to Be Modeled - 2-, 5-, 10-, 50-, 100-year
f. Development Status - Existing and Future Fully Developed Conditions

On the basis of this criteria, none of the studies provide the full range of design discharges at Bell Road for both existing and future conditions. The Sun City West development, however, may be excluded from further study if all on-site drainage is diverted to the Agua Fria River as described in the Master Plan.

All drainage reports provide some useful data which may be incorporated into the Bell Road Project Drainage Study, particularly subarea delineations, routing paths and curve numbers.

The following recommendations are presented regarding the course of the Phase II hydrologic investigation with the adoption of appropriate information from previous or concurrent hydrologic studies.

a. On-site drainage and as-builts for Sun City West will be reviewed to determine whether all flows are diverted away from Bell Road and to the Agua Fria River.

b. Drainage patterns developed by previous studies will be evaluated in the field and adopted wherever appropriate.

c. Curve number (CN) values will be adopted from the previous research wherever appropriate.

d. Bureau of Reclamation stage storage data developed for the CAP Canal overchutes will be utilized.

e. The hydrologic results and design recommendations for the East Fork of Cave Creek ADMS, I-17 Project and the Outer Loop Highway, Section B study will be reviewed and adopted wherever appropriate.

f. The Corps of Engineers discharge values and current F.E.M.A. floodplain delineations will be adopted for design and analysis purposes at the Agua Fria River, New River, Skunk Creek and Cave Creek.